Papéis Avulsos de Zoologia
Museu de Zoologia da Universidade de São Paulo

ARTICLE

Echinoderms from the Gulf of Venezuela, north-western coast of Venezuela

Nínive Espinoza-Rodríguez[1,5]; Yumara Pernía[2,6]; Héctor Severeyn[2,7]; Yajaira García de Severeyn[3,8] & Héctor Barrios-Garrido[1,4,9]

[1] Universidad del Zulia (LUZ), Facultad Experimental de Ciencias, Departamento de Biología, Laboratorio de Ecología General (LEG). Maracaibo, Zulia, Venezuela.
[2] Universidad del Zulia (LUZ), Facultad Experimental de Ciencias, Departamento de Biología, Laboratorio de Sistemática de Invertebrados Acuáticos (LASIA). Maracaibo, Zulia, Venezuela.
[3] Universidad del Zulia (LUZ), Facultad Experimental de Ciencias, Departamento de Biología, Laboratorio de Cultivo de Invertebrados Acuáticos (LACIA). Maracaibo, Zulia, Venezuela.
[4] James Cook University (JCU), Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER). Townsville, QLD, Australia.
[5] ORCID: http://orcid.org/0000-0002-6133-267X. E-mail: espinozaninive@gmail.com (corresponding author)
[6] ORCID: http://orcid.org/0000-0003-4079-3730. E-mail: yumarapernia@gmail.com
[7] ORCID: http://orcid.org/0000-0003-4200-1602. E-mail: hectorsevereyn@yahoo.com
[8] ORCID: http://orcid.org/0000-0001-7099-5531. E-mail: ygsevereyn@yahoo.com
[9] ORCID: http://orcid.org/0000-0002-7027-2656. E-mail: hbarriosg@fec.luz.edu.ve

Abstract. Echinoderms are a major group of marine invertebrates that often play integral roles within the marine ecosystem. Studies about their occurrence, abundance, and distribution in Venezuela are focused in the central-eastern coasts; hence the aim of this study is to describe the echinoderm community in the north-western coast of the Gulf of Venezuela. Samples were collected from three sites in the Venezuelan Guajira Peninsula (Castilletes, Porshoure, and Kazuzain) where patchy coral reefs and seagrass meadows are abundant. According to the substrate, two methods were performed using quantitative (1 m^2 quadrates), and qualitative free-diving observations. All organisms were counted and identified to the lowest possible taxonomic level; finally, diversity (Shannon diversity index), richness (number of species), and dominance in the different sampled substrates were recorded. The updated list of echinoderms of the Gulf of Venezuela reported in this research, includes 20 genera, 15 families, 10 orders, four classes, and 28 species. The richest class was Ophiuroidea, with 18 species, followed by Asteroidea, Echinoidea and Holothuroidea, with three species each. Castilletes was the sampling site with the higher number of species (18 species), followed by Porshoure (15 species), and lastly Kazuzain (12 species). Our observations indicate that the number of species and abundance were higher when found in coral reefs (21 species, 80.69% of the total collected individuals) in contrast to the species found in seagrass beds (16 species, 19.31% of the total of individuals collected). This updated list of echinoderms represents 11.54% of the total diversity of the phylum in the marine areas from the coast of Venezuela; it is suggested that this percentage is greatly influenced by the differences of habitats and substrates alongside the north-western coast in the Gulf of Venezuela.

Keywords. Marine invertebrates; Venezuelan Guajira Peninsula; Coral reefs; Seagrass beds.

INTRODUCTION

The phylum Echinodermata is, except for a few brackish water forms, a group of marine animals with radial symmetry that includes sea lilies (Crinoidea), brittle stars, basket stars (Ophiroidea), starfish (Asteroidea), sea urchins, sand dollars (Echinoidea), and sea cucumbers (Holoturoidea) (Hendler *et al.,* 1995; Pawson, 2007; Azofeifa-Solano *et al.,* 2017; Kuk-Dzul *et al.,* 2019). This phylum consists of approximately 7,000 living species and 13,000 extinct species (Pawson, 2007). It is well known that the Caribbean Sea is considered a unique bio-geographic region, and it is among the top five hotspots in the world for marine biodiversity (Rivera-Monroy *et al.,* 2004). In the Wider Caribbean, the echinoderm diversity is composed of 433 species, 237 genera, 80 families, and 29 orders, catalogued in five classes, with four endemic species (Alvarado, 2011; Alvarado & Solís-Marín, 2013), which represents 6.5% of the total diversity of the phylum worldwide (Alvarado, 2011).

In Venezuela, echinoderms have been poorly studied, in contrast to other groups of marine invertebrates (Noriega *et al.,* 2006; Alvarado, 2011; Alvarado & Solís-Marín, 2013). Lodeiros *et al.* (2013) listed 234 species, 97.97% from the Caribbean coast, and 2.13% from the Atlantic

Pap. Avulsos Zool., 2021; v.61: e20216151
http://doi.org/10.11606/1807-0205/2021.61.51
http://www.revistas.usp.br/paz
http://www.scielo.br/paz
Edited by: Marcelo Veronesi Fukuda
Received: 10/02/2021
Accepted: 26/04/2021
Published: 04/06/2021

ISSN On-Line: 1807-0205
ISSN Printed: 0031-1049
ISNI: 0000-0004-0384-1825

coast of Venezuela. The most diverse class is Asteroidea (26.92%), followed by Holothuroidea (22.65%), and lastly Crinoidea (6.84%). However, they suggest that the list of echinoderms from Venezuela is more extensive than presented, and the distribution of these organisms requires the incorporation of more detailed spatial analyses including the entire Venezuelan coastline.

Thirteen ecoregions were described for the Venezuelan coast, characterized by their ecological, physical, and oceanographic features (Miloslavich *et al.,* 2003). Previous research has found that the Gulf of Venezuela has the smallest number of echinoderms species recorded for the country (1.67%), with only eight species identified, distributed in six genera, six families, and five orders (Lodeiros *et al.,* 2013). Studies on taxonomy, ecology of echinoderm populations and communities have been focused primarily in the central-eastern coasts of the country, mostly referring to abundance and distribution of Echinoidea, Holothuroidea, and Ophiuroidea (Lodeiros *et al.,* 2013); hence the small representation of the phylum in the Gulf of Venezuela. The aim of this study is to describe the echinoderm community from the north-western coast of the Gulf of Venezuela and present an updated list of the echinoderms for this region.

MATERIAL AND METHODS

Study area

The study sites are located in the Gulf of Venezuela, northern South America (00°45′-15°40′N, 59°47′-73°22′W), and comprise the northwest coast Venezuelan Guajira Peninsula. This border area has an extension of approximately 88 km, from the town of Neima to Castilletes. Within this coastline, three sampling sites with coral reefs and seagrass meadows were chosen: Castilletes, Porshoure, and Kazuzain (from north to south) (Fig. 1) (Morán *et al.,* 2014).

These localities present an arid-semiarid climate, which is marked seasonally in its precipitation and the action of the northeast trade winds (Masciangioli & Febres, 2000; Medina & Barboza, 2003). The total annual rainfall

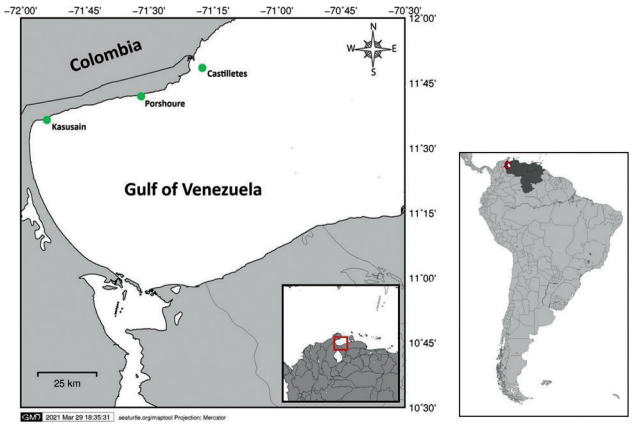

Figure 1. Geographical location of sampling sites (Kazuzain, Porshoure, Castilletes) within the Gulf of Venezuela and its relative position in South America.

is 1,000 mm and it is distributed in different amounts throughout the annual cycle, with two marked periods (dry and wet). The dry period is from December to April, with its peak between February and March; these months are characterized by the total absence of rain. The rain period is from July to November, with maximum precipitation records in October, with approximately 200 mm. From April to June, it is known to be a transition stage between these two periods (Masciangioli & Febres, 2000; Álvarez-León *et al.,* 2003).

General descriptions of the sampling sites

Kazuzain (K) is located at 11°36′27.5″N, 71°53′48.7″W (Fig. 1): It is an area surrounded by the creeks Neima, at the south, and Cojoro, to the north, which discharge a large volume of water during rainy seasons and produce a high rate of sediment resuspension (Rodríguez, 2000; Morán *et al.,* 2014; Rojas-Cañizales *et al.,* 2020). This locality is characterized by patches of seagrass meadows with short leaves (López-Hernández *et al.,* 2010) and some scattered stony corals (Barrios-Garrido *et al.,* 2016). Sample collection average depth was 3 m (Pernía, 2011).

Porshoure (P) is located at 11°41′58″N, 71°31′47″W (Fig. 1): This locality is characterized by large patches of seagrass meadows and small patches of scattered coral reefs. The sediment resuspension rate is lower than in Kazuzain, recording at several points total water transparency (Nava & Severeyn, 2010; Wildermann, 2012; Morán *et al.,* 2014). Sample collection average depth was 4 m (Pernía, 2011; Morán *et al.,* 2014).

Castilletes (C) is located at 11°48′30″N, 71°23′25″W (Fig. 1): It is characterized by large patches of seagrass meadows with larger leaves than in Kazuzain (López-Hernández *et al.,* 2010) and large patches of coral reefs (Barrios-Garrido *et al.,* 2016). The sediment resuspension is almost non-existent, and it is heavily influenced by the Caribbean Sea currents and winds (Rodríguez & Morales, 2000; Wildermann, 2012; Barrios-Garrido *et al.,* 2016). Sampling average depth was 4 m (Pernía, 2011; Morán *et al.,* 2014).

Data collection and analysis

Data was collected between April and September 2010, following two methodologies depending on the substrate where the specimens were collected: seagrass beds and coral reef patches. For the patches of seagrass beds, we established a 100 m transect perpendicular to the coast, and at every 20 m we placed a 1 m^2 quadrate to count and collect all visible echinoderms, together with a random sediment sample using an Ekman dredge (capture area 0.022 m^2) to identify small, buried echinoderms (Gómez Gaspar, 2000; Pernía, 2011).

In places with coral reefs, we evaluated three randomly chosen patches. Each patch was measured and

checked to identify and collect by hand any visible echinoderms. In addition, a coral sample (500-7,000 cm^3) and a sediment sample (with an Ekman dredge 0.022 m^2) were taken to collect small echinoderms inside the rocky/coral substrate and buried in the surrounding areas (CARICOMP, 2001; Pernía, 2011).

Samples were placed in hermetically sealed and properly labelled plastic bags. Echinoids, asteroids, and ophiuroids were relaxed with progressive decreases in salinity, while holothuroids were narcotized by adding effervescent antacid tablets, then both ends were tied to prevent evisceration (Smaldon & Lee, 1979). Subsequently, all organisms were preserved in 70% ethyl alcohol, changing it every 48 hours until the liquid remained clear (Smaldon & Lee, 1979; Pernía, 2011).

In the laboratory, all specimens were identified to the lowest possible taxonomic level by direct observation, using a stereoscopic magnifying glass and the identification keys by Zoppi de Roa (1967) and Hendler *et al.* (1995). All species names were confirmed and updated according to the WoRMS (2020). Indices of diversity and richness were calculated (Pernía, 2011; Morán *et al.,* 2014). All data were inserted and analized in an Excel® 2010 spreadsheet. Diversity indices were compared across the sampling sites with a Kruskal-Wallis analysis (STATISTICA, 2004; Pernía, 2011; Morán *et al.,* 2014).

RESULTS

A total of 259 specimens were collected at the three sampling sites. The list of echinoderms of the Gulf of Venezuela reported in this research, includes 28 species (Table 2), 20 genera, 15 families, 10 orders and four classes (Table 1). The richest class was Ophiuroidea with 18 species, then Asteroidea, Echinoidea and Holothuroidea with three species each. All 18 ophiuroid species are reported as new species for the Maracaibo Lake System. Castilletes was the sampling site with the highest number of species (18 species), followed by Porshoure (15 species), and lastly Kazuzain (12 species) (Fig. 2).

The Shannon-Weiner diversity index (H') presented a slight difference regarding the order of the most diverse sampling site; Porshoure showed the highest diversity (H' = 3.44), followed by Castilletes (H' = 3.03), and Kazuzain (H' = 3.01). It is important to mention that this index is biased towards the relative abundance of the species, and even though Castilletes showed the highest number of species, this locality did not show large numbers of individuals per species, which results in no significant differences among the sampling sites (H = 26.00; p = 0.4631).

Table 1. Number of echinoderm species, genera, families and orders recorded at the Gulf of Venezuela.

Class	Order	Family	Genus	Species
Asteroidea	2	3	3	3
Echinoidea	3	3	4	4
Holothuroidea	3	3	3	3
Ophiuroidea	2	6	10	18
Total	10	15	20	28

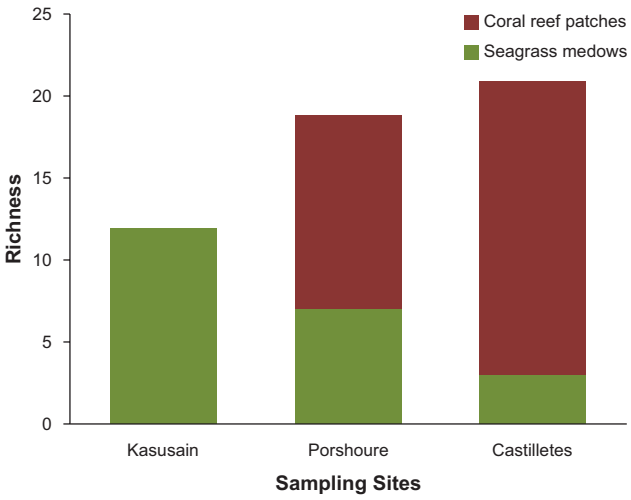

Figure 2. Number of echinoderm species encountered in each sampling site according to the substrate (seagrass medows or coral reef patches) during the sampling period.

Overall, the most dominant species in the Gulf of Venezuela was *Echinometra lucunter* (Linnaeus, 1758) (23.55%), followed by *Ophiactis savignyi* (Müller & Troschel, 1842) (21.24%). The least dominant species were *Tripneustes ventricosus* (Lamarck, 1816), *Ophiothrix angulata* (Say, 1825), *Ophiophragmus wurdemanii* (Lyman, 1860), *Ophiothrix oerstedii* (Lütken, 1856), *Ophiothrix lin-*

Table 2. List of Echinoderms identified in the Gulf of Venezuela.

Class	Order	Family	Species
Asteroidea	Valvatida	Oreasteridae	*Oreaster reticulatus*
		Ophidiasteridae	*Linckia guildingi*
	Spinulosida	Echinasteridae	*Echinaster echinophorus*
Echinoidea	Camarodonta	Toxopneustidae	*Lytechinus variegatus*
			Tripneustes ventricosus
		Echinometridae	*Echinometra lucunter*
	Diadematoida	Diadematidae	*Diadema antillarum*
Holothuroidea	Synallactida	Stichopodidae	*Isostichopus badionotus*
	Aspidochirotida	Holothuriidae	*Holothuria surinamensis*
	Dendrochirotida	Sclerodactylidae	*Euthyonidiella trita*
Ophiuroidea	Ophiacanthida	Ophiodermatidae	*Ophioderma appressum*
	Amphilepidida	Ophiolepididae	*Ophiolepis gemma*
		Ophionereididae	*Ophionereis reticulata*
		Ophiactidae	*Ophiactis muelleri*
			Ophiactis savignyi
		Ophiotrichidae	*Ophiothrix angulata*
			Ophiothrix brachyactis
			Ophiothrix oerstedii
			Ophiothrix lineata
			Acanthophiothrix suensoni
		Amphiuridae	*Microphiopholis atra*
			Amphioplus sepultus
			Amphioplus thrombodes
			Amphioplus sp.
			Amphipholis squamata
			Ophistigma sp.
			Ophiostigma isocanthum
			Ophiophragmus wurdemanii

eata (Lyman, 1860), *Acanthophiothrix suensoni* (Lütken, 1856), *Amphipholis squamata* (Delle Chiaje, 1828), and *Ophiostigma* sp. with 0.39% of dominance. According to the sampling sites, in Porshoure, two species of ophiuroids (*O. brachyactis* and *O. oerstedii*) were the most dominant (18.52%), in Kazuzain *Ophiothrix brachyactis* (H.L. Clark, 1915) (30%) and *E. lucunter* (23%) showed the highest dominance. In Castilletes, *T. ventricosus* presented 34.86% of dominance, and secondly, *O. brachyactis* (20.57%). *Diadema antillarum* (Philippi, 1845) was only recorded once by direct observations in the neighboring localities, and, for this reason, it was not included in the ecological analysis but added in the final species list (Table 2).

Table 3. Distribution of echinoderm species according to the type of substrate in the north-western coast of the Gulf of Venezuela.

Type of Substrate		
Coral Reefs	**Coral reefs and Seagrass meadows**	**Seagrass meadows**
Echinaster echinophorus	*Oreaster reticulatus*	*Echinometra lucunter*
Tripneustes ventricosus	*Linckia guildingi*	*Ophioderma appressum*
Euthyonidiella trita	*Lytechinus variegatus*	*Ophiothrix angulata*
Ophiolepis gemma	*Isostichopus badionotus*	*Ophiothrix oerstedii*
Ophionereis reticulata	*Holothuria surinamensis*	*Ophiothrix lineata*
Ophiactis muelleri	*Ophiactis savignyi*	*Amphipholis squamata*
Acanthophiothrix suensoni	*Ophiothrix brachyactis*	
Ophistigma sp.	*Microphiopholis atra*	
Ophiostigma isocanthum	*Amphioplus sepultus*	
Ophiophragmus wurdemanii	*Amphioplus thrombodes*	
Diadema antillarum	*Amphioplus* sp.	

DISCUSSION

The Gulf of Venezuela is known as an important area for recruitment and development of marine organisms (Alió, 2000). It is considered as a refuge (alongside the Caribbean coast of Colombia) due to the occurrence of cold and nutrient-rich upwelling waters (Miloslavich *et al.,* 2010; Rueda-Roa & Muller-Karger, 2013). Filled with an enormous biotic richness (Rodríguez & Morales, 2000) it has a total of 28 species of echinoderms, representing 11.54% of the total diversity of the phylum in marine areas from the coast of Venezuela (Lodeiros *et al.,* 2013). The composition of echinoderm species in the Gulf of Venezuela is similar to that of the Caribbean, presenting an apparent homogeneous distribution mostly attributed to the local current patterns and semi-enclosed nature (Alvarado, 2011; Alvarado & Solís-Marín, 2013). This area has been recognized as an important region for other species of marine benthic faunal groups, with many habitats ideal for the development of echinoderms that are known to be key species in several marine ecosystems (Alvarado, 2011; Lodeiros *et al.,* 2013).

Our records indicate that the number of species and abundance were higher in coral reef habitats (21 species, 80.69% of the total of individuals collected) in contrast to seagrass beds (17 species, 19.31% of the total of individuals collected) (Table 3) (Fig. 2). García *et al.* (2008) explain that coral reefs provide not only nutrients, but also larger spectrum habitats for refuge and growth of several species. The Gulf of Venezuela could also be recognized as an important region for coral reef settlements (Barrios-Garrido *et al.,* 2016), with a few cryptic habitats ideal for the development of the Ophiuroidea, which is the most diverse echinoderm group in the area (18 species, N = 28); our findings are contrary to that of Lodeiros *et al.* (2013), which documented no records of this class for the Gulf of Venezuela and other regions alongside the Venezuela coast (*e.g.,* Cariaco trench, Tocuyo, and some Oceanic areas). Despite the availability of nutrients found in the Gulf of Venezuela, the distribution of species is likely to be influenced by the substrate for recruitment and development. Similar findings were described by previous researchers (Bitter, 1999; Alvarado, 2011). Further research is needed to understand the role of this ecosystem in the distribution of echinoderms in the Southern Caribbean.

Our results show that 13 species (n = 21 species) of ophiuroids were found in coral reef patches. According to the sampling sites, Castilletes exhibits the highest species diversity of echinoderms (18 species, N = 28) (Fig. 2), due in part to the rich coastal habitats (large patches of coral reefs), which are known to be the most diverse ecosystems in the marine realm (Pandolfi *et al.,* 2003; Nava & Severeyn, 2010; Alvarado, 2011; Barrios-Garrido *et al.,* 2016). Previous authors have found ophiuroids as the most diverse group in other coastal areas in Venezuela (Gómez Maduro & Hernández Ávila, 2011, Noriega & Fuentes-Carrero, 2014), mostly recorded in coral reefs, rocky reefs, and mangroves (Noriega & Fuentes-Carrero, 2014). The high diversity of ophiuroids in Castilletes sampling sites may be related to the notorious influence of marine currents, nutrients, and larvae dispersal from the Caribbean as stated by Alvarado (2011) for echinoderm communities within the Caribbean basin.

Although the class Ophiuroidea had the highest number of species in the Gulf of Venezuela, the most dominant species was *Echinometra lucunter* (23.55%), a sea urchin that, in our study, was found only in Castilletes. This species is frequently associated with rocky reef environments, close to Castilletes in Punta Perret (Pulido-Petit *et al.,* 2017). It is known that species of *Echinometra* maintain erosion levels in the areas they inhabit and are commonly found in limestone reefs (Hendler *et al.,* 1995). Similarly, other authors have reported *E. lucunter* in environments closely related to rocky substrates, and it is indicated as common and an abundant species in several places throughout the Caribbean and other areas towards the northeastern coast of Brazil (Hendler *et al.,* 1995; Bolaños *et al.,* 2005; Alvarado *et al.,* 2008, Gaitán Espitia, 2008; Gondim *et al.,* 2018; McClanahan & Muthiga, 2020).

The extraction and fishing of sea urchins and sea cucumbers in Venezuela is mainly documented in the eastern coast, although not always commercially exploited under the administration of the corresponding authorities (Lodeiros *et al.,* 2013); and it is suggested that the consumption, extraction and/or fishing of echi-

noderm species in the Gulf of Venezuela is non-existant. Nevertheless, an illegal trade of several marine benthic invertebrates has been reported, mainly for ornamental and decorative uses (Lodeiros *et al.,* 2013; Rojas-Cañizales *et al.,* 2020). It is important in the future to understand the ecological role (food webs, erosion functionality, and compartmentalisation of the habitat) of sea urchins and sea cucumber species in the study area, and its potential use as a food item by local human communities if needed (Alió, 2000; Lodeiros *et al.,* 2013).

Several studies about benthic communities in the Venezuelan Guajira have been performed mostly focusing on mollusks, due to their economic value in the region, often collected as a protein source, bait, decorations, among others (Alió, 2000; Rodríguez & Morales, 2000). Echinoderms are ranked as the last group of invertebrates studied in the Maracaibo System, mainly due to its estuarine nature (Rodríguez & Morales, 2000), where most echinoderms are not well adapted to develop and survive (Alvarado, 2011; Lodeiros *et al.,* 2013). Marine environments are only found in the Gulf of Venezuela, a region essentially isolated and difficult to access (Rodríguez, 2000). Despite these facts, this study has provided some information on the different classes, families and species of echinoderms in the north-western coast of the Gulf of Venezuela. The spatial-temporal distribution of these echinoderms, as well as their density, growth rates, reproduction, and other population and community parameters require detailed additional studies. The inclusion of other areas (*e.g.,* Cocinetas marine lagoon and its mangrove submerged roots), also will generate information in order to develop strategies for their conservation and management (Alvarado, 2011; Lodeiros *et al.,* 2013; Morán *et al.,* 2014).

ACKNOWLEDGMENTS

Authors would like to acknowledge the inhabitants of the different sampling sites alongside the north-western coast of the Gulf of Venezuela, who were an essential part of the effortless completion of this research. Thanks to the volunteers, assistants, students, and professors who collaborated during the sampling period. We thank the Laboratory of General Ecology and the Aquatic Invertebrate Systematic Laboratories from the Biology Department of the Experimental Faculty of Science at the University of Zulia, as well as every helping hand from the Research Division at the Postgraduate Department, and the Dean office of this distinguished faculty. We also appreciate the effort and help provided by Professor Nicida Noriega from the "Universidad de Oriente-Venezuela" who guided the identification of some of the species documented.

AUTHORS' CONTRIBUTIONS

N.E-R.: Conceptualization, Data collection and curation, Formal analysis, Writing – original draft, Visualization, Investigation. Writing – review & editing. Y.P.: Conceptualization, Data collection and curation. Writing – review. H.S.: Supervision, Conceptualization, Writing – review & editing. Y.G.S.: Supervision, Conceptualization, Writing – review & editing. H.B.-G.: Supervision, Conceptualization, Methodology, Data collection and curation, Writing – review & editing. All the authors actively participated in the discussion of the results; they reviewed and approved the final version of this paper. Authors declare there are no conflicts of interest.

REFERENCES

Alió, J. 2000. Los recursos vivos del Sistema de Maracaibo. *In:* Rodríguez, G. (Eds.). *El Sistema de Maracaibo.* Caracas, Instituto Venezolano de Investigaciones Científicas (IVIC). Cap. 11, p. 153-172.

Alvarado, J.J. 2011. Echinoderm diversity in the Caribbean Sea. *Marine Biodiversity,* 41: 261-285. DOI

Alvarado, J.J. & Solís-Marín, F.A. 2013. Echinoderm research and diversity in Latin America. *In:* Alvarado, J.J. & Solís-Marín, F.A. (Eds.). *Echinoderm research and diversity in Latin America.* Berlin, Springer-Verlag. Cap. 1, p. 1-9. DOI

Alvarado, J.J.; Solís-Marín, F.A. & Ahearn, C. 2008. Equinodermos (Echinodermata) del Caribe Centroamericano. *Revista Biología Tropical,* 56(3): 37-55.

Álvarez-León, R.; Mendoza-Mazzeo, L.A. & Vernette, G. 2003. Factors involved in coastal lagoons formation in Colombian southwest Caribbean. *Acta Científica Venezolana,* 54(3): 180-188.

Azofeifa-Solano, J.C.; Mena, S.; Alvarado, J.J.; Chacón-Monge, J.L.; Clarke, T.M.; Herrera-Correal, J. & Wehrtmann, I.S. 2017. Echinoderm diversity of a tropical estuary in the largest river basin of the Costa Rican Pacific, Eastern Tropical Pacific. *CheckList,* 13(3): 2113. DOI

Barrios-Garrido, H.; Petit-Rodríguez, M.J.; Vera, F.; Montiel-Villalobos, M.G.; Morán, L. & Wildermann, N. 2016. Riqueza y distribución de corales pétreos en la costa noroccidental del Golfo de Venezuela. *Ciencia,* Maracaibo, 24(1): 27-40.

Bitter, R. 1999. Benthic communities associated to *Thalassia testudinum* (Hydrocharitaceae) at three localities of Morrocoy National Park, Venezuela. *Revista Biología Tropical,* 47(3): 443-452.

Bolaños, N.; Bourg, A.; Gómez, J. & Alvarado, J.J. 2005. Diversidad y abundancia de equinodermos en la laguna arrecifal del Parque Nacional Cahuita, Caribe de Costa Rica. *Revista Biología Tropical,* 53: 285-290.

Caribbean Coastal Marine Productivity Program (CARICOMP). 2001. *Methods Manual Levels 1 and 2: Manual of Methods for Mapping and Monitoring of Physical and Biological Parameters in the Coastal Zone of the Caribbean.* West Indies, Kingston University West Indies.

Data Analysis Software System (STATISTICA). 2004. *StatSoft, Inc., version 7.061.0.*

Gaitán Espitia, J.D. 2008. Estructura de la comunidad del phyllumEchinodermata en aguas someras de la Bahía de Taganga, Caribe Colombiano. *Revista U.D.C.A Actualidad & Divulgación Científica,* 11(1): 85-93.

García, R. del Valle; Abreu Pérez, M.; Rodríguez, R.; Solís-Marín, F.A.; Laguarda-Figueras, A. & Durán González, A. de la L. 2008. Equinodermos (Echinodermata) del occidente del Archipiélago Sabana-Camagüey, Cuba. *Revista Biología Tropical,* 56(3): 19-35.

Gómez Gaspar, A. 2000. Abundancia de *Lytechinus variegatus* (Echinoidea: Toxopneustidae) en la isla de Cubagua, Venezuela. *Revista Biología Tropical,* 48(1): 125-131.

Gómez Maduro, M.C. & Hernández Ávila, I. 2011. Equinodermos de la Bahía de Tunantal, Estado Sucre, Venezuela. *Boletín del Instituto Oceanográfico de Venezuela,* 50(2): 209-231.

Gondim, A.I.; Moura, R.B.; Christoffersen, M.L.; Dias, T.L. 2018. Taxonomic guide and historical review of echinoids (Echinodermata: Echinoidea) from north Eastern Brazil. *Zootaxa,* 4529(1): 1-72.

Hendler, G.; Miller, J.E.; Pawson, D.L. & Kier, P.M. 1995. *Sea Stars, Sea Urchins, and allies. Echinoderms of Florida and the Caribbean.* Washington, Smithsonian Institution. 390p.

Kuk-Dzul, J.G.; Solís-Marín, F.A.; Herrera-Dorantes, M.T. & Ardisson, P.L. 2019. Brittle stars (Echinodermata: Ophiuroidea) of coastal lagoons from the northern Yucatán Peninsula, Mexico. *Revista Mexicana de Biodiversidad,* 90: e902698. DOI

Lodeiros, C.; Martín, A.; Francisco, V.; Noriega, N.; Díaz, Y.; Reyes, J.; Aguilera, O. & Alió, J. 2013. Echinoderms from Venezuela: Scientific Recount, Diversity and Distribution. *In:* Alvarado, J.J. & Solís-Marín, F.A. (Eds.). *Echinoderm research and diversity in Latin America.* Heidelberg, Springer. Cap. 7, p. 235-275. DOI

López-Hernández, M.; Morales-Montero, P.; Pernía, Y.; Espinoza-Rodríguez, N.; Wildermann, N.; Barrios-Garrido, H. & Morán, L. 2010. Longitud y Biomasa de *Thalassia testudinum* y *Syringodium filiforme* en el Golfo de Venezuela en periodo de sequía (XIIJNIP_101_2010). *In: Jornadas Nacionales de Investigación y Postgrado, 12º. FEC.* Maracaibo, Universidad del Zulia.

Masciangioli, P. & Febres, G. 2000. Climatografía de la cuenca de Maracaibo. *In:* Rodríguez, G. (Eds.). *El sistema de Maracaibo.* Caracas, Instituto Venezolano de Investigaciones Científicas (IVIC). p. 21-33.

McClanahan, T.R. & Muthiga, N.A. 2020. Echinometra. *In:* Lawrence, J.M. *Sea Urchins: Biology and Ecology.* Academic Press. p. 497-517. (Developments in Aquacuture and Fisheries Science, n. 43)

Medina, E. & Barboza, F. 2003. Mangroves of the Maracaibo Lake system: physiographic and ecological characterization. *Ecotrópicos,* 16: 75-82.

Miloslavich, P.; Díaz, J.M.; Klein, E.; Alvarado, J.J.; Díaz, C.; Gobin, J.; Escobar-Briones, E.; Cruz-Motta, J.J.; Weil, E.; Cortes, J.; Bastidas, A.C.; Robertson, R.; Zapata, F.; Martin, A.; Castillo, J.; Kazandjian, A. & Ortiz, M. 2010. Marine biodiversity in the Caribbean: regional estimates and distribution patterns. *PLos ONE,* 5(8): e11916. DOI

Miloslavich, P.; Klein, E.; Yerena, E. & Martin, A. 2003. Marine biodiversity in Venezuela: status and perspectives biodiversidad marina en Venezuela: estado actual y perspectivas. *Gayana,* Concepción, 67(2): 275-301.

Morán, L.; Severeyn, H. & Barrios-Garrido, H. 2014. Moluscos bivalvos perforadores de rocas coralinas submareales de la Alta Guajira, Golfo de Venezuela. *Interciencia,* 39(2): 136-139. https://www.redalyc.org/articulo.oa?id=33930068010.

Nava, M. & Severeyn, H. 2010. Variación espacial del macrobentos intermareal en playas arenosas de alta energía del noroeste del Golfo de Venezuela. *Ciencia,* Maracaibo, 18(4): 235-246.

Noriega, N. & Fuentes-Carrero, Y. 2014. Contribución al conocimiento de la diversidad de los equinodermos del Parque Nacional Archipiélagos de los Roques, Venezuela. *Acta Biológica Venezuelica,* 34(2): 285-292.

Noriega, N.; Pauls, S.M. & del Mónaco, C.A. 2006. Abundancia de *Diadema antillarum* (Echinodermata: Echinoidea) en las costas de Venezuela. *Revista Biología Tropical,* 54(3): 793-802.

Pandolfi, J.M.; Bradbury, R.H.; Sala, E.; Hughes, T.P.; Bjorndal, K.A.; Cooke, R.G.; McArdle, D.; McClenachan, L.; Newman, M.J.H.; Paredes, G.; Warner, R.R. & Jackson, J.B.C. 2003. Global trajectories of the long-term decline of coral reef ecosystems. *Science,* 301(5635): 955-958.

Pawson, D.L. 2007. Phylum Echinodermata. *Zootaxa,* 1668: 749-764.

Pernía, Y. 2011. *Comparación de comunidades de equinodermos en praderas de fanerógamas y arrecifes de coral en la zona nor-occidental del Golfo de Venezuela* (Bachelor Thesis). Universidad del Zulia. Maracaibo, Venezuela.

Pulido-Petit, G.; Wildermann, N. & Barrios-Garrido, H. 2017. Comunidades de macroinvertebrados asociadas a piscinas de marea del litoral rocoso Punta Perret, estado Zulia, Venezuela. *Ciencia,* 25(1): 15-28.

Rivera-Monroy, V.H.; Twilley, R.R.; Bone, D.; Childers, D.L.; Coronado-Molina, R.C.; Feller, I.C.; Herrera-Silveira, J.; Jaffe, R.; Mancera, E.; Rejmankova, E.; Salisbury, J.E. & Weil, E. 2004. A conceptual framework to develop long-term ecological research and management objectives in the wider Caribbean region. *Bioscience,* 54: 843-856.

Rodríguez, G. 2000. Fisiografía del Sistema de Maracaibo. *In:* Rodríguez, G (Eds.). *El sistema de Maracaibo.* Caracas, Instituto Venezolano de Investigaciones Científicas (IVIC). p. 7-20.

Rodríguez, G. & Morales, F. 2000. Capítulo 5: Las comunidades bentónicas del Sistema de Maracaibo. *In:* Rodríguez, G. (Ed.). *El sistema de Maracaibo.* Caracas, Instituto Venezolano de Investigaciones Científicas (IVIC). p. 75-85.

Rojas-Cañizales, D.; Espinoza-Rodríguez, N.; Petit-Rodríguez, M.J.; Palmar, J.; Mejías-Balsalobre, C.; Wildermann, N.; Barros, T. & Barrios-Garrido, H. 2020. Marine turtle mortality in a southern Caribbean artisanal fishery: a threat for immature green turtles. *Regional Studies in Marine Science,* 38(101380). DOI

Rueda-Roa, D.T.; & Muller-Karger, F.E. 2013. The southern Caribbean upwelling system: Sea surface temperature, wind forcing and chlorophyll concentration patterns. *Deep Sea Research Part I: Oceanographic Research Papers,* 78: 102-114.

Smaldon, G. & Lee, E.W. 1979. *A Synopsis of Methods for the Narcotisation of Marine Invertebrates.* Royal Scottish Museum Information Series, Natural History 6. Edinburgh, Scotland. 96 pp.

Wildermann, N. 2012. *Distribución y estructura comunitaria de esponjas marinas en parches arrecifales y pastos marinos del Golfo de Venezuela* (Master Dissertation Thesis) Universidad del Zulia. Maracaibo, Venezuela.

World Register of Marine Species (WoRMS). 2020. *World Register of Marine Species.* WoRMS Editorial Board. Available: http://www.marinespecies.org. Access: 02/09/2020. DOI

Zoppi de Roa, E. 1967. Contribución al estudio de los equinodermos de Venezuela. *Acta Biológica Venezuelica,* 5: 267-333.

Published with the financial support of the "Programa de Apoio às Publicações Científicas Periódicas da USP"