ACTA BIOLÓGICA COLOMBIANA
http://www.revistas.unal.edu.co/index.php/actabiol

Facultad de Ciencias
Departamento de Biología
Sede Bogotá

UNIVERSIDAD NACIONAL DE COLOMBIA

ARTÍCULO DE INVESTIGACIÓN / RESEARCH ARTICLE
BIODIVERSIDAD

FISH SPECIES RICHNESS OF A CORAL REEF UNDER SUBOPTIMUM CONDITIONS: THE CASE OF VARADERO (CARTAGENA BAY, COLOMBIA)

Riqueza de especies de peces de un arrecife bajo condiciones subóptimas: el caso de Varadero (Bahía de Cartagena, Colombia)

Mateo LÓPEZ-VICTORIA[1]*, María Alejandra HERRERA[1], Valeria MUÑOZ-LÓPEZ[1], Melina RODRÍGUEZ-MORENO[2], Alejandra PUENTES-SAYO[3], Javier TORRES-RODRÍGUEZ[3], Olga TORRES[4], Luis H. CHASQUI[5], José TAVERA[4], Arturo ACERO P.[3]

1. Faculty of Engineering and Sciences, Pontificia Universidad Javeriana Cali, Calle 18 # 118-250, Cali, Colombia.
2. Fundación para la Investigación y Conservación Biológica Marina – ECOMARES, Cali, Colombia.
3. Universidad Nacional de Colombia, Sede Caribe, Calle 25 # 2-55, Playa Salguero, Santa Marta, Colombia.
4. Departamento de Biología, Universidad del Valle, Calle 13 # 100-00, El Ingenio, Cali, Colombia.
5. Instituto de Investigaciones Marinas y Costeras – INVEMAR, Calle 25 # 2-55, Playa Salguero, Santa Marta, Colombia.

* *For correspondence:* malov@WWjaverianacali.edu.co

Received: 04th February 2021. **Returned for revision**: 03rd December 2021. **Accepted**: 11th April 2022.
Associate Editor: Michael Ahrens

Citation/ citar este artículo como: López-Victoria, M., Herrera, M.A., Muñoz-López, V., Rodríguez-Moreno, M., Puentes-Sayo, A., Torres-Rodríguez, J., Torres, O., Chasqui, L.H., Tavera, J. and Acero, P.A. (2023). Fish species richness of a coral reef under suboptimum conditions: the case of Varadero (Cartagena Bay, Colombia). *Acta Biol Colomb*, *28*(1), 108-117. https://doi.org/10.15446/abc.v28n1.92440

ABSTRACT

Coral reefs inside Cartagena Bay have disappeared, largely due to the constant discharge of contaminated, sediment-rich freshwater from the Dique Channel. Recently, which might be the last healthy coral reef in the bay was found between Bocachica and Barú. Despite the unfavorable conditions for coral development, this reef exhibits an average coral cover of around 45 %. To study its fish diversity, inventories were made between 2015 and 2019, based on censuses during errant dives, band transects, photographs, and video recordings. A list of all fish species observed at Varadero reef, where 147 species belonging to 49 families have been recorded is presented; seven of those species (5%) are cataloged under threat. This study is the first approach to the fish diversity in this unusual reef, and a starting point for future studies that address the functionality and proper conservation of this ecosystem, currently threatened by projects that seek to dredge it.

Keywords: contamination, corals, dredging, fishes, sediments.

RESUMEN

Los arrecifes de coral dentro de la bahía de Cartagena han desaparecido, en gran parte debido a la constante descarga de agua dulce contaminada y rica en sedimentos del Canal del Dique. Recientemente, el que podría ser el último arrecife de coral saludable de la Bahía fue encontrado entre Bocachica y Barú. A pesar de las condiciones desfavorables para el desarrollo de los corales, este arrecife exhibe una cobertura de coral promedio de alrededor del 45 %. Para estudiar su diversidad de peces, se hicieron inventarios entre 2015 y 2019, basados en censos durante buceos errantes, transectos de bandas, fotografías y grabaciones de video. Se presenta una lista de todas las especies de peces observadas en el arrecife de Varadero, donde se han registrado 147 especies pertenecientes a 49 familias; siete de esas especies (5%) están catalogadas como amenazadas. Esta investigación es el primer acercamiento a la diversidad de peces en este inusual arrecife, y un punto de partida para futuros estudios que aborden su funcionalidad y adecuada conservación, actualmente amenazada por los proyectos que pretenden su dragado.

Palabras clave: contaminación, corales, dragados, peces, sedimentos.

INTRODUCTION

Coral reefs are one of the world's most diverse ecosystems, harboring more than 25 % of marine fish species (Sale, 1980; Moberg and Folke, 1999; Coker *et al*., 2014), at a level that in some reef systems in the Indo-Pacific Ocean more than 1000 species occur (Tittensor *et al*., 2010; Kulbicki *et al*., 2011). For Colombian Caribbean reef systems, up to 500 fish species can be found in some oceanic complexes in the Seaflower Biosphere Reserve (Mejía and Garzón-Ferreira, 2000; Bolaños-Cubillos *et al*., 2015; Acero *et al*., 2019) or between 300 to 400 species in coastal reefs in the continental platform (e.g., San Bernardo, Rosario or Santa Marta; Acero and Garzón, 1987).

Despite the importance of these ecosystems in economic, social, and environmental assets, coral reefs have continued to deteriorate due to human impacts such as overfishing, declining water quality (Johnston and Roberts, 2009), and rising ocean temperatures (Hoegh-Guldberg *et al*., 2007). Despite the discouraging forecast for coral reefs worldwide, and especially for the Caribbean where the hard coral cover has been reduced by 80 % since the 1970's (Gardner *et al*., 2003), one of the last well-developed coral reefs in the Colombian Caribbean was recently discovered in the bay of Cartagena (López-Victoria *et al*., 2014). The so-called, Varadero Reef is located in the southern mouth of the bay, where environmental conditions are far away from the optimal for coral growth: water is turbid, polluted, and with high levels of sedimentation due to the constant discharges of the Dique Canal, which drains 7 % of the Magdalena River, the largest lotic system in Colombia (Tosic *et al*., 2016; Pizarro *et al*., 2017).

Currently, national plans for dredging the area to create an alternate navigation canal for large cargo ships are being developed (INVÍAS, 2015), and this would, directly and indirectly, damage about 50 % of this unusual but well-developed reef, with catastrophic effects on the marine life that thrive in this area. To contribute to the knowledge of the extant fish fauna present in this coral reef, we conducted research during both rainy and dry seasons. The inventory was carried out with different methods. The aim of this study was to assess the reef fish inventory of this unusual reef to serve as a starting point for future investigations, and to create awareness of the richness of organisms and the uniqueness of this ecosystem.

MATERIALS AND METHODS

Study area

The bay of Cartagena is located in the Colombian continental Caribbean (Fig. 1). Sea surface temperature ranges between 27 and 31 °C, and salinity varies from 6 near the river mouth to 37 outside the bay (Pfaff, 1969; Alonso *et al*., 2000; Grisales-López *et al*., 2014). Climate in this region is dominated by two main periods, the dry season from December to April and the rainy season from May to November (Delgadillo-Garzón and Zapata-Ramírez, 2009). This bay receives constant discharges of freshwater, sediments, and sewage water from the Dique Canal, which varies throughout the year in accordance with the seasonal water flow (Leble and Cuignon, 1987; Restrepo *et al*., 2006). This huge sediment discharge has caused high turbidity and sediment load. In addition to this, deep draft vessel traffic, ship discharges, wastewater dumping by industrial companies, and constant dredging that resuspend heavy metals and other substances that are usually accumulated on the seabed have also caused the decrease in the water quality inside the bay (Aguilera, 2006; Parra *et al*., 2011; Jaramillo-Colorado *et al*., 2016; Tosic *et al*., 2017, 2019).

The Varadero Reef is located 5 km away from the mouth of the canal (Fig. 1). It is part of a large coastal coral formation that begins on the island of Tierra Bomba (Fig. 1) and continues throughout the southern margin of Barú Peninsula. The mean coral formations considered for this study extend over an area of 1.12 km^2 between 1.5 and 25 m deep (Pizarro *et al*., 2017). The area consists of well-developed coral reefs, seagrass platforms, bioturbated sediment patches, and a reef slope that ends at 25-30 m deep. Even with the high turbidity and sediment load (López-Londoño *et al.*, 2021, 2023), the reef has an average of 45 % of live coral cover, with 38 coral species listed. The most common hard coral species are *Orbicella flaveolata* (Ellis and Solander, 1786), *O. annularis* (Ellis and Solander, 1786), *Agaricia agaricites* (Linnaeus, 1758) y *A. tenuifolia* Dana, 1846 (López-Victoria *et al*., 2014; Pizarro *et al*., 2017).

Surveys

The sampling took place from March 2015 to November 2019. Visual censuses were conducted during both dry and wet seasons. In different years, SCUBA divers carried out a total of 61 hours of observation on random dives, 19 hours during the dry season, and 42 hours during the rainy season. Also, 13 videos were recorded at different sites of the reef during March 2019 (dry season). Each camera Fitfort 4k was attached to a PVC tripod and recorded about 5 m^2 of the reef for 40 to 60 min (for a total of 5 hours of underwater videos). The videos were then analyzed on a computer. We focused specifically on species richness, due to the different methods and sampling efforts used during the studies, which makes comparisons with reefs in other areas of the Caribbean difficult. In this sense, the species inventory is a starting point for comparative studies over time, especially considering eventual dredging works that would severely alter the reef. The classification of teleost fish species was made according to Betancur *et al*. (2017) and cartilaginous fishes were classified following Nelson *et al*. (2016).

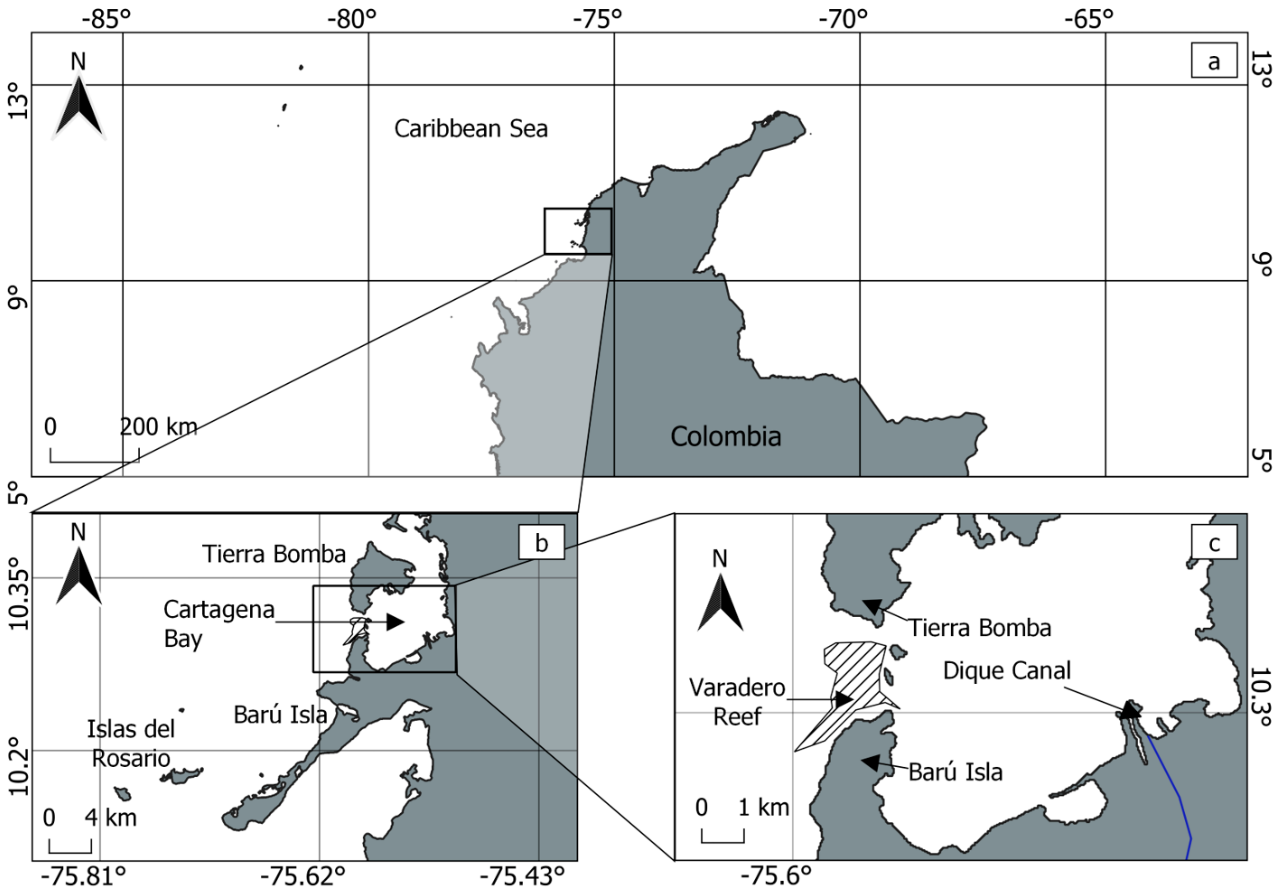

Figure 1. Map of the study area. (a) Cartagena location in relation to the Colombian Caribbean Coast. (b) Cartagena bay and the location of the nearby National Natural Park: sector of Islas del Rosario. (c) Location and approximate size of Varadero reef and the Dique Canal**.**

RESULTS

We recorded 147 species from 27 orders and 49 families (Supplemental material: Table 1). The richest families were Labridae, with 17 species (11.6 %), Serranidae with 16 species (10.9 %), and Pomacentridae with 11 species (7.5 %). Seven of the observed species have received national threat status (Chasqui *et al.*, 2017): the Crevalle Jack [*Caranx hippos* (Linnaeus, 1766)], the Black Grouper [*Mycteroperca bonaci* (Poey, 1860)], the Mutton Snapper [*Lutjanus analis* (Cuvier, 1828)] and the Cubera Snapper [*L. cyanopterus* (Cuvier, 1828)] are listed as vulnerable (VU); the Rainbow Parrotfish (*Scarus guacamaia* Cuvier, 1829) is listed as endangered (EN); the Atlantic Goliath Grouper [*Epinephelus itajara* (Lichtenstein, 1822)] and the Nassau Grouper [*E. striatus* (Block, 1792)] are listed as critically endangered (CR). At a global scale, three of these species are also listed by the IUCN as vulnerable VU (*L. cyanopterus*, Lindeman *et al.*, 2018; *E. itajara*, Bertoncini *et al.*, 2018) and as critically endangered CR (*E. striatus*, Sadovy *et al.*, 2018; Fig. 2).

DISCUSSION

Considering the high anthropogenic pressures and the suboptimal water conditions at Varadero Reef (Roitman *et al.*, 2020; López-Londoño *et al.*, 2021, 2023), the species richness found is particularly high when compared to other coral reefs in the Colombian Caribbean. Even though this initial list might not be complete, the 147 species found here, represent more than a quarter of the maximum reached in other coral systems in Colombia, all of them orders of magnitude larger in area than Varadero (among them, those found in the Seaflower Biosphere Reserve, Bolaños *et al.*, 2015; Acero *et al.*, 2019). All the species recorded were found inside an area of about 1 km^2, which is the area of the whole well-developed reef that was sampled. To put this value in perspective, the total number of species observed in Islas del Rosario, a protected area nearby with 50 km^2 of coral formations, is 270 species (Acero and Garzón, 1985, 1986; Garzón and Acero, 1988; Acero *et al.*, 1994; Mejía *et al.*, 1994; Delgadillo-Garzón and Zapata-Ramírez, 2009).

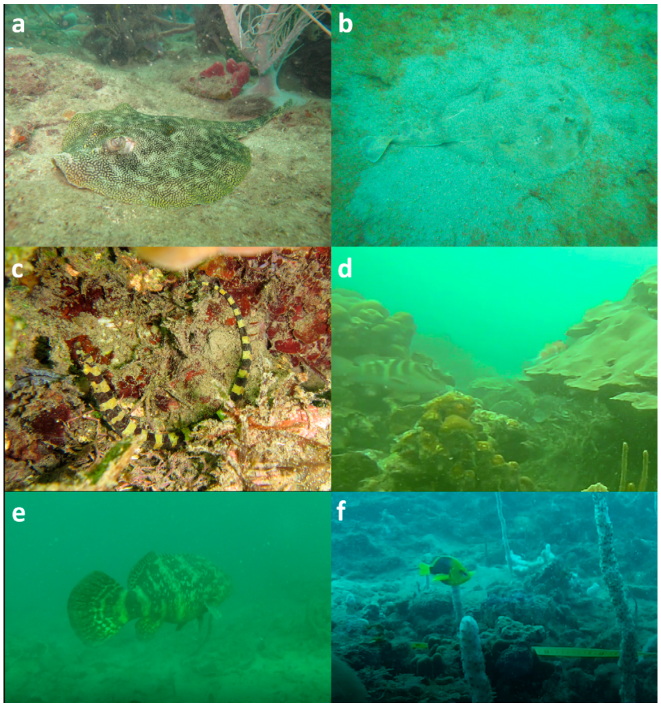

Figure 2. Some of the fish species found in Varadero: a) *Urobatis jamaicensis*, b) Narcine bancroftii, c) *Micrognathus crinitus*, d) *Epinephelus striatus*, e) *E. itajara*, f) *Hypoplectrus guttavarius* (All pictures taken by the authors).

Varadero has more than half the number of fish species found in a coral system almost 50 times bigger in extension. This could be attributed to the fact that it is a shallow water reef, with light conditions equivalent to those of a mesophotic (deep water) reef (López-Londoño *et al.*, 2021, 2023), in addition to the proximity of the reef to estuarine systems (such as the bay of Cartagena; Restrepo *et al.*, 2006) and mangrove formations. These conditions could make Varadero a reef where a wealth of fish species from different ecosystems converge.

This study represents a baseline of knowledge for further research about changes in species composition in this paradoxical reef. There are some common species that are usually found in coral reefs around Cartagena and were not found in Varadero, but this could be due to insufficient sampling effort. However, the sighting of the Nassau grouper is noteworthy, because the last record of this species in the region was published 40 years ago (Köster, 1979). The sighting of the Atlantic Goliath grouper is also outstanding, as this species is critically endangered, globally, and nationally (Chasqui *et al.*, 2017).

Although the fish richness values are not the highest compared to other reef systems worldwide, the water conditions on which the reef is found are suboptimal for coral reef development and are usually associated with a decrease in fish richness and abundance (McKinley and Johnston, 2010). Therefore, the species observed here could represent the highest concentration of fish species to be found in the bay of Cartagena, an aspect that should be considered before continuing the plans of dredging a canal through the reef.

CONCLUSIONS

The Varadero coral reef supports a fish species richness that corresponds to its amazing structure and state of conservation, despite the poor water conditions under which it survives. This fish community is comparable to other coral areas in the Colombian Caribbean of greater extension and traditionally considered centers of biodiversity. Other groups of organisms in Varadero should reflect an equivalent richness, and the ecosystem should be protected from developments that threaten its survival.

ACKNOWLEDGEMENTS

The authors would like to thank Pablo Avendaño and his family for their support during the fieldwork, and Cartagena Divers for the help with the dive gear logistics. We also thank all the colleagues that accompanied us during the fieldwork of the different projects, in particular the support provided by Valeria Pizarro (Fundación Ecomares) and Mónica Medina (Penn State University).

REFERENCES

Acero P A, Garzón J. Peces de las islas del Rosario y San Bernardo (Colombia). I. Caracterización del área y lista de especies. Act Biol. 1985;14:37-148.

Acero P A, Garzón J. Peces de las islas del Rosario y de San Bernardo (Colombia) II. Tres nuevos registros para el Caribe sur y 16 más para la costa norte continental colombiana. Anal Inst Invest Mar Punta Betín. 1986;15–16:67-177.

Acero P A, Garzón J. Peces arrecifales de la región de Santa Marta (Caribe colombiano). I. Lista de especies y comentarios generales. Acta Biol Colom. 1987;1(3):83-104.

Acero P A, Tavera JJ, Polanco A, Bolaños-Cubillos N. Fish biodiversity in three northern islands of the Seaflower Biosphere Reserve (Colombian Caribbean). Front Mar Sci. 2019;6(113):1-11. Doi: //doi.org/10.3389/fmars.2019.00113

Aguilera M. El canal del Dique y su subregión: una economía basada en la riqueza hídrica. Docum Trab Econ Reg. 2006;(72):16-19.

Alonso D, Pineda P, Olivero J, González H, Campos N. Mercury levels in muscle of two fish species and sediments from the Cartagena Bay and the Ciénaga Grande de Santa Marta, Colombia. Environ Pollut. 2000;109(1):157-163. Doi: https://doi.org/10.1016/S0269-7491(99)00225-0

Bertoncini AA, Aguilar-Perera A, Barreiros J, Craig MT, Ferreira B, Koenig C. *Epinephelus itajara*. The IUCN Red List of Threatened Species 2018. 2018; e.T195409A46957794. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T195409A46957794.en

Betancur-R R, Wiley E, Arratia G, Acero A, Bailly N, Miya M, *et al*. Phylogenetic classification of bony fishes. BMC Evol Biol. 2017;17(162): Doi: https://doi.org/10.1186/s12862-017-0958-3

Bolaños-Cubillos N, Abril-Howard A, Bent-Hooker H, Caldas JP, Acero P A. Lista de peces conocidos del archipiélago de San Andrés y Providencia, Caribe occidental colombiano. Bol Invest Mar Cost. 2015;44(1):127-162.

Chasqui L, Polanco A, Acero A, Mejía-Falla A, Navia A, Zapata LA, *et al*. Libro rojo de peces marinos de Colombia. Instituto de Investigaciones Marinas y Costeras Invemar, Ministerio de Ambiente y Desarrollo Sostenible. Serie de Publicaciones Generales de Invemar 93, Santa Marta. 2017. 552 p.

Coker DJ, Wilson SK, Pratchett MS. Importance of live coral habitat for reef fishes. Reviews in Fish Biology and Fisheries. 2014;24(1):89-126. Doi: https://doi.org/10.1007/s11160-013-9319-5

Delgadillo-Garzón O, Zapata-Ramírez P. Evaluación rápida de peces arrecifales y su relación con la estructura del sustrato en las islas del Rosario, área marina protegida del Caribe colombiano. Rev Acad Colomb Cienc Exactas Fis Nat. 2009;33(127):273-283.

Garzón J, Acero A. A new species of *Lythrypnus* (Pisces: Gobiidae) from the tropical western Atlantic. Bull Mar Sci. 1988;43(2):308-314.

Grisales-López CH, Salgado Mesa JA, Molares Babra RJ. Proceso de intercambio de masas de agua de la bahía de Cartagena (Caribe colombiano) basado en la medición de parámetros oceanográficos. Bol Cient CIOH. 2014;32, 47-70. Doi: https://doi.org/10.26640/22159045.263

Hoegh-Guldberg O, Mumby PJ, Hooten AJ, Steneck RS, Greenfield P, Gómez E, *et al*. Coral reefs under rapid climate change and ocean acidification. Science. 2007;318(5857):1737-1742. Doi: http://doi.org/10.1126/science.1152509

INVÍAS. INVÍAS firma memorando de entendimiento para construir canal alterno a la bahía de Cartagena. INVÍAS [internet] 2015 Aug. Available in: https://www.invias.gov.co/index.php/sala/noticias/2240-invias-firma-memorando-de-entendimiento-para-construir-canal-alterno-a-la-bahia-de-cartagena. Cited: 23 Jul 2020.

Jaramillo-Colorado BE, Aga DS, Noguera-Oviedo K. Heavy metal contamination of estuarine sediments from Cartagena Bay, Colombia. Toxicol Lett. 2016;259:S170. DOI: 10.1016/j.toxlet.2016.07.405

Johnston EL, Roberts DA. Contaminants reduce the richness and evenness of marine communities: A review and meta-analysis. Environ Pollut. 2009;57(6):1745-1752. Doi: https://doi.org/10.1016/j.envpol.2009.02.017

Kulbicki M, MouTham G, Vigliola L, Wantiez L, Manaldo E, Labrosse P, *et al*. Major coral reef fish species of the South Pacific with basic information on their biology and ecology. CRISP-IRD Report. Noumea SPC; 2011. 107 p.

Leble S, Cuignon R. El archipiélago de las islas del Rosario, estudio morfológico, hidrodinámico y sedimentológico. Bol Cient CIOH. 1987;7:37-52. Doi: https://doi.org/10.26640/01200542.7.37_52

Lindeman K, Anderson W, Carpenter KE, Claro R, Cowan J, Padovani-Ferreira B,

Rocha LA, Sedberry G, Zapp-Sluis M. *Lutjanus cyanopterus*. The IUCN Red List of

Threatened Species 2016. 2016; e.T12417A506633. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T12417A506633.en

López-Victoria M, Rodríguez-Moreno M, Zapata FA. A paradoxical reef from Varadero, Cartagena Bay, Colombia. Coral Reefs. 2014;34(1):231. Doi: https://doi.org/10.1007/s00338-014-1246-y

López-Londoño T, Galindo-Martínez CT, Gómez-Campo K, González-Guerrero LA, Roitman S, Pollock FJ, Pizarro V, López-Victoria M, Medina M, Iglesias-Prieto R. Physiological and ecological consequences of the water optical properties degradation on reef corals. Coral Reefs. 2021;40: 1243-1256. Doi: https://doi.org/10.1007/s00338-021-02133-7

López-Londoño T, Gómez-Campo K, Galindo-Martínez CT, González-Guerrero LA, Roitman S, Pollock FJ, Pizarro V, López-Victoria M, Medina M, Iglesias-Prieto R. Survival and physiological responses of corals exposed to elevated turbidity in the Varadero reef, Colombian Caribbean. Bol Invest Mar Cost. 2023(in press);52(1).

McKinley A, Johnston EL. Impacts of contaminant sources on marine fish abundance and species richness: A review and meta-analysis of evidence from the field. Mar Ecol Prog Ser. 2010;420:175-191. Doi: https://doi.org/10.3354/meps08856

Mejía LS, Garzón-Ferreira J. Estructura de comunidades de peces arrecifales en cuatro atolones del archipiélago de San Andrés y Providencia (Caribe sur occidental). Rev Biol Trop. 2000;48(4):883-896.

Mejía LS, Solano O, Rodríguez-Ramírez A. Ocho nuevos registros para la fauna íctica de las islas del Rosario. Bol Invest Mar Cost. 1994;23(1):189-192.

Moberg F, Folke C. Ecological goods and services of coral reef ecosystems. Ecol Econ. 1999;29(2):215-233. Doi: https://doi.org/10.1016/S0921-8009(99)00009-9

Nelson JS, Grande TC, Wilson MVH. Fishes of the world. 5 ed. Hoboken: Wiley; 2016. 752 p.

Parra JP, Betancourt J, Espinosa LF, Garay J. Evolución y estado de la contaminación por metales pesados y compuestos orgánicos en la bahía de Cartagena, Colombia. Santa Marta: Invemar; 2011. 16 p.

Pfaff R. Las scleractinia y milleporina de las islas del Rosario. Mitteil Inst Colombo-Alemán Invest Cient Punta de Betín. 1969;3:17-24.

Pizarro V, Rodríguez SC, López-Victoria M, Zapata FA, Zea S, Galindo-Martínez CT, *et al.* Unraveling the structure and composition of Varadero Reef, an improbable and imperiled coral reef in the Colombian Caribbean. Peer J. 2017;2017(12):1-18. Doi: https://doi.org/10.7717/peerj.4119

Restrepo JD, Zapata P, Díaz JM, Garzón-Ferreira J, García CB. Fluvial fluxes into the Caribbean Sea and their impact on coastal ecosystems: The Magdalena River, Colombia. Glob Planet Change. 2006;50(1-2):33-49. Doi: https://doi.org/10.1016/j.gloplacha.2005.09.002

Roitman S, López-Londoño T, Pollock JF, Ritchie KB, Galindo-Martínez CT, Gómez-Campo K, González-Guerrero LA, Pizarro V, López-Victoria M, Iglesias-Prieto R, Medina M. Surviving marginalized reefs: assessing the implications of the microbiome on coral physiology and survivorship. Coral Reefs 2020;39: 795-807. Doi: https://doi.org/10.1007/s00338-020-01951-5

Sadovy Y, Aguilar-Perera A, Sosa-Cordero E. *Epinephelus striatus*. The IUCN Red List of Threatened Species 2018. 2018; e.T7862A46909843. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T7862A46909843.en

Sale PF. The ecology of fishes on coral reefs. Ann Rev Mar Sci. 1980;18:367-421.

Smith-Vaniz WF, Carpenter KE. Review of the crevalle jacks, *Caranx hippos* complex (Teleostei: Carangidae), with description of a new species from West Africa. Fish Bull. 2007;105(2):207-233.

Tittensor DP, Mora C, Jetz W, Lotze HK, Ricard D, Berghe EV, *et al.* Global patterns and predictors of marine biodiversity across taxa. Nature. 2010;466(7310):1098-1101.

Tosic M, Restrepo JD, Lonin S, Izquierdo A, Martins F. Water and sediment quality in Cartagena Bay, Colombia: seasonal variability and potential impacts of pollution. Estuar Coast Shelf Sci. 2017;216:187-203. Doi: https://doi.org/10.1016/j.ecss.2017.08.013

Tosic M, Lonin S, Izquierdo A, Restrepo JD. Hydrodynamic modelling of a polluted tropical bay: assessment of anthropogenic impacts on freshwater runoff and estuarine water renewal. J Environ Manag. 2019;236:695-714.

Supplemental material

Table 1. Fish species recorded in Varadero Reef.

Order	Family	Species
Myliobatiformes	Dasyatidae	*Hypanus americanus* (Hildebrand and Schroeder, 1928)
	Myliobatidae	*Mobula* sp.
	Aetobatidae	*Aetobatus narinari* (Euphrasen, 1790)
	Urotrygonidae	*Urobatis jamaicensis* (Cuvier, 1819)
Torpediniformes	Narcinidae	*Narcine bancroftii* (Griffith and Smith, 1834)
Elopiformes	Elopidae	*Elops smithi* McBride, Rocha, Ruiz-Carús and Bowen, 2010
Anguilliformes	Congridae	*Heteroconger longissimus* Günther, 1870
	Muraenidae	*Echidna catenata* (Bloch, 1795)
		Gymnothorax funebris Ranzani, 1839
		Gymothorax moringa (Cuvier, 1829)
	Ophichthidae	*Myrichthys breviceps* (Richardson, 1848)
Clupeiformes	Clupeidae	*Harengula* sp.
		Opisthonema oglinum (Lesueur, 1818)
	Spratelloididae	*Jenkinsia* sp.
Aulopiformes	Synodontidae	*Synodus intermedius* (Spix and Agassiz, 1829)
Holocentriformes	Holocentridae	*Holocentrus adscensionis* (Osbeck, 1765)
		Holocentrus rufus (Walbaum, 1792)
		Myripristis jacobus Cuvier, 1829
		Neoniphon marianus (Cuvier, 1829)
		Sargocentron vexillarium (Poey, 1860)
Scombriformes	Scombridae	*Scomberomorus regalis* (Bloch, 1793)
Syngnathiformes	Aulostomidae	*Aulostomus maculatus* Valenciennes, 1841
	Syngnathidae	*Halicampus crinitus* (Jenyns, 1842)
	Mullidae	*Mulloidichthys martinicus* (Cuvier, 1829)
		Pseudupeneus maculatus (Bloch, 1793)
Kurtiformes	Apogonidae	*Apogon maculatu*s (Poey, 1860)
		Phaeoptyx sp.
Gobiiformes	Gobiidae	*Coryphopterus dicrus* Böhlke and Robins, 1960)
		Coryphopterus glaucofraenum Gill, 1863
		Coryphopterus personatus (Jordan and Thompson, 1905)
		Elacatinus illecebrosus (Böhlke and Robins, 1968)
		Priolepis hipoliti (Metzelaar, 1922)
		Ptereleotris helenae (Randall, 1968)
		Tigrigobius saucrus (Robins, 1960)
	Oxudercidae	*Gnatholepis thompsoni* Jordan, 1904
incertae sedis- Carangaria	Sphyraenidae	*Sphyraena barracuda* (Edwards, 1771)

(*Continued*)

Order	Family	Species
Carangiformes	Echeneidae	*Echeneis* sp.
	Carangidae	*Caranx bartholomaei* (Cuvier, 1833)
		Caranx crysos (Mitchill, 1815)
		Caranx hippos (Linnaeus, 1766)
		Caranx ruber (Bloch, 1793)
		Decapterus sp.
Pleuronectiformes	Bothidae	*Bothus maculiferus* (Poey, 1860)
incertae sedis- Ovalentaria	Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758)
		Azurina cyanea (Poey, 1860)
		Azurina multilineata (Guichenot, 1853)
		Chromis insolata (Cuvier, 1830)
		Microspathodon chrysurus (Cuvier, 1830)
		Stegastes adustus (Troschel, 1865)
		Stegastes diencaeus (Jordan and Rutter, 1897)
		Stegastes leucostictus (Müller and Troschel, 1848)
		Stegastes partitus (Poey, 1868)
		Stegastes planifrons (Cuvier, 1830)
		Stegastes xanthurus (Poey, 1860)
	Grammatidae	*Gramma loreto* Poey, 1868
	Opistognathidae	*Opistognathus aurifrons* (Jordan and Thompson, 1905)
Blenniiformes	Blenniidae	*Ophioblennius macclurei* (Silvestre, 1915)
	Chaenopsidae	*Acanthemblemaria aspera* (Longley, 1927)
		Acanthemblemaria betinensis Smith-Vaniz and Palacio, 1974
		Acanthemblemaria spinosa Metzelaar, 1919
		Emblemariopsis sp.
incertae sedis- Eupercaria	Pomacanthidae	*Holacanthus ciliaris* (Linnaeus, 1758)
		Holacanthus tricolor (Bloch, 1795)
		Pomacanthus arcuatus (Linnaeus, 1758)
		Pomacanthus paru (Bloch, 1787)
	Sciaenidae	*Equetus lanceolatus* (Linnaeus, 1758)
		Equetus punctatus (Bloch and Schneider, 1801)
		Odontoscion dentex (Cuvier, 1830)
		Pareques acuminatus (Bloch and Schneider, 1801)
Gerreiformes	Gerreidae	*Gerres cinereus* (Walbaum, 1792)
Labriformes	Labridae	*Bodianus rufus* (Linnaeus, 1758)
		Clepticus parrae (Bloch and Schneider, 1801)
		Halichoeres bivittatus (Bloch, 1791)
		Halichoeres garnoti (Valenciennes, 1839)
		Halichoeres maculipinna (Müller and Troschel, 1848)
		Halichoeres radiatus (Linnaeus, 1758)
		Scarus guacamaia Cuvier, 1829

(*Continued*)

Order	Family	Species
		Scarus iseri (Bloch, 1789)
		Scarus taeniopterus Lesson, 1829
		Scarus vetula Bloch and Schneider, 1801
		Sparisoma atomarium (Poey, 1861)
		Sparisoma aurofrenatum (Valenciennes, 1840)
		Sparisoma chrysopterum (Bloch and Schneider, 1801)
		Sparisoma radians (Valenciennes, 1840)
		Sparisoma rubripinne (Valenciennes, 1840)
		Sparisoma viride (Bonnaterre, 1788)
		Thalassoma bifasciatum (Bloch, 1791)
Chaetodontiformes	Chaetodontidae	*Chaetodon capistratus* Linnaeus, 1758
		Chaetodon ocellatus Bloch, 1787
		Chaetodon sedentarius Poey, 1860
		Chaetodon striatus Linnaeus, 1758
Acanthuriformes	Acanthuridae	*Acanthurus chirurgus* (Bloch, 1787)
		Acanthurus coeruleus Bloch and Schneider, 1801
		Acanthurus tractus Poey, 1860
Lutjaniformes	Haemulidae	*Anisotremus surinamensis* (Bloch, 1791)
		Anisotremus virginicus (Linnaeus, 1758)
		Brachygenys chrysargyreum (Günther, 1859)
		Haemulon aurolineatum Cuvier, 1830
		Haemulon carbonarium Poey, 1860
		Haemulon flavolineatum (Desmarest, 1823)
		Haemulon macrostomum Günther, 1859
		Haemulon plumierii (Lacepéde, 1801)
		Haemulon sciurus (Shaw, 1803)
	Lutjanidae	*Lutjanus analis* (Cuvier, 1828)
		Lutjanus apodus (Walbaum, 1792)
		Lutjanus cyanopterus (Cuvier, 1828)
		Lutjanus jocu (Bloch and Schneider, 1801)
		Lutjanus mahogoni (Cuvier, 1828)
		Lutjanus synagris (Linnaeus, 1758)
		Ocyurus chrysurus (Bloch, 1791)
		Rhomboplites aurorubens (Cuvier, 1829)
Priacanthiformes	Priacanthidae	*Heteropriacanthus cruentatus* (Lacepède, 1801)
Lophiiformes	Ogcocephalidae	*Ogcocephalus* sp.
Tetraodontiformes	Diodontidae	*Diodon holocanthus* Linnaeus, 1758
		Diodon hystrix Linnaeus, 1758

(*Continued*)

Order	Family	Species
	Tetraodontidae	*Canthigaster rostrata* (Bloch, 1786)
		Sphoeroides spengleri (Bloch, 1785)
		Sphoeroides testudineus (Linnaeus, 1758)
	Balistidae	*Canthidermis sufflamen* (Mitchill, 1815)
	Monacanthidae	*Aluterus scriptus* (Osbeck, 1765)
		Cantherhines macrocerus (Hollard, 1853)
		Cantherines pullus (Ranzani, 1842)
	Ostraciidae	*Acanthostracion polygonius* Poey, 1876
		Acanthostracion quadricornis (Linnaeus, 1758)
		Lactophrys bicaudalis (Linnaeus, 1758)
		Lactophrys triqueter (Linnaeus, 1758)
	Pempheridae	*Pempheris schomburgkii* Müller and Troschel, 1848
Centrarchiformes	Cirrhitidae	*Amblycirrhitus pinos* (Mowbray, 1927)
	Kyphosidae	*Kyphosus sectatrix* (Linnaeus, 1758)
Perciformes	Serranidae	*Cephalopholis cruentata* (Lacepède, 1802)
		Epinephelus itajara (Lichtenstein, 1822)
		Epinephelus striatus (Bloch, 1792)
		Hypoplectrus guttavarius (Poey, 1852)
		Hypoplectrus nigricans (Poey, 1852)
		Hypoplectrus puella (Cuvier, 1828)
		Hypoplectrus affinis (Poey, 1861)
		Hypoplectrus unicolor (Walbaum, 1792)
		Liopropoma rubre Poey, 1861
		Mycteroperca bonaci (Poey, 1860)
		Mycteroperca interstitialis (Poey, 1860)
		Rypticus saponaceus (Bloch and Schneider, 1801)
		Serranus baldwini (Evermann and Marsh, 1899)
		Serranus flaviventris (Cuvier, 1829)
		Serranus tabacarius (Cuvier, 1829)
		Serranus tigrinus (Bloch, 1790)
	Scorpaenidae	*Pterois volitans* (Linnaeus, 1758)
		Scorpaena plumieri Bloch, 1789