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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**Julián Prato-Valderrama[1], Adriana Santos-Martínez[2], Diana Castaño[3], John Carvajal[4]**

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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*

[1] ORCiD: https://orcid.org/0000-0003-4409-0792. Universidad Nacional de Colombia – Sede Caribe. Corporación Centro de Excelencia en Ciencias del Mar-CEMarin. E-mail address: jprato@unal.edu.co

[2] ORCiD: https://orcid.org/0000-0001-7800-3656. Universidad Nacional de Colombia – Sede Caribe. E-mail address: asantosma@unal.edu.co

[3] ORCiD: https://orcid.org/0000-0001-6618-9676. Universidad Nacional de Colombia – Sede Caribe. E-mail address: dcastano@ unal.edu.co

[4] ORCiD: https://orcid.org/0000-0002-3934-2070. Universidad Nacional de Colombia – Sede Caribe. E-mail address: jocarvajalg@unal.edu.co

*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/100$m^2$) | 743 | 209 | 309 |
| Total biomass (g) | 560117 | 117336 | 82768 |
| Biomass per area (g/100$m^2$) | 112023 | 23467 | 16553 |
| Total number of species | 136 | 105 | 32 |

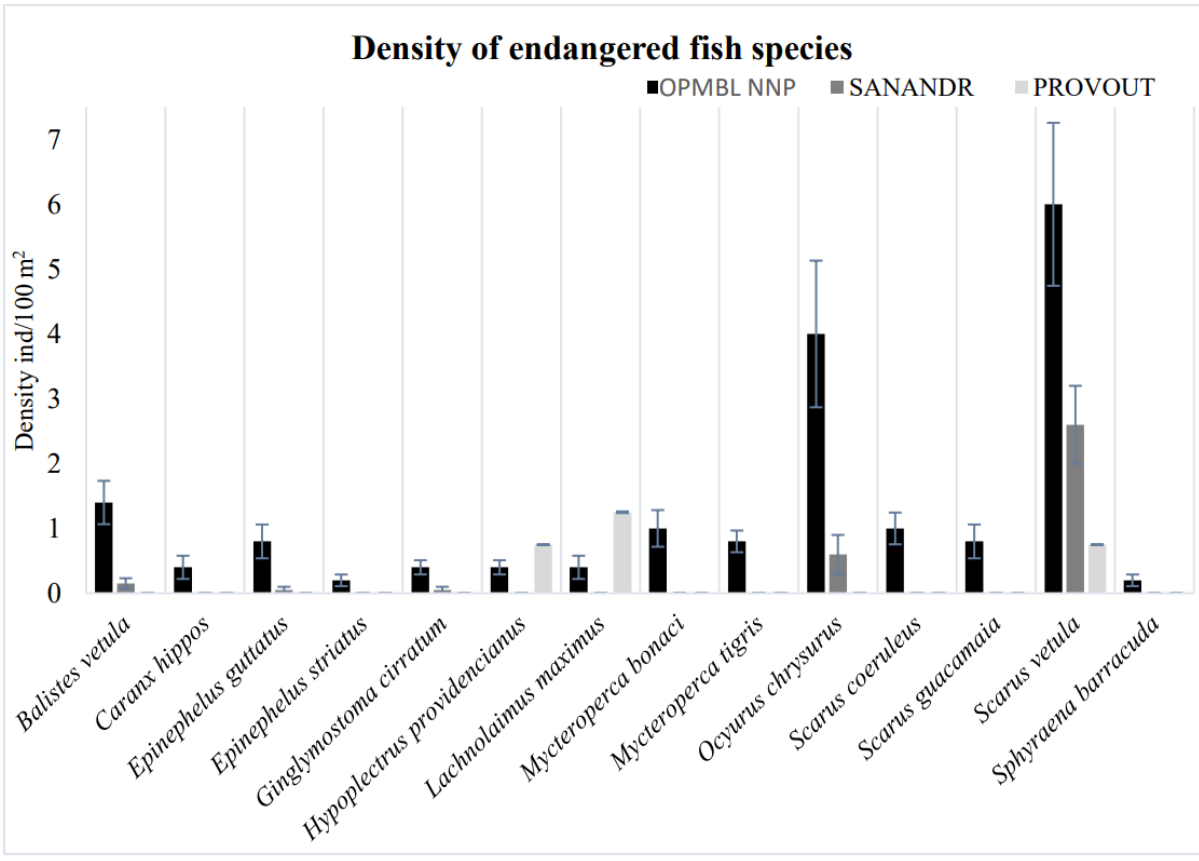
At the station within the MPA of the OPMBL NNP, 136 species were registered, of which 16 correspond to threatened species; fourteen (14) classified into different threat categories defined by the International Union for Conservation of Nature (IUCN) (available online at: IUCN Red List of Threatened Species) (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.

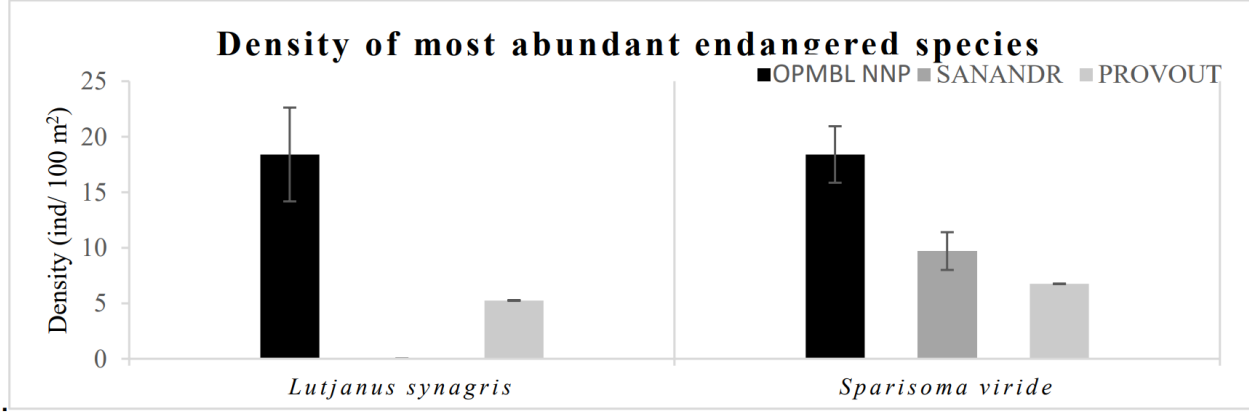



**Figure 1.** Average densities of fish belonging to threatened species recorded at sampling stations inside and outside the MPA OPMBL NNP. **A.** Threatened species. **B.** Most abundant threatened species. In the figures PNNOPML (Spanish abbreviation) means OPMBL NNP.

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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