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RESEARCH ARTICLE

An overview of coral reef fish composition in Punta Francés, Cuba, surveyed using diver operated stereo-video

Composición de peces de arrecife en Punta Francés, Cuba, empleando estéreo video operado por buzos

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Abstract

Punta Francés National Park (PFNP) is valuable for recreational SCUBA diving in Cuba and fishes play an essential role in its attractiveness to divers. Nevertheless, existing knowledge of its fish assemblage is limited. The aims of this study were (i) to update the reef fish inventory and (ii) to analyze the reef fish composition in the PFNP and adjacent area. We performed 411 transects (125 m^2 each) in different coral reef habitats using diver operated stereo-video, in July and August, 2011-2014. We identified 105 species, including 11 with some level of threat. The most important reef herbivores (Scaridae) showed high species richness and abundance (8 species and 5 601 individuals). In contrast, large predators were well-represented but not abundant (e.g., 7 species and 28 individuals of the genera *Epinephelus* and *Mycteroperca*). Fish composition is indicative of a healthy reef affected by fishing pressure, and underscores the importance of more comprehensive studies of this area.

Keywords: biodiversity, Caribbean, checklist, ichthyofauna, marine protected area.

Resumen

El Parque Nacional Punta Francés(PNFP) es valioso para el buceo recreativo en Cuba, y por su atractivo, los peces tienen un rol esencial para los buzos que visitan el área. Sin embargo, el conocimiento existente sobre su ictiofauna es limitado. Los objetivos de este estudio fueron (i) actualizar el inventario de peces de arrecife y (ii) analizar la composición de peces de arrecife en el PNFP y en su arrecife adyacente. Se realizaron 411 transectos (125 m^2 cada uno) en diferentes hábitats de arrecifes de coral empleando estéreo video operado por buzos, en Julio y Agosto, 2011-2014. Se identificaron 105 especies, incluyendo 11 con algún nivel de amenaza. Los peces herbívoros más importantes (Scaridae) mostraron alta riqueza de especies y abundancia (8 especies y 5 601 individuos). Por el contrario, grandes depredadores estuvieron bien representados pero no fueron abundantes (e.g., 7 especies y 28 individuos de los géneros *Epinephelus* y *Mycteroperca*). La composición de peces es

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indicativa de un arrecife saludable afectado por la presión de pesca y muestra la importancia de estudios más integrales en esta área.

Palabras clave: áreas marinas protegidas, biodiversidad, Caribe, ictiofauna, lista de especies.

Introduction

Taxonomic inventories provide essential information to studies focused on ecological and management aspects of biological communities and ecosystems. For instance, they are important for identifying patterns of diversity and biogeography (Kulbicki et al., 2013) and for determining the distributional limits of individual species (Mora et al., 2008; Miloslavich et al., 2010). Incorporation of areas with no or incomplete species inventories are needed to increase the accuracy of biodiversity models, which require diversity data at fine resolution (Mora et al., 2008). In addition, basic studies about biodiversity are important precursors to conservation projects (Costello et al., 2015a).

The Caribbean Sea is the hotspot of reef fish biodiversity in the tropical Atlantic (Roberts et al., 2002; Kulbicki et al., 2013) and their coral reefs are relatively well-studied in term of their taxonomic composition (Miloslavich et al., 2010). The current decline of coral reefs in this area threatens the health and species composition of these fish assemblages (Jackson et al., 2014), with overfishing being one of the most serious and widespread problems affecting conservation efforts in the Caribbean and other regions (Costello et al., 2010). One possible solution to this problem is the creation of marine protected areas (Roberts and Hawkins, 2000; Strain et al., 2019). However, their insufficient number and the lack of rigorous management in many of them is a major concern in the scientific community (Mora et al., 2006; Costello et al., 2015b). Therefore, the assessment of the various components of a coral reef ecosystem can offer valuable information about the effectiveness of protection from fishing (e.g., Kelaher et al., 2014; Smith et al., 2014). But, the first step in these ecological assessments is usually a species inventory.

Coral reef fish inventories are fundamental, since fishes are widely used in the assessment of coral reef health. Because of their ecological characteristics, e.g., diversity, functional roles, mobility capabilities and resource requirements, fishes are considered excellent indicators of reef ecosystem conditions (Mumby et al., 2008; Pratchett et al., 2014; Harborne et al., 2017). Additionally, because they are targeted in many fisheries, fishes are valuable in the assessment of marine protected areas (Watson et al., 2007; Micheli et al., 2014; Strain et al., 2019). Their interesting behaviors and diversity in coloration patterns and body shapes has also made them an economically important resource in the SCUBA diving tourism industry (Angulo-Valdés, 2005; Figueredo-Martín et al., 2010). Therefore, systematic assessment of fish assemblages is essential in areas where SCUBA diving represents a touristic product.

The Cuban archipelago is surrounded by a large and well-developed coral reef system, and some of the reefs having particular importance to tourism are included within marine protected areas (Perera-Valderrama et al., 2018). Nevertheless, little ecological information exists about many of these areas (Navarro-Martínez & Angulo-Valdés, 2015). A clear example of this fact is the Punta Francés coral reef system.

Punta Francés is an important reef for recreational SCUBA diving in Cuba (Angulo-Valdés, 2005), and is located on the southwestern coast of the Isle of Youth, the second largest island of Cuba. A portion of the reef includes Punta Francés National Park (PFNP) (Consejo de Ministros, 2012) where fisheries other than commercial lobster fishing are banned, although a small-scale, illegal subsistence fishery occurs. Coral reef habitats exist both inside the park as well as in the adjacent, unprotected area. However, essential habitats for reef fish development such as mangroves and seagrass beds only occur inside the National Park. Despite interest in conservation of this site, little information exists about

its biodiversity. A preliminary checklist of fishes prepared as part of a brief biodiversity analysis of the PFNP (Guardia et al., 2004) is the only source of scientific information about the number and identities of fishes in this area. In addition, a recently published article (Horta e Costa et al., 2020) compared commercially and ecologically important fishes inside and outside PFNP.

The present study aims to (i) update the reef fish inventory and (ii) analyze the reef fish composition in the PFNP and adjacent area. These results are a first approach to assess the status of these reef fish assemblages, provide a baseline for future monitoring efforts, and contribute greater resolution to the distribution of Cuban fishes for future biogeographical analyses. In addition, this study represents some of the first regarding the use of an alternative technology for surveying reef fish assemblages in Cuba, i.e., diver operated stereo-video.

Material and methods

Study site

Sampling was carried out in the PFNP and its adjacent area, on the southwest shore of the Isle of Youth, Cuba, between 21°38'00" N, 083°14'00" W and 21°30'00" N, 083°06'00" W (Fig. 1). The coral reef at PFNP has high habitat heterogeneity. Fore reef habitats including terrace, slope, deep patch reef, and spur and groove occur throughout the study area, and reef crest is found in some locations inside the park. The

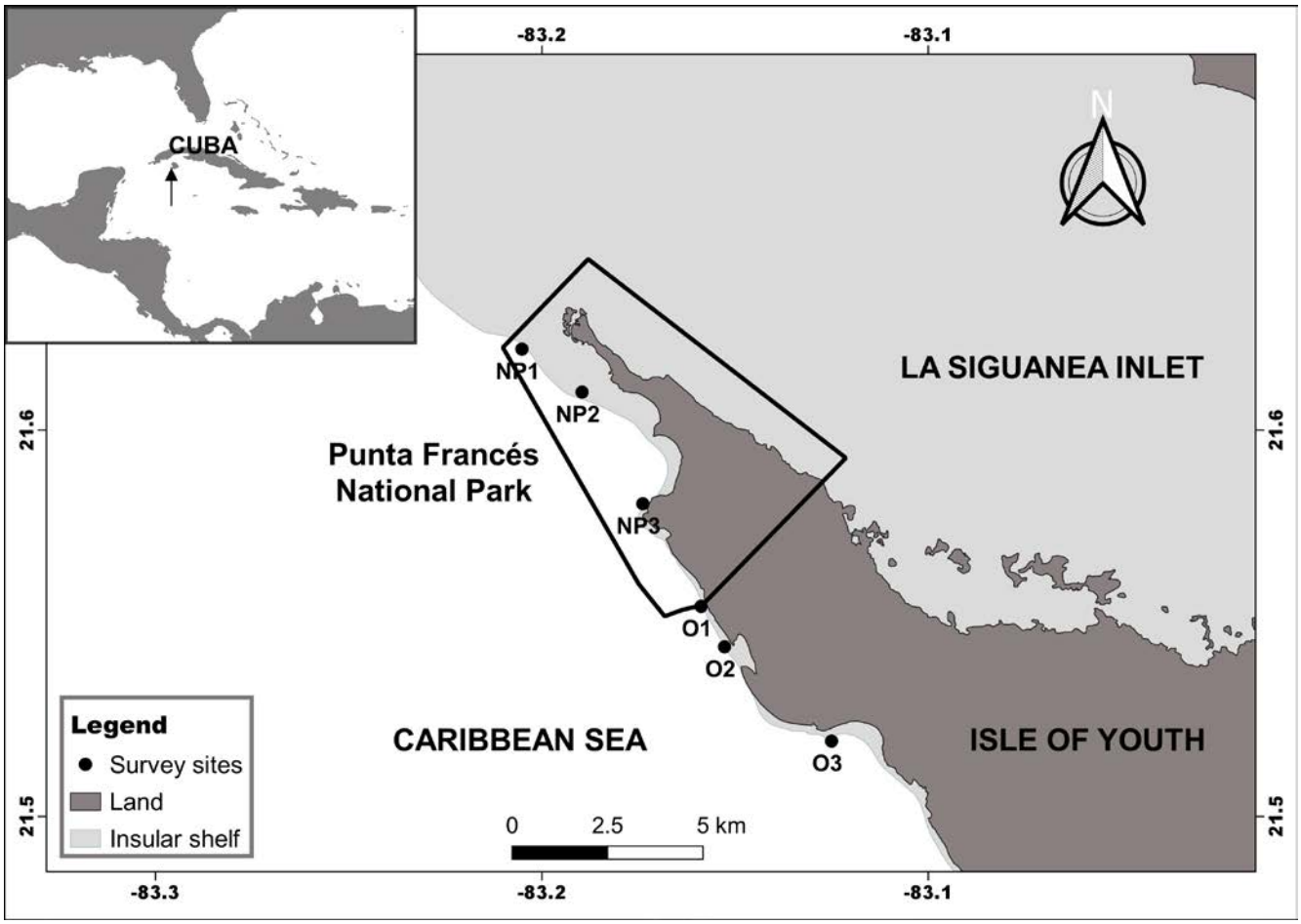

Fig. 1. Map showing the study area and survey sites in Punta Francés National Park (NP) and in the adjacent area (O).

seaward portion of the fore reef is bordered by a deep wall, and on the shoreward side is a shallow back reef with seagrass beds, sandy bottom with scattered macroalgae and small patch reefs. The western shoreline is plenty of mangroves. These diverse habitats provide high ecological and economical value to this protected area (Guardia et al., 2004; Angulo-Valdés, 2005). Outside of PFNP (at the eastern side), the reef is narrower and more exposed to the open ocean, and lacks mangroves, seagrass beds and reef crest.

The Isle of Youth has among the highest proportion of forested area, including natural and plantation forest, in Cuba (ONEI, 2016). Punta Francés lacked of human settlements in their proximities, being the closest, the coastal settlements Cocodrilo, which is located at 9 km to the southeast of the PFNP southeastern boundary. Settlements included around 295 persons in the surveyed period (ONEI, 2016). Non large-scale agriculture activities are developed, but small-scale agricultural activities could be taking place in closer areas. Most important human activities in the PFNP are tourism related, mainly cruise ship and diving activities.

Data collection

We conducted 35 surveys (411 transects) during July and August from 2011-2014, including 26 inside of PFNP and 9 in the adjacent area. We surveyed the reef crest (2-3 m deep), both shallow (7-14 m) and deep (14-15 m) portions of the reef slope, and spur and groove habitats (15-23 m). Each survey was conducted along the reef tract parallel to the shore.

Surveys were conducted using a diver operated stereo-video technique (stereo-DOV) (Harvey & Shortis, 1996). Stereo-DOV equipment consisted on a Canon HF S21 Full HD camcorder with a Raynox HD 6600 Pro conversion lens, which was provided by SeaGIS Pty Ltd. Surveys were conducted by two divers, one operating the cameras and the other 35 m away at the far end of a fiberglass metric line marking the beginning and the end of the transect (Navarro-Martínez et al., 2017). The average speed of swimming was 0.3 m s^{-1}. The tilt of the camera was 30° down and the distance to the bottom was approximately 0.5 m. Each survey consisted of 12 straight-line transects 25 m long x 5 m wide (125 m^2) and approximately 5 m high, separated by 10 m between transects. Our surveys followed the methodology and recommendations from other studies (e.g., Watson et al., 2005; Delacy, 2008; Goetze et al., 2019). Surveys were carried out between 0900-1900 h.

Videos were analyzed with the Event Measure program, version 3.32., provided by SeaGIS Pty Ltd. All fishes observed inside transects were identified and counted by an ichthyologist. The technology used did not allow us to observe cryptic and tiny fishes (e.g., flounders, gobies and blennies). Fishes were generally identified to species, but in some cases could only be identified to the genus level.

Data analysis

Taxonomic classification followed FishBase (Froese & Pauly, 2019). Conservation status was determined based on the IUCN Red List of Threatened Species (IUCN, 2020).

We recorded the total number of individuals per species identified during the study, and we calculated frequency of occurrence as the number of surveys (n= 35) in which each species appeared. Information about where each species was observed (only in PFNP, only in the adjacent area or in both) was also noted. We calculated the mean abundance per transect (with 95 % confidence intervals and standard error) of the species contributing to 95 % of the total abundance. Because of the frequent difficulty of distinguishing between *Scarus iseri* and *Scarus taeniopterus* juveniles, between *Acanthurus tractus, Acanthurus bahianus* and *Acanthurus chirurgus*, and between *Stegastes adustus* and *Stegastes diencaeus*, these species groups were included as species complexes in the graphical analysis.

Hypanus americanus was included in the checklist but not in further analyses because it was only observed outside of transects.

Data were processed in R (R Core Team 2020). The graph was also created with R using ggplot2 (Wickham 2016) and Hmisc (Harrell et al., 2021) packages.

Results

Reef fish inventory

A total of 51 623 individuals were recorded. These were distributed in 105 species, 54 genera, 32 families, 8 orders and 2 classes. We identified 3 species of elasmobranchs, and 102 actinopterygians.

Class Elasmobranchii
- Order Myliobatiformes
  - Family Dasyatidae
    - *Hypanus americanus* (Hildebrand & Schroeder, 1928)
  - Family Potamotrygonidae
    - *Styracura schmardae* (Werner, 1904)
  - Family Aetobatidae
    - *Aetobatus narinari* (Euphrasen, 1790)

Class Actinopterygii
- Order Anguilliformes
  - Family Muraenidae
    - *Gymnothorax funebris* Ranzani, 1839
    - *Gymnothorax moringa* (Cuvier, 1829)
- Order Aulopiformes
  - Family Synodontidae
    - *Synodus intermedius* (Spix & Agassiz, 1829)
- Order Beryciformes
  - Family Holocentridae
    - *Holocentrus adscensionis* (Osbeck, 1765)
    - *Holocentrus rufus* (Walbaum, 1792)
    - *Myripristis jacobus* Cuvier, 1829
    - *Neoniphon marianus* (Cuvier, 1829)
- Order Syngnathiformes
  - Family Aulostomidae
    - *Aulostomus maculatus* Valenciennes, 1841
- Order Scorpaeniformes
  - Family Scorpaenidae
    - *Pterois* sp.
- Order Perciformes
  - Family Serranidae
    - *Cephalopholis cruentata* (Lacepède, 1802)
    - *Cephalopholis fulva* (Linnaeus, 1758)

Epinephelus adscensionis (Osbeck, 1765)
Epinephelus guttatus (Linnaeus, 1758)
Epinephelus morio (Valenciennes, 1828)
Epinephelus striatus (Bloch, 1792)
Hypoplectrus guttavarius (Poey, 1852)
Hypoplectrus indigo (Poey, 1851)
Hypoplectrus puella (Cuvier, 1828)
Hypoplectrus nigricans (Poey, 1852)
Hypoplectrus unicolor (Walbaum, 1792)
Mycteroperca bonaci (Poey, 1860)
Mycteroperca tigris (Valenciennes, 1833)
Mycteroperca venenosa (Linnaeus, 1758)
Serranus tigrinus (Bloch, 1790)

Family Grammatidae
Gramma loreto Poey, 1868

Family Opistognathidae
Opistognathus sp.

Family Malacanthidae
Malacanthus plumieri (Bloch, 1786)

Family Carangidae
Caranx crysos (Mitchill, 1815)
Caranx hippos (Linnaeus, 1766)
Caranx ruber (Bloch, 1793)

Family Lutjanidae
Lutjanus analis (Cuvier, 1828)
Lutjanus apodus (Walbaum, 1792)
Lutjanus buccanella (Cuvier, 1828)
Lutjanus cyanopterus (Cuvier, 1828)
Lutjanus griseus (Linnaeus, 1758)
Lutjanus jocu (Bloch & Schneider, 1801)
Lutjanus mahogoni (Cuvier, 1828)
Lutjanus synagris (Linnaeus, 1758)
Ocyurus chrysurus (Bloch, 1791)

Family Gerreidae
Gerres cinereus (Walbaum, 1792)

Family Haemulidae
Anisotremus surinamensis (Bloch, 1791)
Anisotremus virginicus (Linnaeus, 1758)
Haemulon album Cuvier, 1830
Haemulon carbonarium Poey, 1860

Haemulon chrysargyreum Günther, 1859
Haemulon flavolineatum (Desmarest, 1823)
Haemulon parra (Desmarest, 1823)
Haemulon plumierii (Lacepède, 1801)
Haemulon sciurus (Shaw, 1803)
Haemulon striatum (Linnaeus, 1758)

Family Sparidae
Calamus sp.

Family Mullidae
Mulloidichthys martinicus (Cuvier, 1829)
Pseudupeneus maculatus (Bloch, 1793)

Family Kyphosidae
Kyphosus sp.

Family Chaetodontidae
Chaetodon capistratus Linnaeus, 1758
Chaetodon ocellatus Bloch, 1787
Chaetodon striatus Linnaeus, 1758

Family Pomacanthidae
Holacanthus ciliaris (Linnaeus, 1758)
Holacanthus tricolor (Bloch, 1795)
Pomacanthus arcuatus (Linnaeus, 1758)

Family Pomacentridae
Abudefduf saxatilis (Linnaeus, 1758)
Chromis cyanea (Poey, 1860)
Chromis multilineata (Guichenot, 1853)
Microspathodon chrysurus (Cuvier, 1830)
Stegastes adustus (Troschel, 1865)
Stegastes diencaeus (Jordan & Rutter, 1897)
Stegastes leucostictus (Müller & Troschel, 1848)
Stegastes partitus (Poey, 1868)
Stegastes planifrons (Cuvier, 1830)

Family Labridae
Bodianus rufus (Linnaeus, 1758)
Clepticus parrae (Bloch & Schneider, 1801)
Halichoeres bivittatus (Bloch, 1791)
Halichoeres garnoti (Valenciennes, 1839)
Halichoeres maculipinna (Müller & Troschel, 1848)
Halichoeres poeyi (Steindachner, 1867)
Halichoeres radiatus (Linnaeus, 1758)
Lachnolaimus maximus (Walbaum, 1792)

Thalassoma bifasciatum (Bloch, 1791)

Family Scaridae

Scarus guacamaia Cuvier, 1829
Scarus iseri (Bloch, 1789)
Scarus taeniopterus Lesson, 1829
Scarus vetula Bloch & Schneider, 1801
Sparisoma aurofrenatum (Valenciennes, 1840)
Sparisoma chrysopterum (Bloch & Schneider, 1801)
Sparisoma rubripinne (Valenciennes, 1840)
Sparisoma viride (Bonnaterre, 1788)

Family Acanthuridae

Acanthurus tractus Poey, 1860/ *Acanthurus bahianus* Castelnau, 1855
Acanthurus chirurgus (Bloch, 1787)
Acanthurus coeruleus Bloch & Schneider, 1801

Family Sphyraenidae

Sphyraena barracuda (Edwards, 1771)

Family Scombridae

Scomberomorus regalis (Bloch, 1793)

Order Tetraodontiformes

Family Balistidae

Balistes vetula Linnaeus, 1758
Canthidermis sufflamen (Mitchill, 1815)
Melichthys niger (Bloch, 1786)
Xanthichthys ringens (Linnaeus, 1758)

Family Monacanthidae

Cantherhines macrocerus (Hollard, 1853)
Cantherhines pullus (Ranzani, 1842)

Family Ostraciidae

Lactophrys bicaudalis (Linnaeus, 1758)
Lactophrys trigonus (Linnaeus, 1758)

Family Tetraodontidae

Canthigaster rostrata (Bloch, 1786)
Sphoeroides spengleri (Bloch, 1785)

Family Diodontidae

Diodon hystrix Linnaeus, 1758

Reef fish composition

We recorded 11 species that are included in the Red List of Threatened Species (IUCN, 2020) as threatened or near threatened species. One is listed as Critically Endangered (*E. striatus*), three as Vulnerable (*La. maximus*, *Lu. cyanopterus*, *E. morio*) and seven as

Table 1. Species richness and abundance of fishes per family in the Punta Francés National Park and the adjacent area surveyed between 2011-2014.

Family	Species richness	Abundance
Pomacentridae	9	23 521
Labridae	9	8 838
Scaridae	8	5 601
Haemulidae	10	4 615
Acanthuridae	3	2 256
Lutjanidae	9	1 833
Balistidae	4	918
Holocentridae	4	807
Chaetodontidae	3	627
Grammatidae	1	492
Carangidae	3	442
Mullidae	2	439
Serranidae	15	261
Pomacanthidae	3	205
Sparidae	1	61
Kyphosidae	1	49
Malacanthidae	1	30
Scorpaenidae	1	12
Aulostomidae	1	11
Tetraodontidae	2	9
Monacanthidae	2	8
Muraenidae	2	6
Sphyraenidae	1	5
Gerreidae	1	3
Opistognathidae	1	3
Ostraciidae	2	3
Aetobatidae	1	2
Dasyatidae	1	1
Potamotrygonidae	1	1
Diodontidae	1	1
Scombridae	1	1
Synodontidae	1	1

Near Threatened (*Ae. narinari*, *Ba. vetula, Lu. analis, Lu. synagris, Sc. guacamaia*, *My. bonaci*, *My. venenosa*).

The most diverse families were Serranidae (15 species), Haemulidae (10), Pomacentridae, Lutjanidae and Labridae (9 each), and Scaridae (8) (Table 1). The most abundant families were Pomacentridae with 23 521 individuals, Labridae with 8 838, Scaridae with 5 601 and Haemulidae with 4 615 (Table 1).

Six species (*Ac. tractus/ Ac. bahianus/ Ac. chirurgus, Ac. coeruleus, Ha. plumierii, Sc. iseri, Sp. aurofrenatum* and *Sp. viride*) were present in all surveys (Table 2). Several species were only observed inside of PFNP, including *Ae. narinari, Ba. vetula, Sc. guacamaia* and *E. morio*, whereas *Lu. bucanella* and *X. ringens* were observed only in the adjacent area (Table 2).

Twenty-seven species made up more than 95 % of the total abundance of fishes. These included *Ch. cyanea, St. partitus, T. bifasciatum* and the species complex *Sc. iseri/ Sc. taeniopterus*, each with more than seven individuals per transect (Table 2, Fig. 2). The invasive species *Pterois* sp. was recorded only 12 times.

Discussion

Fish inventory in Punta Francés compared with other Cuban fish assemblages

Surveyed fishes were diverse, representing 12.5 % of the Cuban marine coastal fishes and 30.0 % of the reef fishes, based on the ichthyofauna reported in Cuba by Claro and Robertson (2010). Previous to this checklist, 79 reef fishes were reported in PFNP, all them bony fishes (Guardia et al., 2004). The present checklist updates the status of fishes in this area, including the adjacent zone which previously lacked information. Thirty-one new records of fishes for Punta Francés were added, representing 29.5 % of the current inventory. Nevertheless, *Diodon holocanthus* Linnaeus, 1758, *Pomacanthus paru* (Bloch, 1787), *Prognathodes aculeatus* (Poey, 1860), *Scarus coeruleus* (Bloch, 1786) and *Stegastes variabilis* (Castelnau, 1855) were not seen in surveys, but were recorded by Guardia et al. (2004).

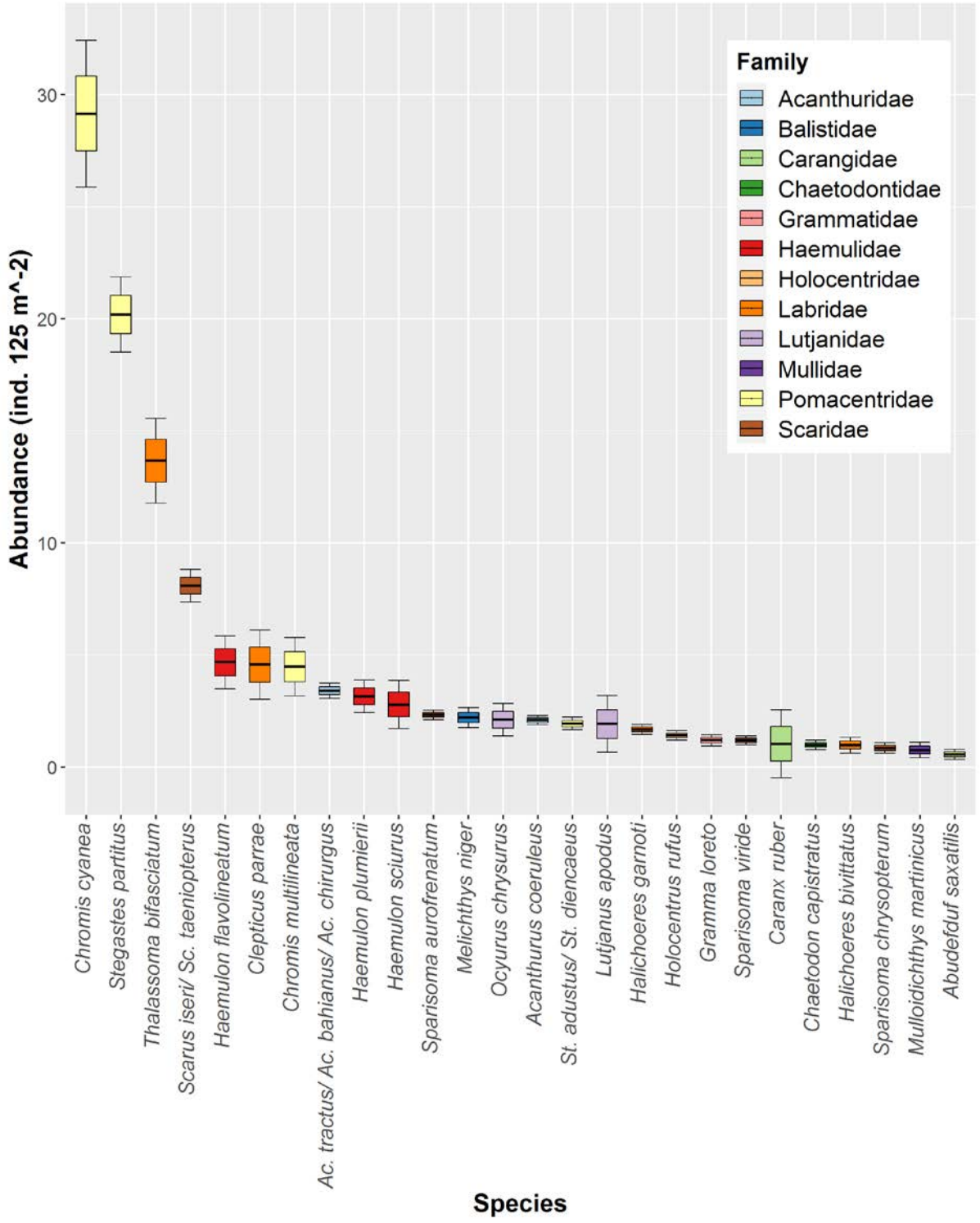

Fig. 2. Abundance of fish species per 125 m^2 transect conducted in Punta Francés National Park and the adjacent area, from 2011-2014. Only species that contributed to 95 % of total abundance are included. Horizontal lines indicate the mean, boxes indicate the standard error, and error lines indicate the 0.95 confidence interval.

Table 2. Fishes identified in coral reef areas of Punta Francés National Park (PFNP) and the adjacent area, between 2011-2014. The species order is based on abundance. Presence indicates if fishes were observed only inside of the National Park (NP), in the adjacent area (O), or in both (B). Frequency of occurrence (FO) is the number of surveys in which each species occurred and total abundance (TA) is the total number of individuals per species. Both metrics were also given as percentage between parentheses.

Species	Presence	FO (% of surveys)	TA (% of total)
Chromis cyanea (Poey, 1860)	B	33 (94.29)	11 980 (23.207)
Stegastes partitus (Poey, 1868)	B	34 (97.14)	8 300 (16.078)
Thalassoma bifasciatum (Bloch, 1791)	B	34 (97.14)	5 617 (10.881)
Scarus iseri (Bloch, 1789)	B	35 (100.00)	2 045 (3.961)
Haemulon flavolineatum (Desmarest, 1823)	B	33 (94.29)	1 921 (3.721)
Clepticus parrae (Bloch & Schneider, 1801)	B	22 (62.86)	1 879 (3.640)
Chromis multilineata (Guichenot, 1853)	B	25 (71.43)	1 839 (3.562)
Acanthurus tractus/Ac. bahianus/ Ac. chirurgus	B	35 (100.00)	1 400 (2.712)
Haemulon plumierii (Lacepède, 1801)	B	35 (100.00)	1 297 (2.512)
Haemulon sciurus (Shaw, 1803)	B	32 (91.43)	1 147 (2.222)
Sparisoma aurofrenatum (Valenciennes, 1840)	B	35 (100.00)	957 (1.854)
Melichthys niger (Bloch, 1786)	B	27 (77.14)	907 (1.757)
Ocyurus chrysurus (Bloch, 1791)	B	34 (97.14)	870 (1.685)
Acanthurus coeruleus Bloch & Schneider, 1801	B	35 (100.00)	860 (1.666)
Lutjanus apodus (Walbaum, 1792)	B	28 (80.00)	789 (1.528)
Stegastes adustus (Troschel, 1865)	B	33 (94.29)	771 (1.494)
Halichoeres garnoti (Valenciennes, 1839)	B	34 (97.14)	690 (1.337)
Holocentrus rufus (Walbaum, 1792)	B	33 (94.29)	582 (1.127)
Gramma loreto Poey, 1868	B	23 (65.71)	492 (0.953)
Sparisoma viride (Bonnaterre, 1788)	B	35 (100.00)	490 (0.949)
Caranx ruber (Bloch, 1793)	B	20 (57.14)	426 (0.825)
Chaetodon capistratus Linnaeus, 1758	B	30 (85.71)	405 (0.785)
Halichoeres bivittatus (Bloch, 1791)	B	20 (57.14)	405 (0.785)
Sparisoma chrysopterum (Bloch & Schneider, 1801)	B	26 (74.29)	351 (0.68)
Mulloidichthys martinicus (Cuvier, 1829)	B	24 (68.57)	313 (0.606)
Abudefduf saxatilis (Linnaeus, 1758)	B	11 (31.43)	234 (0.453)
Scarus taeniopterus Lesson, 1829	B	26 (74.29)	221 (0.428)
Microspathodon chrysurus (Cuvier, 1830)	B	24 (68.57)	176 (0.341)

Species	Presence	FO (% of surveys)	TA (% of total)
Sparisoma rubripinne (Valenciennes, 1840)	B	18 (51.43)	176 (0.341)
Holacanthus tricolor (Bloch, 1795)	B	30 (85.71)	152 (0.294)
Chaetodon striatus Linnaeus, 1758	B	29 (82.86)	130 (0.252)
Pseudupeneus maculatus (Bloch, 1793)	B	25 (71.43)	126 (0.244)
Haemulon carbonarium Poey, 1860	NP	6 (17.14)	125 (0.242)
Lutjanus mahogoni (Cuvier, 1828)	B	14 (40.00)	112 (0.217)
Cephalopholis cruentata (Lacepède, 1802)	B	26 (74.29)	102 (0.198)
Haemulon parra (Desmarest, 1823)	B	6 (17.14)	93 (0.180)
Bodianus rufus (Linnaeus, 1758)	B	23 (65.71)	89 (0.172)
Chaetodon ocellatus Bloch, 1787	B	26 (74.29)	88 (0.17)
Stegastes leucostictus (Müller & Troschel, 1848)	B	24 (68.57)	86 (0.167)
Calamus sp.	B	20 (57.14)	61 (0.118)
Cephalopholis fulva (Linnaeus, 1758)	B	19 (54.29)	49 (0.095)
Kyphosus sp.	B	7 (20.00)	49 (0.095)
Holacanthus ciliaris (Linnaeus, 1758)	B	25 (71.43)	47 (0.091)
Lutjanus synagris (Linnaeus, 1758)	B	3 (8.57)	39 (0.076)
Myripristis jacobus Cuvier, 1829	B	12 (34.29)	35 (0.068)
Malacanthus plumieri (Bloch, 1786)	B	14 (40.00)	30 (0.058)
Stegastes diencaeus (Jordan & Rutter, 1897)	B	13 (37.14)	28 (0.054)
Holocentrus adscensionis (Osbeck, 1765)	B	9 (25.71)	28 (0.054)
Neoniphon marianus (Cuvier, 1829)	B	9 (25.71)	23 (0.045)
Lachnolaimus maximus (Walbaum, 1792)	B	9 (25.71)	19 (0.037)
Anisotremus virginicus (Linnaeus, 1758)	B	10 (28.57)	15 (0.029)
Caranx crysos (Mitchill, 1815)	NP	1 (2.86)	15 (0.029)
Halichoeres radiatus (Linnaeus, 1758)	B	6 (17.14)	14 (0.027)
Haemulon striatum (Linnaeus, 1758)	NP	1 (2.86)	14 (0.027)
Pterois sp.	B	5 (14.29)	12 (0.023)
Aulostomus maculatus Valenciennes, 1837	NP	9 (25.71)	11 (0.021)
Serranus tigrinus (Bloch, 1790)	B	8 (22.86)	10 (0.019)
Epinephelus guttatus (Linnaeus, 1758)	B	7 (20.00)	10 (0.019)
Stegastes planifrons (Cuvier, 1830)	B	4 (11.43)	10 (0.019)

Species	Presence	FO (% of surveys)	TA (% of total)
Epinephelus striatus (Bloch, 1792)	B	8 (22.86)	9 (0.017)
Balistes vetula Linnaeus, 1758	NP	6 (17.14)	9 (0.017)
Haemulon chrysargyreum Günther, 1859	NP	2 (5.71)	9 (0.017)
Hypoplectrus indigo (Poey, 1851)	NP	5 (14.29)	8 (0.015)
Canthigaster rostrata (Bloch, 1786)	B	6 (17.14)	6 (0.012)
Halichoeres maculipinna (Müller & Troschel, 1848)	B	4 (11.43)	6 (0.012)
Gymnothorax funebris Ranzani, 1839	B	5 (14.29)	5 (0.010)
Hypoplectrus puella (Cuvier, 1828)	B	5 (14.29)	5 (0.010)
Sphyraena barracuda (Edwards, 1771)	B	5 (14.29)	5 (0.010)
Pomacanthus arcuatus (Linnaeus, 1758)	B	4 (11.43)	5 (0.010)
Cantherhines pullus (Ranzani, 1842)	NP	4 (11.43)	5 (0.010)
Halichoeres poeyi (Steindachner, 1867)	NP	1 (2.86)	5 (0.010)
Scarus vetula Bloch & Schneider, 1801	NP	3 (8.57)	3 (0.006)
Hypoplectrus unicolor (Walbaum, 1792)	B	3 (8.57)	3 (0.006)
Mycteroperca venenosa (Linnaeus, 1758)	B	3 (8.57)	3 (0.006)
Cantherhines macrocerus (Hollard, 1853)	B	3 (8.57)	3 (0.006)
Lutjanus buccanella (Cuvier, 1828)	O	1 (2.86)	3 (0.006)
Opistognathus sp.	NP	1 (2.86)	3 (0.006)
Gerres cinereus (Walbaum, 1792)	NP	1 (2.86)	3 (0.006)
Lutjanus analis (Cuvier, 1828)	B	2 (5.71)	2 (0.004)
Lutjanus cyanopterus (Cuvier, 1828)	NP	2 (5.71)	2 (0.004)
Lutjanus jocu (Bloch & Schneider, 1801)	B	2 (5.71)	2 (0.004)
Hypoplectrus guttavarius (Poey, 1852)	B	2 (5.71)	2 (0.004)
Mycteroperca bonaci (Poey, 1860)	NP	2 (5.71)	2 (0.004)
Mycteroperca tigris (Valenciennes, 1833)	B	2 (5.71)	2 (0.004)
Lactophrys bicaudalis (Linnaeus, 1758)	B	2 (5.71)	2 (0.004)
Lutjanus griseus (Linnaeus, 1758)	NP	1 (2.86)	2 (0.004)
Scarus guacamaia Cuvier, 1829	NP	1 (2.86)	2 (0.004)
Aetobatus narinari (Euphrasen, 1790)	NP	1 (2.86)	2 (0.004)
Gymnothorax moringa (Cuvier, 1829)	NP	1 (2.86)	1 (0.002)
Synodus intermedius (Spix & Agassiz, 1829)	NP	1 (2.86)	1 (0.002)

Species	Presence	FO (% of surveys)	TA (% of total)
Caranx hippos (Linnaeus, 1766)	NP	1 (2.86)	1 (0.002)
Anisotremus surinamensis (Bloch, 1791)	NP	1 (2.86)	1 (0.002)
Haemulon album Cuvier, 1830	NP	1 (2.86)	1 (0.002)
Scomberomorus regalis (Bloch, 1793)	NP	1 (2.86)	1 (0.002)
Epinephelus adscensionis (Osbeck, 1765)	NP	1 (2.86)	1 (0.002)
Epinephelus morio (Valenciennes, 1828)	NP	1 (2.86)	1 (0.002)
Hypoplectrus nigricans (Poey, 1852)	NP	1 (2.86)	1 (0.002)
Canthidermis sufflamen (Mitchill, 1815)	NP	1 (2.86)	1 (0.002)
Xanthichthys ringens (Linnaeus, 1758)	0	1 (2.86)	1 (0.002)
Diodon hystrix Linnaeus, 1758	NP	1 (2.86)	1 (0.002)
Lactophrys trigonus (Linnaeus, 1758)	NP	1 (2.86)	1 (0.002)
Sphoeroides spengleri (Bloch, 1785)	NP	1 (2.86)	1 (0.002)
Styracura schmardae (Werner, 1904)	NP	1 (2.86)	1 (0.002)

Other studies in coral reefs with similar protection in Cuba have reported more species than in Punta Francés. These include Jardines de la Reina National Park with 283 species (Pina-Amargós et al., 2012), Guanahacabibes National Park with 201 species (Cobián-Rojas et al., 2011) and San Felipe National Park with 201 species as well (Guardia et al., 2018). However, only 97 species were reported in the Desembarco del Granma National Park (Hernández-Fernández & Salvat-Torres 2014).

Differences in survey effort used in coral reef fish studies in Cuba preclude strong comparisons of fish composition between those areas (Navarro-Martínez & Angulo-Valdés, 2015; Guardia et al., 2021). In the former studies that detected higher number of species than did the present study, sampling effort was greater than that employed at Punta Francés, whereas it was lower in those studies recording fewer species. Other illustrative examples are the checklists from the Archipelago Sabana-Camagüey (Hernández-Albernas, 2019; 399 species) and from Cuban southcentral reefs (Medina-Valmaseda et al., 2014; 201 species), which included longer period of time and information from other sources. Sometimes, those checklists include other coastal habitats, e.g., seagrass beds and mangroves.

Beside survey effort, survey technique accounts for important differences found in species richness between the previously mentioned studies. Contrasting with the current inventory in Punta Francés using stereo-DOV, the other mentioned inventories have been mainly based on underwater visual census. For both of these methods, the presence of the investigators in the water can modify the behavior of fishes, increasing the chance they go unnoticed (Lindfield et al., 2014), and cryptic species can be underestimated (Harvey et al., 2001; Willis et al., 2001). However, despite the multiple advantages of video techniques with respect to visual surveys (Harvey et al., 2001; Watson et al., 2005; Cappo et al., 2006; Pelletier et al., 2011; Goetze et al., 2019), video techniques are less adequate in sampling cryptic and tiny species (Harvey et al., 2001; Navarro-Martínez et al., 2017; Goetze et al., 2019). For instance, in other inventories of Cuban reef fishes that documented fewer species than in the current work, including

Caballero et al., (2004; 80 species) and Hernández-Fernández & Salvat-Torres (2014; 97 species), very small species were detected such as blennies (families Chaenopsidae, Labrisomidae and Blenniidae), gobies (Gobiidae), and herrings (Clupeidae), as well as cryptic species such as flounders (Bothidae), none of which were recorded in this inventory.

Diver operated stereo-video does not allow a complete inventory of all fishes, including many species that are either, rare, pelagic, nocturnal, cryptic, very small, or those that bury or reside in other concealed locations such as rock crevices. However, no survey method is entirely non-invasive and able to detect the complete range of fishes present. Despite the underestimation of some species due to methodological limitations, the data presented here can offer valuable information about the fishes of Punta Francés and will remain as a permanent registry of information available for future analyses. Considering that besides the fish inventory we were interested on to asses the abundance and frequency of the fish species, we used only the information provided by stereo-DOV. This has been the largest study covering all the ichthyofauna in PFNP and the adjacent area, and therefore provide the most comprehensive information. These facts explain why we exclude the information (e.g., new records) provided by more traditional techniques used in this area (e.g., underwater visual census).

Reef fish assemblage composition in Punta Francés

The presence of eleven threatened or near threatened species, three more than reported previously by Guardia et al. (2004) in PFNP, demonstrates the potential of the national park to serve as a refuge for these species. However, the low abundance of these species in the area indicates that there are limits to the park's ability to conserve these species, given its current level of protection, i.e., illegal fishing inside the national park boundaries. The fact that most of the eleven species in threatened or near threatened categories occurred only inside of the PFNP has three plausible and non-exclusive explanations: (i) the potential effect of the national park, (ii) the higher survey effort inside PFNP compared with the adjacent area and (iii) the scarcity of appropriate juvenile habitats in the adjacent unprotected area for dependent nursery species, e.g., *Sc. guacamaia* which depends strongly on mangroves for its juvenile development (Mumby et al., 2004). Importantly, mangrove forests, seagrass beds and reef crests are present only inside the national park boundaries, and they are sources of shelter and food for young stages of reef fishes (Adams et al., 2006; Harborne et al., 2006). The absence of these well-known nursery habitats may therefore threaten the abundance of other species as well, including those with essential functional roles, e.g., herbivores, predators (Nagelkerken et al., 2002; Mumby et al., 2004). In this regards, a previous study in the nearby mangrove and seagrass bed from La Siguanea inlet, recorded high proportion of juvenile fishes (Rodríguez-Viera et al., 2017), and these habitats could be highly connected to PFNP coral reefs.

Among the most important identified families, the family Scaridae was well-represented in surveys, contributing 10.97 % of the total fish abundance (with 5 601 individuals). As herbivores, scarids make important contributions to the control of macroalgal growth and facilitate increased coral cover (Hughes, 1994; Mumby et al., 2006, 2007; Jackson et al., 2014). In contrast, the economically and ecologically important Serranidae had very low abundance (0.51 %, only 261 individuals), despite being the family with the greatest species richness. Particularly, the genera *Epinephelus* and *Mycteroperca*, which include large predators, were represented by 7 species and 28 individuals. Usually, the abundance of predator species such as serranids tends to be increased where fisheries are banned (e.g., Aburto-Oropeza et al., 2011; Pina-Amargós et al., 2012), though they never exceed the abundance of families such as Scaridae (Mumby et al., 2006). The poor

representation of Serranidae in Punta Francés could be the result of fishing both inside and outside the park.

The most abundant species in Punta Francés coincide with those found in other Cuban coral reefs, including Bahía de Cochinos (Chevalier & Cárdenas, 2005), Guanahacabibes (Cobián-Rojas et al., 2011), and northwest Cuba (González-Sansón et al., 2009). As in other Cuban areas, large species and species important to fisheries were either completely absent (e.g., *Epinephelus itajara* (Lichtenstein, 1822), *Sc. coeruleus*) or rare (e.g., *Sc. guacamaia, Lu. cyanopterus, Lu. jocu*), probably due to many years of overfishing (e.g., González-Sansón et al., 2008). Even inside PFNP, illegal fishing occurs by private and commercial fishermen (Angulo-Valdés & Hatcher, 2013). Since overfishing is one of the most serious threats to Caribbean biodiversity (Miloslavich et al., 2010), and widespread fishing inside of marine protected areas constrains their effectiveness (Mora et al., 2006; Costello et al., 2015b; Strain et al., 2019), more attention to fish assemblages from PFNP turn necessary.

The low abundance of lionfish *Pterois* sp. could be a result of an underestimation associated with the survey technique due to its cryptic behavior and use of holes as shelters (Pimiento et al., 2015). In contrast, a study focused on lionfish in PFNP had showed the abundance of lionfish in mangrove, seagrass bed and coral reefs (del Río et al., in revision), which is not concordant with the low abundance recorded in the present checklist. Thereby, the development of surveys focused only on *Pterois* sp. in Punta Francés will be very useful to define its actual contribution to reef fish assemblages.

General considerations

Our study presents information on the reef fishes of a poorly-examined area that will be useful in future investigations of biogeography, diversity patterns, and the abundance and distribution of threatened and near threatened species in Cuban marine protected areas. The data will also be useful in developing conservation actions at a time when Caribbean reefs are feeling the synergic effects of multiple stressors that negatively affect biodiversity.

The composition and high species richness of the ichthyofauna found here suggest that Punta Francés functions adequately as a coral reef ecosystem, but indications of fishing pressure are evident which may impede conservation efforts and potential in this area. Further scientific studies are required to guide the improvement of management strategies at Punta Francés.

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Conflicts of Interest

The authors have declared that no exist financial or non-financial competing interests relevant to the manuscript content.

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