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Original article

Contributions to the biodiversity of Echinoderms (Echinodermata) in the Department of Atlántico, Caribbean Sea, Colombia

Contribuciones a la biodiversidad de los equinodermos en el departamento del Atlántico, mar Caribe de Colombia

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Abstract

Echinoderms are a marine invertebrate group with important ecological functions in the ocean; they are the source of bioactive compounds, and some species are important for fisheries and aquaculture. Their study in the Colombian Caribbean has focused on taxonomic and ecological aspects and they are a well-documented group of invertebrates. However, small-scale studies of the group are required given the geomorphological and oceanographic diversity along the entire Colombian coastline. The Magdalena River runoff strongly influences the coastal ecosystems of the Department of Atlántico, which has the shortest continental shoreline with only 72 km. The benthic fauna in its surroundings is the biotic component receiving the influence of this river directly, but it has not been the object of deep taxonomic and ecological studies. Field echinoderm surveys were conducted at several sites from 2004 to 2019. Observations and direct collections were carried out from 0 to 5 m depth. We identified four classes, seven orders, eight families, ten genera, and 16 species. Thirteen of these species were first records for Atlántico: *Luidia senegalensis*, *Astropecten articulatus*, *Amphiodia riisei*, *Amphiodia trychna*, *Echinometra lucunter lucunter*, *Encope michelini*, *Leodia sexiesperforata*, *Mellita quinquesperforata*, *Isostichopus badionotus*, *Isostichopus* sp., *Holothuria grisea*, *Holothuria glaberrima*, and *Holothuria princeps*. The most frequently observed species were *M. quinquesperforata* and *H. glaberrima*. We provide the local geographic distribution, illustrations, and remarks on each species. This study attempts to close gaps regarding the knowledge of the distribution of marine invertebrates in the Colombian Caribbean Sea.

Keywords: Echinoderms; Marine biodiversity; Baseline; Coastal zone.

Resumen

Los equinodermos son un grupo de invertebrados marinos con funciones ecológicas únicas en el océano; son fuente de compuestos bioactivos y algunas especies son importantes recursos económicos para la pesca y la acuicultura. Los estudios en el Caribe colombiano se han enfocado en aspectos taxonómicos y ecológicos, y en el primer componente, son uno de los grupos de invertebrados mejor documentados. Sin embargo, se requieren estudios del grupo a pequeña escala dada la diversidad geomorfológica y oceanográfica que se presenta a la largo de la línea de costa colombiana. Las descargas del río Magdalena influyen fuertemente en los ecosistemas costeros del departamento del Atlántico, el más pequeño de toda el área continental, con una extensión de sólo 72 km de línea costera. Uno de los componentes bióticos que recibe directamente la influencia de este río es la fauna bentónica que habita en sus alrededores, la cual no ha sido objeto de estudios taxonómicos y ecológicos profundos. Entre el 2004 y el 2019 se hicieron censos de equinodermos en varias localidades realizando observaciones y recolecciones directas entre los 0 y los 5 m de profundidad. Se identificaron cuatro clases, siete órdenes, ocho familias, diez géneros y 16 especies. Trece de ellas son primeros registros para el departamento del Atlántico: *Luidia senegalensis*, *Astropecten*

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articulatus, *Amphiodia riisei*, *Amphiodia trychna*, *Echinometra lucunter lucunter*, *Encope michelini*, *Leodia sexiesperforata*, *Mellita quinquiesperforata*, *Isostichopus badionotus*, *Isostichopus* sp., *Holothuria grisea*, *Holothuria glaberrima* y *Holothuria princeps*. Las especies más frecuentemente observadas fueron *M. quinquiesperforata* y *H. glaberrima*. Se proporciona aquí su distribución geográfica local, con ilustraciones y comentarios sobre cada especie. Este estudio intenta llenar vacíos en el conocimiento de la distribución de los invertebrados marinos en el mar Caribe colombiano.

Palabras clave: Equinodermos; Biodiversidad marina; Línea de base; Zona costera.

Introduction

Echinoderms are of great interest due to their extensive fossil record, their ecological importance as essential components of food webs, the number of key species within marine ecosystems, and because they are fundamental for the bioturbation of sediments contributing to the dynamics of benthic communities, among others (Pawson, 2007; Belaústegui *et al.*, 2017). Some groups like sea urchins and sea cucumbers are important for fisheries trade worldwide. The green sea urchin *Hemicecentrotus pulcherrimus* (= *Strongylocentrotus pulcherrius*), distributed in Japan, Korea, and China, the red sea urchin *Mesocentrotus franciscanus* (= *Strongylocentrotus franciscanus*) found in the North East Pacific (Alaska to California), and the purple sea urchin *Strongylocentrotus intermedius* in Japan, Russia, and Korea have the highest demand globally (Stefánsson *et al.*, 2017). Sea cucumber species are also appreciated in the Asian market for medicinal and aphrodisiac uses (Vergara *et al.*, 2016). México, Belize, Panamá, Colombia, and Cuba have the highest species diversity in the Caribbean Sea possibly due to two factors: the rich coastal habitats, which are the most diverse in the region, and the increased research activity (Alvarado, 2011). In this context, it is important to study the species and their populations as some species from the Colombian Caribbean are extracted without any control and fished illegally for international commercialization (Alvarado, 2011).

Thanks to their diversity, mobility, and lifestyles, several species can live as epifauna or infauna (in burrows, perforated rocks, tide pools, etc.) in all marine benthic ecosystems and colonize different habitats including some pelagic species which spend most of their lives swimming in the water column, for example, *Eynypniastes eximia* (Class Holothuroidea, Order Elasipodida) (McClintock, 1994; Solís-Marín *et al.*, 2014). Echinoderms exhibit a variety of feeding strategies ranging from body absorption, herbivory, and detritivory to feeding on deposited material and suspended particles, although there are cases of strict specialists (McClintock, 1994; Solís-Marín, 1997; Lessios *et al.*, 2001; Belaústegui *et al.*, 2017), which increases the chances of finding them in different habitats and under different environmental conditions.

The phylum Echinodermata has approximately 7,510 species (WoRMS, 2022) divided into five classes: Crinoidea (lilies or sea feathers, 673 species); Asteroidea (starfish, 1,923 species); Ophiuroidea (brittle stars, 2,126 species); Echinoidea (sea urchins, 1,015 species), and Holothuroidea (sea cucumbers, 1,773 species) (Pawson, 2007; Pawson *et al.*, 2009; WoRMS, 2022), all of which have been recorded for the Colombian Caribbean whose current inventory includes 298 species (Benavides-Serrato *et al.*, 2011; Borrero-Pérez *et al.*, 2012; López-Sánchez *et al.*, 2013; Borrero-Pérez *et al.*, 2019; Borrero *et al.*, 2020). However, these studies do not include localities in the shallow coastal zone of the Department of Atlántico.

In a recent study, the CRA (2016) recorded the presence of the echinoids *Euclidaris tribuloides* (in Puerto Caimán), *Lytechinus variegatus*, and *Diadema antillarum* in the Department. No reference material or collection with specific localities was included in this study, except for the first species. Atlántico is one of the Colombian Caribbean coast departments where ecosystems studies and fauna registers are ongoing.

In this framework, and in the idea of suggesting measures for the protection and conservation of marine biodiversity, our study aimed to continue strengthening the knowledge of Atlántico's coastal zone by identifying the echinoderm species in this area and some

of the environmental conditions in which they are found. We conducted a taxonomic study with reference material of the species identified so far in several localities of the Department. This baseline information will be helpful for conservation issues, studying adaptations to extreme environments, management plans, and for decision-makers in the region.

Materials and methods

Study area

Atlántico is in the last stretch of the Magdalena River on its left flank, from the Canal del Dique (south) to its mouth in the Caribbean Sea. The coastal area of the department has a strong influence from the Magdalena River due to the contribution of sediments and organic and inorganic materials (Rangel-Buitrago *et al.*, 2015; Rangel-Buitrago *et al.*, 2017). Its 72-km coastline has diverse coastal ecosystems including beaches, coastal dunes, incipient coral communities, rocky shores, mangroves, and soft bottoms, and seagrasses have been recently recorded in some sectors (CRA, 2016).

The annual average surface water temperature in the department ranges from 25.5 °C to 29.5 °C and salinity is between 34.5 and 37 ppm (Posada & Henao, 2008). Seasonal variation includes two rainy periods (April-May and October-November) and two dry periods (December-March and July-September) (Rangel *et al.*, 2017). The average wind speed is less than 23 knots; higher velocities are associated with winds blowing from the NE during the dry periods. Lower values are observed from September to November related to winds blowing from the east (Rangel *et al.*, 2017).

Surveys were conducted from 2004 to 2019 along the coastline north to south from the mouth of the Magdalena River including the localities of Bocas de Ceniza and Puerto Mocho (Barranquilla municipality), and the beaches of Salgar, Solinilla, Castillo de Salgar (Puerto Colombia municipality), Puerto Velero, Caño Dulce, Turipana, Playa Mendoza, Santa Verónica (Juan de Acosta municipality), and Punta Astilleros (Piojo municipality) (Figure 1).

Sampling

Sampling and/or observations were done in different littoral areas along the Department's coastline. Unstructured sampling was done in rock formations, between groins and cliffs, in zig-zag trajectories along the sandy coast. For some ophiuroid collections, we used a 0.5 mm sieve.

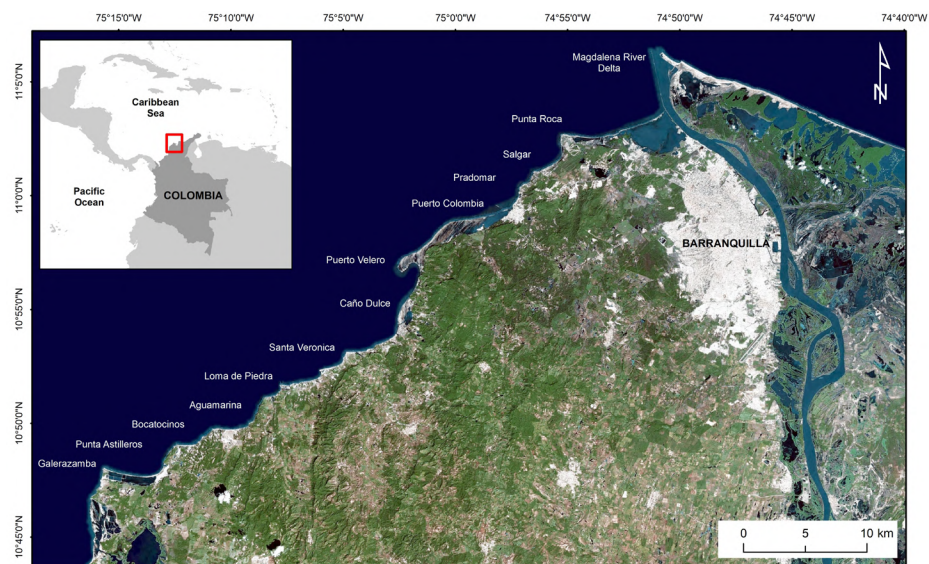


Figure 1. Locations where echinoderm collections or observations were done on the Atlántico Department coastline

Observations in the field included the habitat of collected or observed organisms. The organisms collected were anesthetized in $MgCO_3$ diluted in seawater and subsequently fixed in 70% alcohol (Hendler *et al.*, 1995). In the laboratory, specimens were placed in distilled water, dried on absorbent paper, and photographed. Taxonomic keys available for each class were used for species identification. We followed the taxonomic order of Clark & Downey (1992) for the Asterozoa, Smith *et al.* (1995) for Ophiurozoa, Serafy (1979) for Echinozoa, and Miller & Pawson (1984) for Holothurozoa. We used the spicules extracted from tentacles and dorsal and ventral epidermis tissue for holothurian identification. Specimens were deposited in the Echinodermata collection of the Museo de Historia Natural Marina de Colombia (MHNMC, MAKURIWA) in Santa Marta. The habitat item describes the environment where the species were observed in the department, plus general information on the species.

Results

We identified four classes, seven orders, eight families, ten genera, and 16 species. The most frequently observed species were *Mellita quinquesperforata* and *Holothuria (Selenkothuria) glaberrima*. This is the first record of *Amphiodia trychna* in continental areas of the Colombian Caribbean since Borrero *et al.* (2019) recorded this species in insular areas. Thirteen species were recorded for the first time in Atlántico, of which only three had been previously recorded. The species are presented in taxonomic order below.

Class **Asterozoa** De Blainville, 1830

Order **Paxillosida** Perrier, 1884

Family **Luidiidae** Sladen, 1889

Luidia senegalensis (Lamarck, 1816) (Figures 2A-B)

Collected material: One specimen INV EQU5155, September 16, 2018, Punta Astilleros. It was found dead on the beach during local fishing activities.

Locations in Atlántico Department: Puerto Mocho, Puerto Velero, Caño Dulce, Santa Verónica, and Punta Astilleros.

Previous records in Colombia: La Guajira, Magdalena, Bolívar, Córdoba, and Sucre Departments (references in Benavides-Serrato *et al.*, 2011).

Distribution: From South Florida, North America, along the coast of Central America to southern Brazil (references in Benavides-Serrato *et al.*, 2011).

Depth: Individuals were observed between 1 and 5 m depth. Although it inhabits between 1 and 64 m depth, it is rarely found at more than 40 m (Clark & Downey, 1992).

Habitat: The species was observed solitary on sandy or muddy sediments, generally in waters with low wave action.

Remarks: *Luidia senegalensis* may be threatened in tourist areas as bathers find them easily and extract them from their environment. This is a common species in the area; it is caught incidentally in trammel nets and other fishing nets and later thrown on the beach, which could be affecting resident populations and their role in the ecosystem.

Family **Astropectinidae** Gray, 1840

Astropecten articulatus (Say, 1825) (Figures 2C-D)

Collected material: Two specimens INV EQU5156, October 10, 2004, Bocas de Ceniza, collected >5m depth by a fishing trammel net. Two specimens INV EQU5157, July 2, 2006, Puerto Mocho, collected >5m depth by a fishing trammel net.

Locations in Atlántico Department: Bocas de Ceniza and Puerto Mocho.

Previous records in Colombia: La Guajira, Gulf of Urabá, and San Andres Island (Benavides-Serrato *et al.*, 2011).

Distribution: From southern Florida, North America, along the coast of Central America to southern Brazil (References in Benavides-Serrato *et al.*, 2011).

Depth: Material was collected at > 5m.

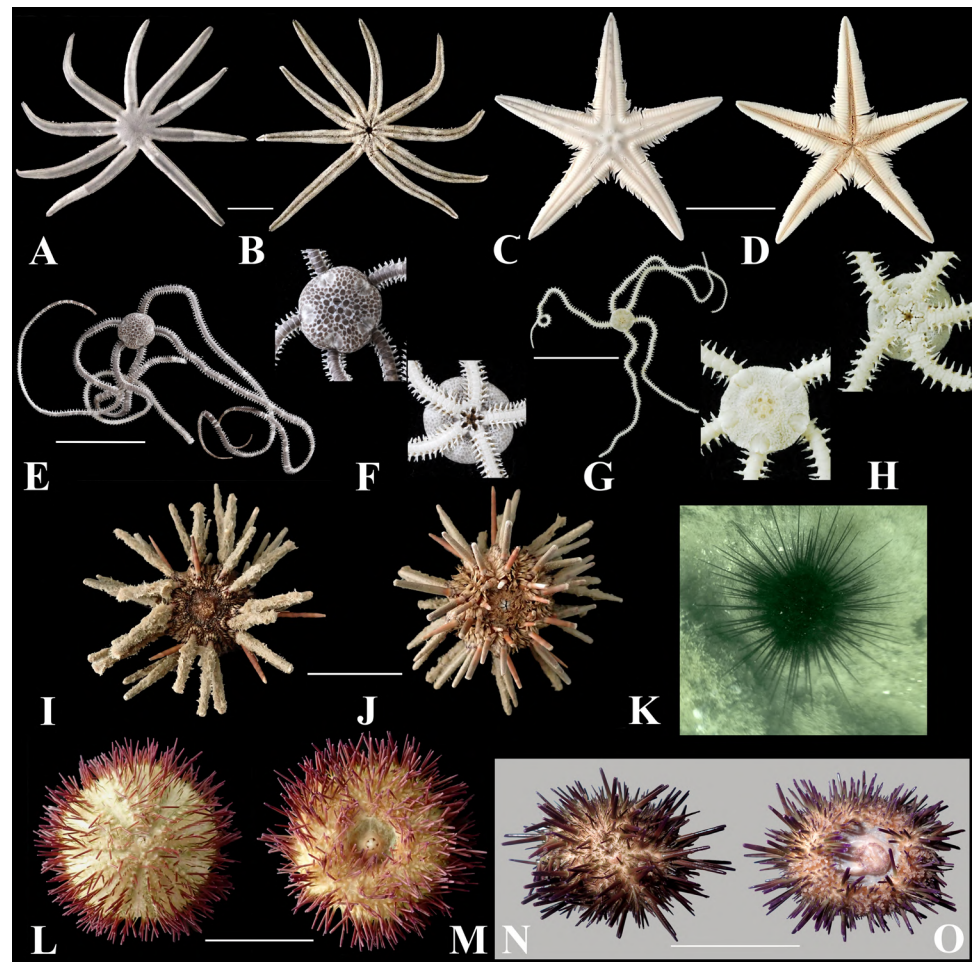


Figure 2. Species of echinoderms present on the coastline of the Atlántico Department. **A-B.** *Luidia senegalensis* INV EQU5155; **C-D.** *Astropecten articulatus* INV EQU5157; **E.** *Amphiodia riisei* INV EQU5159, **F.** Detail aboral and oral views; **G.** *Amphiodia trychna* INV EQU5141, **H.** Detail aboral and oral views; **I-J.** *Eucidaris tribuloides tribuloides* INV EQU5160; **K.** *Diadema antillarum*; **L-M.** *Lytechinus variegatus variegatus* INV EQU5161; **N-O.** *Echinometra lucunter lucunter* INV EQU5164. Scales: **A-D, I-J, L-O:** 5 cm, **E, G:** 1 cm

Habitat: The species was found on sandy mud sediments, generally solitary, in waters with moderate action. This is a common species in soft-bottom habitats along continental shelves of North and South America (Abreu-Pérez *et al.*, 2005).

Remarks: Like *L. senegalensis*, this species was caught in fishing nets incidentally by fishermen and is subject to the same problems.

Class Ophiuroidea Gray, 1840

Order **Ophiurida** Müller and Troschel, 1840

Family **Amphiuridae** Ljungman, 1867

Amphiodia riisei (Lütken, 1859) (Figures 2E-F)

Collected material: One specimen INV EQU5159, March 21, 2017, Puerto Velero, collected at 50 cm depth.

Locations in Atlántico Department: Puerto Velero.

Previous records in Colombia: Sucre and Bolívar departments (references in Benavides-Serrato *et al.*, 2011 as *Ophiophragmus riisei* (Lütken in: Lyman, 1860)).

Distribution: From southern Florida, North America, along the coast of Central America to southern Brazil (references in **Benavides-Serrato et al.**, 2011).

Depth: Material observed at 50 cm.

Habitat: The species was collected in moderate wave action, on the thinnest surface layer of sediment with a muddy texture. According to **Manso et al.** (2008) and **Pawson et al.** (2009), the species is found in sandy sediments formed by very fine sand, fine sand, medium sand, coarse sand, and clay.

Amphiodia trychna H.L. Clark, 1918 (**Figures. 2G-H**)

Collected material: One specimen INV EQU5141, October 12, 2010, Puerto Velero, collected at 30 cm depth by sieving sediments.

Locations in Atlántico Department: Puerto Velero.

Previous records in Colombia: San Andres Island (**Borrero et al.**, 2019).

Distribution: From southern Florida, North America, along the coast of Central America to southern Brazil (references in **Hendler et al.**, 1995).

Depth: Material observed at 30 cm.

Habitat: The species was collected in the thin surface layer of sediment on muddy substrates with low wave action. Arms of other ophiuroid species were also found but they were not included due to the lack of disks. According to **Hendler et al.** (1995), the species can be found in sandy or muddy bottoms without vegetation, in *Thalassia* beds, mangrove channels, and sandy plains associated with reefs.

Remarks: First record for continental areas in the Colombian Caribbean Sea.

Class Echinoidea (Leske, 1778)

Order **Cidaroidea** Claus, 1880

Family **Cidaridae** Gray, 1825

Eucidaris tribuloides tribuloides (Lamarck, 1816) (**Figures 2I-J**)

Collected material: One specimen INV EQU5160, July 29, 2017, Puerto Caiman bank, collected on hard substrates at 1.5 m depth.

Locations in Atlántico Department: Salgar, Castillo de Salgar, Puerto Caiman bank.

Previous records in Colombia: Recorded throughout the Colombian Caribbean including the common area between Colombia and Jamaica (references in **Borrero-Pérez et al.**, 2012).

Distribution: From Cape Hatteras in North America to southern Brazil (references in **Borrero-Pérez et al.**, 2012).

Depth: The species was observed between 0.3 and 2 m.

Habitat: Observed in outstanding cavities under the Castillo de Salgar rock formations associated with *Echinometra lucunter lucunter*, gastropods (*Nerita versicolor*, *Nerita tessellata*, *Plicopurpura patula*), some chitons, and a large community of algae. Castillo de Salgar is an area with highly turbid water, high wave action, and coastal drains from nearby houses. The individuals in Puerto Caiman bank were observed in exposed areas, in coral formations mainly composed of *Millepora* spp., and on rocky bottoms sharing the habitat with sponges, corals, and annelids. This species is usually found on coral reefs, especially within crevices; it has also been seen associated with seagrasses or under rocks and calcareous fragments in shallow waters (**Hendler et al.**, 1995).

Remarks: 1 ind/m² was observed in the rock formation below Castillo de Salgar; in contrast, a high density of 20 ind/m² was found in Puerto Caiman bank.

Order **Diadematoidea** Duncan, 1889

Family **Diadematidae** Gray, 1855

Diadema antillarum Philippi, 1845 (**Figure 2K**)

Collected material: No material was collected, only visual records of the species.

Locations in Atlántico Department: Marina de Puerto Velero, Puerto Caiman bank.

Previous records in Colombia: Distributed along the Colombian Caribbean Sea (references in **Borrero-Pérez et al.**, 2012).

Distribution: Eastern Atlantic, and western Atlantic from the Gulf of México to Brazil (references in **Borrero-Pérez et al.**, 2012).

Depth: The species was observed between 1 and 2 m, although it can be found from 0 to 400 m, usually at less than 50 m (**Pawson et al.**, 2009).

Habitat: In Puerto Caiman bank it was found in hard bottoms dominated by *Millepora* spp. together with *Eucidaris tribuloides tribuloides*, *Echinometra lucunter lucunter*, and *Lytechinus variegatus*. It was observed on the dock piles in the marina of Puerto Velero.

Remarks: Several individuals were observed in Puerto Caiman bank in May 2016 (dry season), although only once. It seems that the species migrates at certain times of the year. It should be noted that the species photographed in **CRA** (2016) clearly does not correspond to *Diadema antillarum*, but rather to *Echinometra lucunter lucunter*.

Order **Temnopleuroida** Mortensen 1942

Family **Toxopneustidae** Troschel, 1872

Lytechinus variegatus variegatus (Lamarck, 1816) (**Figures 2L-M**)

Collected material: One specimen INV EQU5161, July 29, 2017, Puerto Caiman bank, collected on hard bottoms at 1.5 m depth. One specimen INV EQU5162, December 18, 2017, Puerto Velero, was collected on soft bottoms at 1.5 m depth.

Locations in Atlántico Department: Puerto Velero and Puerto Caiman bank.

Previous records in Colombia: The subspecies *L. variegatus variegatus* has been recorded along the coasts of the Colombian Caribbean (references in **Borrero-Pérez et al.**, 2012).

Distribution: The subspecies inhabits from southern Florida to Sao Paulo, Brazil (**Serafy**, 1979).

Depth: Material observed at 30 cm. It has been recorded between 0 and 250 m (**Pawson et al.**, 2009).

Habitat: This species is frequent in the hard bottoms of Puerto Caiman bank; high-wave action is common in the area, although the species is known to inhabit waters with low wave dynamics, mainly associated with seagrasses (**Gómez-Gaspar**, 2000). It can cover part of its upper test with seagrass leaves, fragments of shells, and gravel (**Hendler et al.**, 1995), as seen in our area of study; it can also live on soft bottoms (**Pawson et al.**, 2009).

Remarks: The species was observed in the same habitat with *Echinometra lucunter lucunter* and *Eucidaris tribuloides tribuloides*.

Order **Echinoida** Claus, 1876

Family **Echinometridae** Gray, 1825

Echinometra lucunter lucunter (Linné, 1758) (**Figures 2N-O**)

Collected material: One specimen INV EQU5163, May 24, 2009, Castillo de Salgar, was collected on hard bottoms <1m depth. Two specimens INV EQU5164, May 31, 2009, Castillo de Salgar, were collected on hard bottoms <1 m depth.

Locations in Atlántico Department: Castillo de Salgar, Salgar, Puerto Caiman bank.

Previous records in Colombia: Throughout the Colombian Caribbean, including San Andrés y Providencia (**Borrero-Pérez et al.**, 2002).

Distribution: The species is widely distributed in the Caribbean reaching the coasts of Brazil. It has also been recorded in West Africa (**Hendler et al.**, 1995).

Depth: Material observed at <1 m depth. It has been recorded between 0 and 45 m (**Hendler et al.**, 1995).

Habitat: The species was found in soft bottoms living between the spaces of the groin (on sand) and in crevices of the rocky coast with high and strong wave dynamics.

Remarks: Five individuals were observed on sediments in a gregarious disposition half-hidden among rocky cavities in a 3 m² area of an ancient groin in Salgar beach; there

the animals had a light brown color in the spines of their aboral region and purple tubercles in the anterior region; the peristomic membrane was pale pink with white spots and purple inter-ambulatory grooves covered by spines with blunt-tipped terminals, small teeth not very visible, the diameter of the test ranged from 58.5-44.10 mm and the height was 32.6-22.4 mm. These sea urchins were found in a different way than what is commonly observed in the Colombian Caribbean, as they perched on sandy substrates with the oral side directly attached to the sediment, possibly due to the absence of a consolidated rocky substrate in the study area. The species adapt to environmental limitations, which could explain the small size of the teeth. Several individuals were also observed on hard bottoms of Puerto Caiman bank. The species was found sharing the habitat with *Holothuria (Selenkothuria) glaberrima*, *Eucidaris tribuloides tribuloides*, and *Lytechinus variegatus variegatus*.

Order **Clipeasteroidea** A. Agassiz, 1872

Family **Mellitidae** Stefanini, 1911

Encope michelini (L. Agassiz, 1841) (**Figures 3A-B**)

Collected material: Six specimens INV EQU5165, April 10, 2008, Santa Verónica, were collected on sandy bottoms at 1 m depth. One specimen INV EQU5166, July 23, 2017, Puerto Velero, was collected on the beach. One specimen INV EQU5167, August 3, 2017, Santa Verónica, was collected on the beach.

Locations in Atlántico Department: Puerto Velero and Santa Verónica.

Previous records in Colombia: Magdalena (**Borrero-Pérez et al.**, 2012) and Córdoba departments (**Quirós-Rodríguez**, 2015).

Distribution: From Cape Hatteras (North America) to Colombia (references in **Borrero-Pérez et al.**, 2012).

Depth: Material observed at 1 m. It has been recorded between 3 and 90 m (**Hendler et al.**, 1995).

Habitat: In Atlántico it was found on sand in the most superficial part of the sediments. This species is associated with sandy substrates with calcareous fragments and soft bottoms (**Pawson et al.**, 2009).

Remarks: The species was found in Santa Verónica sharing its habitat with *Mellita quinquiesperforata*. *Encope michelini* was found less frequently, around 2 ind/m². The species had an olive-green color on the dorsal surface, lighter in the oral part, unlike those recorded by **Hendler** (1995) in Florida, whose dorsal surface presents a range of brown to purple coloration.

Leodia sexiesperforata (Leske, 1778) (**Figures 3C-D**)

Collected material: One specimen INV EQU5168, October 4, 2008, Santa Verónica, was collected on the sandy bottom at 80 cm depth. One specimen INV EQU5169, August 3, 2017, Santa Verónica, was collected on the beach.

Locations in Atlántico Department: Salgar, Castillo de Salgar, Puerto Caiman Bank, Balneario de Turipana, and Santa Verónica.

Previous records in Colombia: La Guajira, Magdalena, Bolívar, and San Andrés y Providencia departments (references in **Borrero-Pérez et al.**, 2012).

Distribution: From southern Florida, along the coast of Central America to southern Uruguay (references in **Borrero-Pérez et al.**, 2012).

Depth: Material observed at 80 cm. It has been recorded between 0 and 60 m but is common at less than 25 m (**Hendler et al.**, 1995).

Habitat: Apparently, the species is distributed along the Atlántico Department coastline, although it is not frequent throughout the year.

Mellita quinquiesperforata (Leske, 1778) (**Figures 3E-F**)

Collected material: 30 specimens INV EQU5170, October 4, 2008, Santa Verónica, were collected on sandy bottoms at 80 cm depth. Eleven specimens INV EQU5171, May 16, 2009, Puerto Colombia, were collected on sandy bottoms at 80 cm depth. Four

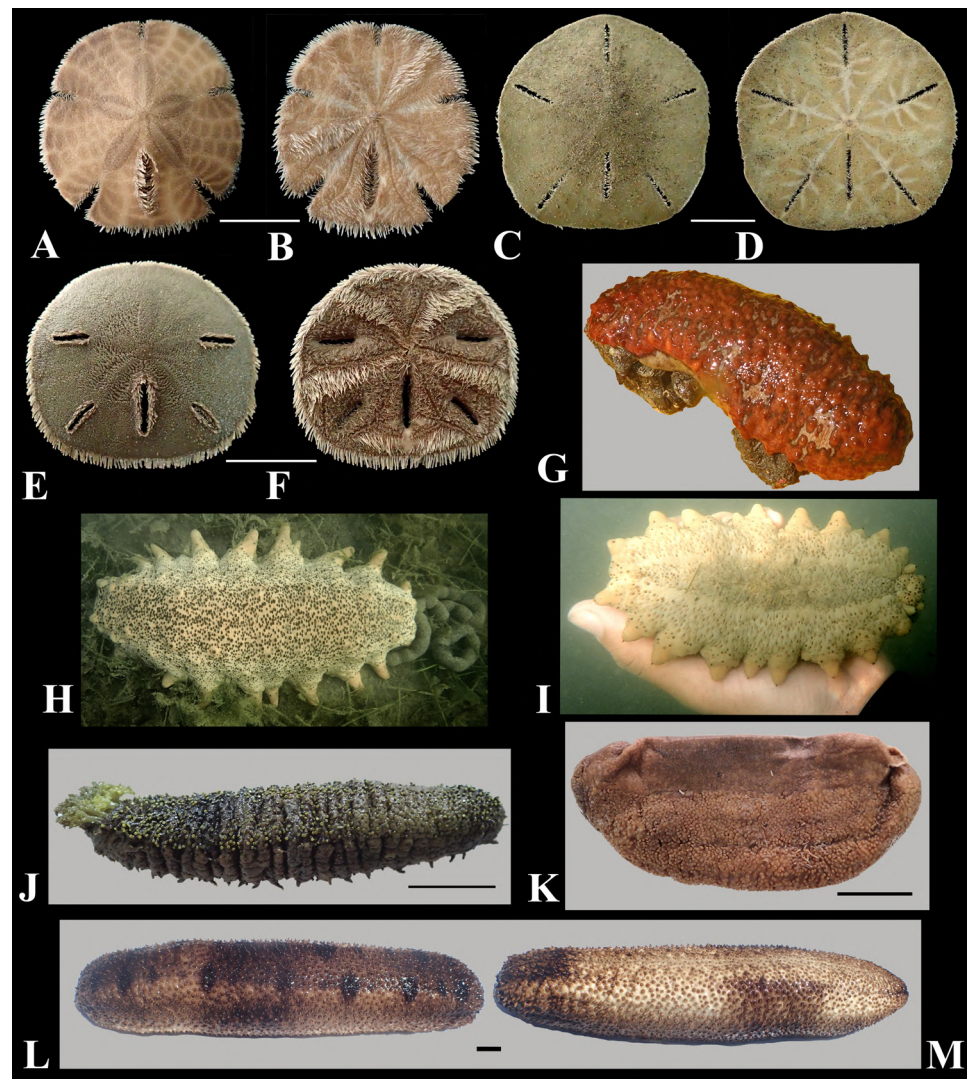


Figure 3. Species of echinoderms present on the coastline of the Atlántico Department. **A-B.** *Encope michelini* INV EQU5165; **C-D.** *Leodia sexiesperforata* INV EQU5169; **E-F.** *Mellita quinquesperforata* INV EQU5172; **G.** *Isostichopus* sp.; **H-I.** *Isostichopus badionotus*; **J.** *Holothuria (Halodeima) grisea* INV EQU5174; **K.** *Holothuria (Selenothuria) glaberrima* INV EQU5175; **L.** *Holothuria (Theelothuria) princeps* recorded on April 10, 2016. Scales: **A-F:** 2 cm, **H-I:** hand scale, **J-K:** 2 cm, **L-M:** 1.2 cm

specimens INV EQU5172, September 16, 2018, Punta Astilleros, were collected on the beach. Five specimens INV EQU5173, August 3, 2017, Playa Mendoza, were collected on the beach.

Locations in Atlántico Department: Salgar, Puerto Colombia, Turipana, Playa Mendoza, Santa Verónica, and Punta Astilleros.

Previous records in Colombia: Magdalena, Bolívar, and Córdoba Departments (References in Borrero-Pérez *et al.*, 2012; Quirós-Rodríguez, 2015).

Distribution: On the coasts of North America, Florida, and the Bahamas Islands (Hendler *et al.*, 1995).

Depth: Material observed at 80 cm. It has been recorded between 1 and 180 m (Pawson *et al.*, 2009).

Habitat: It was common to observe individuals half-buried or covered by a light layer of sand, unlike *Encope michelini* which was recorded in the most superficial part of the sediment.

Remarks: This was the most frequent and abundant species in the study area with a density greater than 50 ind/m² according to the count done with a 1-m² grid. This sand dollar was commonly found in large agglomerations of sandy infralittoral mud at 1 m depth, generally in high wave areas. In some records, malformations in the test were found in over 20 ind/m², similar to that reported by **Gray & Weihe** (1968 in **Hendler** 1995), who attributed them to predation by the blue crab *Callinectes sapidus* and wave action during storms. In Puerto Colombia, an unidentified crab species is a potential predator of this sand dollar.

Class **Holothuroidea** (Brainville, 1834)

Order **Aspidochirotida** Grube, 1840

Family **Stichopodidae** Haeckel, 1896

***Isostichopus* Deichmann, 1958**

***Isostichopus* sp. (Figure 3G)**

Collected material: No material was collected; only the photographic record was obtained. May 22, 2016.

Locations in Atlántico Department: Puerto Caiman bank.

Depth: The individual was observed at 1 m.

Habitat: This species was observed on sandy sediments among corals and rocks.

Remarks: The individual observed could correspond to a new species. A study is currently underway to determine the differences within the genus *Isostichopus* in the Colombian Caribbean (pers. com. G. Borrero-Invemar).

***Isostichopus badionotus* (Selenka, 1867) (Figures 3H-I)**

Collected material: No material was collected; only the photographic record was obtained. April 23, 2017.

Locations in Atlántico Department: Puerto Velero.

Previous records in Colombia: Distributed throughout the Colombian Caribbean including San Andrés y Providencia (references in **Borrero-Pérez et al.**, 2012).

Distribution: Western Atlantic, from South Carolina to Brazil. Also recorded in the eastern Atlantic (references in **Borrero-Pérez et al.**, 2012).

Depth: The individual was observed at 1 m depth. It has been recorded between 0 and 70 m (**Hendler et al.**, 1995).

Habitat: The species was observed on sandy bottoms among underdeveloped seagrasses.

Remarks: Only one individual was observed during sampling. However, the species can reach high densities in other Caribbean areas; for example, 24 individuals were observed in 400 m² in a study in Yucatán (**López-Rocha**, 2012). The species was confirmed by G. Borrero-Invemar.

Family **Holothuriidae** Ludwig, 1894

***Holothuria (Halodeima) grisea* Selenka, 1867 (Figure 3J)**

Collected material: Two *specimens* INV EQU5174, July 23, 2017, Puerto Velero, were collected on the beach.

Locations in Atlántico Department: Puerto Velero.

Previous records in Colombia: La Guajira, Magdalena, Bolívar, San Andrés Island (references in **Borrero-Pérez et al.**, 2012).

Distribution: Western Atlantic, from Florida to southern Brazil. Also recorded in the eastern Atlantic (references in **Borrero-Pérez et al.**, 2012).

Depth: The material was observed at 40 cm.

Habitat: The species was observed exposed on intertidal sandy bottoms or wrapped-among seaweed, probably by wave action or due to bathers' intervention.

Remarks: According to **Hendler *et al.*** (1995), red or reddish-yellow coloration predominates in the species contrasting with brown spots while the papillae show yellow tips on the dorsal surface of the body. However, the individuals found in this study have white papillae with generally brown spots.

Holothuria (Selenkothuria) glaberrima Selenka de 1867 (**Figure 3K**)

Collected material: Two specimens INV EQU5175, November 4, 2006, Salgar, were collected close to a groin.

Locations in Atlántico Department: Salgar, Castillo de Salgar, and Caño Dulce.

Previous records in Colombia: Isla Tierra Bomba and Santa Marta (**Caycedo, 1978; Ortiz-Gómez, 2006**).

Distribution: From the Gulf of México to Venezuela (references in **Borrero-Pérez *et al.*, 2012**).

Depth: The material was observed at 30 cm.

Habitat: The individuals were collected on rocky substrates covered with abundant algae and exposed to strong wave action. This species is found from intertidal zones down to 42 m (**Pawson *et al.*, 2009**).

Remarks: This species was recorded in areas with high wave action, half-buried in the sand, in the intermediate spaces of the rocks that make up the groin, but rarely on the surface of that structure. In contrast to the observations by **Caycedo (1978)**, the species was recorded on sandy substrates with three-quarters of the U-shaped body buried and the tentacles extended.

On the Castillo de Salgar rock formation, 1-2 individuals were recorded for each rock associated with *Echinometra lucunter lucunter*, the gastropods *Nerita versicolor*, *Nerita tessellat*, and *Plicopurpura patula*, as well as some chitons and hermit crabs. Some individuals were observed in sediments with trapped litter (sticks, bottles, plastic). They were observed feeding on pieces of *Eichhornia crassipes*, a widespread plant that floats from the Magdalena River.

Holothuria (Theelothuria) princeps Selenka, 1867 (**Figures 3L-M**)

Collected material: One specimen INV EQU5023, June 18, 2019, Puerto Velero. Photographic records in the field: three individuals, April 10, 2016; one individual, May 11, 2019, Puerto Velero.

Locations in Atlántico Department: Puerto Velero.

Previous records in Colombia: Santa Marta (**Borrero-Pérez *et al.*, 2012**).

Distribution: From the Gulf of México to Venezuela (references in **Borrero-Pérez *et al.*, 2012**).

Depth: The material was observed at 50 cm.

Habitat: The species was observed on sandy bottoms among underdeveloped seagrasses.

Remarks: The species was confirmed by G. Borrero-Invemar.

Discussion

Sixteen species were found in this study. However, this number is expected to increase significantly in the future since there are still various locations, depths, and ecosystems to explore, especially in ophiuroids inhabiting the coastal zone as the sampling intensity in this class was low. It is important to emphasize that more quantitative and population studies are needed to establish the temporality of the species.

With the information obtained so far, we may conclude that coastline Atlántico echinoderm taxonomic composition is not so rich as that found in studies in other Colombian Caribbean areas (*e.g.*, **Caycedo, 1978; Gallo, 1988a, 1988b; Borrero-Pérez *et al.*, 2019**). This may be explained by the fact that the study area is especially affected by high sedimentation and low salinity in some periods of the year due to the Magdalena River (**Molina *et al.*, 1998**). Based on our observations, the influence of sedimentation

caused by the river plume and the increase in water turbidity may not be a very favorable factor for the larval establishment of the most common Colombian Caribbean echinoderm species. Atlántico's coastline may be an exceptional laboratory regarding the adaptation to extreme turbidity and suspended sediment environments that have not been explored on the Colombian Caribbean coast.

We observed that some species do not correspond to the ecological conditions that have been documented in other areas. For example, *Eucidaris tribuloides tribuloides* was observed with higher frequency on hard bottoms but also in sandy sediments, in contrast to the description by **Hendler et al.** (1995) affirming that the species is found in coral reef cracks. It is perhaps the most abundant echinoid species in the Department according to the photographic records and the field data where coral communities and seagrasses are incipient. Many species normally found in those ecosystems were not reported until now, or their population densities are very low, as is the case of *Echinometra lucunter lucunter*. In the Tayrona National Park there has been a maximum of 176 sea urchins/m² (**Romero-Paz**, 2009) while in the Magdalena Department, *Diadema antillarum* recorded density has been 12 ind/m² (**González & García**, 2011).

Class Holothuroidea stands out; no previous records of this class were known for the area. As in other localities of the Colombian Caribbean, this class was massively and illegally exploited in Atlántico's coastal area in the early 2000s (Pers. Com. fishers of the region, 2022). The impact caused on the species identified, or others that may have been affected, is unknown. Therefore, it is essential to continue studying and monitoring this group.

Conclusions

We identified four classes, seven orders, eight families, ten genera, and 16 species, 13 of which were the first records for Atlántico. The most frequently observed species were *M. quinquiesperforata* and *H. (S.) glaberrima*. It should be noted that *E. tribuloides tribuloides* was found exposed on rocks or sediments, and *E. michelini* was always found sharing the habitat with *M. quinquiesperforata*. Also, some *E. lucunter* individuals are different from those found in the department of Magdalena in terms of size, the shape of the test, spines, and teeth.

Some species of the community of echinoderms in the shallow waters of Atlántico occur regularly but not permanently throughout the year. This fauna is composed of species adapted to high stress or highly disturbed environmental conditions in an area of high sedimentation and turbidity. Future studies will obtain information on other species as more localities and habitats are explored. Further studies on taxonomy, including molecular aspects, are required, as well as population and development studies, among others. Finally, the effect of sedimentation on these species should be investigated.

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Authors' contributions

YFCR: Collecting data, Writing – original draft, Writing – review & editing. AGC: Conceptualization, Collecting data, Writing – original draft, Writing – review & editing. JERP: Collecting data, Writing – review & editing.

Conflicts of interest

Authors declare that they have no conflicts of interest.

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