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First community level description of rocky reefs at the Cabo Blanco absolute natural reserve on Costa Rica's Pacific Coast

Primera descripción comunitaria de arrecifes Rocosos de la reserva natural absoluta Cabo Blanco en el pacífico de Costa Rica

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ABSTRACT
The Cabo Blanco Absolute Natural Reserve (RNACB) is located at the southern end of the Nicoya Peninsula in Costa Rica. This research aimed to provide the first community-level description of rocky reefs within RNACB. Data was collected in June 2018, covering a total area of 1680 m² monitored across six transects at two depths: -5 m and -20 m. A total of 44 macroinvertebrate species were recorded, primarily represented by suspension feeders and filter feeders, mainly including ascidians and octocorals, as well as 48 fish species, notably dominated by macroinvertivore species such as surgeonfish and parrotfish. The biomass recorded was 4.91 tons.ha-1, with the highest values predominantly observed at deeper sites. Sessile macroinvertebrates were predominantly found in deeper areas, while mobile organisms showed no specific depth preference. The average biomass of fish was greater in the deeper zones, and in general, RNACB biomass exceeded the expected values for the Costa Rican Pacific.

Keywords: Cabo Blanco Reserve, rocky reefs, community level description, biomass, PRONAMEC

RESUMEN
La Reserva Natural Absoluta Cabo Blanco (RNACB) se localiza en el extremo sur de la Península de Nicoya, Costa Rica. El objetivo principal de esta investigación fue realizar la primera descripción comunitaria de los arrecifes rocosos dentro

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Recepción 23 noviembre 2023 • Corregido 16 enero 2025 • Aceptado 16 enero 2025
DOI: http://dx.doi.org/10.15359/revmar.17-1.1
Rev. Mar. Cost. Vol. 17 (1): 19-42, enero-junio 2025
ISSN: 1659-455X • e-ISSN: 1659-407X

de la RNACB. Los datos se obtuvieron en junio del año 2018. 1 680 m² se monitorearon en seis transeptos a dos profundidades: -5 m) y -20 m; se registraron 44 especies de macroinvertebrados dominadas por suspensívoros y filtradores especialmente ascidias y octocorales; y 48 especies de peces dominado por especies macroinvertívoras como cirujanos y loros; la biomasa obtenida fue de 4.91 ton·ha $^{-1}$. Principalmente, la mayor riqueza se presentó en los sitios más profundos. Los macroinvertebrados sésiles dominaron los sitios profundos, pero los organismos móviles no tuvieron preferencia. La biomasa de peces tuvo promedios más altos en las zonas profundas y en general la biomasa en RNACB está por encima de los valores esperados para el Pacífico costarricense.

Palabras clave: Reserva Cabo Blanco, arrecife rocoso, descripción comunitaria, biomasa, PRONAMEC

INTRODUCTION

Marine Protected Areas (MPAs) are crucial to ensuring the environmental services on which millions of people around the world depend (FAO, 2012; Cabral *et al*. 2019). They are important spawning and nursery sites for numerous marine species, assisting in the recovery of commercially valuable populations that are seriously damaged by overfishing and pollution, and also protect the physical structure of habitats from damage caused by fishing gear and other anthropogenic and incidental impacts (FAO, 2012).

Rocky reefs are very diverse and productive marine environments and are present on coasts with geological formation processes of volcanic origin (Horn & Ferry-Graham, 2006). Both rocky and coral reefs are an important source of economic income for many countries due to their contribution to local economies through tourism. They also constitute barriers that protect coastal areas from the effects of hurricanes and storms, and serve as a refuge breeding area for many species of commercial importance, especially in their juvenile stages, which is critically important for the fishing sector (Ahmed *et al*. 2005; van Oppen & Gates, 2006; NOAA, 2016).

The Cabo Blanco Absolute Natural Reserve (RNACB) is located at the southern end of the Nicoya Peninsula, Costa Rica. It was established in 1963 as the country's first Protected Wildlife Area (PWA) and the only such area assigned to the management category of an Absolute Nature Reserve; its marine protected area (MPA) was created in 1982, which was also the first of its kind in Costa Rica (ACT *et al*. 2009). This is the only marine protected area among all the PWAs in the country in which any type of tourist, recreational, or resource use is not allowed within the marine area (ACT *et al*. 2009). These restrictive measures are intended to maintain the ecological

Rev. Mar. Cost. Vol. 17 (1): 19-42, enero-junio 2025
ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1

integrity of the ecosystems present at the site, making it particularly interesting for carrying out research that evaluates the state of conservation of these ecosystems (Alvarado *et al*. 2006; Wehrtmann & Cortés, 2009). Community-level ecological assessments allow for a broader assessment of the health status of marine ecosystems inside and outside protected areas, providing reliable information on the effects of protection of a reef from fishing pressure and temporal changes in the structure of the community being studied (Aburto-Oropeza *et al*. 2015).

In MPAs, these community-level studies generate a solid and standardized baseline that can be replicated over time. The results of such studies are critically important in evaluating the condition of an ecosystem and guiding its adequate management. They also allow the evaluation of ecological phenomena such as "Top-Down" control, where organisms at higher levels in the food chain exert pressure and population control on organisms at lower trophic levels, maintaining ecosystem balance (Ulate *et al*. 2018; Jenkinson *et al*. 2020).

The main objective of this research was to carry out the first community-level description of rocky reefs within the RNACB and describe the biological community associated with the ecosystem of the oldest marine protected area in Costa Rica. This will contribute to achieving sustainable development goal 14 of the United Nations in improving knowledge of Costa Rica's marine ecosystems for their conservation and sustainable use.

MATERIALS AND METHODS

The methodology proposed by SINAC (2016), with adjustments for rocky reefs, was used for the ecological monitoring of coral formations, incorporating methodologies for the evaluation of fish biomass, density and size of macroinvertebrates, and the calculation of coverage of colonial sessile macroinvertebrates (SINAC-UNA, 2021).

The sampling sites were chosen through a bathymetric assessment of the rocky reefs in the RNACB, to corroborate the depths needed for sampling during June 2018 one shallow dive (~5m deep) and a separate deep dive (~20m deep). Each sampling site had three teams of two divers each, one dedicated to fish monitoring and one to macroinvertebrates, plus a safety diver (Dive Guide). Three (3) fish transects (50m x 5m x 5m) and three (3) invertebrate transects (30m x 1m) were conducted at two (2) different depths for a total sampling area of 1,680 m².

Study area:

Two sites were sampled within the RNACB, one shallow (~5 meters deep) and one deep (~20 meters). These rocky reefs were selected due to the structural composition of the substrate, which corresponds to a porous stone of volcanic origin (Horn & Ferry-Graham, 2006); the sampled sites did not contain walls or underwater slopes with high slope indices because these variables modify the community structure of the rocky reefs due to the incidence of light and influence of currents (Horn & Ferry-Graham, 2006) (Fig. 1).

Vertebrates:

To quantify the abundance and diversity of fish in the reef, six transects of 50 m x 5 m each were established parallel to the coast, three at each depth, along an imaginary tunnel five meters wide (2.5 meters on each side of the transect) and five meters high; the individuals encountered were counted, and their sizes estimated, by species. Three transects were established at a depth of ~5 m (750 m^2 total) and the other three at a depth of ~20 m (750 m^2 total), for a total sampling area of 1 500 m^2. Recorded fish were identified by *in situ* observations when possible and by using photographic records for subsequent identification at the species level with taxonomic guides (Allen & Ross-Robertson, 1998; Bussing & López, 2005; Humann & Deloach, 2004). Their abundance was counted, and their lengths

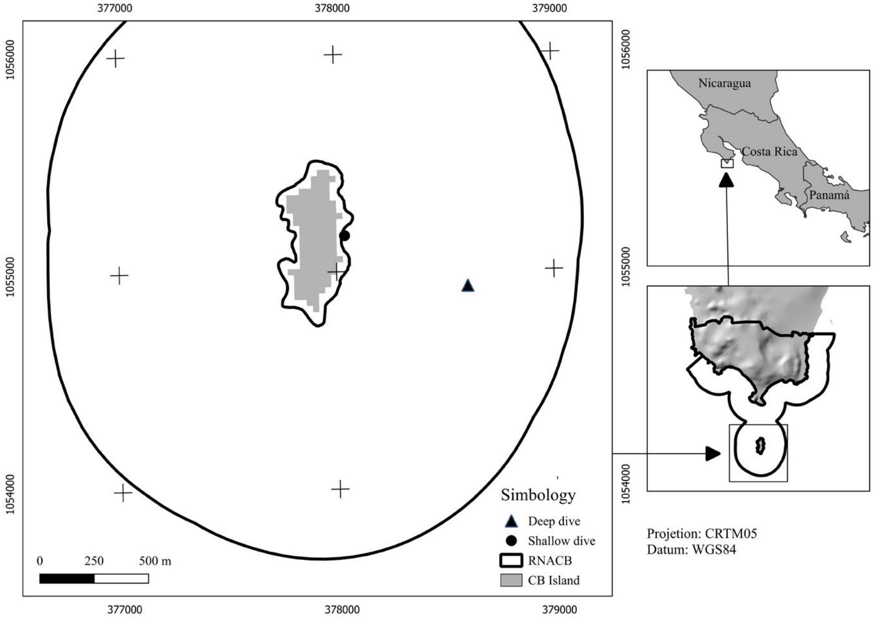

Fig. 1. Survey sites of the study area
Fig. 1. Sitios de muestreo en área de estudio

Rev. Mar. Cost. Vol. 17 (1): 19-42, enero-junio 2025
ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1

were estimated using PVC tubes with alphanumeric scales that were graduated in 5 cm units. These measurements were made *in situ* without touching the individuals, using visual estimates.

The divers made runs along the transect at a constant speed without stopping, noting first the species in the water column, and upon returning focused on the observation of cryptic or hidden species in the substrate to improve the representativeness of the organisms found according to their distribution in the water column and the substrate.

Subsequently, the trophic levels of each of the identified fish were determined according to the following definitions (Froese & Pauly, 2014): Piscivores: Fish that feed mainly on other fish; Macro invertivores: Fish that feed mainly on macroinvertebrates; Herbivores: Fish that feed on algae; and Planktivores: Fish that feed on zooplankton.

As a population parameter, all abundance and size data for fish species were used to calculate biomass using the allometric length-weight conversion W=a*(Lt)b, where the parameters a and b are constant and specific for each species, Lt is the total length in cm, and W is the weight in grams. The length-weight parameters for each fish species were obtained from FishBase (Froese & Pauly, 2014).

Macroinvertebrates:

In the case of macroinvertebrates, the same six fish transects were used (the site locations and sampling depths remained the same – three at ~5m and three at ~20m), but with differences in the size of the sampling area, each of which was 30 m x 1 m, for a total sampling area of 180 m². All macroinvertebrates present within 50 cm on both sides of the transect were counted and measured.

All epibenthic macroinvertebrates larger than 1 cm (>1 cm) were identified *in situ* at the species level, when possible. Their abundance abundance was counted and their length or largest diameter was measured using PVC tubes with 2 cm scales, without touching individuals. Organisms that could not be identified at the species level were also considered as operant taxonomic units (OTU), and their identification was carried out using photographs. The censused organisms were not extracted or manipulated, focusing only on the epibenthos, and preserving the marine landscape, while an attempt was made to take as many photographs as possible for later identification (Behrens & Hermosillo 2005; Bertsch & Kerstitch 2007; Gotshall 1998; Humann & Deloach 2012).

Subsequently, the trophic levels of the observed macroinvertebrates were identified according to the following definitions (Ulate *et al*. 2016): Carnivores: Macroinvertebrates whose primary consumption is the meat of fish or other macroinvertebrates, either caught directly or available due to other circumstances; Herbivores: Macroinvertebrates whose diet is based on macroalgae; Filter feeders: Macroinvertebrates that obtain their food (plankton or organic particles) using water pumping and filtration systems within their bodies; Suspensivores: Macroinvertebrates that obtain their food by capturing plankton and/or organic particles suspended in the water column; and Hetero/Autotrophs: Macroinvertebrates that alternate their diets, consuming either by products derived from photosymbionts (e.g., zooxanthellae that live in corals), or organisms or food particles that they can capture for themselves.

The density of organisms per square meter (org.m^2) was used as a population parameter to report unitary or non-colonial mobile and sessile macroinvertebrates.

Coverage of colonial sessile macroinvertebrates

To define the average cover of colonies of colonial sessile macroinvertebrates such as colonial hydrozoans and colonial ascidians, including zooxanthellate scleractinian corals (stony corals), the same transects of macroinvertebrates were used following the method of Chiappone & Sullivan (1991), determining the diameter of the macroinvertebrate colony using the formula for the area of a circle (area = $\pi * r^2$). Thus, based on the reported size (diameter) for each colony, the area (m^2) occupied by the species in each transect was estimated (Chiappone & Sullivan, 1991).

Descriptive analysis of the fauna:

To determine the ecological dominance of the species encountered, population parameters were derived using densities (org.m^2) in the case of macroinvertebrates and biomass (ton.ha^{-1}) in the case of fish, concerning the percentage of occurrence in each site at each sampling depth. Groups of dominant species were then estimated using the Olmstead-Tukey method (Rohlf & Sokal, 1981), based on graphs of the average densities or biomasses of all species and/or OTUs (X axis), against the percentage of occurrence of appearance in the transects of the species and/or OTUs (Y axis). This technique allows establishing a classification according to values of means density or biomass and frequency of concurrence of the organisms, following García de León (1988):

- **Dominant:** Those species whose values for both density or biomass and frequency of occurrence exceed the arithmetic mean of these estimators.
- **Frequent:** Those species whose values for frequency of occurrence are higher than the average for this estimator but whose values for relative density or

Rev. Mar. Cost. Vol. 17 (1): 19-42, enero-junio 2025
ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1

biomass are not higher than the average value of these estimators

- **Occasional:** Those species whose density or biomass values are higher than the average for these estimators but whose values for frequency of occurrence are not higher than the average value of this estimator.
- **Rare:** Those species that are characterized by values for both density or biomass and frequency of occurrence below the arithmetic mean for these estimators.

RESULTS

We determined that the survey sites with a highly complex and irregular substrate with a horizontal orientation, due to their morphological characteristics and rock composition of volcanic origin, with incrustations of living organisms, correspond to a rocky reef.

In the study area, 1 680 m^2 were monitored, and data on a total of 3 204 were recorded, of which 2047 individuals were macroinvertebrates while 1157 individuals were fish.

Macroinvertebrate richness

The biodiversity of macroinvertebrates in the RNACB was distributed as follows: 7 *phyla*, 16 families, 44 species and 2047 individuals (Annex 1).

When comparing the sampled sites, the average values of macroinvertebrate species richness are highest for deep zones in the RNACB ($\bar{x}$ = 19.33 ± 8.57), where groups of filter feeders (mainly ascidians) and suspension feeders (octocorals) contain the most species, while in the shallow zones the average richness was $\bar{x}$ = 15.33 ± 3.46 (Fig. 2).

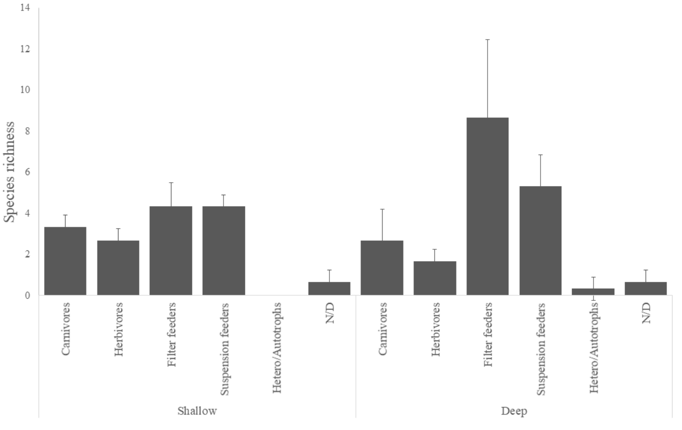

Fig. 2. Average macroinvertebrate species richness in the rocky reefs of the RNACB. N/D Not identified organisms

Fig. 2. Promedio de riqueza de especies de macroinvertebrados en los arrecifes rocosos de la RNACB. N/D organismos no identificados

Vertebrates richness

The biodiversity of fish in the RNACB was distributed as follows: 17 families, 48 species and 1157 individuals (Annex 2). The average values of fish species richness were lowest in shallow zones in the RNACB ($\bar{x}$ = 12.66 ± 11.24). The group with the highest number of fish species was macro invertivores, while in the deep zones the average richness was $\bar{x}$ = 19 ± 6.74 (Fig. 3).

Average coverage of colonial sessile macroinvertebrates

According to the values obtained for average coverage or area of the size of colonies of colonial macroinvertebrates (deep zones $\bar{x}$ = 5.81m^2 ± 4.78 and shallow zones $\bar{x}$ = 1.25m^2 ± 1.30), suspension feeders such as the snowflake octocoral (*Carijoa riisei*), and two species of gorgonians (*Leptogorgia rigida* and *Leptogorgia alba*) have the largest average areas ($\bar{x}$= 4.92m^2 ± 3.94 in the deep zones). Furthermore, it is important to note that the coverage of rocky coral colonies (Hetero/Autrophs) was very low in all sampling sites $\bar{x}$ = 0.03m^2 ± 0.05 (Fig. 4).

Average macroinvertebrate density

Average density values for non-colonial macroinvertebrates show that filter feeders such as the blue sea squirt (*Rhopalaea*

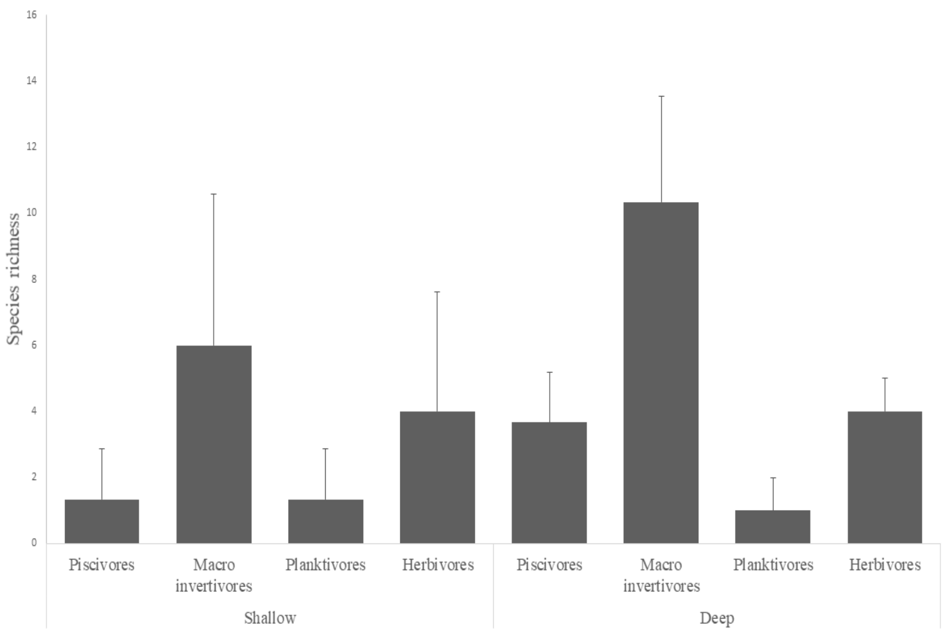

Fig. 3. Average vertebrate species richness in the rocky reefs of the RNACB
Fig. 3. Promedio de riqueza de especies de vertebrados en los arrecifes rocosos de la RNACB

Rev. Mar. Cost. Vol. 17 (1): 19-42, enero-junio 2025
ISSN: 1659-455X • e-ISSN: 1659-407X
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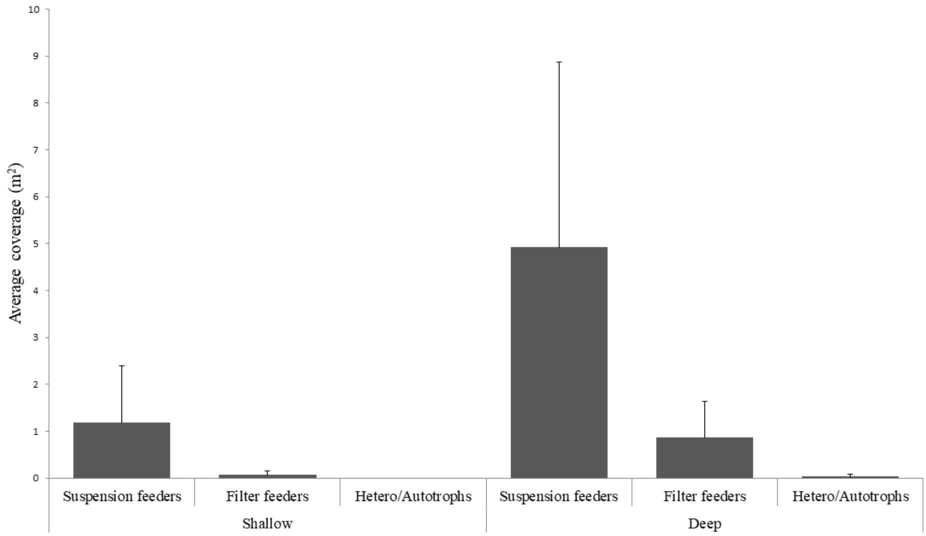

Fig. 4. Average coverage of macroinvertebrates in the rocky reefs of the RNACB
Fig. 4. Cobertura promedio de macroinvertebrados en los arrecifes rocosos de la RNACB

birkelandi), the mother-of-pearl bivalve (*Pinctada mazatlanica*), and some species of oysters that are difficult to identify *in situ* (*Ostrea* sp) had the highest density per square meter ($\bar{x}$ = 1.37org.m^2 ± 0.82 in deep zones and $\bar{x}$ = 0.78org.m^2 ± 0.38 in shallow zones). Likewise, the trophic level of suspension-feeding organisms such as the polychaetes called Christmas trees of the genus *Spirobranchius*, the polychaetes known as spaghetti worms of the family Terebellidae, and suspension-feeding sea cucumbers of the genus *Neothyonidium* sp, were the species with the highest density ($\bar{x}$ = 0.11org.m^2 ± 0.17 in deep zones and $\bar{x}$ = 1.38org.m^2 ± 0.36 in shallow zones). In general, deep RNACB reefs had an average macroinvertebrate density of 1.81 org.m^2 ± 1.31 (Fig. 5).

Average Vertebrates biomass

The biomass values show significant differences between strata and sizes of organisms. Figure 6 shows that the deep zones had higher average biomass values ($\bar{x}$ = 8.26 ± 8.34), while at the shallow zones the average biomass was $\bar{x}$ =1.55 ± 1.38; the sum of average biomasses at each trophic level indicates that the RNACB has a total average biomass of 4.91 ± 4.86 ton.ha-^{1}.

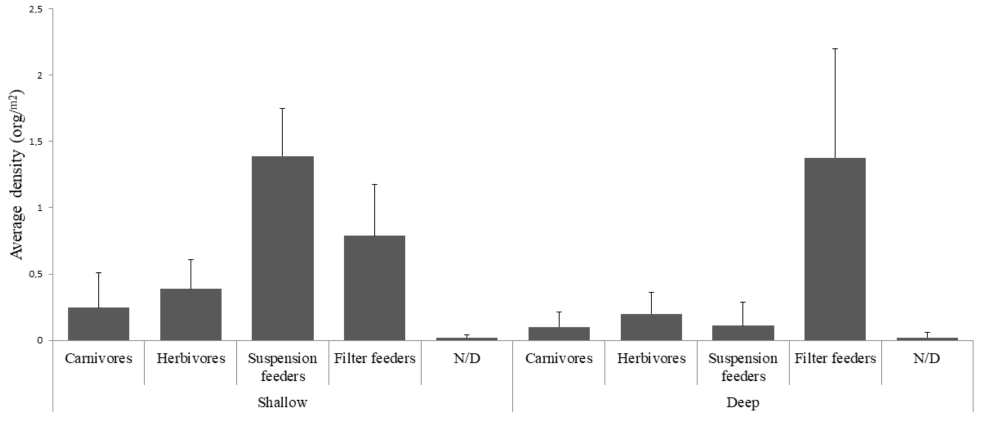

Fig. 5. Average density of macroinvertebrates in the rocky reefs of the RNACB. N/D means unidentified organisms
Fig. 5. Densidad promedio de macroinvertebrados en los arrecifes rocosos de la RNACB. N/D organismos no identificados

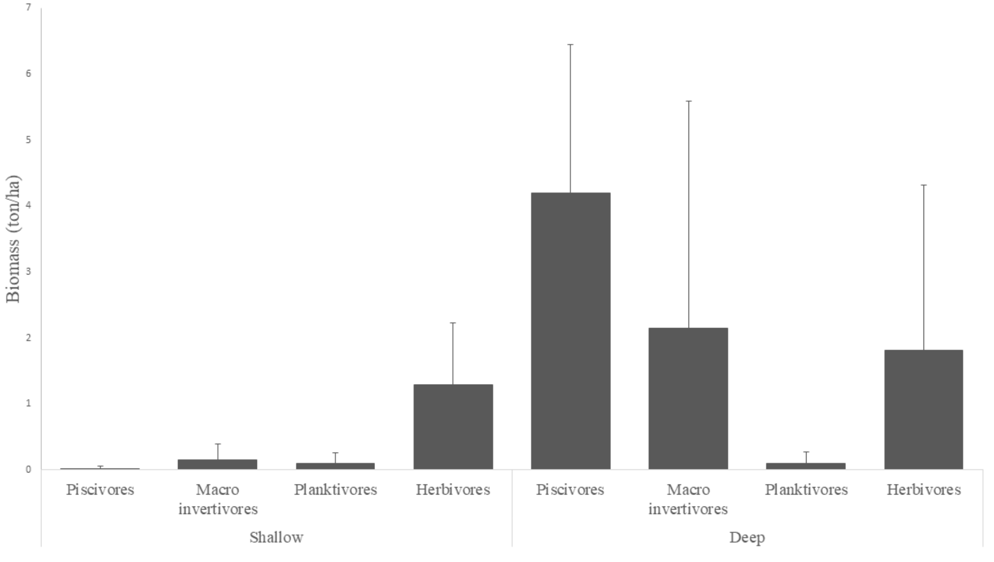

Fig. 6. Vertebrate biomass in the rocky reefs of the RNACB
Fig. 6. Biomasa de vertebrados en los arrecifes rocosos de la RNACB

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Macroinvertebrate dominance analysis

Dominance analyses were used to describe the composition of the species at each sampling site. Analysis of dominance by depth showed that two species were dominant in both deep and shallow zones – the blue sea squirt (*R. birkelandi*) and the gorgonian *Leptogorgia alba*. Other species such as the sea urchin (*Diadema mexicanum*) and the pencil urchin (*Eucidaris thouarsii*) were dominant mainly in the shallow sites, although they were also present in the deep sites. The gorgonian known as snowflake coral (*Carijoa riisei)* was dominant mainly in deep sites, with very little presence in the shallow environments sampled (Fig. 7 and Fig. 8). These species are also classified as dominant for RNACB in the results of analysis of pooled data for both deep and shallow sites (Fig. 9).

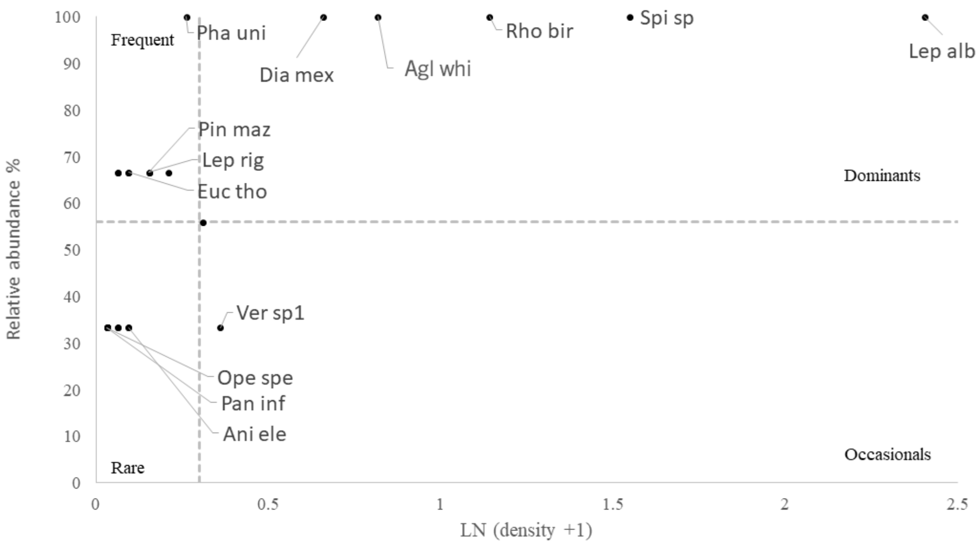

Fig. 7. Dominance of macroinvertebrates in the shallow zones of rocky reefs of the RNACB (species acronyms include the first three letters of the genus and the first three letters of the species)
Fig. 7. Dominancia de macroinvertebrados en las zonas someras de los arrecifes rocosos de la RNACB (los acrónimos de las especies incluyen las tres primeras letras del género y las tres primeras letras de la especie)

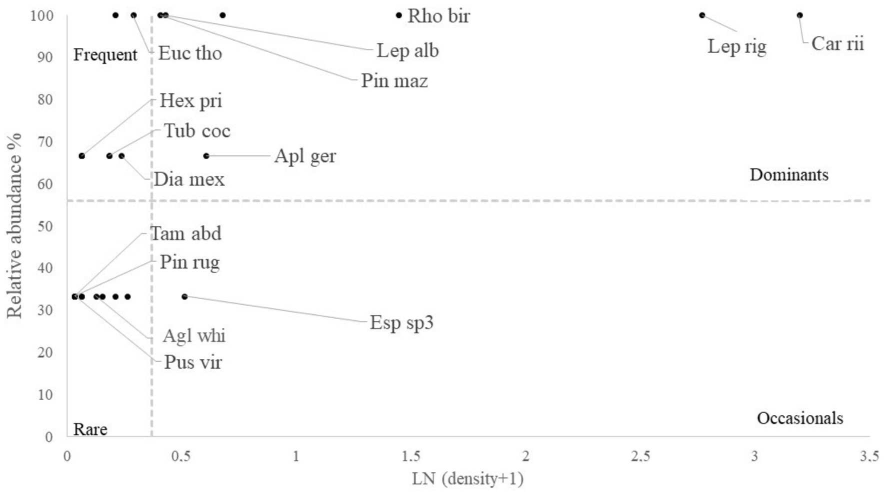

Fig. 8. Dominance of macroinvertebrates in the deep zones of rocky reefs of the RNACB (species acronyms include the first three letters of the genus and the first three letters of the species)

Fig. 8. Dominancia de macroinvertebrados en las zonas profundas en los arrecifes rocosos de la RNACB (Los acrónimos de las especies incluyen las tres primeras letras del género y las tres primeras letras de la especie)

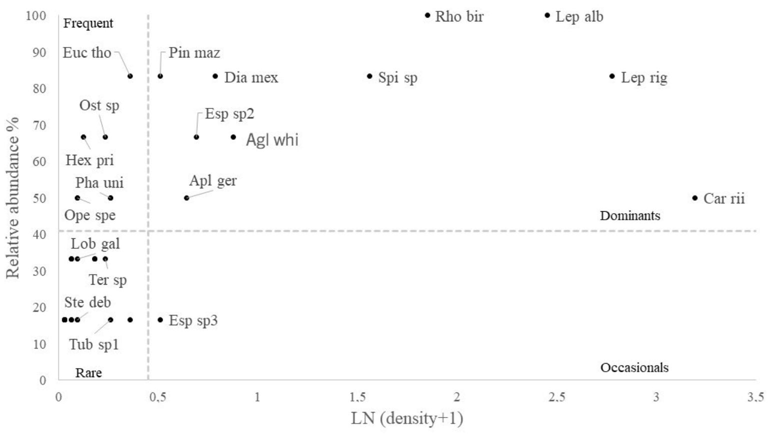

Fig. 9. Dominance of macroinvertebrates at all depths in the rocky reefs of the RNACB (Species acronyms include the first three letters of the genus and the first three letters of the species)

Fig. 9. Dominancia de macroinvertebrados en todas las profundidades en los arrecifes rocosos de la RNACB. (los acrónimos de las especies incluyen las tres primeras letras del género y las tres primeras letras de la especie)

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Fish dominance analysis

In the shallow RNACB, only the razor surgeonfish (*Prionurus laticlavius*) was recorded as dominant (Fig. 10), while in the deep zone, the dominant species were herbivorous and macroinvertivorous species such as the razor surgeonfish (*Prionurus laticlavius*) and the blacknosed butterflyfish (*Johnrandallia nigrirostris*) (Fig. 11). The piscivorous species known as the bigeye jack (*Caranx sexfasciatus*), in particular, was recorded as occasional in the deep RNACB, being very abundant but found in only a few transects; however, in the analysis of the ecosystem as a whole (using pooled data from shallow and deep strata sites) for the RNACB, this species was classified as dominant (Fig. 12).

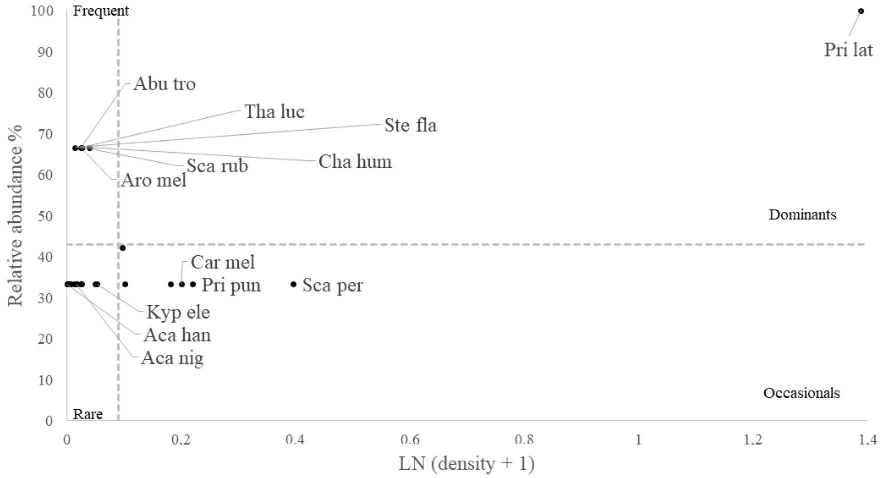

Fig. 10. Dominance of vertebrates in the shallow zones of rocky reefs of the RNACB (species acronyms include the first three letters of the genus and the first three letters of the species)
Fig. 10. Dominancia de vertebrados en las zonas someras los arrecifes rocosos de la RNACB (los acrónimos de las especies incluyen las tres primeras letras del género y las tres primeras letras de la especie)

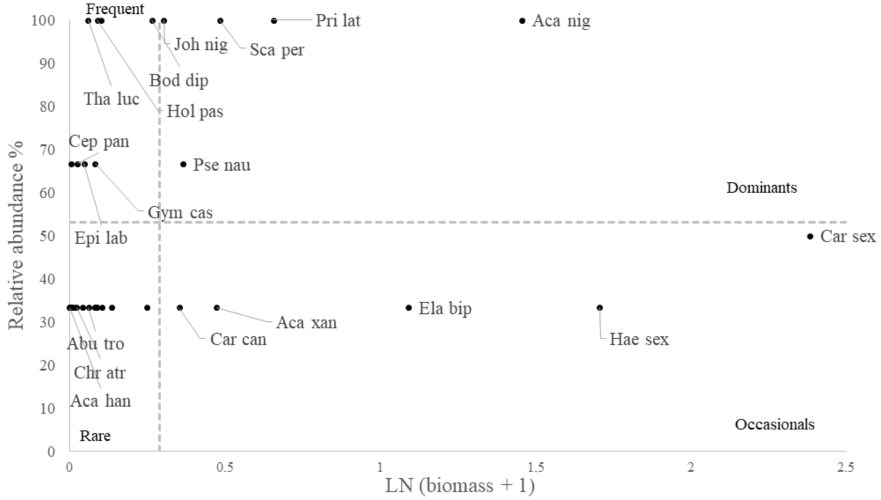

Fig. 11. Dominance of vertebrates in the deep zones of rocky reefs of the RNACB (species acronyms include the first three letters of the genus and the first three letters of the species)

Fig. 11. Dominancia de vertebrados en las zonas profundas en los arrecifes rocosos de la RNACB (los acrónimos de las especies incluyen las tres primeras letras del género y las tres primeras letras de la especie)

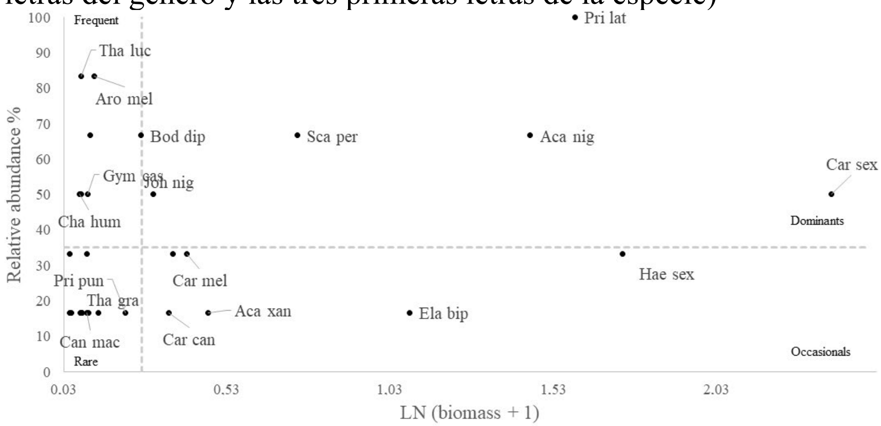

Fig. 12. Dominance of vertebrates at all depths in the rocky reefs of the RNACB (species acronyms include the first three letters of the genus and the first three letters of the species)

Fig.12. Dominancia de vertebrados en todas las profundidades en los arrecifes rocosos de la RNACB (los acrónimos de las especies incluyen las tres primeras letras del género y las tres primeras letras de la especie)

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DISCUSSION

The rocky reefs of the RNACB are characterized by a reduced and very patchy distribution of corals throughout the reef area (BIOMARCC-SINAC-GIZ, 2013). Corals are therefore not dominant, and their function as providers of shelter and reproductive areas is assumed by irregular structures and cavities within the rock formations, mostly of volcanic origin, inhabited by macroalgae and a diversity of macroinvertebrates such as octocorals, sponges, ascidians, crustaceans and mollusks, in addition to fish that forage on these organisms (Robertson & Allen, 2015).

This situation was evident in all the sites studied in this investigation, which encountered a great diversity and abundance of organisms, mainly in the groups of invertebrate suspension feeders (Octocorallia) and filter feeders (Demospongiae and Ascidiacea), as well as fish, which were also highly diverse, particularly piscivores, macro invertivores and herbivores, which had the highest values for species richness.

This richness and abundance of species belonging to the groups of filter feeders and suspension feeders in all monitoring sites may be associated with the fact that these sites are high energy areas exposed to currents resulting from waves and changes in tides (Lizano & Alfaro, 2014), which could facilitate obtaining food carried in the water. However, more information about this topic is needed to reliably relate oceanic conditions of a particular site to the establishment of suspension-feeding and filter-feeding organisms.

Herbivorous organisms dependent on macroalgae, such as the urchins *Eucidaris thouarsii* and *Diadema mexicanum*, were recorded as frequent in the deep sites of the RNACB, probably as a result of higher competitive pressure in the shallow sites from fish of the same trophic level, or by an abundance of juvenile stages of predators present in the shallow areas. These species of urchins, being herbivorous, depend on the production of algae for their food; their presence indicates that there is adequate light penetration in the sites studied that provides the conditions for establishing both macroalgae and the organisms that feed on them. *Diadema mexicanum* is a widely distributed and abundant species in tropical reefs (Muthiga & Mcclanahan, 2007; Benitez Villalobos *et al*. 2008); and is considered to be an important bioeroder of reefs, with a great impact on the restructuring and modeling of these ecosystems (Arias-Godínez *et al*. 2019; Glynn *et al*. 2020); therefore, constant monitoring of this organism is essential for ecosystem evaluation. Additionally, the presence and sizes of these organisms are an indirect indication of the absence

ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1

of predatory fish at the macroinvertivorous trophic level, demonstrating an imbalance in the trophic chain and therefore inefficient management of the protected area.

Other sessile invertebrates that were an important component in the sampling sites were the octocorals *Leptogorgia alba* and *Carijoa riisei*, whose dominance in the ecosystem analysis results is consistent with comments by Liberman *et al*. (2018) and Romero-Hernández (2018) about the importance of light for the establishment of corals and octocorals. *Leptogorgia alba* is a common and dominant species in the rocky reefs of the Pacific of Costa Rica and particularly in the RNACB (Breedy & Cortés, 2014) but uncommon in others in the Pacific such as the Malpelo Islands of Colombia (Sánchez *et al*. 2016). For its part, *Carijoa riisei* is a widely distributed species and considered an invasive pest in South American reefs (Sánchez *et al*. 2016; Sánchez & Ballesteros, 2014). The percentage of coverage of this species was found to be substantial in this study; however, until its coverage is evaluated over time, its presence cannot yet reliably be considered a problem, requiring recommendations for its management.

Another species that is not as dependent on light but was dominant in all sites at both depths was the blue sea squirt (*R. birkelandi*). This species is considered to be common and dominant in studies carried out on rocky reefs in the Panamanian Pacific (Bullard *et al*. 2011) and Costa Rica (Nova-Bustos *et al*. 2010), in addition to being very important in the diet of chelonians, especially the Hawksbill turtle (*Eretmochelys imbricata*) in the northern Pacific of the country (Carrión-Cortez *et al*. 2013).

In the case of fish, the dominant species in deep sites are all herbivores. There was no dominance of top species, since large schools of the browsing herbivorous species White-cheeked Surgeonfish (*Acanthurus nigricans*) and the razor surgeonfish (*Prionurus laticlavius*) dominated reefs (Carr *et al*. 2018; Zgliczynski *et al*. 2019), together with the bumphead parrotfish (*Scarus perrico*), a herbivorous species (Melgarejo-Damián *et al*. 2018), of interest due to the pressure it has been suffering from human consumption and its importance in reef communities in grazing algae, and as builders of fine reef sediments (Robertson & Allen, 2015; Ross *et al*. 2017). Similarly, in the shallow sites, the razor surgeonfish *(Prionurus laticlavius*) was the only species considered to be dominant; as an herbivore (Carr *et al*. 2018), its presence is expected in sites with adequate light penetration.

A species that stood out in the monitoring was the bigeye jack (*Caranx sexfaciatus*), since large schools of individuals of this species were occasionally observed, causing biomass to

Rev. Mar. Cost. Vol. 17 (1): 19-42, enero-junio 2025
ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1

increase sharply in the deep RNACB. This species has been used in the Philippines as an indicator of good health in marine protected areas due to its importance for recreational tourism and fishing, and for being a top species in food chains (Maypa, 2012); and the large biomass levels of this species are associated with unfished or 'pristine' areas (Barrett *et al*. 2019). In Costa Rica, it is commercially important in artisanal and sport fishing (Ross *et al*. 2017), and the presence of this species in the RNACB can therefore be regarded as an indicator of adequate management of the marine protected area.

In areas with strict protection such as the RNACB, it is reasonable to expect to find healthier ecosystems in nearly optimal conditions which could function as a reference point for other sites (Brander *et al*. 2020). It has been shown that biomass of all fish assemblages increases significantly in areas with absolute, and even partial, protection (Beita-Jiménez *et al*. 2019; Sala & Giakoumi, 2018). Using statistical methods, McClanahan *et al*. (2007) and McClanahan & Graham (2015) determined that, in unfished areas within national parks in the Indian Ocean with more than 12 years of protection, a healthy biomass of fish larger than 10 cm should be between 1.1 and 1.2 ton.ha^{-1}. In the Cabo Pulmo National Park in Mexico, Aburto-Oropeza *et al*. (2015) estimated that fish biomass had increased by 3.4 ton.ha^{-1}. The results obtained for the RNACB (4.91 ton.ha^{-1}) are higher than these figures, although lower than biomass estimates of 12.5 ton.ha^{-1} for the Cocos Island National Park in the Pacific of Costa Rica (Fourriére *et al*. 2019), but the data obtained in this study should be interpreted with caution. It must be taken into account that the Costa Rican Pacific Coast has been subject to fishing for many years, so biomass values greater than 1.5 ton.ha^{-1} are considered normal for the region (Alvarado *et al*. 2018; Cordero-Umaña & Santidrián-Tomillo, 2020).

CONCLUSIONS

The Cabo Blanco Absolute Nature Reserve is a protected marine area, made up in its marine sector mainly of rocky reefs with the presence of small patches of rocky coral, with octocorals and sponges predominating in the rock formations of the reef.

The richness of invertebrates was greatest in deep sites, especially species of sponges and octocorals.

Fish richness was similar at both shallow and deep zones, with herbivores dominating. The greatest richness of piscivores was recorded in deep sites.

The sessile macroinvertebrates that dominated the deep sites were mostly suspension feeders such as octocorals and filter feeders such as ascidians.

ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1

The density of mobile organisms was higher for the filter-feeding and suspension-feeding groups at both depths of the RNACB.

The average biomass of fish was higher in the deep zones, and in general the biomass in RNACB is above the expected values for the Costa Rican Pacific.

The snowflake octocoral (*Carijoa riisei*) was found to have a high coverage that could be considered a demographic explosion. There are reports in the Panamanian and Ecuadorian Pacific indicating that it can negatively affect the reefs in which it establishes itself.

The low abundances and large sizes of sea urchin populations of the species *Diadema mexicanum* and *Eucidaris thouarsii*, as well as the high fish biomass values obtained in the RNACB could be considered to indicate that the reef of the Cabo Blanco Absolute Nature Reserve is in good condition compared to other sites on the northern Pacific Coast of Costa Rica.

ACKNOWLEDGEMENTS

The work was funded by the Special Fund for Higher Education (FEES) of the National University as part of the project called: "Health status of the rocky reef ecosystems of the marine protected areas in the Costa Rican North Pacific" of the School of Biological Sciences of the National University, SIA: 0592-16.

We also wish to recognize the assistance of the staff of the Cabo Blanco Absolute Nature Reserve, the National System of Conservation Areas, the Tempisque Conservation Area and the diving company Iguana Divers. And finally, we would like to thank reviewers for taking the time and effort necessary to evaluate the manuscript. We sincerely appreciate all valuable comments and suggestions, which helped us to improve the quality of the manuscript.

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ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1

ANNEX 1. List of macroinvertivores sampled in the Cabo Blanco Absolute Natural Reserve
ANEXO 1. Lista de macroinvertebrados muestreados en la Reserva Natural Absoluta Cabo Blanco

Trophic level	Species	Strata	
		Deep	Shallow
Carnivores	*Aniculus elegans*		X
	Panulirus gracilis		X
	Stenorhynchus debilis		X
	Phataria unifascialis		X
	Tambja abdere	X	
	Octopus sp	X	
	Hexaplex princeps	X	X
	Opeatostoma pseudodon	X	X
	Pustulatirus virginensis	X	X
	Triplofusus princeps		X
	Turbo sp	X	
Herbivores	*Diadema mexicanum*	X	X
	Eucidaris thouarsii	X	X
	Elysia diomedea		X
	Titanostrombus galeatus		X
Suspension feeders	*Carijoa riisei*	X	
	Leptogorgia alba	X	X
	Leptogorgia rigida	X	X
	Aglaophenia whiteleggei	X	X
	Tubastraea coccinea	X	
	Neothyonidium sp	X	
	Spirobranchius spp	X	X
	Terebellidae	X	X
	Vermetidae sp1		X

Trophic level	Species	Strata	
		Deep	Shallow
Filter feeders	*Aplysina gerardogreeni*	X	X
	Ascidian Morphotype sp1		X
	Bivalve Morphotype sp1	X	
	Sponge Morphotype sp1	X	
	Sponge Morphotype sp2	X	X
	Sponge Morphotype sp3	X	
	Sponge Morphotype sp4	X	X
	Sponge Morphotype sp7	X	X
	Sponge Morphotype sp8	X	X
	Sponge Morphotype sp11	X	
	Hyotissa hyotis	X	
	Ostrea sp.	X	X
	Pinctada mazatlanica	X	X
	Pinna rugosa	X	
	Pycnoclavella stanleyi	X	
	Rhopalaea birkelandi	X	X
Hete/Autotrophs	Coral Morphotype Tubastrea	X	
	Porites panamensis	X	
N/D	Gastropod Morphotype sp2	X	X
	Gastropod Morphotype sp3	X	

ANNEX 2. List of fish species sampled in the Cabo Blanco Absolute Natural Reserve
ANEXO 2. Lista de especies de peces muestreados en la Reserva Natural Absoluta Cabo Blanco

Trophic level	Species	Strata		Trophic level	Species	Strata	
		Deep	Shallow			Deep	Shallow
Herbivores	*Acanthurus nigricans*	X	X	Macroinvertivores	*Alphestes inmaculatus*	X	X
	Acanthurus xanthopterus	X			*Anisotremus taeniatus*	X	
	Kyphosus elegans		X		*Arothron meleagris*	X	X
	Microspathodon dorsalis	X	X		*Bodianus diplotaenia*	X	X
	Ophioblennius steindachneri	X	X		*Canthidermis maculata*		X
	Prionurus laticlavius	X	X		*Canthigaster punctatissima*		X
	Prionurus punctatus		X		*Chaetodon humeralis*	X	X
	Scarus ghobban		X		*Cirrhitichthys oxycephalus*	X	
	Scarus perrico	X	X		*Gnathanodon speciosus*	X	
	Scarus rubroviolaceos		X		*Haemulon sexfasciatum*	X	X
Piscivores	*Caranx caballus*		X		*Halichoeres chierchiae*		X
	Caranx caninus	X			*Halichoeres dispilus*	X	
	Caranx melampygus	X	X		*Halichoeres nicholsi*	X	
	Caranx sexfaciatus	X			*Holacanthus passer*	X	X
	Cephalopholis panamensis	X			*Johnrandallia nigrirostris*	X	
	Echidna nocturna		X		*Paranthias colonus*	X	
	Elagatis bipinnulata	X			*Plagiotremus azaleus*		X
	Epinephelus labriformis	X			*Pseudobalistes naufragium*	X	
	Gymnothorax castaneus	X	X		*Stegastes flavilatus*	X	X
	Lutjanus argentiventris	X			*Sufflamen verres*	X	X
	Lutjanus novemfasciatus	X			*Thalassoma grammaticum*	X	
Plancktivores	*Abudefduf troschelii*	X	X		*Thalassoma lucasanum*	X	X
	Acanthemblemaria hancocki	X	X		*Trachinotus rhodopus*	X	X
	Chromis atrilobata	X					
	Kyphosus ocyurus		X				

Rev. Mar. Cost. Vol. 17 (1): 19-42, enero-junio 2025
ISSN: 1659-455X • e-ISSN: 1659-407X
DOI: http://dx.doi.org/10.15359/revmar.17-1.1