Proceeding Paper

Size Structure of the Macrofuna Community in La Azufrada Coral Reef (Isla Gorgona, Colombian Pacific) †

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Abstract: Fauna associated with coral reefs is mainly comprised of macroinvertebrates. In order to predict the impact that disturbances such as coral reef degradation could have on these macrofauna communities, it is essential to characterize their community attributes, and particularly their size distributions. In this research, biomass, and community structure of macrofauna assemblages associated with La Azufrada coral reef (Colombian Pacific), were compared between live and inert coralline substrates, and among size groups of the same coralline substrate. Transitions from live to inert coralline substrates could lead to macrofaunal assemblages with remarkably lower organic matter contributions, and higher proportions of smaller crustacean macroinvertebrates (< 1mm).

Keywords: macrofauna; coralline substrates; community attributes; size groups; size distribution; Colombian Pacific

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1. Introduction

Coral reefs are considered one of the most diverse ecosystems in the world, hosting a similar number of species and habitat complexity than tropical forests [1]. Coral reef services rely largely on their associated macrofauna because they represent the highest abundance and diversity, as well as play a key role in the food webs of reefs by linking primary producers to secondary and tertiary consumers [1–3]; contributing to organic matter and nutrient recycling [4]; or promoting the erosion of the coralline substrate [4]. However, due to their cryptic behavior, small size, and polemic taxonomic classifications, research of macrofauna communities associated with coral formations are still very scarce, particularly when compared with research targeting fishes and larger animals [5–7]. In the Eastern Tropical Pacific (ETP), early studies of macrofauna communities associated with coral reefs were conducted during the seventies in Panama and Colombia, focusing mainly on the description of species of Decapoda intimately associated with the branching coral of the genera *Pocillopora* Lamarck, 1816 [8].

Awareness regarding the degradation of coral reefs has risen, as it is a worldwide and growing phenomenon [9]. In the ETP, coral degradation is linked with suboptimal climatic and oceanographic conditions, particularly with the warming events during El Niño Southern Oscillation (ENSO) [10], which are also intensified due to climate change [11]. Coral mortality is followed by changes in the dominance of the type of coralline substrate from live corals to dead coral fragments covered mainly by turf algae [10,12]. Hence, understanding the impact that coralline substrate transformation has on these macrofauna assemblages is essential.

Another attribute that is important to evaluate is body size, considering that it affects basic ecological processes such as metabolic rates, generation times, or predator-prey interactions [13]. Therefore, changes in the community size spectrum can affect the direction and efficiency of energy and organic matter flows through the food webs [13,14]. In order to make predictions of the impacts linked to size distribution changes, it is crucial to understand how attributes, such as density, biomass, or taxonomic composition are allocated among size groups. However, only recently, Fraser et al. (2021a,b) characterized the size spectrum of these community attributes in macrofauna assemblages associated with different coralline substrates in the Great Barrier Reef of Australia [15,16].

This research documents differences in macrofauna assemblages between live and inert coralline substrates in a Colombian Pacific reef, through the evaluation of two community attributes, biomass and community structure. More notable, this research highlights how these attributes are distributed among size groups, and how each size group contributes to the overall biomass and community structure in each coralline substrate.

2. Materials and Methods

2.1. Study Area

Gorgona is a continental island located approximately 35 km off the coast (Figure 1A). The area around Isla Gorgona is characterized by high precipitations (mean annual >6600 mm), high sea surface temperatures (26–29 °C), high turbidity (transparency < 6–12 m), salinities ranging 25–33, and a semidiurnal tidal regime with high fluctuations (>5 m) [17].

Despite the suboptimal conditions for corals to grow, coral formations with different degrees of development can be found in Gorgona [10] (Figure 1B). La Azufrada is indeed one of the most developed coral reefs in the Colombian Pacific [18] (Figure 1B,C). Coral framework in La Azufrada is dominated by *Pocillopora* branching corals [10,18].

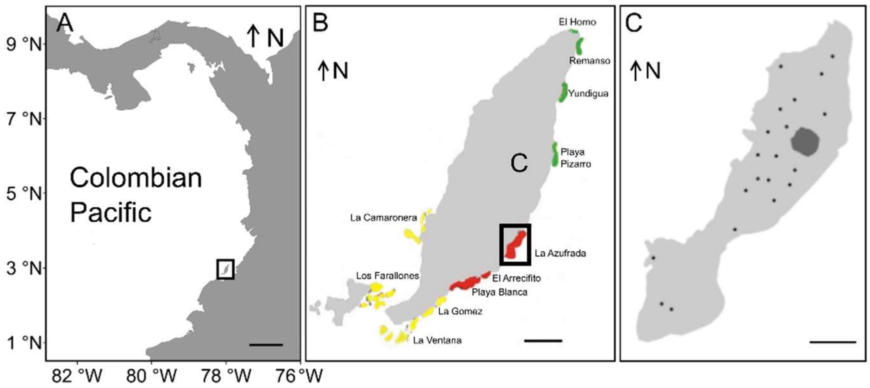

Figure 1. Map of Isla Gorgona and La Azufrada coral reef in the Colombian Pacific: (**A**) Map of the Colombian Pacific coast indicating Isla Gorgona (black square). Scale: 100 km; (**B**) Map of Isla Gorgona showing the distribution of coral formations around the island according to their type. Legend: Patchy coral communities (green); Incipient reefs (yellow); Fringing reefs (red) [18]-modified. Scale: 1 km; (**C**) Map of La Azufrada coral reef showing the 20 sampling points. Scale: 100 m.

2.2. Sampling

To characterize the macrofauna community inhabiting the coralline substrate in La Azufrada, 40 samples were collected at 20 points randomly distributed along the reef (Figure 1C). Two samples were collected at each point within a 1 m^2 area: (1) live coralline substrate, defined as entire Pocillopora spp. colonies, and (2) inert coralline substrate, defined as the coral skeleton without live tissue. Live colonies were firstly covered with a zip lock bag, detached from the floor, and then sealed underwater. The inert coralline substrate was collected in 3.5 L containers in a 30 cm quadrat. In the laboratory, each sample unit was defaunated, poured through a 0.5 mm sieve, and preserved in 96% ethanol.

2.3. Laboratory Processing

Samples were filtered through a sieving tower composed of five sieves. Hence, according to their size, macroinvertebrates were retained within the different meshes, and sorted into five size groups: 0.5–1 mm, 1–2 mm, 2–4 mm, 4–8 mm, >8 mm. Wet weight biomass of each size group was measured in an analytical balance (0.001 g resolution) after removing the excess water from invertebrates by lightly blotting the sample in a paper towel. Afterwards, macroinvertebrates of each size group were counted, classified at high taxonomic levels, and preserved in 96% ethanol.

2.4. Data Analysis

All data were firstly standardized to 100 cm^2. Biomass differences between coralline substrates were tested using a paired t-test. Furthermore, an ANOVA of the Linear Mixed-Effect Model was run to test statistical differences between the size groups within each coralline substrate. Biomass data were previously transformed to meet data symmetry (ln+1). Afterwards, the Tukey's Honestly-Significant Difference post-hoc test was performed to evaluate pairwise differences between size groups.

Densities per taxonomic group were used to test differences in macrofauna community composition between coralline substrates using an ANOSIM test. Hence, a dissimilarity matrix was previously built using the Manhattan distance. Afterwards, the SIMPER analysis was used to evaluate the contribution of each taxon to these dissimilarities.

3. Results

3.1. Biomass

Wet weight biomass of the macrofauna assemblage was significantly different between coralline substrates ($p < 2.058\text{e-}09$) (Figure 2A). Significant differences in biomass were also found between size groups in both, live and inert coralline substrates ($p < 0.0001$). All pairwise comparisons were statistically significant ($p < 0.05$), except for the size groups 0.5–1 mm and 1–2 mm in inert coralline substrates. Moreover, in both coralline substrates, biomass values increased as the size of the organisms increased, and biomass in the size group >8 mm were largely responsible for total biomass (Figure 2B,C and Table 1). The dominance of the largest size group was, however, considerably more outstanding in live than in inert coralline substrates (Figure 2B,C and Table 1).

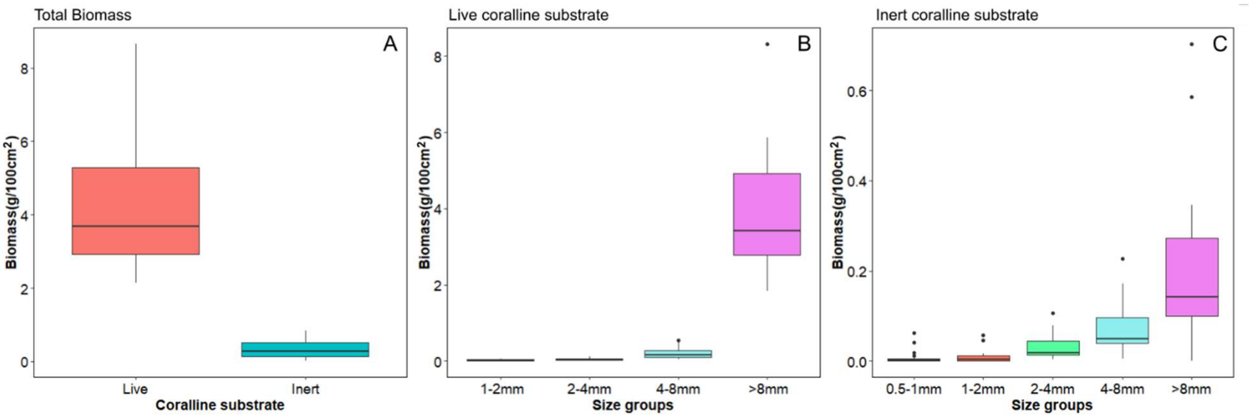

Figure 2. Boxplots of wet weight biomass (g/100cm^2) of macrofauna showing the median (horizontal bar), the interquartile range (boxes), and the outliers (black points): (**A**) Biomass between live and inert coralline substrates; (**B**) Biomass among size groups in live coralline substrates. The 0.5–1 mm group was not included in the analysis because none of the obtained measurements was >0.004 g (error of the analytical balance); (**C**) Biomass among size groups in inert coralline substrates.

Table 1. Average biomass (95% IC) according to coralline substrate (live and inert) and size groups (0.5–1 mm, 1–2 mm, 2–4 mm, 4–8 mm, >8 mm). Values are standardized to 100 cm^2.

Substrate	0.5–1 mm	1–2 mm	2–4 mm	4–8 mm	>8 mm	Total
Live	-	0.028 (0.009)	0.051 (0.015)	0.209 (0.067)	3.877 (0.753)	4.166 (0.772)
Inert	0.008 (0.007)	0.010 (0.007)	0.032 (0.013)	0.075 (0.028)	0.205 (0.084)	0.330 (0.109)

3.2. Community Structure

Twenty-six taxonomic groups were found considering both coralline substrates, with 19 taxa occurring in live and 25 taxa in inert substrates. Relative densities per taxonomic group revealed a single taxon dominance in live (Caridea: 49%) and in inert coralline substrates (Tanaidacea: 35%) (Figure 3A). The difference in macrofauna assemblage composition between substrates was statistically significant (p = 1e-04), accounting for ≈ 78%. Caridea contributed the most to this dissimilarity (0.28, average dissimilarity contribution), followed by Tanaidacea (0.11), and Polychaeta (0.09). Relative densities of these taxa varied greatly between live and inert coralline substrates, Caridea (49% vs. 0.3%, respectively), Tanaidacea (5% vs. 35%), and Polychaeta (7% vs. 19%) (Figure 3A).

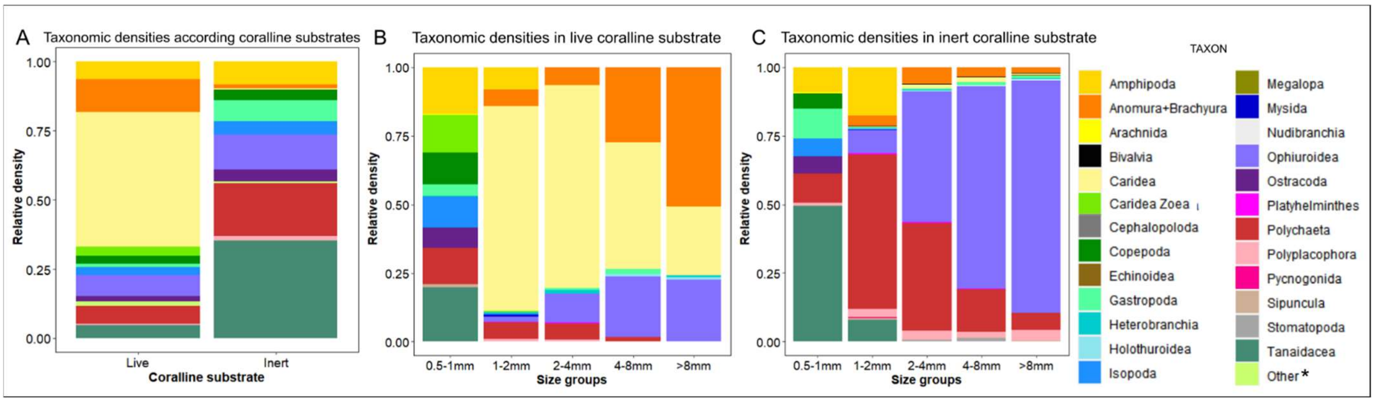

Figure 3. Taxonomic composition of macrofauna assemblages: (**A**) Bar graph comparing the relative taxonomic densities between live and inert macrofauna communities. * Taxa grouped as Other comprise Sipuncula, Arachnida, Mysida, Holothuroidea, Heterobranchia, and Platyhelminthes; (**B**) Relative taxonomic densities among size groups in live coralline substrates; (**C**) Relative taxonomic densities among size groups in inert coralline substrates. .

In live coralline substrates, dominance by a single taxon was observed in all but the 0.5–1 mm group (Figure 3B). This dominance was particularly pronounced in the 1–2 mm and 2–4 mm groups (Caridea densities >70%) (Figure 3B). In the >8 mm group, invertebrates belonging to the Caridea and Anomura-Brachyura taxa were mainly shrimps of the genus *Alpheus* Fabricius, 1798 and crabs of the genus *Trapezia* Latreille, 1828, respectively.

In inert coralline substrates, a single taxon dominance pattern was observed in all size groups, which was more conspicuous in the 4–8 mm and >8 mm groups, where densities were dominated by Ophiuroidea (Figure 3C). Dominance of Ophiuroidea decreased in the smallest size fractions and it was progressively replaced by Polychaeta. The 0.5–1 mm size group was dominated by Tanaidacea (Figure 3C).

4. Discussion

4.1. Biomass

Macroinvertebrate biomass showed the most conspicuous difference between coralline substrates, with live coral having >12 times biomass than inert coralline substrates (Figure 2A and Table 1). Higher biomass values in live than inert coralline substrates have also been reported in the Western Micronesia [7] and the ETP [4].

Biomass distribution in live coralline substrates is remarkably outstanding because total biomass is not only mainly contained in the >8 mm group, but also in very specific taxa, the genera *Trapezia* and *Alpheus*. Several authors have described the intimate association between these two Decapoda and *Pocillopora* colonies in different regions [8,19,20], including Isla Gorgona [21,22]. Therefore, total biomass in live coralline substrates is mainly comprised of decapods that are obligate symbionts of *Pocillopora* colonies.

4.2. Community Structure

Macrofauna community composition is different between coralline substrates (Figure 3A). When compared to other studies, the consistency of our result is not surprising, considering that habitat has been widely identified as a key factor structuring the composition of benthic communities [4,5,23,24], outweighing even latitude [6,15]. In our study, this difference is due to taxa present in both substrates, but strongly correlated to only one of them. Particularly, Caridea is strongly correlated to live coralline substrates and Tanaidacea to inert coralline substrates (Figure 3A). Hence, both macrofauna assemblages are dominated by crustaceans. The importance of crustaceans in macrofauna communities associated with different coralline microhabitats has been highlighted by several authors [15,24,25].

In live coralline substrate, crustaceans are mainly comprised by Decapoda (Figure 3B). The dominance of Decapoda in macrofauna assemblages associated with live coralline substrates, and particularly with branching corals, is consistent across the literature due to their symbiotic associations [8,19,20,25]. Highest contribution of Decapoda to total macrofauna density is maintained in all size groups, except the 0.5–1 mm group, which is dominated by Peracarida (Figure 3B). The dominance of crustaceans according to size groups in live coralline substrate has also been described by Fraser et al. (2021a)[15].

However, when the distribution of crustaceans is studied among size groups in inert coralline substrates, dominance of this taxonomic group is only observed in the 0.5–1 mm group (Peracarida) (Figure 3C). The remaining size groups are dominated by Polychaeta and by Ophiuroidea (Figure 3C). The occurrence of both taxa in macrofauna communities associated with inert coralline substrates has been highlighted by different authors [5,6,26], including in the ETP of Panama [27]. Furthermore, ophiuroids and polychaetes have also been identified as key components in structuring these macrofauna assemblages, due to their role as bioeroders [26].

5. Conclusions

This study suggests that a coral degradation event in La Azufrada reef, induced for example by thermal stress associated with an El Niño event could have a significant impact on this reef system. On the one hand, the composition of the macrofauna assemblage could significantly change towards the dominance of smaller crustaceans (< 1 mm), likely affecting the trophic relationships. On the other hand, and more outstanding, the amount of energy and organic matter available for higher trophic levels could drastically decrease following the death of obligate symbionts like the decapods associated with *Pocillopora* colonies. These Decapoda are responsible for almost the total biomass contained in live coralline substrates. Hence invertivore populations, such as coral-dwelling species, might decline due to a decrease in their food resources.

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Conflicts of Interest: The authors declare no conflict of interest.

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