EDITORIAL

Seaflower Scientific Expeditions: A Decade of Knowledge and Conservation of Our Insular Caribbean

Expediciones científicas Seaflower: una década de conocimiento y conservación de nuestro Caribe insular

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The General Maritime Directorate (Dimar) is the Colombian maritime authority in charge of leading and coordinating government policy focused on strengthening national "maritime power". Its priorities include comprehensive maritime security, the protection of human life at sea, the promotion of maritime activities and the scientific and technological development of the nation, with sustainability as its axis, with the aim of contributing to the growth of the country.

To ensure the fulfillment of its functions and objectives, the Entity has an administrative structure that allows it to get closer to the Maritime Sector. These functions are carried out under three figures: coastal State, port State and flag State.

In addition, DIMAR has eighteen (18) regional and sectional offices called port captaincies, distributed in the country's maritime and river ports; two (2) oceanographic and hydrographic research centres (in the Caribbean and the Pacific); three (3) maritime signaling groups, located in the Caribbean, the Pacific and the Magdalena River, and three (3) regional intendancy groups located in Barranquilla, Cartagena and Buenaventura. Finally, it has fourteen (14) floating units, whose work includes the development of missions such as a platform for marine scientific research, maritime signaling, transport of equipment and support personnel; support and assistance in marine research; positioning of navigational aids; equipment placement; assistance to offshore and onshore platforms; transportation of supplies, equipment and operating machinery; support for naval operations, peace operations and humanitarian aid; environmental control and protection; search and rescue, firefighters, and other oceanographic, hydrographic, and geological scientific research. All these activities, without a doubt, contribute jointly to the fulfillment of the vision of the Entity, which is to become by 2042, the axis that consolidates the maritime, river, coastal and insular country, contributing to the positioning of Colombia as a bioceanic power with high international incidence.

Therefore, it is of great relevance for DIMAR to disseminate how, through different guidelines, policies, projects, strategies, agreements and goals, it contributes to the maritime development of Colombia. For this reason, for the current term, it was decided to make an issue of the CIOH Scientific Bulletin, dedicated to communicating part of the findings, scientific and technological advances derived from the expeditions carried out for a decade to the Seaflower Biosphere Reserve (RBS), which have contributed significantly to the knowledge and management of this important world-class protected area.

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The Seaflower scientific expeditions represent an articulated effort between multiple national entities in favor of the generation of knowledge about RBS, which has the respect and support of the scientific and academic community of the country. Its main objective is to know and study the social, physical, biological and chemical characteristics of the archipelago of San Andrés, Providencia and Santa Catalina, in order to contribute to its preservation.

In this sense, we thank each of the researchers and peer evaluators for their dedication to academic excellence and for their valuable contribution to the enrichment of the published manuscripts.

Without further ado, we invite you to explore our publications, which seek to raise awareness and ensure a safe and sustainable future for our coasts and oceans.

RESEARCH ARTICLE

Contributions of the Seaflower expeditions to the knowledge of decapod crustaceans of the Archipelago of San Andrés, Providencia y Santa Catalina with new records

Aportes de las expediciones Seaflower al conocimiento de los crustáceos decápodos del archipiélago de San Andrés, Providencia y Santa Catalina con nuevos registros

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ABSTRACT

The Man and the Biosphere Program recognized the natural wealth of the Archipelago of San Andrés, Providencia y Santa Catalina, and declared it a Seaflower Biosphere Reserve in 2000; Minambiente later declared it a Marine Protected Area in 2005. Between 2017 and 2018, within the framework of the Seaflower Scientific Expeditions, crustaceans were collected from coral remains and soft bottoms. Representatives of 17 families were collected on the Serranilla Bank (SB) and Southwest Cays (SC). The results show a greater wealth in SC, with 46 species of 31 genera, while in SB only 37 species and 27 genera were recorded. In total, 67 decapod morphospecies are recorded in the two cays, contributing to knowledge with 26 new records for the Archipelago and six new ones for Colombia. With these results, the number of species for the Archipelago is 236, with an increase of 12.38%, and 16.7% of the total number of registered species. These records highlight the importance of the reserve for the Colombian Caribbean, contributing 32.3% of the species registered for Colombia.

KEYWORDS: Crustacea, Decapoda, Seaflower, biodiversity, wealth.

RESUMEN

El Programa sobre el Hombre y la biosfera reconoce la riqueza natural del archipiélago de San Andrés, Providencia y Santa Catalina y lo declara en el año 2000 Reserva de la biosfera Seaflower; posteriormente, en el 2005, esta es declarada como área marina protegida por el Ministerio de Ambiente y Desarrollo Sostenible. Entre 2017 y 2018, en el marco de las expediciones científicas Seaflower fueron recolectados crustáceos de restos coralinos y en fondos blandos. Se recolectaron representantes de 17 familias, en la isla Cayos de Serranilla (ICS) y la isla Cayos de Alburquerque (ICA). Los resultados muestran una mayor riqueza en ICA, con 46 especies de 31 géneros, mientras que en ICS solo se registraron 37 especies y 27 géneros. En total se registran 67 morfoespecies de decápodos en los dos cayos, se hace un aporte

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en el conocimiento de 26 registros nuevos para el archipiélago y seis nuevos para Colombia. Con estos resultados, el número total de especies para el archipiélago es de 236, con un incremento del 12.38 % y un 16.7 % al total de especies registradas. Estos registros resaltan la importancia de la reserva para el Caribe colombiano, aportando el 32.3 % de las especies registradas para Colombia.

Palabras clave: *Crustacea; Decapoda; Seaflower; biodiversidad; riqueza*

Introduction

Colombia has about 2,900 km^2 of coral areas, of which 1,091 km^2 comprise bottoms with high coral cover. Among the coral areas of the Colombian Caribbean, most are found around the islands, lowlands and oceanic atolls of the Archipelago of San Andrés, Providencia y Santa Catalina (77%), where the most complex and developed reefs are also observed. For this reason, the Seaflower Biosphere Reserve (SBR) was declared by the United Nations Educational, Scientific and Cultural Organization (UNESCO), in 2000, as a World Heritage Site (Abril-Howard, *et al.*, 2012). Additionally, various studies indicate that this (group of islands, keys, banks and reefs have an important richness of species and a variety of marine environments that highlight their significance as possible reservoirs of biodiversity in the Colombian Caribbean, most of which have not been studied (Díaz *et al.,* 2000; Vega *et al.*, 2015).

The lack of knowledge related to benthic communities (epifauna and macrobenthos) in the SBR is evident, therefore, it is necessary to complement the faunal inventories of shallow and deep organisms that have been carried out in the Reserve, among which the study developed by the Instituto de Investigaciones Marinas y Costeras "José Benito Vives de Andréis" (Invemar) in the Common Regime Area between Colombia and Jamaica (Invemar-ANH, 2012). Since 2015, as a comprehensive strategy for the exercise of sovereignty in the Archipelago of San Andrés, Providencia y Santa Catalina, the Presidency of the Republic of Colombia launched the Scientific Expeditions Plan In order to strengthen the management and conservation of the Biosphere Reserve. The strategy aims to increase the criterion of ecosystem unity in this protected marine area. In line with this, the Seaflower National Technical Board, led by the Colombian Ocean Commission (CCO), has focused its efforts on strengthening the generation of knowledge about the Reserve, thanks to an inter-institutional process, where different actors have contributed to scientific research, and to the coordination and execution of scientific expeditions.

Among these, it is worth highlighting the participation of the Colombian Navy (ARC), the CCO, the Government of the Department Archipelago of San Andrés, Providencia y Santa Catalina, the Corporation for the Sustainable Development of the Archipelago of San Andrés, Catalina (Coralina), and the General Maritime Directorate (Dimar), through its Caribbean Oceanographic and Hydrographic Research Center (CIOH).

Within the arthropods, Crustaceans are the most abundant arthropods after insects, and although they are predominantly aquatic organisms, they have managed to adapt and conquer the terrestrial environment. Currently, around 1,003 families, 9,522 genera and 66,914 species have been described (Ahyong *et al.*, 2011).

Coralline rocks are home to a cryptofauna that, in addition to being specific, is excavated or used for cavities. In addition, they serve as a substrate for a high number of epifaunal species that take advantage of the niche created by the macroalgae that grow in this type of substrate. This fauna in the area of influence of the Archipelago is little or not at all known.

The Decapoda are possibly the most important group within the crustaceans. More than 14,900 species have been described worldwide (Ahyong *et al.,* 2011). In the Colombian Caribbean region, more than 700 different species of decapod crustaceans have been recorded, which allows estimating the presence in that region of more than 1,000 species.

Currently, the number of species of decapod crustaceans recorded throughout the Archipelago is 210 and 24 unique records. In the chapter on crustaceans in the book 'Biodiversity of the Sea of the Seven Colors', 198 species were listed, belonging to 125 genera and 52 families (Martínez *et al*., 2016).

The purpose of these investigations was to characterize the communities of benthic decapod crustaceans associated with shallow sedimentary bottoms and the cryptofauna in calcareous rocks of the SB and SC.

Study Area

Serranilla Bank (SB) is located north of the SBR, between 15°50′ and 16°′04′N, and 80°03′ and 79°40′ W. It is a bank that covers an area of 1,200 km^2 with the presence of small nearby cays (West Breaker, Middle Cay, East Cay and Beacon Cay). The shallow area has a carbonate shelf about 8 m deep, with bottoms composed of algae, sponges, small extensions of hard corals and some areas covered with seagrasses in the southeast sector (Abril-Howard *et al.,* 2012; CCO, 2015) (Fig. 1).

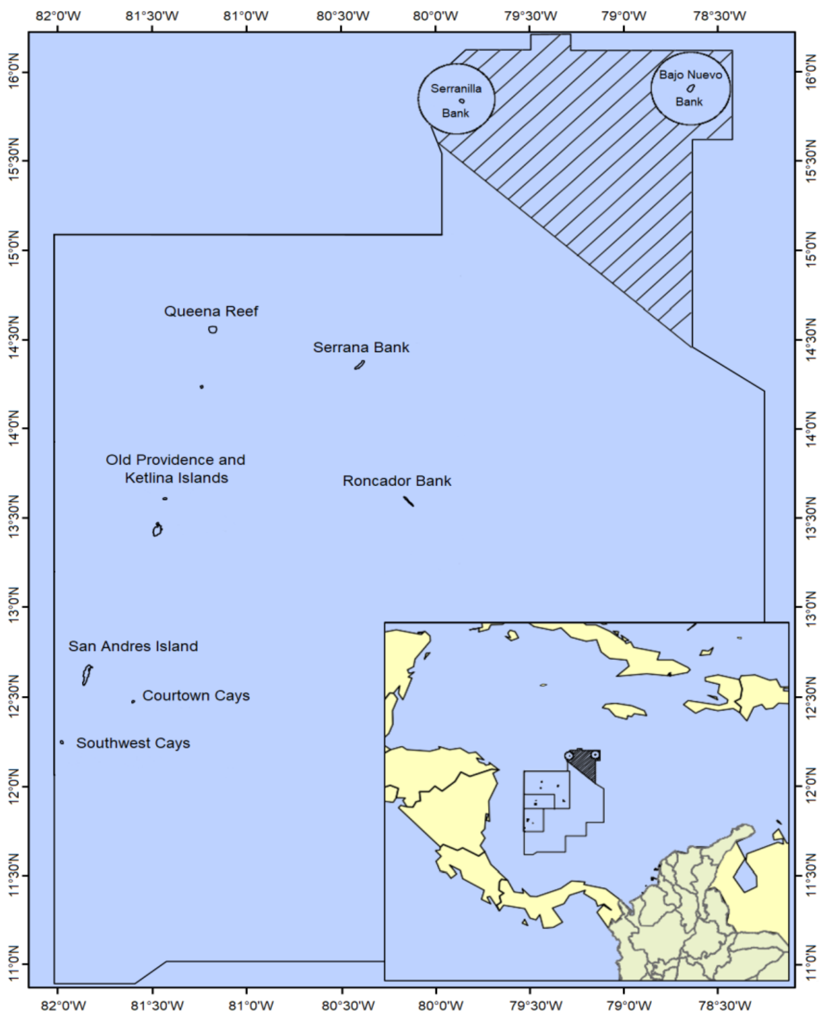


Figure 1. Location of study areas.

During the month of September 2017, the soft bottom benthic community was evaluated. Stations in the eastern sector (E11 and E12) and west (E0 to E10) of the SB (Fig. 2) were selected, samples were taken at 10.2 m and 30 m depth in the shallow zone, and one more sample was taken at 320 m at the end of the plain in the central area (E7). In turn, in the western sector of the cay, where there is no marked slope, but rather a plain approaching the limit of Colombia's jurisdiction, samples were taken in the internal zone and on the right and left margin of the plain.

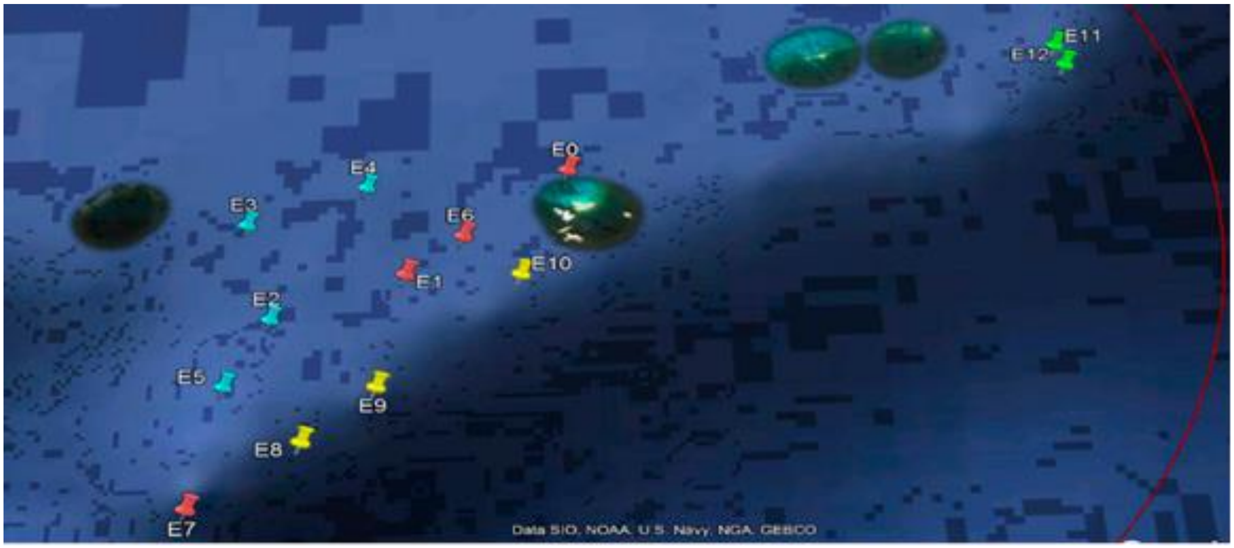


Figure 2. Serranilla Bank, location of the dredger sampling stations. (Courtesy: CCO - expedition coordination).

In September 2018, the expedition to Southwest Cays (SC) was carried out. During this outing, the research platform was not available, therefore, no sediment samples with dredge were collected and sampling was limited to the collection of crypto- and epifauna, which were carried out in the North Cay and South Cay sectors (Fig. 3).

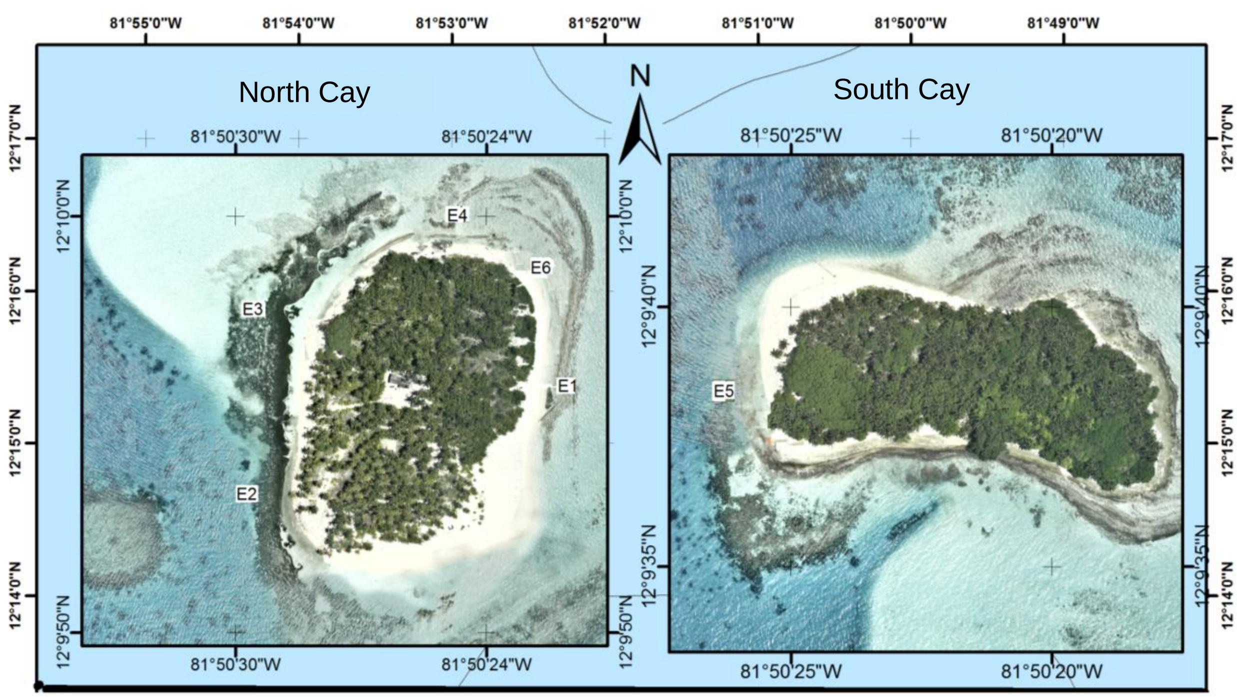


Figure 3. Southwest Cays. Location of sampling stations. (Courtesy: CCO - expedition coordination).

METHODOLOGY

In SB, sediment sample collection was carried out by means of a Chipec type dredge for the deep sample (320 m), and van Veen type for shallow samples (10 m – 30 m), until a minimum area of 0.1 m^2 was completed. On board the platform, the macrofauna was separated and the specimens were fixed in 96% alcohol. Subsequently, a preliminary wash of the sediment samples was done on a 500 µm mesh eye sieve to retain the macrofauna.

Marine benthos sediment samples were placed in plastic bags with 500 ml of magnesium chloride solution for 15-20 min. Subsequently, 500 ml of 12% formalin with borax and reactive Bengal rose were added.

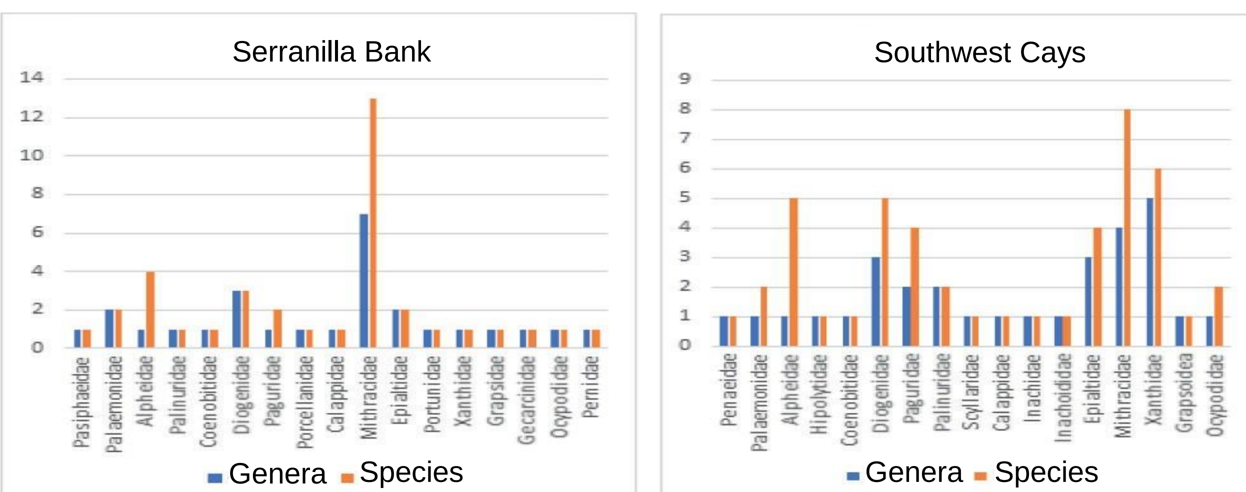
At the SB, most of the stations were made up of soft substrates with a high percentage of macroalgae (collected by means of the dredge). Sampling sites (20) were chosen where coral remains accumulate, and coral stones (5 – 7) were manually extracted from them and fractured to collect crypto and epifauna.

At the SC, the collection of samples was done by free diving using two methods: *i)* on sandy bottoms with an iron framed net with an opening of 0.1 m^2, an attached mesh of 500 µm mesh eye, and with the help of a plexiglass sheet introduced between the dredge and the substrate; *ii)* 23 sites were selected for manual collection, where coral rocks (5 – 7) were extracted at each station, then, with the help of a hammer and chisel, they were fractured, the organisms were collected and deposited in plastic bags, separated into groups and fixed in 96% alcohol. Additionally, some representatives of terrestrial decapods were collected.

The samples were transported to the laboratories of the Instituto de Estudios en Ciencias del Mar (Cecimar), where they were identified and deposited in containers separated by species and sampling place. The identification was made based on the books of Rathbun (1918, 1925, 1930 and 1937) for crabs, Chace (1972) for shrimp and the 'Illustrated Guide to Decapod Crustaceans of Florida' (Abele and Kim, 1986). This activity was carried out with the help of stereoscopy. The specimens will be deposited in the reference collection of the Natural History Museum "Makurigua" of Invemar.

RESULTS

In the two cays, SB and SC, specimens from 17 families were collected. However, there are differences in terms of the number of genera and species per family. In SB, there is a clear dominance of the Mithracidae (superfamily) with seven genera and thirteen species, most of the remaining families were present with a single genus and one species. In SC, there is no clear dominance of one family; in the case of genera, the highest number is found in Xanthidae, with five, followed by Mithracidae, with four; while, in the case of species, Mithracidae is present with eight, and Xanthidae is present with only six (Fig. 4).



(A) **(B)**

Figure 4. Number of genera and species by family of decapod crustaceans present in (A) Serranilla Bank and (B) Southwest Cays.

Table 1 lists the species present in both cays. Of the total number of species recorded (66 and one megalopa postlarvae), 35 and the megalopa were collected in the SB and 45 in the SC. Of these, six are new records for the Colombian Caribbean (N. R.). For the Archipelago, 26 species of decapods (N. R, and A. D.) are recorded for the first time; of these, only three were collected in the two sampling sites (*Paguriste puncticeps, Mithraculus cinctimanus* and *Actaea bifrons*), and a total of thirteen species of the lists are present in both cays.

Table 1 Species recorded in the Serranilla Bank (SB) and Southwest Cays (SC). A. D: Record for the Archipelago. N. R.: Record for the Colombian Caribbean. X: presence of the species.

N°.	Genus and species	SB	SC	N°.	Genus and species	SB	SC
1	*Rimapenaeus sp.*		A.D.	35	*Ericerodes gracilipes*		A.D.
2	*Anchistioides antiguensis*	A. D.		36	*Thoe puella*	A. D	X
3	*Periclimenaeus wilsoni*	N. R.		37	*Epialtus dilatatus*		N.R.
4	*Ancylomenes pedersoni*		X	38	*Epialtus sp.*	X	
5	*Leptochela carinata*	N. R.		39	*Pitho sp 1.*	X	
6	*Alpheus amblyonyx*		A.D.	40	*Pitho sp 2.*	X	
7	*Alpheus bouvieri cf.*		N.R.	41	*Pitho aculeata*		X
8	*Alpheus candei*		X	42	*Pitho lhermineri*		A.D.
9	*Alpheus heterochaelis*		X	43	*Teleophrys ruber*	X	X
10	*Alpheus normanni*		X	44	*Amphithrax hemphilli*	A. D	
11	*Alpheus nuttingi*		X	45	*Mithrax sp 1.*	X	
12	*Alpheus peasei*	X		46	*Mithrax sp 2.*		X
13	*Synalpheus brevicarpus*	N. R.		47	*Mithraculus coryphe*	X	X
14	*Synalpheus brooksi*	A. D.		48	*M. forceps*	X	
15	*Synalpheus rathbunae*	X		49	*M. sculptus*	X	X
16	*Thor floridanus*		A.D.	50	*M. cinctimanus*	A. D.	X
17	*Coenobita clypeatus*	X	X	51	*Nonala holderi*	A. D.	
18	*Clibanarius tricolor*	X	X	52	*Omalacantha bicornuta*	X	X
19	*Calcinus tibicen*	X	X	53	*O. antillensis*	A. D.	
20	*Paguristes puncticeps*	A. D.	X	54	*Macrocoeloma laevigatum*		A.D.
21	*Paguristes cadenati*		X	55	*M. subparalellum*		X
22	*Petrochirus diogenes*		X	56	*Achelous spinicarpus*	X	
23	*Pagurus brevidactylus*		X	57	*Carpilius coralinos*		X
24	*Pagurus* sp 1.	X		58	*Actaea bifrons*	A. D.	X
25	*Pagurus* sp 2.	X		59	*Platyactaea setgera*		X
26	*Phimochirus operculatus*		A.D.	60	*Williamstimpsonia denticulatus*		X
27	*Phimochirus holthuisi*		A.D.	61	*Cataleptodius floridanus*		A.D.
28	*Petrolishes galathinus*	X		62	*Pilumnus sp.*		X
29	*Panulirus argus*		X	63	*Pachygrapsus transversus*	X	
30	*Phyllamphion gundlachi*		A.D.	64	*Gecarcinus lateralis*	X	X
31	*Scyllarides aequinoctialis*		A.D.	65	*Percnon gibbesi*	X	X
32	*Cyclozodion angustum*		N.R.	66	*Ocypode quadrata*	X	X
33	*Calappa* sp. (Juv.)	X		67	Megalopa	X	
34	*Stenorhynchus seticornis*		X				

Figure 5 compares the number of shared and exclusive species. Of the 67 morphospecies present, eleven were collected at both sites, for the SB it represents the 37.14 % and for SC, 29.55 % of the species present; while 65.71% and 70.45% are present only in the SB and the SC, respectively.

Figure 5. Number of shared and exclusive species present (100%) at each of the two sampling sites.

Discussion

The records of decapod crustaceans in the Archipelago of San Andrés, Providencia y Santa Catalina date back to the beginning of the last century (Rathbun, 1918, 1925, 1930 and 1937) by listing numerous species present in Old Providence, based on the material deposited in the National Museum of Natural History, Smithsonian Institution, as a product of scientific expeditions such as the Albatross and the Fish Hawk, mainly. Expeditions have also been carried out by national institutions (Werding, *et al.* 1981; Vides, *et al.* 2016).

Table 2. Number of families, genera and species recorded for the Colombian Caribbean and for the Archipelago of San Andrés, Providencia y Santa Catalina. (Modified from: Campos, et al. 2011; Martínez-Campos *et al*. 2016).

	Families	Genera	Species
Number in the Colombian Caribbean	94	315	651
Number in the Archipelago of San Andrés, Providencia y Santa Catalina	53	126	210
Percentage of presence in the Archipelago in relation to the total for the Colombian Caribbean	54.6 %	49 %	32.3 %

Recently, and with the coordination of Invemar and Coralina, the book 'Biodiversity of the Sea of the Seven Colors was published, in which the species of the main taxonomic groups were listed, including crustaceans (Vides *et al.* 2016). In the chapter on crustaceans (Martínez-Campos *et al.* 2016), 198 species belonging to 125 genera and 52 families are listed.

Taking into account these records, Table 2 compares the number of species as well as genera and families recorded by Martínez-Campos *et al*. (2016), with the number of records, including those listed in this study. Likewise, the percentage of participation by families, genera and species registered in the Archipelago was calculated, in relation to the total number of records for the Colombian Caribbean. The number of families is present in the Archipelago with more than 50% of them registered in the Colombian Caribbean, while for species they only reach 32% of the national records.

The contribution to the knowledge of species richness of this study highlights the importance of the Archipelago as a reservoir of the biodiversity of the Caribbean Sea, and it justifies the deepening of the evaluation of this richness to really know its role as a biosphere reserve.

Taking into account the records included in this study (Table 3), the contribution is significant if previous records are compared with current ones. The increase in the number of genera and species stands out, with 9.6% and 10.64%, respectively.

Table 3. Number of previous and current records of families, genera and species of decapods of the Archipelago of San Andrés, Providencia y Santa Catalina.

	Families	**Genera**	**Species**
Previous records	52	126	210
Current records	53	137	236
Increase	1.9 %	9.6 %	11.06 %

The study of the crustacean fauna in the Archipelago is equally relevant for the knowledge of crustacean biodiversity in the Colombian Caribbean. Of the 37 species listed for the SB, twelve are new records, and of those listed for the SC (46), 14 are new records for the SBR. Additionally, three species from each of the keys are new records for the Colombian Caribbean, increasing the number by six, for a total of 657 species recorded.

The six new records for the Colombian Caribbean are the shrimp *Periclimenaeus wilsoni, Leptochela carinata, Synalpheus brevicarpus* (Serranilla Bank), *Alpheus bouvieri cf.* and the crabs *Epialtus dilatatus and Calappa angusta* (Southwest Cays).

When comparing the percentage of exclusive species (Fig. 2), the SC presents a higher percentage, considering that the two keys are located one distance apart from the other. The SB is located in the north of the Archipelago, on the borders with Nicaragua, Honduras and Jamaica (Zambrano and Andrade, 2011)— according to these authors the SB is under the action of the Caribbean current that flows in a northwesterly direction, after passing through the Lesser Antilles—; while the SC is located in the southern part of the Archipelago, 37 km southwest of San Andres Island (Coralina, 2003). The behavior of the currents defines significant differences between the two cays. The SC is under the effect of the Panama-Colombia countercurrent for much of the year (Coralina-Invemar, 2012), unlike the SB, which is directly influenced by the Caribbean current. Therefore, the crustacean fauna will depend on the proximity to other ecosystems or the influence of the continental margin. In the SC, there are changing environmental conditions, due to its proximity to Central America, while in the SB the influence is clearly oceanic, with more stable conditions.

Conclusions

The results of the study of the crustacean fauna on the Southwest Cays and the Serranilla Bank demonstrate the importance that the Archipelago represents for biodiversity in the Colombian Caribbean, increasing the number of species recorded to six.

The differences in species richness between the two cays islands is directly related to the environmental conditions of each. SB is under the influence of the Caribbean current, with more stable conditions, and SC is influenced by the Panama-Colombia countercurrent, with more changing conditions.

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Authors' Contribution

Conceptualization: N.H.C., A.D.L., and P.R.D.; methodology: N.H.C., A.D.L., and P.R.D.; validation: N.H.C., A.D.L., and P.R.D.; analysis: N.H. C., A. D. L y P. R. D.; research: N. H. C., A. C. D. L. y P. R. D.; resources: N. H. C., A. D. L y P. R. D.; data curation: N.H.C., A.D.L., and P.R.D.; drafting-preparation of the original draft: N. H. C., A. D. L and P. R. D; writing-revision and editing: N.H.C., A.D.L. and P.R.D.; visualization: N. H. C., A. D. L y P. R. D.; supervision: N. H. C., A.D.L. and P.R.D.; project management: N. H. C.; fundraising: N.H.C. All authors have read and accepted the published version of the manuscript.

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RESEARCH ARTICLE

New records of the Saint George Island Gecko (*aristelliger georgeensis*) in the Seaflower Biosphere Reserve, Colombia

Nuevos registros del geco pestañudo (Aristelliger georgeensis) en la Reserva de la Biósfera Seaflower, Colombia

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ABSTRACT

The Saint George Island Gecko is a Caribbean species recorded on the coasts and islands of Mexico, Belize and Honduras, which prefers rocky substrates, trees and shrubs. Its distribution in Colombia is limited to the archipelago of San Andrés, Providencia and Santa Catalina in the Seaflower Biosphere Reserve, where it has been recorded on the three most populated islands and on Roncador Bank. During the scientific expeditions to the Reserve between 2014 and 2021, the search for this species was intensified through surveys in the emerged areas (islands and cays) of Serranilla, Serrana, Roncador, Southwest, Old Providence and Ketlina. This species of gecko was recorded in all the localities visited, which broadens our knowledge of its geographic distribution. Since this is a nationally threatened species, these new records represent potential opportunities for its conservation. However, the introduced and invasive species recorded in most localities (i.e., *Rattus* spp., *Gallus gallus domesticus*, *Hemidactylus frenatus* and *Periplaneta americana*) pose a threat to this gecko and require urgent management measures.

KEYWORDS: Caribbean islands; invasive species; threats

RESUMEN

El geco pestañudo es una especie caribeña, registrada en las costas e islas de México, Belice y Honduras, y que tiene preferencia por sustratos rocosos, árboles y arbustos. Su distribución en Colombia se limita al archipiélago de San Andrés, Providencia y Santa Catalina en la Reserva de la Biósfera Seaflower, en donde había sido registrada en las tres islas más pobladas y en la isla Cayos de Roncador. Durante las expediciones científicas a la Reserva entre 2014 y 2021, se intensificó la búsqueda de esta especie a partir de recorridos en las áreas emergidas de las islas y cayos de Serranilla, Serrana, Roncador, Alburquerque, Providencia y Santa Catalina. En todas las localidades visitadas se registró esta especie de geco, lo que amplía el conocimiento sobre su distribución geográfica. Por tratarse de una especie amenazada a nivel nacional, estos nuevos registros constituyen potenciales oportunidades para su conservación. Empero, las especies introducidas e invasoras registradas en la mayoría de las localidades (i.e., Rattus spp., Gallus gallus domesticus, Hemidactylus frenatus y Periplaneta americana) suponen una amenaza para este geco, que demandan medidas urgentes de manejo.

PALABRAS CLAVE: *islas del Caribe; especies invasoras; amenazas*

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Introduction

The Saint George Island gecko (*Aristelliger georgeensis*, Bocourt, 1873) is a species of gecko discovered on Saint George Island, Belize, in the Caribbean, which belongs to a genus that includes several species of lizards endemic to the West Indies and coastal areas of Central America (Bauer and Russell, 1993). It exhibits typical characteristics of the genus *Aristelliger*, such as a robust body and a short tail relative to its total body length (Bauer and Russell, 1993). It is a small to medium-sized gecko with adult specimens between 7 and 10 cm in total length. Their coloration varies from brown and gray to lighter tones, with orange spots on their sides (Bauer and Russell, 1993). It is nocturnal, preferring coral rocks, low trees and shrubs. It has been recorded in human buildings, where it seems to have being displaced by the common house gecko (*Hemidactylus frenatus*; Caicedo-Portilla, & Dulcey-Cala, 2011).

In Colombia, this species has only been recorded in the Archipelago department of San Andrés, Providencia and Santa Catalina, and at the national level it is considered threatened (Vulnerable category: VUD2) due to its reduced distribution (<26 km^2), and to the negative effect that invasive species can have on its populations (Caicedo-Portilla and López-Victoria, 2015). At the international level, it is considered a species of least concern (LC: Caicedo-Portilla, Mandujano, and Lee, 2016). The most recent published record of this species in Colombia corresponds to that of Roncador Bank, which is part of the Seaflower Biosphere Reserve (SBR), where it inhabits rocky coral substrates and human-made buildings (López-Victoria and Daza, 2015).

As part of the comprehensive assessment of the status of terrestrial tetrapod populations present in the SBR islands, and with the aim of contributing to the knowledge about the distribution of this threatened gecko species, the purpose of this study was: 1) to establish the presence/absence of the Saint George Island gecko on the SBR islands visited, and 2) to estimate the potential risks (e.g., habitat quality, introduced species, human activities) faced by populations of this species on those islands. This study seeks to contribute to the analyses and classifications that are carried out on threatened reptiles in Colombia, within the framework of the update of the red books.

Study Area

Between 2014 and 2021, intensive searches for the Saint George Island gecko were conducted on all the islands and cays visited during the the Seaflower scientific expeditions. The islands, cays and sandbanks visited included the following coral complexes, from north to south and from east to west: Serranilla Bank, Serrana Bank, Roncador Bank, Southwest Cays, and the Old Providence and Ketlina Island; no visit was made to the island of Courtown Cays (Bolívar), nor were any observations made on San Andres Island, a locality about which there is sufficient information and records of this species (Fig. 1). Except for Old Providence and Ketlina, which have emerged surfaces of volcanic origin, all the islands and cays visited are of coral origin, featuring flat relief, with sand soils and coral debris of various sizes. Shrub vegetation, some trees, and coconut palms are present on all the main cays of the different coral- origin islands. In Serranilla, Serrana, Roncador and Southwest or Alburquerque, there are buildings of different sizes that correspond to the prominent posts of the Colombian Navy (ARC). In the cays and other smaller emerged portions (i.e., sandbanks) only small patches of shrubs and creeping plants were found.

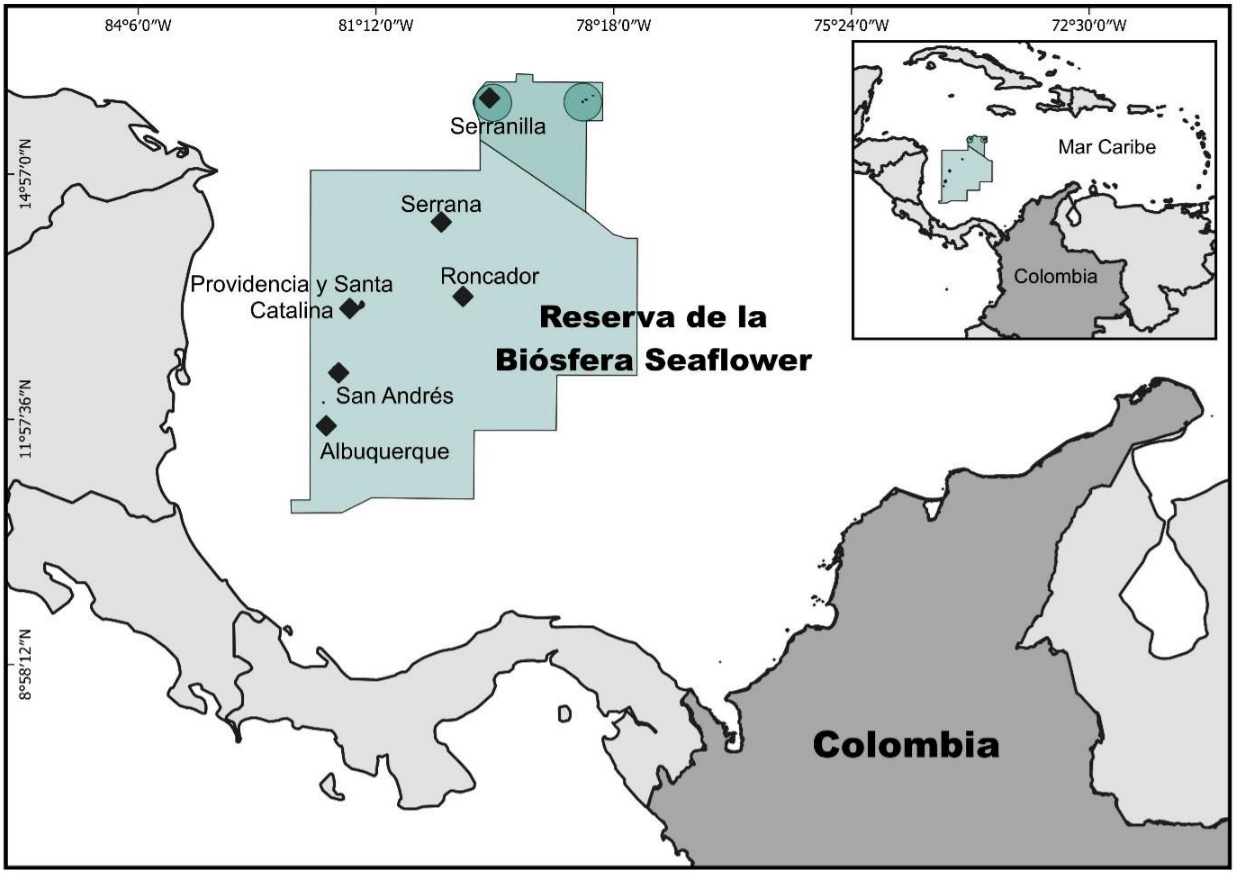

Figure 1. Islands and cays visited in the Seaflower Biosphere Reserve in search of the Saint George Island gecko during the 2014 and 2021 Seaflower expeditions.

METHODOLOGY

Previous records of the Saint George Island gecko and its respective localities were obtained from databases of published scientific literature (Bauer & Russell, 1993; Caicedo-Portilla & López- Victoria, 2015; Charruau, Díaz de la Vega Pérez, & Méndez de la Cruz, 2015; López-Victoria & Daza, 2015). They were then complemented with records from the iNaturalist platform (inaturalist. org) and ratified using the reptile database (Uetz, Freed, Aguilar, Reyes, Kudera, & Hošek, 2024). From all the consolidated records, the distribution map shown in Figure 2 was generated. Doubtful records or without a specified location were discarded.

Records in the new locations were obtained during exhaustive tours (*e.g.*, routes lasting between 1 h and 2 h), primarily conducted at night. These explorations involved inspecting areas between and beneath rocks and coral debris, as well as among the branches and foliage of trees and shrubs. Explorations were also made in the buildings of the ARC. No individuals were counted or marked.

The potential threats to the Saint George Island gecko are the result of direct field observations, mainly focused on the presence of invasive species with predatory potential or transmission of pathogens, widely known for their negative effects on island fauna (in particular introduced species such as rodents and insects). In this sense, particular emphasis was placed in and around the ARC facilities. The threats were synthesized in a summary table, and for each threat the respective observation/recommendation was made.

Results

The new records of the Saint George Island gecko on the islands of Serranilla, Serrana and Southwest represent new island and remote locations where this species has been observed. Serranilla is the furthest town from the continent of Central America, more than 350 km in linear distance, and, in turn, the most isolated locality known; the closest locality to Serranilla is 160 km in linear distance (Serrana). Altogether, the records in the islands and cays of the SBR constitute the largest number of oceanic locations where this species is present (Fig. 2).

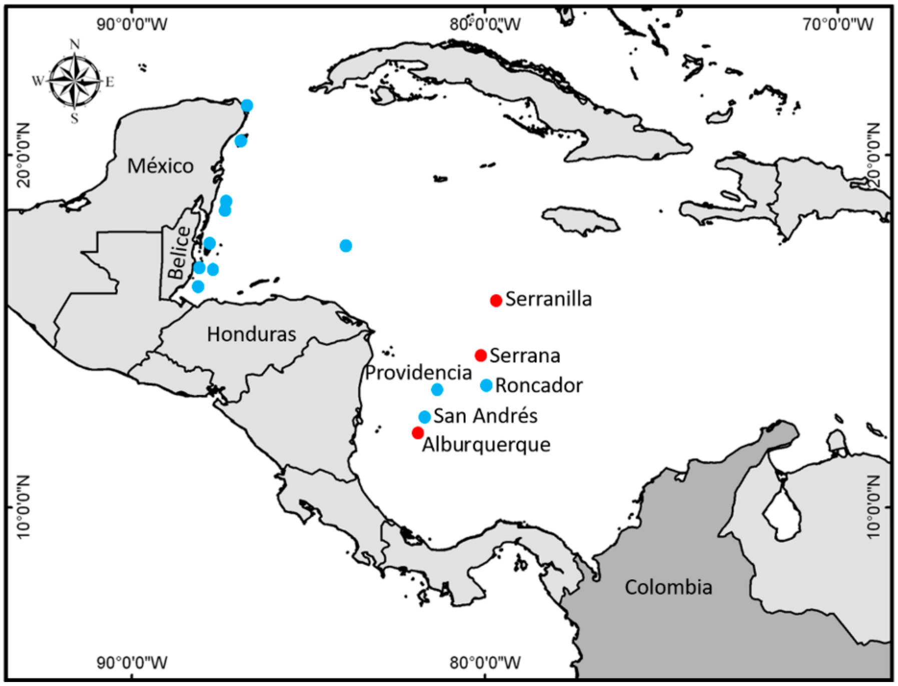

Figure 2. Previously known and documented distribution of the Saint George Island gecko (blue circles) and the new locations provided by this study (red circles).

Individuals of the Saint George Island gecko were observed in different microhabitats on the islands, including debris and coral rocks, shrubs, palm trees, and human-made buildings (Fig. 3). Although the samplings were not focused in population size estimates, the highest concentration of individuals was observed in Cangrejo Cay, in the coral complex of Old Providence, where more than 30 individuals occupied the branches and foliage of a beach grape (Fig. 3D).

Figure 3. The Saint George Island gecko on the islands of the Seaflower Reserve: **A)** juvenile caught and released among coral rocks, on the Serranilla Bank, **B)** adult on a coconut palm, on the Serranilla Bank, **C)** adult on a leaf of beach grape (*Coccoloba uvifera*), in Cangrejo Cay, Old Providence. (Photo: Laura Giraldo).

The presence of introduced and invasive species was found to be a threat present on all the main islands (i.e., permanently inhabited) and, to a lesser extent, on smaller cays and sandbanks (Table 1). In particular, the case of rats (*Rattus* spp.) on the Serranilla Bank, cockroaches (*Periplaneta americana)* on the Serrana Bank, and chickens and hens (*Gallus gallus domesticus*) on the Southwest Cays were striking (Fig. 3). In all the locations visited that correspond to new records for the Saint George Island gecko, the common house gecko (*Hemidactylus frenatus*) was also observed. Garbage was another striking aspect, due to its large accumulation, particularly on the southern island of Southwest Cays (Fig. 4).

Table 1. Introduced and invasive species considered to be a potential threat to the populations of the Saint George Island gecko on the islands of the Seaflower Reserve visited. Some management measures are suggested.

Location	Introduced /invader species	Observation	Potential risk	Potential risk
Serranilla Bank	*Rattus* spp.	The two species of common rats (*R. rattus* and *R. norvegicus*) are probably found.	Direct predation on the gecko.	Direct competition (Caicedo-Portilla & Dulcey-Cala, 2011).
	Periplaneta americana	In particular in the vicinity of the ARC buildings.	Direct predation on the gecko. (Pérez, 1989).	Optimize the management of garbage and waste, and carry out cockroach control from natural baits.
	Hemidactylus frenatus	In particular in the buildings of the ARC.	Direct competition (Caicedo-Portilla & Dulcey-Cala, 2011).	Manual removal of introduced geckos, under the supervision of biologists (herpetologists).
Serrana Bank	Same species	Same observations	Ditto.	Same recommendations.
Southwest Cays (main island)	Same species	Same observations	Ditto.	Same recommendations
Southwest Cays (South Island)	*Gallus gallus domesticus*	Apparently introduced by fishermen as an alternative source of protein.	Direct predation on the gecko.	Removal of these hens and chickens from the island.

As for the Southwest Cays, and in general in all the islands and cays of the SBR, the presence of garbage was a constant. On the Southwest Cays, this garbage seems to be derived from temporary permanence of people and not from garbage dragged by the sea currents, since it was observed agglomerated in the interior area of the island, associated with improvised houses (tents) present there (Fig. 4).

Figure 4. Panoramic view of the area for improvised shelters and garbage associated with the temporary camps south of the coral complex of the Southwest Cays. (Photo: Felipe Estela).

Discussion

The new distribution records reported in this study for the Saint George Island gecko represent conservation opportunities for this threatened species (Caicedo-Portilla & López-Victoria, 2015; López-Victoria & Daza, 2015). This is mainly because the three islands (and associated islets) are part of the SBR, which is a vocation towards the care of the organisms that inhabit this reserve. Additionally, these three locations are aligned in a south-north direction, and they are the southernmost and northernmost records of this species in Colombian territory, and the records of Colombia are the easternmost of this species, expanding its distribution considerably (Fig. 2).

Regarding the biogeography of this species of gecko, and although it continues to be treated as a species, it should be noted that Cloud's study (1993), supported by molecular tools, suggests that Aristelliger praesignis forms a complex of species with A. georgeensis nested inside. Since this study did not account for the entire distribution of A. georgeensis, including the new locations, it is possible that it represents a clade with multiple taxa, which is worth examining in depth, especially if we consider the fact that it has been catalogued under some degree of threat or potential conflict with species introduced in some locations throughout its distribution (Caicedo-Portilla & López-Victoria, 2015; Charruau et al., 2015).

Particular attention has been drawn to the threat posed by the introduction of the species Hemidactylus frenatus, a species of gecko of Asian origin, currently present worldwide, which appears to be a potential competitor of *A. georgeensis* in San Andres and Old Providence (Colombia) and in the Chinchorro Bank (Mexico) (Caicedo-Portilla and Dulcey-Cala, 2011; Charruau *et al.,* 2015). This species of introduced gecko was observed in the three new locations for the Saint George Island gecko in the SBR, which poses a challenge for its conservation.

In addition to the impact that the introduced gecko species may have, the other invasive species recorded (i.e., rats, chickens and cockroaches) are also a concern, due to their devastating effect on native species, especially on islands around the world (Holmes et al., 2019; GISD, 2024). Timely management of these invasive species would be beneficial for all native species, especially for seabirds that nest on those islands, for other resident (non-marine) birds, for sea turtles that use the islands for nesting, for terrestrial invertebrates, such as crabs of the family Gecarcinidae, and, of course, for the Saint George Island geckos.

Finally, solid waste of different origin (*i.e.,* dragged by sea currents or abandoned by visitors on the islands) requires immediate management, due to the multiple health problems and risk of death that they present to the tetrapod fauna of the SBR islands. So far, its effects on turtles and birds have been widely studied (Wilcox, Sebille, & Hardesty, 2015; Moon, Shim, & Hong, 2023), but there are no published studies on their effects on geckos.

With the new locations reported in this study, the geographical distribution of this species of terrestrial reptile, common to almost all the islands within the SBR is considerably expanded. Future studies should focus on estimates of the population sizes of this species, as well as its genetic structures. In the meantime, measures to manage the threats that loom over this and other native species of the Reserve are more than urgent.

Conclusions

The Saint George Island gecko has a broader geographical distribution than previously reported for the SBR. These new locations represent potential opportunities for its conservation, since it is a threatened species at the national level. Despite this opportunity, introduced and invasive species, as well as poor disposal of solid waste on the islands, must be mitigated urgently, as they pose a threat of extinction not only to *Aristelliger georgeensis*, but also to all native fauna of the islands and cays of the SBR. Seaflower is home to a considerable number of endemic species (McNish, 2011; Caicedo-Portilla, 2014), therefore, as part of the substantive commitment to a biosphere reserve, environmental authorities, both local and national, must take urgent measures to dispel these possible threats, especially considering that the localities in Colombia correspond to the southernmost and easternmost distribution of this species.

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RESEARCH ARTICLE

Old Providence McBean Lagoon NNP: evidence of refuge for threatened fish species and herbivores during the 2019 Seaflower Expedition

PNN Old Providence McBean Lagoon: evidencias de refugio para especies de peces amenazadas y de herbívoros durante la Expedición Seaflower 2019

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ABSTRACT

The Old Providence McBean Lagoon National Natural Park (PNN OPMBL) was created with purposes such as conserving ecosystems and key species that contribute to local and regional fishing productivity. Overfishing and habitat loss have threatened several commercial fish species and some herbivorous fish as well. The PNN OPMBL can constitute an important refuge for these species in fulfillment of their conservation objectives. During the 2019 Seaflower Expedition in Old Providence Island, the richness, abundance, size ranges and biomass of the fish community were evaluated inside and outside the park. In the PNNOPML station within the park, 16 species of fish categorized as threatened were registered, 15 of them included in the Red book of fish in Colombia. The biomass, abundance and density of these species were higher than those registered for other sites outside the park. The biomass of herbivorous fish considered important for the resilience of coral reefs due to their ecological role was also higher within the park. These results demonstrate the important role of these areas to protect species under conservation and contribute to natural and social sustainability.

KEYWORDS: marine fish; marine protected areas; conservation; biodiversity refuge; Colombian Caribbean

RESUMEN

El Parque Nacional Natural Old Providence McBean Lagoon (PNN OPMBL) fue creado con propósitos como el de conservar ecosistemas y especies clave que aporten a la productividad pesquera local y regional. La sobrepesca y la pérdida de hábitat han puesto en amenaza de extinción a diversas especies de peces de interés comercial y algunos peces herbívoros. El PNN OPMBL puede constituir un importante refugio para estas especies en cumplimiento de sus objetivos de conservación. Durante la Expedición Seaflower

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2019 a la isla de Providencia, se evaluó la riqueza, abundancia y biomasa de la comunidad íctica dentro y fuera del parque. En la estación PNN OPMBL, dentro del Parque, se registraron 16 especies de peces categorizadas como amenazadas, quince (15) de ellas incluidas en el Libro Rojo de Peces Marinos de Colombia. Tanto la biomasa como la abundancia y la densidad de dichas especies fueron superiores a las registradas para otros sitios fuera del parque. La biomasa de peces herbívoros, considerados importantes para la resiliencia de arrecifes coralinos por su papel ecológico, fue también mayor dentro del parque. Estos resultados demuestran el importante papel de estas áreas para proteger especies objeto de conservación y para aportar a la sustentabilidad natural y social.

Palabras clave: *peces marinos; áreas marinas protegidas; conservación; refugio biodiversidad; Caribe colombiano*

Introduction

The National System of National Natural Parks (SN PNN) aims to protect biodiversity, conserving species and ecosystems important for human well-being. The PNN OPMBL, located within the Seaflower Biosphere Reserve (SBR), includes marine ecosystems such as mangroves, seagrasses and coral reefs, as well as species of vertebrates and marine invertebrates that are conservation objects included in the park's management plan, which also has natural connectivity from the tropical dry forest to the open sea.

Marine protected areas (MPAs) are a proposal by the United Nations to conserve life on planet Earth and to recover impacted areas or depleted species (UNEP, 2019). They allow the biomass of stocks to recover when overfishing and environmental impacts have collapsed the main fishery resources (Worm *et al*., 2006; Pauly, 2010; Pauly & Zeller, 2016), and to increase their productivity due to the overflow effect (Roberts *et al*., 2001; Prato & Newball, 2016). Pauly *et al*. (2003) highlight the proper management of MPAs as one of the actions required to maintain environmental sustainability for fisheries and food security.

According to the Food and Agriculture Organization of the United Nations (FAO, 2018), 80% of fish stocks have been fully exploited, overexploited or depleted. In Colombia, production indicators show a downward trend, largely due to overfishing (Rueda *et al*., 2018; Escobar *et al*., 2019). In the Archipelago state of San Andrés, Providencia, and Santa Catalina, fisheries analyses also showed a decreasing trend associated with overfishing, habitat loss, or illegal fishing (Santos-Martínez *et al*., 2019a; Santos-Martínez, *et al*., 2019b).

Overfishing in the Caribbean is also considered one of the factors that widely affects coral reefs and their ecosystem services (Burke, *et al*., 2011). On the island of Old Providence, commercially important fish such as groupers and sea bass have been affected by overfishing, putting them at risk of extinction; due to their scarcity, fishing pressure has been transferred to fish of lower trophic levels such as herbivores, leaving several species of parrotfish in danger of extinction (Chasqui *et al*., 2017). This leads to cycles of reef deterioration with increased algae cover and loss of coral cover known as phase shifts (Mumby, *et al*., 2014). These shifts further exacerbate the loss of 80% of coral cover reported for the Caribbean since the 1970s (Gardner, *et al*., 2003), and result in considerable habitat loss for commercially important reef fish, herbivores, and invertebrates. The high dependence on marine ecosystems for food security in oceanic island territories such as the Archipelago of San Andrés, Providencia and Santa Catalina, make MPAs such as the PNN OPMBL more relevant for human well-being and for the resilience of strategic marine ecosystems themselves.

In this research developed by the Universidad Nacional de Colombia (UNAL) - Caribbean Campus, within the framework of the Project for the Valuation of Ecosystem Services of Reefs Adjacent of Old Providence and Ketlina Islands, and within the projects developed by the

Seaflower scientific expeditions, coordinated by the Colombian Ocean Commission (CCO), it was sought to evaluate the characteristics of the fish communities in sites with similar conditions on Old Providence Island. One of these sites is protected by the National Park (NNP OPMBL) and the other one does not count on the protection of the MPA. The aim was to determine possible differences between attributes (abundance, biomass) of the fish community, especially of the groups of species that have been categorized with different degrees of threat of extinction in Colombia or in international lists defined by the International Union for Conservation of Nature (IUCN) (available online at: IUCN Red List of Threatened Species) (NT, VU, EN, CR) or by the Red Book of Marine Fishes of Colombia (Chasqui *et al*., 2017). Possible differences in the biomass of the group of herbivorous fish that may be related to the special protection factor offered by the MPA were considered. Additionally, the results of both Old Providence sites were compared with a sampling site on San Andres Island that is not part of the McBean Lagoon MPA, which may also be exposed to greater fishing pressure given the higher population density of San Andres Island.

Study area

SBR was declared by the *Man and Biosphere* program of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2000. It is located in the Western Caribbean of Colombia, encompassing the entire department of the Archipelago of San Andrés, Providencia and Santa Catalina. With a total area of 180,000 km², it includes nine reef islands, submerged banks, inhabited sand cays, and structures such as atolls (Coralina-Invemar, 2012). It stands out for its extensive coral reefs, seagrass meadows, mangroves, and tropical dry forests. In addition, it protects more than 2,300 marine species and is part of the Western Caribbean reef hotspot; it has about 77% of the coral reefs of Colombia (Coralina-Invemar, 2012). The people who inhabit the Archipelago islands, including San Andres and Old Providence, greatly benefits from the marine ecosystems of a territory composed of 99% of sea area, with multiple benefits from the ecosystem services provided by the maritory and its ecosystems, which are the foundation which is the basis for the well-being and the economy of the populations living in the largest department of Colombia (Prato & Newball, 2016).

The Old Providence McBean Lagoon NNP is a key protected area at the national level, in the Colombian Caribbean. It is located on the Old Providence and Ketlina Islands, and was declared an MPA in 1995. Since 2000 it has been part of the SBR, and since 2004 it has also been part of the MPAs of the Archipelago of San Andrés, Providencia and Santa Catalina. This NNP spans 1,613.9 hectares and features a unique combination of natural beauty and biodiversity. In its marine portion, there is part of the reef barrier that protects the coasts of the island of Old Providence, and further north a discontinuous barrier formation, formed by multiple submarine mounds, known as the 'Pinnacles', generally covered by fire coral *(Millepora complanata)* in its upper part exposed to waves. This coral reef, together with the reef lagoon located in front of the McBean mangrove, generates a spectacular range of colors, which is commonly known as 'The Sea of Seven Colors'. The Old Providence McBean Lagoon NNP has as its conservation objectives the protection of key elements such as the strategic ecosystems of coral reefs and seagrass beds, as well as threatened fish species, including some from the grouper and sea bass group. These are part of the eight (8) prioritized conservation objectives in the management plan of the PNN OPMBL. (Retrieved online from http://www.parquesnacionales.gov.co/ portal/ wp-content/uploads/2019/12/Cartilla-Old-providence-ESPANOL.pdf).

Methodology

In order to assess the role of the OPMBL NNP for the conservation of threatened species of fish of commercial interest (such as groupers and sea basses) and with a key ecological function for coral resilience (herbivorous fish), during the Seaflower 2019 Scientific Expedition to the Old Providence and Ketlina Islands, visual fish censuses were carried out, based on the methodology of the World Wildlife Fund (WWF, 2006). Five transects (n=5) of 50 m x 2 m band (total 500 m^2) were carried out at each sampling site. During the fish censuses, the number of individuals per species (abundance) and the size ranges of each individual were recorded. With this information, the number of species recorded (richness) and biomass were calculated. This can be estimated from the number of individuals per species, the size range of these individuals and other species-specific allometric equations available at FishBase (https://fishbase.se/home.htm), when using the databases and methodology proposed in WWF (2006).

Visual fish censuses were carried out in two sampling sites located on peripheral windward reefs (east of Old Providence), at similar depths (8 m – 11 m), so that one site was located within the OPMBL NNP and the other further north, outside the park (Provout). Additionally, with the same methodology, visual fish censuses were carried out on the island of San Andrés, in the Bajo Bonito sector (9 m - 12 m) (Sanandr) (Table 1).

The fish species recorded during the surveys were cross-referenced with both international and national lists to determine if they were categorized under some degree of threat of extinction (NT, VU, EN, CR). The Red Book of Marine Fish of Colombia was consulted (Chasqui *et al*., 2017) as well as international listings defined by the International Union for Conservation of Nature (IUCN) (available online at: https://www.iucnredlist.org/en).

Abundance and biomass were the main attributes of the fish community to be evaluated. Then, emphasis was placed on the group of species categorized as extinction threatened, and for the group of herbivorous fishes, including surgeonfishes (Acanthuridae) and parrotfishes (Scaridae), mainly.

According to the particular purpose of this research, the interest groups of threatened fish species and herbivorous fish were analyzed through statistical tests to evaluate possible differences between the analyzed sites in terms of abundance or biomass. Normality tests (Shapiro-Wilk test) were applied to evaluate the feasibility of using and selecting parametric methods such as Anova, or non-parametric. As no normal distribution was found in the data, it was decided to use non-parametric methods such as Kruskal-Wallis and Wilcoxon's paired analysis, using the free software R and R-Studio (Zar, 2010).

RESULTS AND DISCUSSION

During the samplings, a greater richness was recorded in the station located within the MPA OPMBL NNP than in the Provout station. The number of species found in these two stations was notably higher than those recorded in Sanandr. The total abundance and density of fish in NNP OPMBL was twice as big as that found in the other two sites (Table 1).

Table 1. Location of the sampling stations and general results of the fish community recorded in the visual censuses (n=5) carried out at each station.

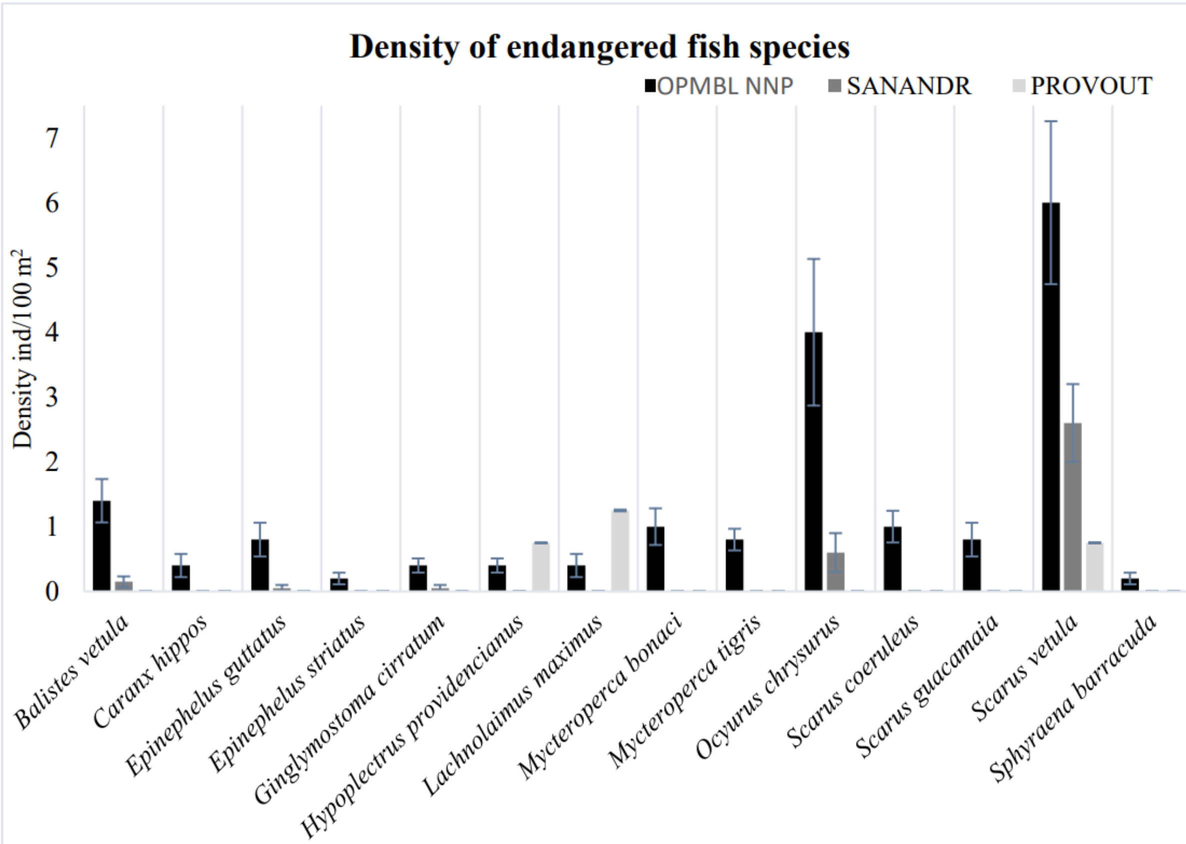
Item/Station	OPMBL NNP	Provout	Sanandr
Coordinates	N 13°23’26.7’’ W 81°20’19.6’’	N 13°25’46.4” W 81°20’07.4”	N 12°35’12.5” W 81°43’15.19”
Depth (m)	8-11	8-10	8-11
Total individuals	3717	1047	1548
Density (ind/100m^2)	743	209	309
Total biomass (g)	560117	117336	82768
Biomass per area (g/100m^2)	112023	23467	16553
Total number of species	136	105	32

At the station within the MPA of the OPMBL NNP, 136 species were registered, of which 16 correspond to threatened species; fourteen (14) classified into different threat categories defined by the International Union for Conservation of Nature (IUCN) (available online at: IUCN Red List of Threatened Species) (NT, VU, EN, CR) and fifteen (15) by the Red Book of Marine Fishes of Colombia (Chasqui *et al*., 2017) (Table 2).

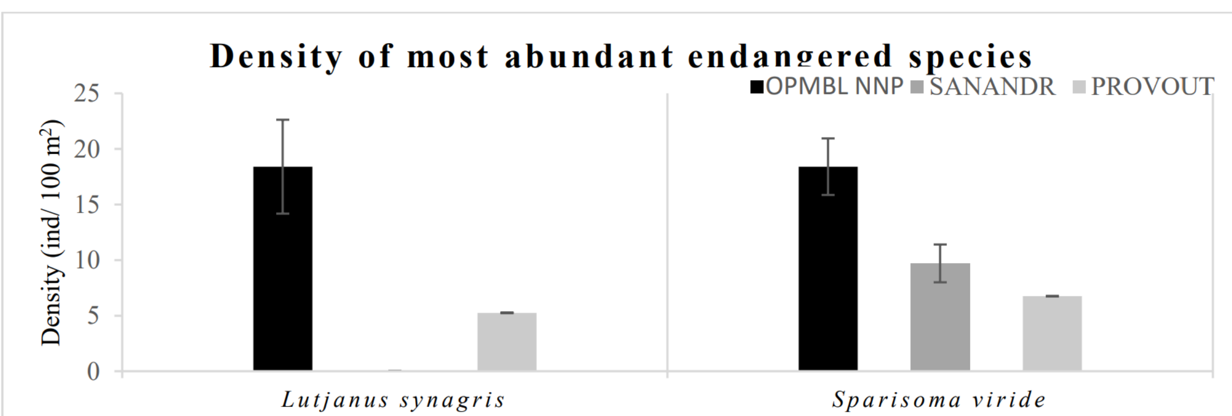
Table 2. Average abundance, density, and biomass of species cataloged under threat categories according to IUCN and/or the Red Book of Marine Fishes of Colombia (Chasqui *et al*., 2017), recorded during the 2019 Seaflower Expedition at the Pnnopml station within the Old Providence McBean Lagoon NNP.

Species	Abundance (Ind/500m²)	Density (Ind/100m²) ± EE	Biomass (g/100m²) ± EE	Category IUCN	Category: Red Book: Marine Fish from Colombia
Balistes vetula	7	1.4 ± 0.3	1282.4 ± 254.7	VU	EN
Caranx hippos	2	0.4 ± 0.2	3048.0 ± 1363.1	LC	VU
Epinephelus guttatus	4	0.8 ± 0.3	193.4 ± 63.0	NT	NT
Epinephelus striatus	1	0.2 ± 0.1	121.1 ± 54.2	CR	CR
Ginglymostoma cirratum	2	0.4 ± 0.1	1561.4 ± 427.6	VU	VU
Hypoplectrus providencianus	2	0.4 ± 0.1	0.01 ± 0.01	LC	NT
Lachnolaimus maximus	2	0.4 ± 0.2	714.1 ± 319.4	EN	EN
Lutjanus synagris	92	18.4 ± 4.2	3003.6 ± 794.9	NT	LC
Mycteroperca bonaci	5	1 ± 0.3	428.4 ± 150.7	VU	EN
Mycteroperca tigris	4	0.8 ± 0.2	756.7 ± 158.3	NT	NT
Ocyurus chrysurus	20	4 ± 0.1	9916.8 ± 2804.9	NT	NT
Scarus coeruleus	5	1 ± 0.2	1581.9 ± 341.3	EN	EN
Scarus guacamaia	4	0.8 ± 0.2	2770.5 ± 1132.1	VU	EN
Scarus vetula	30	6.0 ± 1.1	1819.8 ± 319.8	NT	NT
Sparisoma viride	92	18.4 ± 2.5	3149.1 ± 384.4	NT	NT
Sphyraena barracuda	1	0.2 ± 0.1	209.6 ± 93.8	NT	NT

Among the species recorded in OPMBL NNP, *Epinephelus striatus* stands out. This is listed as 'Critically Endangered' (CR), with an extremely high risk of extinction in the wild; *Mycteroperca bonaci* and *M. tigris* are part of the group of threatened groupers and sea basses (Table 2), a group that is emphasized because it is one of the eight (8) objects of conservation prioritized in the management plan of the OPMBL NNP (Retrieved online from http://www. parquesnacionales.gov.co/portal/ wp-content/ uploads/2019/12/Cartilla-Old-providence- ESPANOL.pdf). These species were only present at the station within the MPA OPBML NNP, with densities of 0.2 ind/m², 1.0 ind/m² and 0.8 ind/m², respectively (Fig. 1).



A.



B.

Figure 1. Average densities of fish belonging to threatened species recorded at sampling stations inside and outside the MPA OPMBL NNP. **A.** Threatened species. **B.** Most abundant threatened species. In the figures PNNOPML (Spanish abbreviation) means OPMBL NNP.

Besides its significance for biodiversity conservation, the presence of endangered species such as groupers and sea basses, as well as the wrasse known as hogfish *(L. maximus)*, the horse mackerel *(C. hippos)* and barracudas *(S. barracuda)*, highlights the park's socio-economic importance. It serves as a reservoir of vital species that contribute to food security and sovereignty for local consumption, as well as having commercial value. In this way, MPA not only provides refuge for these key species for food sovereignty, but may also have the potential to generate a recognized overflow effect for some MPAs (Roberts *et al*., 2001), which can be evaluated in future research.

Martínez-Viloria *et al*. (2014) interviewed 49 fishermen, who confirmed taking advantage of hydrobiological resources within the OPMBL NNP through diving and handline, thus recognizing the importance of the MPA for their well-being. This is very important since artisanal fishing within the park represents 52.9% of fish catches on the Old Providence and Ketlina Islands (Cano *et al*., 2007). Furthermore, since these oceanic islands are located more than 200 km away from the Central American continent and more than 700 km from the nearest port in Cartagena, local fishery resources are vital for food security and well-being in these Caribbean island territories.

In relation to the sites outside the park (Provout and Sanandr), it was found that seven (7) of the 16 threatened species recorded within the park were absent in both sampling sites without MPA protection; in general, they had lower abundance values than in the site evaluated within the MPA (Fig. 1).

Only two of these species were present in all stations. The fish density recorded for fourteen (14) of these threatened species was highest at the station within the park (Figure 1).

The results of the Kruskal-Wallis non-parametric statistical test confirmed significant differences in the abundance of threatened fish species between the assessed sites (chi-square = 16.09, df = 2, p-value = 0.00032*). Wilcoxon's paired tests showed significant differences in the abundance of threatened species between the MPA and the other two locations outside the MPA, confirming higher abundance values for these species at the station within the MPA. Likewise, for the abundance of threatened species, statistical tests showed that there are no significant differences between the sampling station outside the MPA in Old Providence and the one located in San Andres (Table 3).

Table 3. Results of Wilcoxon's paired tests, significant differences are presented in bold*, for p values less than 0.05 (p <0.05).

Place	OPMBL NNP	Provout
Provout	0.0010*	_
Sanandr	0.0044*	0.4534

The presence of herbivorous fish species that play an important ecological role for the resilience of coral reefs such as *Scarus guacamaia* and *S. coerulelus* (Fig. 1) was highlighted within the OPMBL NNP MPA OPMBL NNP. These were not observed in the other two sampling stations and were considered scarce or absent in several sites of the Archipelago, such as on the Serranilla Bank, Bajo Nuevo Bank and Alice Shoal (Bent Hooker, *et al*., 2012; Bolaños- Cubillos, *et al*., 2015) and San Andres (Sierra-Rozo, *et al*., 2012).

Large and medium-sized parrotfish species (Labridae, Scarinae) cataloged at different risk levels such as *Scarus coeruleus* (EN), *S. guacamaia* (EN), *S. vetula* (NT) and *Sparisoma viride* (NT) were present with greater abundance and density within the OPMBL NNP (Fig. 1). This highlights the importance of MPA for their protection, since according to Chasqui *et al*. (2017), these populations have been reduced by more than 50 % and in some locations they are absent. This is mainly due to targeted overfishing and illegal fishing (Castaño, *et al*., 2021), which cause the decline of large parrotfishes species as well as other species of commercial interest such as groupers and sea basses, and of habitat loss.

Other studies also show the absence or low abundance of large parrotfish. Castaño (2024) found a total absence of *S. coelestinus* in fish censuses conducted between 2013 and 2019, and only five (5) observations of *S. guacamaia* in a total of 137 transects (100 m² each, totaling 13,700 m² sampled) in four monitoring sites on the western reefs and the reef lagoon, east of San Andres Island. On the other hand, previous studies based on 348 visual censuses, carried out between 1997 and 2004 in 17 territories of the Greater Caribbean, observed a general absence of large parrotfish (Vallés & Oxenford, 2014).

These species are also remarkably rare on other islands of the SBR, according to several authors (Bolaños-Cubillos, 2006; Abril-Howard, *et al*., 2010; Bolaños-Cubillos, *et al*., 2010; Acero, *et al*., 2011; Bent *et al*., 2012; Bruckner, 2012; Vega-Sequeda, *et al*., 2015) in the Archipelago of San Andrés, Providencia, and Santa Catalina it was possible to observe adult individuals of large parrotfish species. However, in the last ten years they have been selectively fished to the point that it is currently rare to see adults of *S. guacamaia* throughout the island state. Some of these authors claimed that the scarcity of several traditionally exploited reef fish species, such as snappers and groupers, may have increased fishing pressure on large herbivorous fish such as *S. coeruleus* and *S. guacamaia*, which have been directly captured for human consumption, affecting both adults and juveniles. Consequently, these species have experienced a significant decline in abundance and biomass, and are often absent in most locations (Chasqui *et al*., 2017; Rivas & Tavera, 2022). Taking into account the above, the presence and greater abundance of large parrotfish species within the MPA OPMBL NNP demonstrates their importance for the conservation of these species in the Caribbean and in the SBR.

Due to their larger size, these parrotfish species may have greater herbivory capacity. This means they are key species for algae control and recovery of reef ecosystems after disturbances (Adam, *et al*., 2011), contributing to coral reef resilience (Jackson, 1997; Bonaldo, *et al*., 2014; Plass-Johnson, *et al*., 2015) and due to importance of healthy reefs for food security, to their good living conditions in the Archipelago, Seaflower, and the MPA OPMBL NNP.

In addition to large-sized herbivorous parrotfish species, reef herbivores are generally vital for the control of macroalgae communities (Adam *et al*., 2011; Holbrook, *et al*., 2016), and for the support of ecological processes such as bioerosion, sediment production and transport, and provision of space for coral settlement, among others (Bellwood, 1996; Bruggemann, *et al*., 1996; Bonaldo *et al*. 2014).

For this reason, the abundance, density and biomass of herbivorous fish is relevant for the conservation of coral reefs, another of the conservation objectives of the MPA OPMBL NNP. Table 4 presents the density and biomass values of herbivorous fish of the taxa Acanthuridae (surgeonfish) and Scarinae (parrotfish).

Table 4. Density and biomass of herbivorous fish (Acanthuridae and Scarinae) in sectors inside and outside the MPA OPMBL NNP park

	Density (ind/100m²)			Average biomass (g/100m²)		
Species/Station	**OPMBL NNP**	**Provout**	**Sanandr**	**OPMBL NNP**	**Provout**	**Sanandr**
Acanthurus tractus	32.8	7	3	8741.5	1389.4	445.6
Acanthurus chirurgus	2.8	0	0.6	212.6	0.0	45.6
Acanthurus coeruleus	70.4	14.2	4	18938.0	2580.2	1218.1
Scarus coelestinus	0	0	0	0	0.0	0.0
Scarus coeruleus	1.0	0	0	1582.0	0.0	0.0
Scarus guacamaia	0.8	0	0	2770.6	0.0	0.0
Scarus iseri	18.4	4.8	6	910.7	317.7	577.6
Scarus taeniopterus	27.0	16	39.8	2172.6	640.3	5785.7
Scarus vetula	6	0.6	5	1819,8	40.4	453.7
Sparisoma atomarium	0.0	0	0	0.0	0.0	0.0
Sparisoma aurofrenatum	9.4	4	9.4	938.1	189.3	1326.5
Sparisoma chrysopterum	4.8	0.8	0.4	512.5	525.1	204.9
Sparisoma radians	1.6	0	0	292.4	0.0	0.0
Sparisoma rubripinne	13.4	0	0	3277.1	0.0	0.0
Sparisoma viride	18.4	5.4	6.8	3149.2	607.4	1340.6

In general, it was observed that for all species, except *S. taeniopterus* and *S. aurofrenatum*, the density of these fish was higher inside the MPA OPMBL NNP than outside it (Provout) or than in San Andres (Sanandr) (Table 4).

The Kruskal-Wallis statistical test confirmed that the abundance of herbivorous fish was higher at the site within the MPA than at the other two sites (chi-squared = 7.3417, df = 2, p-value = 0.03). Wilcoxon's paired tests confirmed that these differences are significant due to the greater abundance of herbivores between MPA OPMBL NNP and the other two sites (Provout and Sanandr, p=0.04 and p=0.05, respectively). In this case, Sanandr had values of p=0.05, being at the threshold of the test with 95% confidence (Bonovas & Piovani, 2023). Opposite to that, no significant differences were found between sites without MPA protection (p=0.88).

The biomass of herbivorous fish also showed significant differences according to Kruskal-Wallis test (chi-squared=9.0055, df = 2, p-value = 0.01108), showing the same trend as abundance. The biomass of herbivorous fish was strongly higher at the site within the MPA OPMBL NNP than at the other two sites (Provout and Sanandr, p=0.02 and p=0.03, respectively), with no significant differences found between the sites without MPA protection (p=0.67).

Table 4 shows that, besides being higher than the other two stations, the density and biomass of surgeonfish (Acanthuridae) recorded at the station within the park (MPA OPMBL NNP) was also higher than that recorded in the Alacranes Reef National Park in Mexico. This was according to a study that evaluated the structure and composition of herbivorous fish in a MPA, which is part of the largest coral structure in the Gulf of Mexico (Hernández-Landa & Aguilar- Perera, 2019).

From the trophic point of view, the three species of surgeonfish (Acanthuridae) distributed in the Caribbean, together with parrotfish, contribute to modulating the abundance of macroalgae and regulate the abundance of algal mats during successions in disturbed reef environments (Durán, *et al*., 2019). This is why they are also important for the resilience of coral reefs, which are conservation objects of the OPMBL NNP and the natural basis for other fish species.

The role of MPAs, such as the OPMBL NNP, highlights their importance for the protection of threatened fish and herbivore species that are vital for coral reef resilience. In this way, the strengthening of management strategies in the park and their replicability to other areas of the SBR are critical not only for fish biodiversity, but also for the resilience of coral reefs, sovereignty, food security and the well-being of the islander populations and the Raizal community of the Archipelago. The control of illegal fishing and overfishing, as well as the efforts to strengthen coral reef, mangrove and seagrass habitats are also essential management strategies to protect marine biodiversity and human well-being in island territories that depend on their ecosystem services (Mumby *et al*., 2014; Prato & Newball, 2016; Harvey, *et al*., 2018).

Conclusions

The results obtained show that the abundance, biomass and richness of fish species in general, and in particular of threatened fish species in the sampling site located within the MPA OPMBL NNP were higher compared to the sites outside the MPA in Old Providence and San Andres.

The presence and greater abundance of threatened and commercial species such as groupers and sea basses of the species *Epinephelus striatus*, *Mycteroperca bonaci* and *M. tigris*, within the MPA National Park not only highlights their relevance for the conservation of biodiversity, but also the potential for socioeconomic benefits and for food sovereignty in the island territory.

The biomass and presence of herbivorous fish species, including large-sized parrotfish species, some of them in endangered categories, such as *S. coeruleus* (EN), *S. guacamaia* (EN), *S. vetula* (NT) and *Sparisoma viride* (NT), was higher within the site evaluated in the MPA. The biomass of other important herbivores within the National Park such as surgeonfish (Acanthuridae), was also higher. This highlights the importance of MPAs as the MPA OPMBL NNP, for the conservation of the biodiversity of key species for the resilience of coral reefs, due to its recognized herbivory function for the control of macroalgae.

This research presents evidence of the importance of the MPA OPMBL NNP for the protection of fish biodiversity, especially of endangered species for the Caribbean and Colombia, as well as of the conservation objects of the National Park MPA. Thus, it contributes with scientific arguments to strengthen management strategies in the MPA as an example for the SBR, so that its function of the Biosphere reserve on protecting biodiversity and the Raizal culture continues to be fostered, adding to food security and human well-being in the island territory.

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Authors' contribution

Conceptualization: J. P. V. and J. C.; methodology: J. P. V., D. C., A. S. M. y J. C.; software: J. P. V.; validation: J. P. V.; analysis: J. P. V. and J. C.; research: J. P. V., A. S. M., J. C. and D. C.; resources: A.S.M.; data curation: J. P. V., J. C.; drafting-preparation of the original draft: J. P.V., A.S.M., D.C., and J.C.; writing-revision and editing: J. P. V.; project management: A. H. M. All authors have read and accepted the published version of the manuscript.

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Critical review article

Contributions of scientific expeditions to marine litter knowledge in the Seaflower Biosphere Reserve, Colombian Caribbean: analysis of contamination, impacts, and public policies

Contribuciones de las expediciones científicas al conocimiento de la basura marina en la Reserva de la Biósfera Seaflower, Caribe colombiano: análisis del estado de contaminación, impactos y políticas públicas

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Abstract

This study examines marine litter and plastic pollution based on scientific expeditions conducted in the Seaflower Biosphere Reserve, Colombia. It identifies potential sources of pollution, assesses its impacts on marine health, and evaluates the role of public policies in addressing this critical issue. The analysis highlights the vulnerability of remote islands to plastic pollution and the challenges associated with limited and inefficient waste management systems, which have serious consequences for marine and coastal ecosystems. The distribution and impacts of marine litter are analyzed to propose effective environmental protection measures and sustainable management strategies. This study emphasizes the urgent need to reduce plastic usage to mitigate the environmental and economic challenges posed by restricted waste management capacity on remote islands with limited operational space.

Keywords: marine pollution; plastics; marine debris; remote islands; waste management; marine conservation

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Resumen

Este estudio analiza la basura marina y la contaminación por plásticos a partir de las expediciones científicas realizadas en la Reserva de la Biósfera Seaflower, Colombia. Identifica las posibles fuentes de contaminación, evalúa sus impactos en la salud marina y examina el papel de las políticas públicas en la gestión de este problema crítico. El análisis destaca la vulnerabilidad de las islas remotas a la contaminación por plásticos y los desafíos asociados con sistemas de gestión de residuos limitados e ineficientes, que generan serias consecuencias para los ecosistemas marino-costeros. Se analizan la distribución y los impactos de la basura marina para proponer medidas efectivas de protección ambiental y estrategias sostenibles de gestión. Este estudio enfatiza la urgente necesidad de reducir el uso de plásticos para mitigar los desafíos ambientales y económicos derivados de la limitada capacidad de gestión de residuos en islas remotas con espacio operativo restringido.

Palabras clave: *contaminación; plásticos; desechos marinos; islas remotas; gestión de residuos; conservación*

Introduction

Marine litter pollution, defined as solid waste originating from human activities that reaches marine and coastal areas, is a critical environmental issue with severe impacts on ecosystems and human communities worldwide (Stoett *et al.*, 2024). Island regions are especially vulnerable to this problem due to their remote location, isolation, and the influence of ocean currents that transport marine litter from other nearby or distant places to the islands, where it accumulates in their ecosystems (Lavers and Bond, 2017; Jones *et al*., 2021; Pérez-Venegas, *et al.,* 2017; Portz *et al.,* 2022).

The accumulation of litter, primarily plastics, poses an environmental and economic challenge in island regions, due to the effects on biodiversity, the health of marine ecosystems, and tourism and fishing activities, among others (Portz *et al.,* 2020; Rambojun *et al.,* 2024; Thiel, *et al.,* 2021). This situation highlights the need to investigate this problem in island areas to better understand its dynamics, identify its sources and assess its long-term environmental impacts. This knowledge is essential to raise awareness and work on the implementation of sustainable and effective practices at the local, regional and global levels, in order to contribute to the prevention and reduction of this type of pollution (Portz *et al.,* 2020).

The islands of the Caribbean region have been affected by marine litter pollution (Blanke, Steinberg, & Donlevy, 2021; Diez *et al.,* 2019). Some of this marine litter comes from local sources, such as tourism, inadequate waste management practices, low recycling rates, limited environmental awareness, and poor management by local authorities (Garcés-Ordóñez *et al.,* 2020a; Portz *et al*., 2024). Another part of the litter on the islands comes from external sources, such as that transported by ocean currents from other regions or surrounding countries (Courtene-Jones *et al.,* 2021; Ivar do Sul and Costa, 2007; Portz *et al.,* 2022, 2020; Rangel-Buitrago *et al.,* 2019) and illegal dumping of various wastes into the sea from boats (De Scisciolo *et al.,* 2016).

Coastal communities in the Caribbean region also face challenges due to inadequate infrastructure for solid and liquid waste management (Diez *et al.,* 2019). Added to this are the complexities associated with the limitations of the surface area available on the islands to manage their own household waste (Courtene-Jones *et al.,* 2021). As a result, much of the waste generated is disposed of in landfills or burned, but it almost always ends up in the sea, contributing to the pollution of the ecosystems on which the local communities themselves depend economically (Portz *et al.,* 2022).

The Seaflower Biosphere Reserve (BSR), located in the Colombian Caribbean region (Fig. 1), consists of three main islands (San Andres, Old Providence and Ketlina), seven cays (Serrana, Serranilla, Alburquerque or Southwest, Roncador, Queena Reef, Bajo Nuevo and Cayos de Bolívar Islands – also known as Courtown Cays), and multiple shoals and marine banks.

Together, they form an archipelago composed of carbonate platforms and reef barriers of varied geomorphological features (CIOH, 2009; Geister & Díaz, 2007). This protected area is notable for its high biodiversity of ecosystems and marine species. However, its fragility in the face of marine litter pollution raises significant concerns for its long-term preservation.

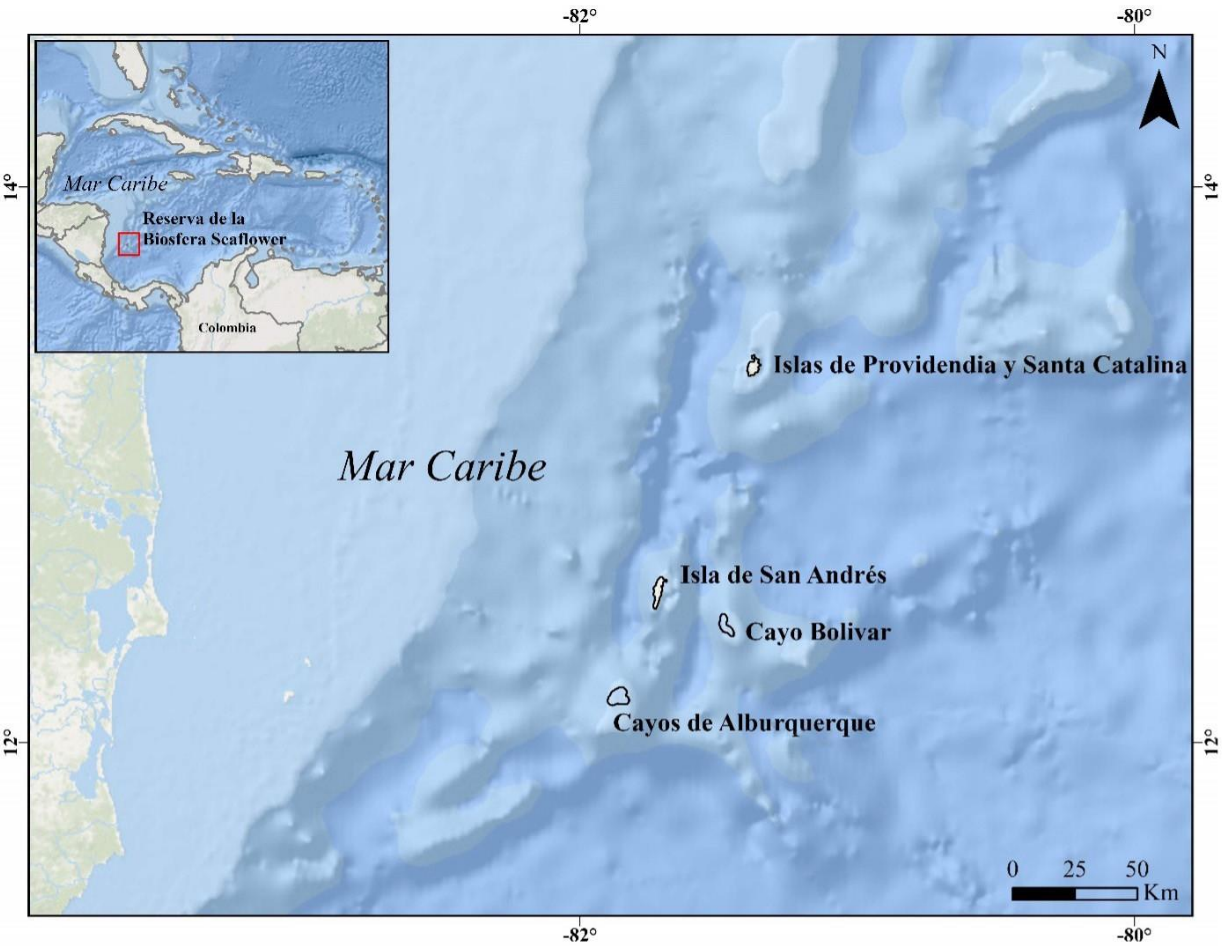

Figure 1. Location of the area of the Seaflower Biosphere Reserve in the department of the Archipelago of San Andrés, Providencia y Santa Catalina, Colombia, highlighting the islands in which scientific expeditions described in this study were carried out.

Multiple scientific expeditions have been carried out in the SBR with the aim of generating knowledge about biodiversity and its state of conservation, including studies to quantify and analyze the marine litter problem. These expeditions are the result of an inter-institutional collaboration coordinated by the Colombian Ocean Commission (CCO) with the participation of the Colombian Navy (ARC), the General Maritime Directorate (Dimar) and the Corporation for the Sustainable Development of the Archipelago of San Andres, Providencia y Santa Catalina (Coralina), among other public and private entities interested in the country's marine sciences. Furthermore, these expeditions aim to establish short-term monitoring plans and, in the medium term, standardize sampling protocols while highlighting the environmental importance of the SBR (Dimar, 2024).

In this context, the main objective of this review is to summarize and analyze the contributions of the Seaflower Expeditions to the knowledge of the problem of marine litter pollution in this insular nature reserve, and to examine its environmental impacts from a comprehensive perspective for the Colombian Caribbean. To this end, this review seeks to answer the following key questions: What are the main sources and magnitude of marine litter pollution in the SBR? What environmental impacts does the accumulation of marine litter generate in the different ecosystems of the reserve (beaches, mangroves and coral reefs)? How do Seaflower expeditions contribute to the understanding and management of marine litter pollution, and what public policies can be most effective to address this problem more efficiently?

These questions guide a critical analysis of the sources of pollution, their magnitude, and the formulation of public policies necessary to tackle this environmental challenge more effectively. The significance of this review lies in its capacity to synthesize existing knowledge and inform future research and public policies in the region. This, in turn, can help mitigate the effects of marine litter pollution in both the Seaflower Biosphere Reserve (SBR) and the Colombian Caribbean.

Description of Seaflower Scientific Expeditions

Alburquerque Cays. They are located 37 km southwest of the island of San Andres and 190 km east of the coast of Nicaragua. This atoll has a circular shape, with a diameter of approximately 8 km in an east-west direction. It is characterized by a semi-enclosed lagoon protected by a coral reef, with depths ranging from 0.3 m to 164 m (CCO, 2015; Martínez-Clavijo *et al.* 2021). The ecosystems present include coral reefs and sandy beaches. The emerging cays are composed of two sandbanks: the North Cay (412 m²), which houses a military base of the Colombian Navy, and the South Cay, which is occasionally occupied by fishermen.

The scientific expedition to Alburquerque Cays took place from October 4 to 14, 2018. In this survey, 71 marine litter sampling sites (>2.5 mm) were carried out on the beaches, as well as 3 microplastic sampling sites on the beach sand and 9 marine transects for the evaluation of macro and microplastics. The study covered both terrestrial areas (beaches) and surface waters in the marine environment. The precise coordinates of the sampling points are available in Portz *et al.* (2020).

The results, along with the specific sampling site coordinates, were published by Portz *et al.* (2020) and can be consulted on the portal: https://pnec.cco.gov.co/ seaflower/.

Old Providence and Ketlina Islands. These islands are remnants of an ancient extinct volcano, characterized by mountainous terrain and Quaternary deposits. The islands are separated by a shallow channel 150 m wide and cover a total area of approximately 18 km². The ecosystems present include mangroves, coral reefs, and beaches. Part of the region's coral reef is protected within the Old Providence McBean Lagoon National Natural Park, which covers an area of 9.95 km² and is part of the Special Area of the Archipelago of San Andres, Providencia y Santa Catalina, as well as the Seaflower Marine Protected Area (Invemar and Coralina, 2012).

Two scientific expeditions were carried out on these islands. The first was the IV Seaflower Expedition, held from September 9 to 19, 2019, while the second took place from July 20 to 26, 2021. The 2019 expedition analyzed 30 marine litter sampling sites on beaches (26 sites) and mangroves (4 sites), along with 13 dive sites for coral assessment. In the 2021 expedition, 27 marine litter sampling sites were evaluated on beaches (23 sites) and mangroves (4 sites), in addition to 11 diving sites in the same sites previously investigated.

Samples collected during both expeditions were used to assess the health of marine and coastal ecosystems. The results and exact location of the sampling points are available in Portz *et al.* (2022), Portz *et al.* (2024) and can be consulted on the website: https://pnec.cco. gov. co/seaflower/.

Courtown Cays. Located 25 km southeast of the San Andres Island, the atoll has a length of 6.4 km and a width of 3.5 km, with a total emerged area of 0.12 km². Pescadores Cay (East Cay) has an area of 8 hectares and is partially covered by vegetation, while Bolívar Cay (West Cay) has 3.7 hectares of emerged area and houses a permanent military base of the Colombian Navy. Ecosystems include coral reefs and beaches (Invemar and Coralina, 2012).

The Seaflower Expedition to the Courtown Cays took place from September 9 to 20, 2022. During this expedition, 44 marine litter sampling sites of 10 m in length were carried out on the beach of Bolívar Cay, as well as 891 marine litter sampling sites on Pescadores Cay. Additional monitoring stations were carried out on the Banco de la Virgen (1 site) and on the Bajo Sunny Boar (1 site). For the analysis of microplastics, 2 monitoring stations were carried out in Bolívar Cay and 5 in Pescadores Cay, collecting a total of 18 samples of sediments and water. Likewise, 9 marine transects were executed for the evaluation of floating marine litter, along with the collection of 9 seawater samples.

The results included the collection and analysis of marine litter in the terrestrial and marine areas of the atoll (López *et al.*, 2024). The exact location of the sampling points, along with the results obtained is available on the https://pnec.cco. gov.co/seaflower/ and https:// seaflower-dimar.hub. arcgis.com/ portals.

Methodologies

Marine litter is any persistent, manufactured, or processed solid material that is discarded, thrown away, or abandoned in the environment (UNEP, 2005). The collection and characterization protocols used in the expeditions are described in detail in Portz *et al.* (2020) and Portz *et al.* (2022). Overall, the sampling environments encompassed a variety of important ecosystems in the Reserve, including mangroves, beaches (both tourist and non-tourist), vegetation areas behind the beachline, and coral reefs. Each of these environments requires specific sampling approaches, due to their unique physical characteristics and environmental dynamics.

On the beaches, both tourist and non-tourist, marine litter (>2.5 cm) was systematically sampled. To this end, 10 m wide sections were established, covering the area from the limit of the water line to the beginning of the vegetation or dunes, depending on the type of beach. This methodology allows capturing the variability in the distribution of marine litter along the beach profile, from the intertidal zone to the areas furthest from the water. In addition, in the vegetated areas behind the upper limit of the beach, the first 5 m of vegetation were included in the survey. This extension ensures that marine litter transported inland by wind, tides, and extreme waves is also accounted for.

In the mangroves, due to the dense vegetation and the presence of aerial roots (pneumatophores), linear transects 5 m wide were established, oriented from the local access points into the mangrove. This method facilitates the identification of marine litter, as mangroves tend to act as natural traps for litter.

In the coral reefs, the sampling of marine litter was carried out on the island shelf (between 10 m and 30 m deep), using diving techniques (3 divers). This allowed researchers to access the most critical underwater areas to assess the amount and types of litter accumulating in and around corals. Marine litter (>2.5 cm) was collected and categorized, providing insight into the level of contamination.

In each of these environments, the collected marine litter was classified according to its type and material. Marine litter types included plastics, metals, glass, rubber, and other anthropogenic materials. Each item was recorded and quantified to provide a detailed overview of the composition of marine litter in each environment (Portz *et al.,* 2020, 2022).

In addition to the field research, a comprehensive bibliographic search was conducted on the associated topic, using Web of Science, Google Scholar, ScienceDirect, and Scopus, prioritizing studies published within the last 20 years. Boolean operators were used with specific keywords such as "Microplastics," "Plastic litter," "Plastic pollution," "Marine litter," and "Marine debris"; in addition to "Coastal," "Coastal zones," "Caribbean," "Islands," and "Colombia," thus ensuring the relevance of the results for the geographical and thematic context.

Marine Litter Results in the SBR

The increase in marine litter pollution poses a threat to the island ecosystems of the SBR. While all islands face marine litter pollution issues, it is clear that some areas are more affected than others. Data collected during the 2018-2022 Seaflower expeditions, along with additional studies, revealed significant differences in pollution levels between the more tourist-focused islands and the more remote cays islands with restricted tourism. Mangroves in Old Providence and Ketlina were identified as the most affected, with levels of up to 9.07 items/m², while tourist beaches showed much lower levels, with an average of 0.22 items/ m². San Andres presented a greater variability, highlighting the non-tourist beaches with an average of 1.45 items/m². Although isolated and remote, Alburquerque Cays and Courtown Cays also recorded significant pollution, particularly on beaches, with a predominance of plastic (Table 1).

Results of Seaflower expeditions

The results of the expedition to Alburquerque Cays, published by Portz *et al*. (2020), revealed an average pollution level of 0.5 items/m² on beaches (Table 1). Plastics dominated the composition of marine litter, accounting for 90% of the total, followed by materials classified as other (6%), glass (2%), and fisheries-related items (0.8%). The other category encompassed building materials (2%), tetra pack packaging (1%), and a combined 1% comprising rubber, fabrics, and non-plastic footwear.

The significant presence of plastic fragments and microplastics in this region suggests persistent and fragmented pollution, with multiple potential sources, such as transport by ocean currents, given that local sources are limited by the island's restrictions on use. Additionally, the high prevalence of plastic fragments, which account for 96% of plastic items collected on beaches, makes it difficult to identify specific sources. Once plastics reach the beaches, they continue to fragment and eventually integrate into natural sediment cycles, making the beaches a secondary source of microplastics for the atoll (Alburquerque).

Furthermore, the importance of hydrodynamics in the distribution of marine litter was analyzed. The results showed a greater accumulation of plastic in the southeastern sector of the atoll, which is directly exposed to prevailing winds and surface currents. Ocean currents and waves appear to concentrate marine litter in this sector, while more protected areas of the atoll had lower litter densities. This finding is crucial for the SBR, as it demonstrates that local hydrodynamic characteristics can influence the accumulation of marine litter, even in remote areas with limited human activity (Portz *et al.,* 2020).

Table 1. Types of marine litter found on the different islands and cays emerged from the Seaflower Biosphere Reserve during the different Seaflower expeditions (tagged with*), as well as other research and field campaigns in which the co-authors have participated.

Year	Place	Ecosystem	Items/m² Min.	Max.	Average	Most frequent items	Reference
Feb. 2017	San Andres	Tourist beaches (n=5)	0.17	0.63	1.22	Plastic, tobacco, paper, metal	Portz *et al.,* (2018)
		Non-tourist beaches (n=3)	0.61	1.45	2.92	Plastic, glass, metal, paper	
		Rocky, tourist beaches (n=3)	0.53	0.54	0.55	Plastic, metal	
		Rocky, non-touristy beaches (n=5)	0.4	0.77	0.65	Plastic, metal, glass	
Feb. – Apr. 2013	San Andres	Beach (n=3)	2.95	3.71	3.3	Plastic, glass	Gavio *et al.,* (2022)
Oct. 2018	Alburquerque	Beaches (n=71)	0.03	1.94	0.5	Plastic, glass, fishing material	Portz *et al.,* (2020) *
		Shallow continental shelf			12 items	Plastic, glass, fishing material	
Aug. 2022	Courtown Cays Bolívar Cay	Beach (n=2)	0.01	1.68	0.85	Plastic, rubber, glass, wood	López *et al.,* (2024) *
	Courtown Cays Pescadores Cay	Beaches (n=3 very long)	0.01	1.56	0.79	Plastic, rubber, glass, wood	López *et al.,* (2024) *
Sept. 2019	Old Providence	Tourist beach (n=8)	0.01	0.72	0.22	Plastic, paper, metal, glass	Portz *et al.,* (2022) *
		Non-tourist beach (n=10)	0.31	5.41	1.87	Plastic, fabrics, metal, glass	
		Mangrove (n=1)	-	-	8.38	Plastic, metal, glass, MO	
		Gravel beach	0.48	16.17	4.69	Plastic, metal, glass, fabrics	
Sept. 2019	Ketlina	Tourist beach (n=1)	-	-	0.72	Plastic, metal, paper	Portz *et al.,* (2022) *
		Non-tourist beach (n=1)	-	-	0.71	Plastic, glass, rubber, fabrics	
		Mangrove (n=3)	8.38	10.4	9.07	Plastic, Metal, Glass, MO	
Sept. 2019		Corals (N=13)	0	0.02	0.01	Glass, line	Portz *et al.,* (2022) *
Dec. 2020-Jan. 2021	Old Providence and Ketlina	Mangrove	0.4	1.4	-	Plastic, metal, glass, processed wood	Garcés-Ordóñez *et al.,* (2021)
		Microplastics					
Oct. 2018	Alburquerque	Beach (N=3)	99 - 141 particles/m²				Portz *et al.,* (2020) *
		Sea surface (N=9)	0.009 - 0.244 particles/m³				

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The results obtained in the two largest emerging areas of Courtown Cays, Bolívar Cay and Pescadores Cay, revealed a high prevalence of plastic waste in areas where all tourist activity is prohibited (Table 1). These findings were published in the Final Report of the Expedition by López *et al.* (2024). Eight categories of marine litter were identified, with plastic (89%) predominating, followed by glass (5%), wood (2%), textiles (2%), metal (1%), paper (1%), rubber (0.1%), and others (1%). PET bottles, polystyrene (styrofoam) and rigid plastic fragments (such as methacrylate, polycarbonate and PVC) were the most abundant types within the plastics category.

In the metal category, aluminum cans were predominant, while in the glass category, glass containers stood out, in terms of rubber, flip-flops or Crocs-type shoes were the most frequent. The density of marine litter showed significant levels of pollution, especially in Pescadores Cay (Table 1).

In terms of distribution, a notable presence of marine litter was observed throughout the atoll. However, Pescadores Cay showed higher levels of pollution compared to Bolívar Cay, when considering the internal vegetated areas of each island. On the other hand, by focusing only on the exposed areas of the beaches, Bolívar Cay presented greater pollution per square meter than Pescadores Cay, though not at the levels observed in the small neighboring sandbanks (Banco de la Virgen and Bajo Sunny Boar).

Old Providence and Ketlina, with their important coastal and marine ecosystems, face significant challenges of marine litter pollution. In 2019, tourist beaches registered an average of 0.22 items/m², while non-tourist beaches showed an average of 1.87 items/m². In 2021, an increase in tourist beaches was observed, with an average density of 1.70 items/m², reflecting the impact of tourism and reconstruction waste after Hurricane Iota (a category 4 event that occurred from November 13 to 18, 2020). However, in non-tourist beaches, the average increased slightly to 2.31 items/m² (Portz *et al.,* 2024).

On the other hand, mangroves, which are critical habitats for many marine species, had a high average of 8.38 items/m² in 2019. In 2021, after the hurricane, it was reduced to 3.22 items/m² due to the destruction of the ecosystem by the hurricane and cleanup campaigns (Portz *et al.,* 2024).

Regarding the characterization of marine litter on the Old Providence and Ketlina Islands, the most common categories of marine litter were plastic (76%), followed by metal (6%), glass (6%), fabrics (3%), and other materials (3%) (average of the 2019 and 2021 expeditions).

The spatial distribution of marine litter on the islands showed that mangroves and beach vegetation areas act as key accumulation zones, especially of plastics. Tourist beaches had a low density of marine litter due to regular cleanups, while non-tourist beaches presented greater accumulation and variety of sources. Coral reefs around the island showed low litter density, indicating a lower connection to this ecosystem.

Complementary studies

The study by Garcés-Ordóñez *et al.* (2021) focused on marine litter pollution in the mangroves of Old Providence and Ketlina after Hurricane Iota. The results showed that mangroves near urban areas registered a greater accumulation of litter compared to those located in areas with less human influence. Plastics of various sizes were the predominant type of marine litter (more than 60%).

This study highlights how extreme weather events, such as hurricanes, can exacerbate the problem of marine litter, especially in critical ecosystems such as mangroves, and how local response actions are critical to the recovery of these ecosystems after disasters. Furthermore, the participation of the local community in the cleaning and recovery of the mangrove was emphasized.

Research conducted on San Andres Island by Portz *et al.* (2018) and Gavio *et al.* (2022) provides valuable complementary insights, offering an additional perspective on the marine pollution problem in the SBR.

San Andres, one of the most visited islands in the region, exhibits moderate levels of pollution on its beaches. According to Portz *et al.* (2018), tourist areas register an average of 0.63 items/m², while non-tourist areas have a higher concentration, with an average of 1.45 items/m². The most common litter includes plastic (74%), cigarette butts (8%), metals (7%), and glass (5%). On the other hand, Gavio *et al.* (2022) found an average of marine litter on beaches of approximately 3.30 items/m². Marine litter is mainly composed of plastic (between 84% and 89%), followed by glass, cigarette butts, and other materials such as paper and metals, in smaller proportions.

Studies conducted at different times provide interesting insights into the extent and distribution of marine litter along the island's coastline. Gavio *et al.* (2022) found a high concentration of marine litter, mainly plastics and glass on tourist beaches, highlighting the need for stricter control over waste disposal in general. On the other hand, Portz *et al.* (2018) revealed a disparity in the amount and origin of marine litter between tourist and non-tourist beaches, highlighting the urgent need for actions to ensure the conservation of interconnected coastal ecosystems, especially in those areas furthest from the tourist center.

Integrated Evaluation of Marine Litter in the SBR

Comparing pollution levels across islands reveals a variety of troubling environmental situations and challenges. In the case of San Andres, an island characterized by an influx of tourists, moderate pollution was observed on the beaches, with a slight tendency to increase in non-tourist areas. This phenomenon suggests a possible correlation between beach cleanup actions and the amount of marine litter present.

However, non-tourist areas do not necessarily have regular cleaning or waste collection services. This is the case of Alburquerque Cays and Courtown Cays. It is worth noting that Bolívar Cay houses a permanent base of the Colombian Navy, while Pescadores Cay is used as temporary accommodation by artisanal fishermen from San Andres during their fishing days.

In contrast, Old Providence and Ketlina Islands face particular challenges in terms of marine litter pollution. On these islands, high levels of litter are recorded in the beach vegetation area and in the mangroves, essential habitats of many marine species.

The analysis of marine litter in the beach vegetation suggests a greater impact from local activities and inefficient disposal practices following beach cleanups. The studies by Portz *et al.* (2022) and Garcés-Ordóñez *et al.* (2021) provide an exhaustive overview of this problem, highlighting the importance of community participation and the application of management strategies adapted to the particularities of each context.

On the other hand, Alburquerque Cays and Courtown Cays have registered relatively low levels of pollution with respect to coastal areas of the islands with the highest population (San Andres, Old Providence and Ketlina Islands). However, these values are still considered high levels of marine litter (Table 1), given that they are remote, uninhabited islands with strict tourism restrictions.

The most significant finding is that the most prevalent type of marine litter (>2.5 cm) in the SBR islands corresponds to plastic, predominantly food storage items such as PET bottles. It is important to emphasize that food packaging is the most common type of marine litter in the Reserve. This pattern is consistently observed across continents, revealing a global trend that reflects the wide distribution of plastic in marine environments (BFFP, 2023).

Comparing SBR to other regions shows that although inhabited islands such as San Andres, Old Providence and Ketlina face significant marine litter problems, pollution levels are lower than on other Caribbean islands and the world.

San Andres, influenced by tourism, has moderate pollution, especially in tourist areas. In Old Providence and Ketlina, litter is high in the vegetation line and the mangrove, similar to what is observed in Santa Marta, Colombia, where tourist beaches register up to 12 items/m², with plastics representing between 35% and 72% of marine litter (Garcés-Ordóñez *et al.,* 2021). On islands such as Hunting Caye, Belize, densities reach up to 4.09 items/m² on beaches without staff responsible for regular maintenance (Blanke *et al.,* 2020b). Variations in the density of litter on beaches, even within the same island, are observed in Bonaire, where densities range from 0.1 items/m² to 5 items/m² (Debrot *et al.,* 2013).

The worrisome presence of microplastics (<2.5 cm) on uninhabited islands reflects a broader and more complex pollution issue (Portz *et al.,* 2020). This finding indicates the significant presence of diverse sources of pollution, such as the fragmentation of materials by local marine-atmospheric processes, the dragging of waste by meta-oceanographic interactions (waves and winds), as well as transport by ocean currents, whose behavior in this region is closely linked to the general pattern of the Panama-Colombia gyre (Andrade *et al.,* 2003; Mooers & Maul, 1998; Richardson, 2005).

Previous research, such as that of Wüst (1963), supports the idea of the existence of this gyre. It is postulated that its dominant influence on oceanographic conditions of the region facilitates the transport of light materials suspended in water. This phenomenon, aggravated by the waves, creates a dynamic context that could explain the presence of pollutants in this remote region of the Caribbean (Portz *et al.,* 2020).

The inhabited islands of the Reserve, especially those with significant tourism, generate marine litter that pollutes both their beaches and the adjacent sea. In addition, these islands can contribute to marine pollution of other nearby islands. For example, Wilson and Verlis (2017) demonstrated the influence of tourism in the southern Great Barrier Reef and its impact on nearby islands.

Several studies have shown that ocean currents can carry marine litter over long distances (Moore *et al.,* 2001; Schneider *et al.,* 2018). This means that pollution generated on an island or even in a neighboring country can substantially affect remote and isolated islands. This phenomenon has been evidenced in Alburquerque Cays and on Courtown Cays, where marine litter and microplastics have been found both in submerged areas and on exposed beaches, including uninhabited areas such as isolated banks and microplastics both in submerged areas and on exposed beaches, including uninhabited areas such as isolated banks.

Effects of Pollution on BioDiversity and Sea Health

Mangroves

Mangroves act as natural traps for marine litter, preventing it from dispersing into the marine environment (Ivar do Sul & Costa, 2014; Martin, Almahashee & Duarte, 2019; Portz *et al.,* 2022; Rambojun *et al.,* 2024). The presence of marine litter in mangroves threatens not only the landscape, but also biodiversity and ecosystem functions. Plastic litter can entangle mangrove roots and pneumatophores, preventing plants from properly absorbing nutrients and oxygen, which can lead to plant death and ecosystem decline (Van Bijsterveldt *et al.,* 2021).

In addition, the presence of plastic waste represents a direct threat to the wildlife that inhabits mangroves, which generates physical barriers and accidental ingestion (Garcés-Ordóñez *et al.,* 2020b; Van Bijsterveldt *et al.,* 2021).

Marine litter can also jeopardize mangrove restoration efforts, harming both adult trees and seedlings. The collision of floating litter with roots and aerial trunks can increase tree mortality, while the accumulation of marine litter prevents natural regeneration by suffocating seedlings and blocking areas suitable for new root growth (Gorman & Turra, 2016; Pranchai *et al.,* 2019).

In the mangrove areas analyzed in the SBR, pollution by litter, especially plastics, represents a serious threat to the recovery and maintenance of these ecosystems. These effects hinder mangrove rehabilitation efforts, especially in areas where restoration programs rely on planting seedlings, which may not prove efficient due to interference from marine litter.

Beaches and dunes

Similar to mangroves, beach and dune environments are also critical accumulation zones for marine litter (Manzolli & Portz, 2024; Poeta *et al.,* 2017; Portz *et al.,* 2011). In addition to compromising the natural beauty of the dune landscape and reducing the tourist appeal of the coastline, marine litter can cause direct damage to local flora and fauna. The vegetation present in the beach system is one of the most important landscape components, as it provides a precious habitat for bird nesting, feeding, and wildlife protection (Martínez and Psuty, 2004).

The vegetation area of the beach serves as a natural barrier that traps and accumulates marine litter, fragments it, and increase its quantity over time with the help of wind (Portz *et al.,* 2011). This pollution can interfere with the structure and development of the dune ecosystem, disrupting natural processes such as germination and seedling-plant interactions that are critical for ecosystem stabilization (Menicagli *et al.,* 2019).

Coral reefs

Coral reefs are affected by pollution caused by marine litter, particularly plastics (macro and micro) and abandoned or discarded fishing materials. The presence of plastics in the oceans can promote microbial colonization by pathogens involved in disease outbreaks. Lamb *et al.* (2018) found that when corals come into contact with plastics, the likelihood of disease increases dramatically from 4% to 89%. Specifically, plastics such as polypropylene, commonly found in bottle caps and toothbrushes, are heavily colonized by bacteria associated with coral diseases, such as white band disease.

Corals, which are filter-feeding organisms, are also exposed to ingesting microplastics, which disrupt their intake of natural food, thereby impairing their development and growth (Hall *et al.,* 2015). Additionally, microplastics interfere with the symbiotic relationship between corals and zooxanthellae, increasing oxidative stress and vulnerability to disease and bleaching (Okubo *et al.,* 2018; Syakti *et al.,* 2019).

Since zooxanthellae provide 90% of corals' food, through photosynthesis, allowing them to live in oligotrophic conditions, any alteration to this relationship would have serious consequences for coral health (Campos *et al.*, 2020). Furthermore, abandoned fishing gear such as nets, hooks, and pots can become entangled in corals, causing physical damage. Marine litter not only affects corals, but also the associated aquatic wildlife species that depend on them for habitat, protection, and feeding, thereby threatening both the reef ecosystem and commercial fish populations.

Impact of Marine Litter on Economic sectors Linked to the Sea

Marine litter pollution negatively affects economic sectors linked to the sea, such as tourism, fishing, and maritime transport (Abalansa *et al.,* 2020; Aretoulaki *et al.,* 2021; Rodríguez *et al*., 2020). The tourism industry, particularly beach tourism, faces significant challenges due to the presence of trash (Grelaud & Ziveri, 2020).

This pollution impacts both the coasts and the surrounding seawater, which directly affects the economy of tourist islands such as San Andres, Old Providence, and Ketlina, whose economies depend heavily on tourism. Marine litter reduces the scenic beauty of these destinations and diminishes the quality of the tourist experience, leading to a decrease in visitor numbers and, consequently, a negative impact on the local economy.

Beyond its visual impact, tourists' negative perception of unclean beaches is a critical factor for the health of the tourism sector. A study conducted in Brazil demonstrated that the presence of trash can reduce recreational activities by up to 39% (Krelling *et al*., 2017). Marine litter on beaches discourages recreational activities due to the perception of an unhealthy environment, influencing people's perceptions of environmental quality (Pendleton *et al.*, 2001).

This issue is a key determinant for the growth of tourism-dependent economic sectors, as confirmed by numerous studies conducted in tourist resorts and beaches (Krelling *et al.,* 2017; Rehman *et al.,* 2022; Santos *et al.,* 2005).

Marine pollution also affects submerged areas, such as diving and snorkeling sites, with aesthetic and ecological impacts. In Taiwan, a study in Kenting National Park and the Yilan Coast recorded 2,841 items of marine litter, the distribution of which varied according to season, location, and tide, highlighting the complexity of the problem (Lin *et al.,* 2022).

In response to this problem, initiatives such as "*Dive Against Debris*" and clean-up dives play a crucial role in mitigating marine litter. These activities not only conduct underwater cleanups, but also convert efforts into data-driven studies, contributing to the prevention of damage to marine life and the environment. In addition, they encourage policy changes towards better waste management practices (https://www.diveagainstdebris.org).

The fishing sector also experiences negative effects from marine litter, as it can damage fishing equipment, reduce catches, and require additional time for repairing or cleaning nets (Galimany *et al.,* 2019). These impacts reduce the overall productivity of the industry and are more pronounced in areas with high concentrations of marine litter, such as shallow areas, where 38% of the total catch consists of marine litter (Galimany *et al.,* 2019).

In addition to damaging fishing equipment, marine litter also impacts captured marine species, many of which show evidence of ingesting marine litter, particularly plastics (Fossi *et al.,* 2018; Garcés-Ordóñez *et al.,* 2020b). For the local community, whose cultural traditions and economy are based on fishing, these consequences represent a significant challenge and put at risk their ancestral way of life, including that of the Raizal people.

The risks to navigation are also considerable. Floating plastics pose hazards to navigation and can damage ships, ports, and coastal infrastructure, resulting in additional costs for port authorities and maritime operators (IMO, 2024).

Policies, Future Guidelines and Ways to Follow

One of the primary factors limiting efforts against marine litter in the Caribbean Sea is the lack of effective regulations and public policies. Many of the countries in this region are island territories with economies that face challenges such as poverty, technological lag, and infrastructure deficiencies (Vélez, 2019). Additionally, these economies depend heavily on imported goods, which generate large quantities of plastic packaging (Clayton *et al.,* 2021).

However, there are positive developments. According to Fernández *et al.* (2021), in recent years, at least 27 of the 33 countries in Latin America and the Caribbean have implemented laws banning or eliminating single- use plastics. Antigua and Barbuda became a pioneer in 2016, by banning the import, distribution and use of plastic bags. In the Bahamas, the ban on single-use plastics was enacted in 2019 and came into force in 2020 with the Environmental Protection Act (2019). Barbados also banned the import of plastics as part of its transition to a green economy, and Grenada passed the Non-Biodegradable Waste Control Act in 2018.

In addition, regional initiatives such as the Regional Action Plan for Marine Litter Management (RAPMaLi) are being implemented in the Wider Caribbean Region. This plan promotes waste management with the support of community groups and the business sector. Countries such as Guyana, Barbados, and Saint Lucia are pilots of this program.

Other countries such as Belize have launched programs like 'Belize: Blue, Clean, Resilient and Strong' to prevent marine litter and improve waste management. Panama has been implementing a national plan to reduce marine litter since 2021, involving the Government, communities and the private sector throughout the country.

National Policies

Colombia has developed a comprehensive policy framework to combat marine pollution caused by single-use plastics, aiming for elimination by 2030. Its Sustainable Plastic Management strategy engages all sectors to prevent, reduce, reuse, recycle, and replace plastics (Fernández *et al.,* 2021).

In 2018, the country launched the National Circular Economy Strategy and in 2019, the National Plan for the Sustainable Management of Single-Use Plastics, focused on reducing plastic consumption and promoting a circular design (Fig. 2).

In 2016, a regulation was imposed that banned and taxed plastic bags, achieving a 35% reduction in their consumption between 2016 and 2019 and a 59.4% decrease in their distribution. The combination of the ban and the tax on single-use plastic bags has had a positive impact on reducing the consumption of plastic bags and has strengthened awareness of the importance of reducing plastic waste in the country (Fernández *et al.,* 2021).

Figure 2 presents a synthesis of Colombia's regulatory and policy framework in relation to solid waste management and its connection with pollution in marine-coastal territories. A chromatic code is used to classify the regulations, not in chronological order, but by categories.

First, the concepts of marine pollution are addressed, followed by regulations on solid waste, sanitation services and circular economy as a tool to reduce and take advantage of waste. Also included are two related standards that establish local committees to organize beaches and create coordination bodies, as well as a technical standard to improve tourism quality under sustainability principles.

Seven standards focused on the reduction of single-use plastics stand out. The scheme covers two large groups of policies and standards of the international framework hosted by Colombia, such as United Nations treaties for the control of pollutants and microplastics.

Finally, policies and documents of the National Council for Economic and Social Policy (Conpes) are presented, which promote sustainable development and the circular economy, allowing the identification of key standards for the reduction of waste at sea, articulated with environmental planning and management instruments.

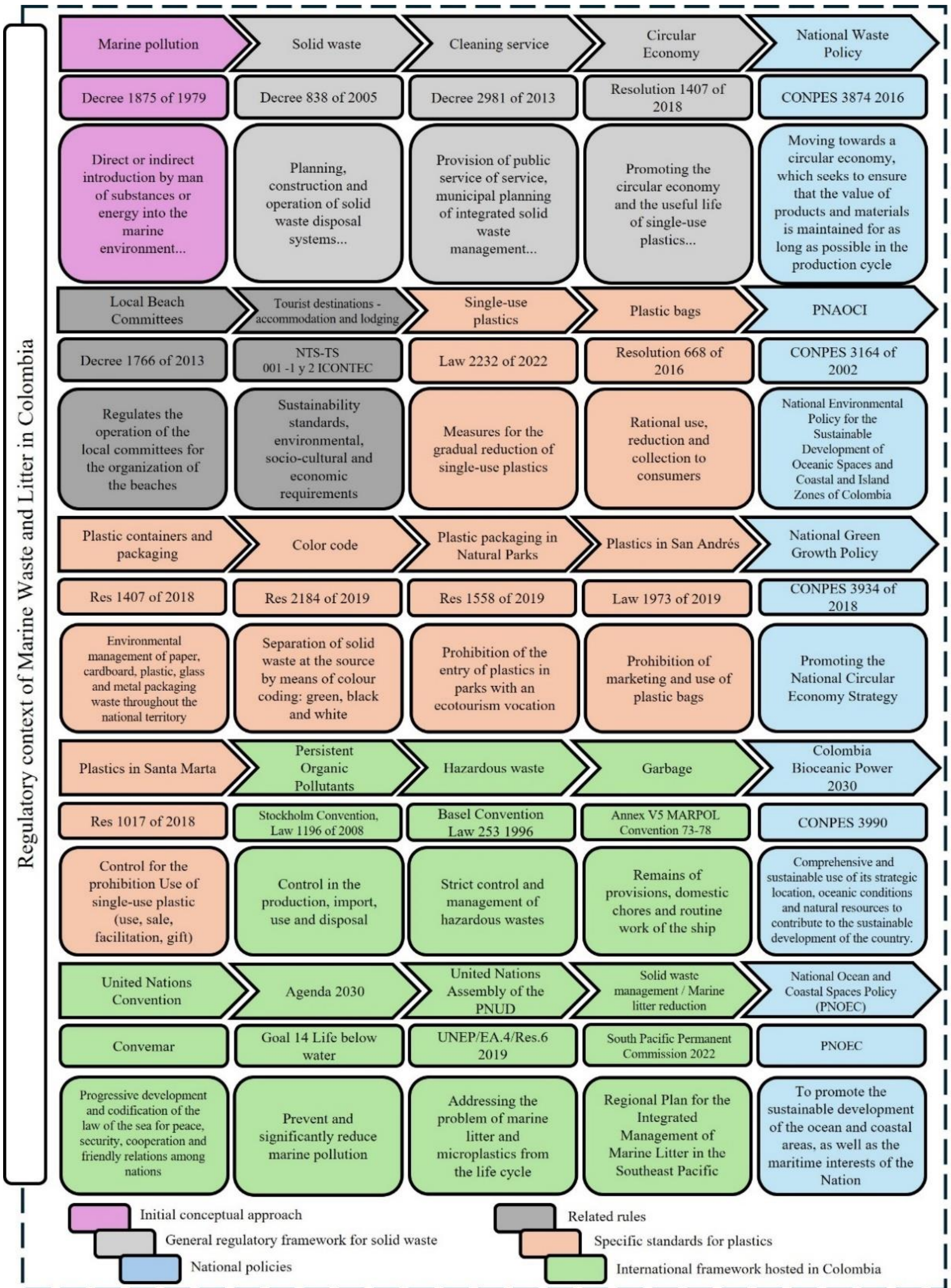

Figure 2. Regulatory context and policies on waste and marine litter in Colombia. [Modified from: Invemar, 2020 (based on the following rules, laws and regulations: Botero, 2018; CCO, 2007, 2018; Permanent Commission of the South Pacific, 2020; Congress of Colombia, 1996, 2019; National Council for Economic and Social Policy, 2002, 2020; International Convention for the Prevention of Pollution from Ships, 1973; CPPS, 2022; District Administrative Department of Environmental Sustainability, 2018, 2019; DNP, 2016, 2018; ICONTEC, 2007a, 2007b; Invemar, 2020; MAVDT, 2005; Ministry of Environment and Sustainable Development of Colombia, 2013, 2016, 2018, 2019a, 2019b, 2019c, 2021; Ministry of Environment, 2001; Ministry of Housing, City and Territory, 2013; United Nations, 1982, 2015, 2019; Republic of Colombia, 1979; Tourism, Cultural and Historical District of Santa Marta, 2018).

Policies for SBR

Specific laws have been established at the SBR to address marine pollution and reduce the use of plastics. Law 1973 of 2019 prohibits the entry, sale and use of bags and other plastic materials on the San Andres, Old Providence and Ketlina Islands. This legislation, supported by Resolution 283, came into force in July 2021 with the objective of reducing plastic pollution and promoting sustainable practices on the islands.

Measures implemented under this law include a ban on single-use plastics and awareness campaigns about plastic pollution. Additionally, incentives have been established to encourage the replacement of plastic materials with biodegradable and sustainable alternatives.

While these policies represent important advances in plastic waste management, it is important to assess their effectiveness and limitations. A major challenge is the effective implementation and enforcement of these laws. Although single-use plastics have been banned, studies show that high levels of plastics and microplastics are still found, suggesting that the ban has not been entirely effective.

The benefits of these policies include raising environmental awareness and promoting the transition from plastics to biodegradable alternatives. However, these regulations have not sufficiently addressed external sources of pollution, such as waste carried by ocean currents from other regions.

Suggested Measures to mitigate Pollution and Promote Health in the Caribbean Sea

This analysis highlights the persistent problem of marine litter, originating both locally and from ocean currents. The ongoing issue threatens a gradual degradation of the affected ecosystems. Although management initiatives exist, they remain insufficiently robust to mitigate environmental pressures.

The Colombian government should adopt integrated measures that incorporate prevention, recycling, and the promotion of a circular economy, alongside corporate social responsibility. Current recycling systems require significant adjustments to effectively limit the production of single-use plastics. As of May 2024, the responsibility for avoiding plastic use lies primarily with consumers, while recyclers are responsible for managing waste. This framework largely exempts companies that continue to produce plastics to minimize costs. It is essential to implement sustainable practices that reduce the use of hazardous substances, encourage innovative technologies, and promote specialized recycling systems.

Both tourists and local residents of the Archipelago of San Andrés, Providencia y Santa Catalina must recognize their role in exacerbating this issue. Raising awareness is critical to reducing its impact on the Reserve’s oceans and ecosystems. The national and regional governments, in collaboration with local entities, can implement educational programs and awareness campaigns. These initiatives should include social media efforts to promote alternatives to single-use plastics, encourage the proper disposal of recyclable materials, and discourage the excessive consumption of plastic products.

Marketing initiatives in hotel chains, shopping centers, and other establishments could also play a key role. For instance, offering incentives to customers who contribute to recycling efforts can reduce the negative effects of plastic waste. Reward systems for recycling in hotels and shops can help mitigate the problem and foster sustainable habits.

A holistic approach is necessary to address marine litter from economic, social, and cultural perspectives. This includes strengthening regulations with penalties for non-compliance and ensuring constant monitoring of enforcement. Furthermore, international environmental agreements should be revisited to promote transboundary conservation efforts. Addressing marine litter in the SBR is essential not only to protect the local economy, but also to ensure the sustainability of fisheries and the preservation of marine ecosystems.

It is important to highlight the need for effective monitoring, rigorous controls and the proper implementation of policies to address the problem of marine litter in the Archipelago. From the perspective of local residents, it is evident that many regulations, resolutions, or laws remain largely unenforced, with inadequate supervision and limited enforcement mechanisms.

According to personal communications with the inhabitants of the Archipelago of San Andrés, Providencia y Santa Catalina, there is no rigorous program for the management and disposal of solid waste on the islands and cays. It is essential to develop education and awareness initiatives, both for the population and for government bodies, since waste management must be an integral part of public policies in the region.

A priority action would involve conducting cleaning and awareness campaigns in Alburquerque and Pescadores Cay (Courtown Cays), which experience high levels of pollution, particularly in areas used by fishermen and in dense vegetation zones. These campaigns should engage the fishermen of San Andres, who use Pescadores Cay as a temporary refuge. Collaboration between state agencies and fishermen could facilitate the collection and transport of waste to San Andres, promoting more sustainable waste management and reducing pollution.

To achieve meaningful change, it is essential to impose stricter penalties for non-compliance with regulations. Substantial fines could serve as an effective incentive for people to understand the importance of reducing their environmental impact and comply with the established provisions. These sanctions must not only be dissuasive, but also educational, so that the community understands the seriousness of the problem and actively commits to its solution. This is especially relevant in the context of the SBR as a protected area, where tourists and tour operators are prohibited by law from entering. Awareness and education campaigns must also include these groups.

It is key to promote recycling as a mandatory practice, starting in educational institutions, where it is integrated into the curriculum. Companies, both public and private, must implement environmental management plans with recycling programs. This would not only reduce marine litter in the ocean, but also foster a culture of environmental responsibility. In addition, it is vital to promote recycling in homes, companies, and the tourism sector through awareness campaigns. Implementing separate collection systems and providing access to recycling points are critical steps to achieve this.

Addressing marine litter in the SBR is critical to protecting the islands' economic sectors and ensuring the sustainable development of the fishing industry. Figure 3 presents examples of short-, medium-, and long-term actions.

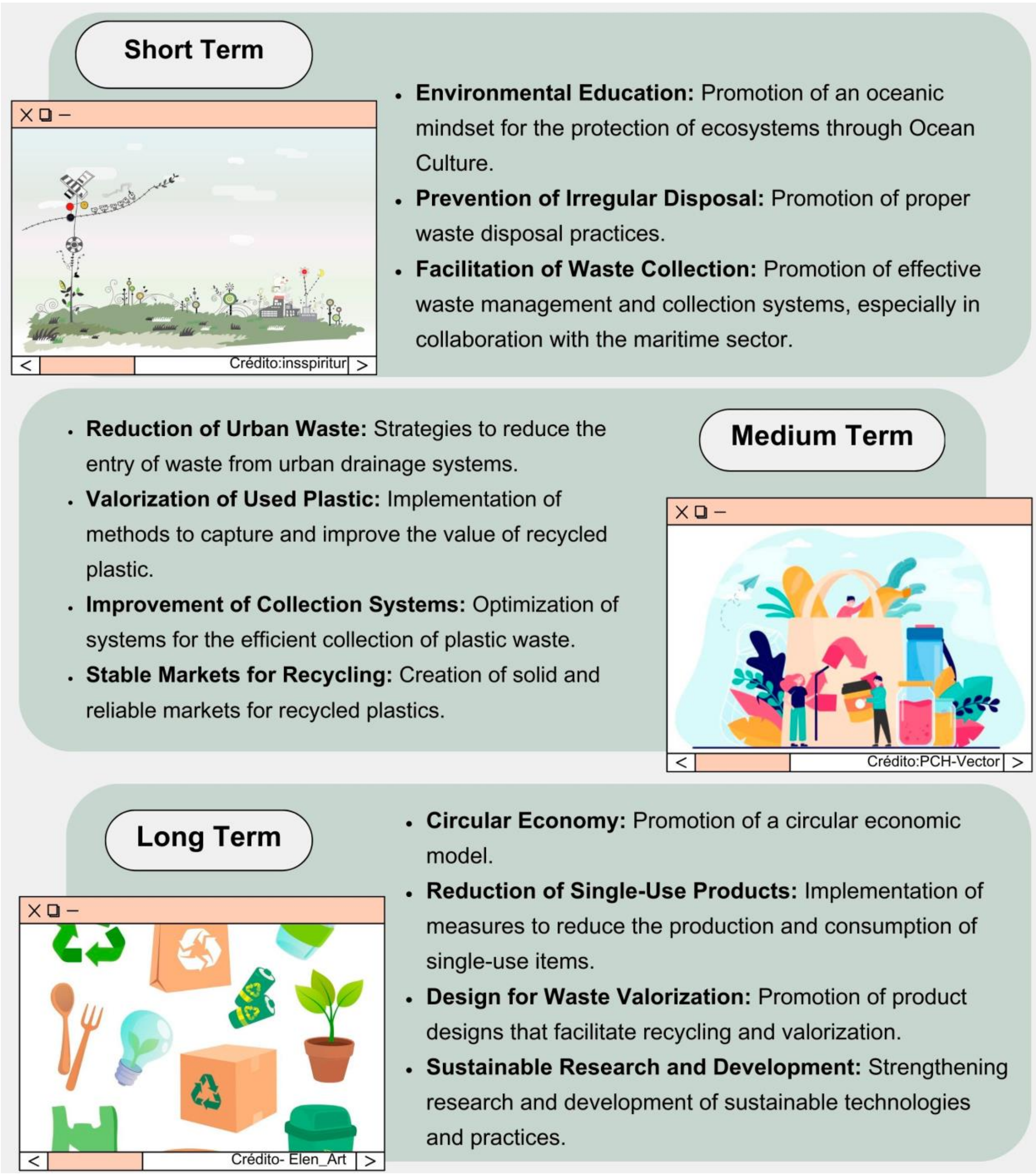

Figure 3. Examples of short-term (1-2 years), medium-term (3-5 years) and long-term (6-10 years) actions to address the problem of marine litter.

Conclusions

Marine litter pollution in the SBR poses a critical challenge to the health of marine and coastal ecosystems in the Caribbean region. The vulnerability of remote islands to this type of pollution underscores the urgent need to implement effective and sustainable environmental management practices.

The analysis of marine litter reveals the presence of multiple sources of pollution, both local and external. Inadequate land-based activities, such as ineffective waste management, combined with the arrival of plastics transported by natural processes like waves and ocean currents, are key factors in the accumulation of marine litter in these ecosystems.

The increasing accumulation of marine litter not only threatens the sustainability of marine and coastal resources, but also negatively impacts vital sectors such as tourism and fisheries, which are pillars of the regional economy. The presence of marine litter and microplastics in sensitive areas, such as mangroves and beach vegetation zones, highlights the need for coordinated actions that involve the community and adapt management strategies to local conditions.

Given the fragility of marine ecosystems in the SBR, it is imperative to adopt stricter management measures and educational programs that respond to the specific needs of each context. Collaboration between the Colombian government and local stakeholders is critical to promoting the conservation of these unique environments and ensuring their long-term sustainability.

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Authors' Contribution

Participation in the different Seaflower expeditions: L.P., P.T.C., G.I.L., N.G.B., G.C.U., R.P.M., R.C.B.; conceptualization and methodology: L.P., G.I.L., N.G.B., R.P.M.; analysis: L.P., P.T.C., G.I.L., N.G.B., R.P.M.; drafting-preparation of the original draft: L. P.; writing-contributions, revision and editing: L.P., P.T.C., G.I.L., N.G.B., G.C.U., R.P.M., D.A.V.D. All authors have read and accepted the published version of the manuscript.

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Short article

Occurrence and body size of common cartilaginous fishes in the Seaflower Biosphere Reserve

Ocurrencias y tamaños corporales de peces cartilaginosos comunes de la Reserva de la Biósfera Seaflower

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Abstract

Coral reefs worldwide face numerous threats, endangering both ecosystems and coastal communities. Collecting population data on marine species, particularly apex predators like sharks and rays, is essential for effective conservation. This study presents data on the occurrences and body size of five common species of cartilaginous fishes recorded through diver-operated stereo-video surveys conducted between 2018 and 2022. Significant variation was found in species sightings across locations, highlighting the importance of continued research to assess population status and to inform conservation strategies tailored to specific species and sites.

Keywords: Archipelago of San Andrés, Providencia y Santa Catalina; elasmobranchs; stereo-video

Resumen

Los arrecifes de coral en todo el mundo enfrentan numerosas amenazas, poniendo en peligro tanto los ecosistemas como las comunidades costeras. Recopilar datos poblacionales sobre especies marinas, especialmente depredadores tope como tiburones y rayas, es crucial para una conservación efectiva. En este estudio se presentan datos de ocurrencia y tamaño corporal de cinco especies comunes de peces cartilaginosos observadas durante censos visuales realizados con la técnica de estéreo-video operado por buzo entre 2018 y 2022. Se encontró una variación relevante en la presencia de especies entre localidades; estos hallazgos subrayan la necesidad de continuar la investigación para evaluar el estado poblacional e informar sobre estrategias de conservación adaptadas a cada especie y localidad.

Palabras clave: archipiélago de San Andrés; Providencia y Santa Catalina; elasmobranquios; estéreo-video

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INTRODUCTION

Coral reefs face multiple threats, including climate change, overfishing, and pollution, resulting in substantial worldwide deterioration and loss of ecosystem functionality which jeopardizes the livelihoods of coastal communities (Hughes *et al*., 2017; Souter, Planes, Eicquart, Logan, Obura, & Staub, 2021). Understanding the dynamics and interactions between species within marine communities is essential for the conservation and effective management of marine resources (Auster, Estes, & Coleman, 2013). Top predators and mesopredators play a critical role in shaping and regulating the structure of these communities (Roff *et al*., 2016).

Cartilaginous fishes (sharks and rays) play important roles as mesopredators and apex predators on coral reefs (Heupel, Knip, Simpfendorfer, and Dulvy 2014). They consume a wide variety of prey, including small and medium-sized fishes, crustaceans, and mollusks, regulating their populations and helping to maintain community structure within the ecosystem (Heupel *et al*., 2014; Ruppert, Travers, Smith, Fortin, & Meekan, 2013). Despite their important functions, chondrichthyans face significant threats due to overfishing and habitat degradation. Their conservation is crucial to maintaining coral reef health and biodiversity (Ferretti, Worm, Britten, Heithaus, & Lotze, 2010; Roff *et al*., 2016; Simpfendorfer *et al*., 2023).

To generate efficient conservation strategies, it is necessary to have as much information as possible on the population status of the different species of sharks and rays. However, this represents a challenge because many of the species in the group are under some category of threat and the frequency of sightings is low.

A total of 33 species of sharks and rays are distributed throughout the Seaflower Biosphere Reserve (SBR) (Bolaños-Cubillos, Abril-Howard, Bent Hooker, Caldas and Acero, 2015). The Nurse Shark *(Ginglymostoma cirratum)* and the Caribbean Reef Shark *(Carcharhinus perezii)* are the most common sharks, and the Southern Stingray *(Hypanus americanus)* and the Spotted Eagle Ray *(Aetobatus narinari)* are the most common rays. To contribute to the knowledge of cartilaginous fishes in the Archipelago, this study presents occurrence and body size data of chondrichthyan species observed during visual censuses conducted at various locations within the SBR between 2018 and 2022.

STUDY AREA

The SBR is a complex of islands, atolls, cays and shoals in the Colombian Caribbean that extends over approximately 180,000 km2. It includes one of the largest coral reef complexes in the Caribbean (Abril-Howard, Bolaños-Cubillos, Machacón, Lasso, Gómez, & Ward, 2012a) and more than 77% of the country's coral reef formations (Abril-Howard, Orozco, Bolaños-Cubillos, & Bent, 2012b). In this study, cartilaginous fishes were recorded in coral reef areas of several SBR islands including San Andres (SA), Courtown Cays or Bolívar Cays (BOL), Southwest Cays or Alburquerque Cays (ALB) and Old Providence and Ketlina (PRO). The main island of the archipelago is SA, located 90 km south of PRO, while BOL and ALB are two cays inhabited by the marines personnel stationed there for protection purposes, situated 25 km and 37 km south of SA, respectively (Fig. 1).

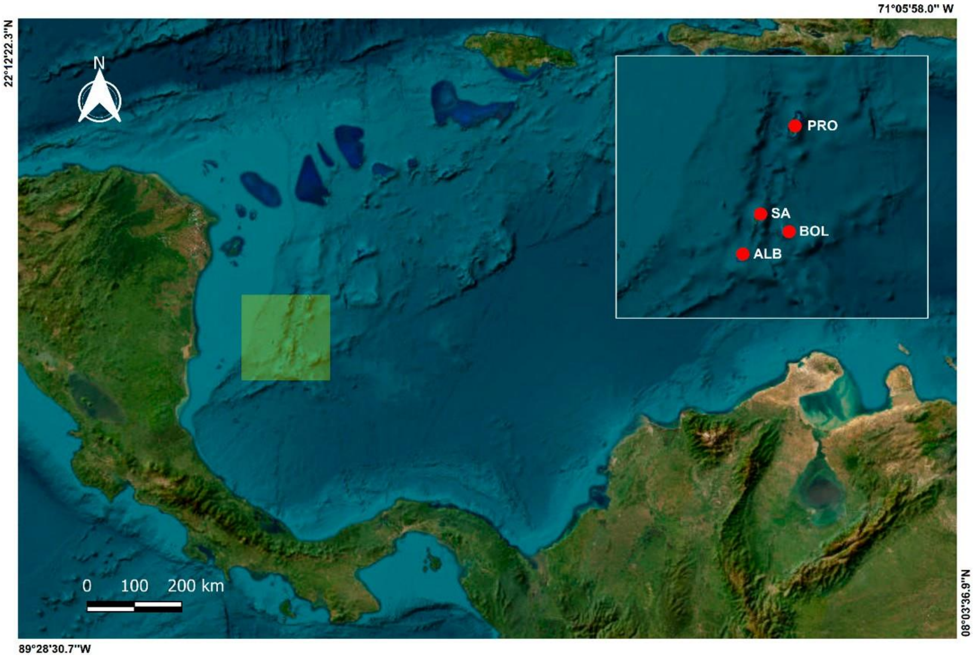

Figure 1. Location of the study area in the SBR and the locations sampled from north to south, Old Providence Island (PRO), San Andres Island (SA), Courtown Cays (BOL) and Southwest Cays (ALB).

METHODOLOGY

Censuses and video processing

The stereo-video technique operated by divers was used, following the methods described in Rivas, Acero, and Tavera (2022, 2023). This approach facilitated the collection of accurate data on individual body size, sex ratio, and overall chondrichthyan composition in the SBR, with minimal estimation error and high resolution. Possible researcher biases were minimized by assigning the same person to perform the processing of all the videos taken, and ensuring a balanced distribution of samples through censuses with specific recording and processing times.

The samplings were carried out between 2018 and 2022, some during the Seaflower scientific expeditions, coordinated by the Colombian Ocean Commission (CCO) (Table 1). The length of all elasmobranch individuals was calculated. In the case of sharks, the total length (TL) taken from the tip of the snout to the tip of the upper caudal lobe was measured; in the case of rays, the disc length (DL) from the tip of the snout to that of the pelvic fins was measured. Additionally and when possible, for the observed rays, their disc width (DW) was calculated, by measuring the distance between the tips of the pectoral fins. Individuals were sexed only when the presence or absence of claspers was evident in the image.

Table 1. Locations and stations sampled between 2018 and 2022. The locations that were evaluated during the Seaflower scientific expeditions (*) and the number of stations with records of cartilaginous fishes in the samplings are detailed.

Year	Location	Stations evaluated	Stations with cartilaginous fish records
2018	ALB*	35	1
2018	BOL	16	5
2018	PRO	16	8
2018	SA	16	0
2019	PRO*	23	11
2019	SA	16	2
2021	PRO*	23	6
2022	BOL*	22	7

RESULTS AND DISCUSSION

Occurrences and body sizes were collected from 82 individuals, belonging to five species of chondrichthyan, including two species of sharks [*Carcharhinus perezii* (Poey, 1876) and *Ginglymostoma cirratum* (Bonnaterre, 1788)] and three species of rays [*Aetobatus narinari* (Euphrasen, 1790), *Hypanus americanus* (Hildebrand & Schroeder, 1928) and *Urobatis* jamaicensis (Cuvier, 1816)]. PRO was the location with the highest frequency of sighting of this group of fishes (Fig. 2). Comparatively, in 2018, the year in which the four locations were evaluated in a short window of time, elasmobranchs were recorded in eight of the 16 stations evaluated in PRO; BOL, chondrichthyans were recorded in five of the 16 stations; in ALB, a single individual of Nurse Shark was observed in the 35 stations evaluated, and in SA, two individuals of the Southern Stingray ray were recorded in two stations (Table 1).

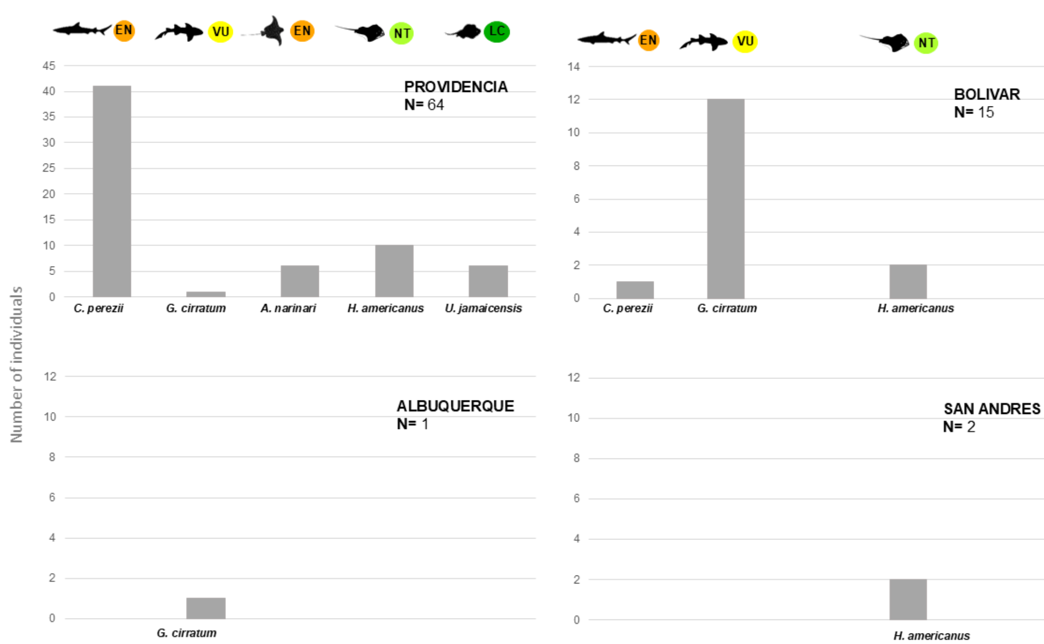

Figure 2. Number of individuals of each species recorded at each location. Colored circles indicate the conservation status of the species.

Size data were collected from 42 specimens of the Caribbean Reef Shark *C. perezii*, of which 41 were observed in PRO and one in BOL. This species is listed as endangered (EN), under the Red List of the International Union for Conservation of Nature (IUCN) (Carlson et al., 2021b). These findings match those of Rodríguez-Barragán (2020), who compared the relative abundances of sharks and carnivorous fishes by means of remote baited chambers in ALB, Serranilla Bank, and PRO. The author found that PRO had the highest relative abundance of *C. perezii*, including females, males, juveniles, and adults. Of the 35 sexed individuals in this study, 20 (19 PRO, 1 BOL) corresponded to females whose sizes ranged between 1,163 mm and 2,098 mm, with an average TL of 1,599.75 mm and 15 corresponded to males that measured 1,504 mm and 1,747 mm, with an average size of 1,597.27 mm (Table 2). The data taken in the SBR indicate that both sexes can reach similar sizes, although only four (4) females exceeded lengths of 1.9 m. Likewise, no males smaller than 1,478 m were detected, while eight (8) females fluctuated between 1,163 m and 1,471 m. Following the sexual maturity height of 1,600 mm, reported by Compagno (1984), 24 individuals were immature and 18 mature (Fig.3).

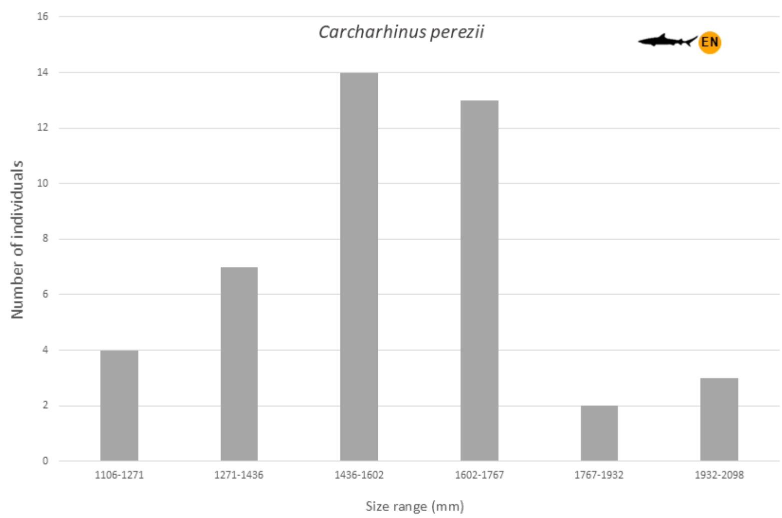

Figure 3. Size frequency of the grey reef shark *Carcharhinus perezii*.
The height ranges in mm and the number of individuals in each range are detailed.

Regarding the other recorded shark species, *G. cirratum*, listed as vulnerable (VU) by the IUCN (Carlson *et al*., 2021c), thirteen (13) specimens were measured, twelve (12) in BOL and one (1) in ALB, of which eight could be sexed and all were females (Table 2). This information could be indicative of some sexual segregation, at least in the sampled area. A sexual maturity height of 2,350 mm for females is reported (Compagno, 1984), indicating that all individuals observed during sampling were immature.

For the group of rays, the Spotted Eagle Ray *A. narinari* and the Yellow Stingray *U. jamaicensis*, classified as EN (Dulvy et al., 2020) and least concern (LC) (Carlson et al., 2021a), respectively, were observed in PRO. A total of six (6) individuals from *A. narinari* individuals were measured, the smallest had an DL of 214.041 mm and a DW of 317.301 mm, and the largest had an DL of 1,005.306 mm and a DW of 1,726.762 mm. According to the sexual maturity size reported by Last, Naylor and Manjaji- Matsumoto (2016), all the individuals observed were immature. Likewise, six (6) individuals of *U. jamaicensis* were measured, their DL ranged between 299.557 mm and 358.907 mm, and their DW between 162.069 mm and 192.097 mm. Of the sexed individuals, one (1) was male and two (2) were female, all with sizes smaller than the size of 200 mm DW sexual maturity reported for the species (Last et al., 2016).

As for the Southern Stingray *H. americanus*, classified as near threatened (NT) (Carlson *et al*., 2020), fourteen (14) individuals were recorded, ten (10) in PRO, two (2) in BOL and two (2) in SA. Only two (2) individuals could be sexed, both were females. Following the sexual maturity size data of 700 mm to 800 mm reported by Last et al. (2016), one (1) immature female was observed in BOL and one (1) mature female in PRO. The DL ranged from 419.687 mm (PRO) to 1,191.741 mm (PRO), with an average of 787.801 mm.

Although it should be considered that sampling was not balanced over the years, PRO appears to be a particularly abundant locality for the cartilaginous fish group in the SBR and stands out as a site that should be prioritized for further study of the group, and on which to focus conservation efforts. PRO had the largest and best protected mangrove swamp in the Archipelago until the passage of Hurricanes Iota and Eta in 2020. This ecosystem is widely considered an essential habitat for sharks and rays (López-Angarita, Villate-Moreno, Díaz, Cubillos-M, & Tilley, 2021). Therefore, due to their ecological role and the data from this study, it is essential to identify and delimit important areas for the maintenance of cartilaginous fish populations.

Table 2. Occurrences and sizes of cartilaginous fishes in four locations of the Seaflower Biosphere Reserve. The date, location and depth of each station are detailed. Shark sizes correspond to their total length (TL), while for rays, disk length (DL) and disk width (DW) were measured when possible. Each individual was assigned an identifier in the SpID_ind column, which, in the case of rays, allows identification of whether the DL and DW correspond to the same individual.

Month	Year	Location	Station	Depth	SpID_ind	Species	Sex	Size	RMS	Length
9	2022	Courtown Cays	9	5	Cp_1	*Carcharhinus perezii*	F	1976,093	2,334	TL
9	2022	Courtown Cays	10	3	Gc_1	*Ginglymostoma cirratum*	F	1294,095	3,191	TL
9	2022	Courtown Cays	11	12	Gc_2	*Ginglymostoma cirratum*	F	2305,639	15,307	TL
9	2022	Courtown Cays	11	12	Gc_3	*Ginglymostoma cirratum*	F	1512,962	3,69	TL
9	2022	Courtown Cays	12	5	Gc_4	*Ginglymostoma cirratum*	F	1503,884	1,29	TL
9	2022	Courtown Cays	6	12	Gc_5	*Ginglymostoma cirratum*	F	2222,279	5,253	TL
9	2022	Courtown Cays	8	6	Gc_6	*Ginglymostoma cirratum*	F	1416,610	2,35	TL
9	2022	Courtown Cays	10	3	Ha_1	*Hypanus americanus*		827,060	2,332	DL
9	2022	Courtown Cays	7	8	Ha_2	*Hypanus americanus*	F	769,011	3,619	DW
9	2022	Courtown Cays	7	8	Ha_2	*Hypanus americanus*	F	654,157	4,041	DL
7	2021	Old Providence	10	10	Ha_3	*Hypanus americanus*	F	862,987	0,445	DL
7	2021	Old Providence	10	10	Ha_3	*Hypanus americanus*	F	795,697	1,277	DW
7	2021	Old Providence	10	10	Ha_4	*Hypanus americanus*		835,303	1,263	DW
7	2021	Old Providence	10	10	Ha_4	*Hypanus americanus*		791,372	0,666	DL
7	2021	Old Providence	11	11	Uj_1	*Urobatis jamaicensis*	M	328,432	16,255	DL
7	2021	Old Providence	11	11	Uj_1	*Urobatis jamaicensis*	M	173,863	0,871	DW
7	2021	Old Providence	11	11	Uj_2	*Urobatis jamaicensis*	F	330,553	6,382	DL
7	2021	Old Providence	11	11	Uj_2	*Urobatis jamaicensis*	F	170,060	0,811	DW
7	2021	Old Providence	13	20	Cp_2	*Carcharhinus perezii*	M	1573,358	1,886	TL
7	2021	Old Providence	13	20	Cp_3	*Carcharhinus perezii*	M	1747,016	5,739	TL
7	2021	Old Providence	13	20	Cp_4	*Carcharhinus perezii*	M	1612,801	5,095	TL
7	2021	Old Providence	13	20	Cp_5	*Carcharhinus perezii*	F	1443,100	7,95	TL
7	2021	Old Providence	13	20	Cp_6	*Carcharhinus perezii*		1299,331	18,797	TL
7	2021	Old Providence	13	20	Cp_7	*Carcharhinus perezii*	F	1389,584	6,437	TL

Month	Year	Location	Station	Depth	SpID_ind	Species	Sex	Size	RMS	Length
7	2021	Old Providence	13	20	Cp_8	*Carcharhinus perezii*	F	1162,799	4,653	TL
7	2021	Old Providence	14	13	Ha_5	*Hypanus americanus*		373,182	3,365	DW
7	2021	Old Providence	14	13	Ha_5	*Hypanus americanus*		939,789	1,548	DL
7	2021	Old Providence	14	13	Uj_3	*Urobatis jamaicensis*	F	358,907	0,643	DL
7	2021	Old Providence	14	13	Uj_3	*Urobatis jamaicensis*	F	192,097	1,835	DW
7	2021	Old Providence	14	13	Ha_6	*Hypanus americanus*		438,976	5,165	DL
7	2021	Old Providence	14	13	Ha_6	*Hypanus americanus*		465,813	2,429	DW
7	2021	Old Providence	5	5	Cp_9	*Carcharhinus perezii*		1268,389	8,347	TL
7	2021	Old Providence	9	9	Cp_10	*Carcharhinus perezii*	F	1959,478	1,295	TL
7	2021	Old Providence	9	9	Cp_11	*Carcharhinus perezii*	F	1637,924	0,391	TL
7	2021	Old Providence	9	9	Cp_12	*Carcharhinus perezii*	F	2097,812	4,049	TL
7	2021	Old Providence	9	9	Cp_13	*Carcharhinus perezii*	F	1792,899	0,813	TL
9	2019	Old Providence	14	10	Ha_7	*Hypanus americanus*		850,918	1,605	DL
9	2019	Old Providence	14	10	Ha_8	*Hypanus americanus*		778,535	3,721	DL
9	2019	Old Providence	16	15	Ha_9	*Hypanus americanus*		759,340	0,116	DL
9	2019	Old Providence	16	15	Ha_10	*Hypanus americanus*		852,410	4,654	DL
9	2019	Old Providence	16	15	Uj_4	*Urobatis jamaicensis*		335,395	1,023	DL
9	2019	Old Providence	17	12	Uj_5	*Urobatis jamaicensis*		299,557	0,206	DL
9	2019	Old Providence	15	10	An_1	*Aetobatus narinari*		1726,762	3,406	DW
9	2019	Old Providence	15	10	An_1	*Aetobatus narinari*		1005,306	3,340	DL
9	2019	Old Providence	19	8	An_2	*Aetobatus narinari*		813,027	2,882	DL
9	2019	Old Providence	19	8	An_2	*Aetobatus narinari*		1042,358	7,527	DW
9	2019	Old Providence	19	8	An_3	*Aetobatus narinari*		859,972	1,961	DL
9	2019	Old Providence	19	8	An_3	*Aetobatus narinari*		1064,975	3,270	DW
9	2019	Old Providence	20	18	An_4	*Aetobatus narinari*		318,898	13,976	DL
9	2019	Old Providence	20	18	An_4	*Aetobatus narinari*		506,291	5,715	DW
9	2019	Old Providence	20	18	An_5	*Aetobatus narinari*		408,602	18,577	DL
9	2019	Old Providence	20	18	An_5	*Aetobatus narinari*		689,821	14,807	DW

Month	Year	Location	Station	Depth	SpID_ind	Species	Sex	Size	RMS	Length
9	2019	Old Providence	20	18	An_6	*Aetobatus narinari*		317,301	15,297	DW
9	2019	Old Providence	20	18	An_6	*Aetobatus narinari*		214,041	0,922	DL
9	2019	Old Providence	21	20	Cp_13	*Carcharhinus perezii*		1676,800	1,720	TL
9	2019	Old Providence	21	20	Cp_14	*Carcharhinus perezii*		1332,362	3,251	TL
9	2019	Old Providence	21	20	Cp_15	*Carcharhinus perezii*		1736,994	1,495	TL
9	2019	Old Providence	22	20	Ha_11	*Hypanus americanus*		1192,741	17,246	DL
9	2019	Old Providence	5	10	Gc_7	*Ginglymostoma cirratum*		791,039	2,027	TL
9	2019	Old Providence	6	10	Cp_16	*Carcharhinus perezii*		1105,719	5,175	TL
9	2019	Old Providence	9	15	Uj_6	*Urobatis jamaicensis*		162,069	0,201	DW
9	2019	Old Providence	9	15	Uj_6	*Urobatis jamaicensis*		316,901	0,565	DL
9	2019	Old Providence	9	15	Ha_12	*Hypanus americanus*		479,144	6,340	DW
9	2019	Old Providence	9	15	Ha_12	*Hypanus americanus*		419,687	4,169	DL
9	2019	San Andres	12	18	Ha_13	*Hypanus americanus*		957,039	5,520	DL
9	2019	San Andres	16	15	Ha_14	*Hypanus americanus*		704,208	1,885	DL
9	2018	Southwest Cays	13	15	Gc_8	*Gynglimostoma cirratum*		1182,939	9	TL
10	2018	Courtown Cays	1	12	Gc_9	*Gynglimostoma cirratum*		1302,759	0,785	TL
10	2018	Courtown Cays	2	18	Gc_10	*Gynglimostoma cirratum*		1079,753	4	TL
10	2018	Courtown Cays	3	18	Gc_11	*Gynglimostoma cirratum*		2189,132	7	TL
10	2018	Courtown Cays	5	15	Gc_12	*Gynglimostoma cirratum*		2136,207	15	TL
10	2018	Courtown Cays	6	14	Gc_13	*Gynglimostoma cirratum*	F	973,852	0,438	TL
10	2018	Courtown Cays	6	14	Gc_14	*Gynglimostoma cirratum*	F	1530,865	5,116	TL
10	2018	Old Providence	1	24	Cp_16	*Carcharhinus perezi*	M	1531,967	2,052	TL
10	2018	Old Providence	1	24	Cp_17	*Carcharhinus perezi*	M	1626,207	18,228	TL
10	2018	Old Providence	1	24	Cp_18	*Carcharhinus perezi*	F	1713,048	3,378	TL
10	2018	Old Providence	1	24	Cp_19	*Carcharhinus perezi*	F	1910,761	15,713	TL
10	2018	Old Providence	2	20	Cp_20	*Carcharhinus perezi*	F	1330,706	11,060	TL
10	2018	Old Providence	2	20	Cp_21	*Carcharhinus perezi*	F	1470,822	3,865	TL

Month	Year	Location	Station	Depth	SpID_ind	Species	Sex	Size	RMS	Length
10	2018	Old Providence	5	19	Cp_22	*Carcharhinus perezi*		1398,265	2,990	TL
10	2018	Old Providence	5	19	Cp_23	*Carcharhinus perezi*	M	1559,285	0,340	TL
10	2018	Old Providence	5	19	Cp_24	*Carcharhinus perezi*	M	1477,766	5,019	TL
10	2018	Old Providence	5	19	Cp_25	*Carcharhinus perezi*	M	1658,137	3,071	TL
10	2018	Old Providence	5	19	Cp_26	*Carcharhinus perezi*	F	1515,272	7,858	TL
10	2018	Old Providence	6	24	Cp_27	*Carcharhinus perezi*	F	1685,787	7,658	TL
10	2018	Old Providence	6	24	Cp_28	*Carcharhinus perezi*	F	1388,097	13,258	TL
10	2018	Old Providence	6	24	Cp_29	*Carcharhinus perezi*	M	1515,918	0,078	TL
10	2018	Old Providence	6	24	Cp_30	*Carcharhinus perezi*	M	1642,870	0,971	TL
10	2018	Old Providence	7	24	Cp_31	*Carcharhinus perezi*	M	1612,737	3,081	TL
10	2018	Old Providence	7	24	Cp_32	*Carcharhinus perezi*	M	1557,779	1,688	TL
10	2018	Old Providence	7	24	Cp_33	*Carcharhinus perezi*	M	1743,006	10,162	TL
10	2018	Old Providence	9	30	Cp_34	*Carcharhinus perezi*	M	1504,473	6,854	TL
10	2018	Old Providence	9	30	Cp_35	*Carcharhinus perezi*	F	1458,141	3,552	TL
10	2018	Old Providence	11	28,1	Cp_36	*Carcharhinus perezi*	F	1279,979	2,150	TL
10	2018	Old Providence	11	28,1	Cp_37	*Carcharhinus perezi*	F	1562,843	0,958	TL
10	2018	Old Providence	11	28,1	Cp_38	*Carcharhinus perezi*	F	1683,936	4,712	TL
10	2018	Old Providence	11	28,1	Cp_39	*Carcharhinus perezi*	M	1597,417	1,551	TL
10	2018	Old Providence	13	10	Cp_40	*Carcharhinus perezi*	F	1535,074	4,827	TL

Conclusions and recommendations

In this work, the data collected on the occurrence and sizes of the most common cartilaginous fishes in four locations of the SBR are presented in a descriptive manner. There is a high variation in the frequency of sightings of the evaluated species between locations relatively close to each other. The information collected indicates that the two sexes reach similar average sizes in *Carcharhinus perezii*, but that the specimens with larger sizes are females. On the other hand, small males of this species do not seem to occupy the sampled area suggesting a possible segregation by size. Meanwhile, in the case of *Ginglymostoma cirratum* some sexual segregation seems to occur, indicated by the absence of males. These results highlight the importance of continuing efforts to collect information on this highly threatened group and thus recognize and better understand the differences in sizes and occurrences according to locations and species, which will allow establishing efficient and particular conservation strategies for each species.

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Authors' Contribution

Conceptualization, N. R., A. P. S., J. T. and A. A. P.; methodology, N.R.; software, N. R.; validation N. R.; analysis, N. R.; research, N. R., A. P. S., J. T. y A. A. P.; resources, N. R., A. P. S., J. T. y A. A. P.; data curation, N. R.; drafting-preparation of the original draft, N. R.; drafting-revision and editing N.R., A.P.S., J.T. and A.A.; visualization N. R., A. P. S., J. T. y A. A.; supervision, N.R., A.P. S., J. T. and A. To; project management, N.R., A.P.S., J.T., and A.A.; fundraising, N.R., A.P.S., J.T. and A.A. All authors have read and accepted the published version of the manuscript.

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