Characterization of the marine macroinvertebrate community associated with artificial hard substrates in Cartagena Bay, during 2018 and 2019 in different climatic seasons

Caracterización de la comunidad de macroinvertebrados marinos asociada a sustratos duros artificiales en la bahía de Cartagena, durante 2018 y 2019 en diferentes épocas climáticas

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Abstract

In order to detect changes in the native communities of marine macroinvertebrates in the Cartagena Bay, biological surveys were carried out on seven artificial substrates (buoys) of the Cartagena Bay in different seasons during 2018 and 2019. Encrusting organisms were scraped from 30x30 cm areas, fixed and subsequently analyzed in the laboratory. A total of 9563 individuals distributed in 57 taxa were identified, among which we confirmed the presence of the bivalve *Perna viridis*, a species native to the Indo Pacific and reported to the region as a bioinvasive organism. 79% of the abundance of organisms consisted of 2 morphotypes of mytilidae (*Mytella charruana* and M1) and three species of barnacles (*Amphibalanus amphitrite, Amphibalanus reticulatus* and *Amphibalanus eburneus*). The correlation of environmental variables with the diversity and abundance of organisms through Principal Component Analysis and Standardized Empirical Orthogonal Functions allowed us to show changes in the macroinvertebrate community between the surveys carried out in addition to differences depending on depth, including a greater variation in the stations that are most influenced by the discharge of freshwater as well as those influenced by ocean waters in the areas of greatest interchange in the Bay, an aspect that probably changes with seasonal variations in the study area and the stability of the community in the water column.

Key words: Biofouling, marine macroinvertebrates, artificial substrates, Colombian Caribbean.

Resumen

Con el fin de detectar cambios en las comunidades nativas de macroinvertebrados marinos de la bahía de Cartagena, durante 2018 y 2019 se realizaron levantamientos biológicos en diferentes épocas climáticas, en siete sustratos artificiales (boyas). Fueron raspadas áreas de organismos incrustantes de 30x30 cm, fijadas y posteriormente analizadas en el laboratorio. Se identificaron un total de 9563 individuos distribuidos en 57 taxa, dentro de los cuales se confirmó la presencia del bivalvo Perna viridis, especie originaria del Indo Pacífico y registrada para la región como organismo bioinvasor. El

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79% de la abundancia de organismos lo conformaron 2 morfotipos de mitílidos (Mytella charruana y M1) y tres especies de cirrípedos; Amphibalanus amphitrite, Amphibalanus reticulatus y Amphibalanus eburneus. La asociación de las variables ambientales con la composición y abundancia de organismos mediante el análisis de componentes principales y funciones empíricas ortogonales estandarizadas, permitió evidenciar cambios en la comunidad de macroinvertebrados entre los monitoreos realizados así como diferencias entre profundidades, donde se evidencia una mayor variación en las estaciones que se ven más influenciadas por la descarga de aguas continentales así como la influencia de aguas oceánicas en las áreas de mayor intercambio en la bahía, aspecto que probablemente responde a las variaciones estacionales del área de estudio y la estabilidad de la comunidad en la columna de agua.

Palabras claves: *bioincrustación, macroinvertebrados marinos, sustratos artificiales, Caribe colombiano.*

Introduction

Marine macroinvertebrate communities inhabiting coastal ecosystems are represented by almost all animal phyla and have been used in monitoring programs, as they serve as indicators of both natural and anthropogenic disturbances (Guzmán-Alvis, Solano, Córdoba-Tejada and López-Rodríguez, 2001; Carrasco and Gallardo, 1989). The native diversity that inhabits places with maritime activity such as port areas has been affected by the introduction of foreign organisms that threaten its survival and destabilize it.

The construction and operation of port areas is one of the activities with the greatest impact on coastal ecosystems because ships function as a major vector for the introduction of non-native species through ballast water and sediments, as well as fouled hulls and other surfaces exposed to the environment (Rilov and Crooks, 2009; Hewitt, Gollasch and Minchin, 2009). Because most marine organisms go through a planktonic phase in their life cycles, ballast water can carry organisms of virtually all taxa (Global Invasive Species Programme (GISP), 2005; Okolodkov and Garcia-Escobar, 2014). The operation of port areas can have impacts on established species and be ecologically complex, acting at the ecosystem, community or species level, and even at the genetic level (Kairo *et al*., 2003).

These non-native organisms transported by maritime activity have the potential to establish themselves in the new environment as they may find conditions similar or better than those of their original habitat, while they might also have a high adaptability either due to their high fecundity and/or physiological tolerance. They may also benefit from the absence of the predators or parasites which normally exert biological control in their native habitat (Torchin and Lafferty, 2009; Olyarnik *et al*., 2009).

Among the identified impacts of bioinvasions, the decline in abundance or extinction of local species is considered to be the second most important cause of diversity loss (Courtenay, 1993). Native species may be directly threatened by the proliferation of a predator or competitor, or indirectly by changes in resource availability (nutrients, light, oxygen, space) and ecosystem structure and function (Kairo *et al*., 2003).

Species introductions may also bring with them diseases and may adversely affect a range of commercial interests in the marine environment related to wildlife conservation (Eno, Clark and Sanderson, 1997).

According to Ahrens *et al*. (2011), a low number of non-native marine taxa are recorded in Colombia, mainly due to the lack of studies on marine biodiversity in port areas, poor comparisons between ports, uncertainty in taxonomic identification and incomplete lists of invasive species.

This study presents information on organisms belonging to the macroinvertebrate community associated with artificial structures (buoys) in the port area of Cartagena Bay (Lat.: 10°24’18’’N, Lon.: 75°32’05’’W) to determine the influence of port activity on the introduction of foreign organisms into these communities.

Previous studies have characterized this area and have shown a strong influence of port activities on macroinvertebrate communities and have even characterized other communities such as bacteria, plankton and fish (Rendón, Vanegas and Tigreros, 2003; Cañón-Páez, López-Osorio and Arregocés-Silva, 2010; Ahrens, *et al*., 2011; Campos and Acero, 2016), in which the presence of non-native organisms and their possible effects on native communities have been demonstrated.

The bay has a high level of anthropogenic intervention through activities and processes such as the discharge of industrial effluents, oil spills, dredging, eutrophication caused by wastewater, heavy metal pollution, busy port and tourist activity, and ship unloading, among others (Cañón *et al*., 2007; INVEMAR, 2019).

Study area

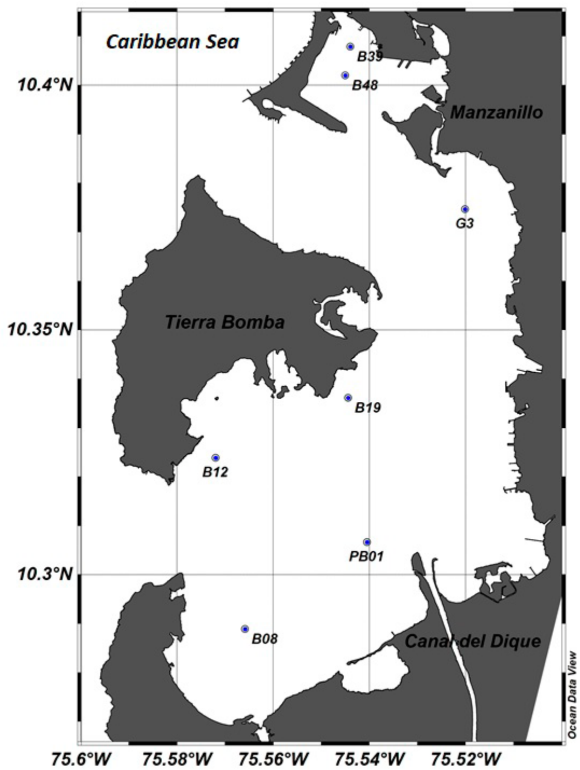

Figure 1. Location of monitoring stations B08, B12, PB01, B19, G3, B39 and B48 in Cartagena Bay, Bolívar, Colombia

The study was carried out in Cartagena Bay (Figure 1), which receives vessels from an estimated 114 countries and at least 432 ports around the world (Montoya and Gómez, 2011), and has 50 docks for cargo and passenger ships (Sociedad Portuaria Regional de Cartagena (SPRC), 2019). It has a direct connection with the Magdalena River through the man-made Canal del Dique and is classified as an estuary due to the influence of freshwater from the latter (CIOH, 2004a).

Methodology

30x30 cm scrapings were taken from artificial substrates on marine marker buoys during two monitoring surveys in October 2018 (5 buoys) and June 2019 (7 buoys) (Table 1). In the latter, the samples were taken at the surface (S) and at the bottom (F), making a total of 19 samples collected in the two surveys. Samples were separated according to the Centre for Research on Introduced Marine Species (CRIMP) protocol (Awad, Haag, Anil and Abdulla, 2014), and fixed in ethanol (70%).

Taxonomic identification was done at the most specific level possible using taxonomic identification guides and referenced scientific articles (Diaz and Puyana, 1994; Abele and Kim, 1986; Kensley and Schotte, 1989; Werding, 1977; Werding 1984; Zea, 1987; Wedler, 2017).

Table 1. Surveys of hard artificial substrates carried out during: 2018 (MI), during which samples were taken from buoys B08, B12, PB01, B19 and B39 at the surface, and 2019 (MII), in which samples were taken from buoys B08, B12, PB01, B19, G3, B39 and B48, both at the surface "S" and the bottom "F" (MIIS and MIIF).

Survey	**MI**	**MII**	
Survey name	**MI**	**MIIS**	**MIIF**
Date	25 October 2018	12 June 2019	
Depth	0.2 m	0.3 m	1.5 m – 3 m
Samples taken	B08 B12 PB01 B19 - B39 -	B08S B12S PB01S B19S G3S B39S B48S	B08F B12F PB01F B19F G3F B39F B48F

Data processing included the construction of Q-type matrices in Excel 2016 to establish the structure and composition of the community. Community attributes were evaluated with the diversity indices in PRIMER v5: Shannon-Weaver Diversity (H'), Pielou Uniformity (J') and Simpson Predominance (λ). In addition, biological associations between stations were established based on species composition (richness and abundance), and the classification was analyzed directly (Q-matrix) using the Bray-Curtis similarity index and square root transformation of the data.

Associations were established based on the unweighted pair group method with arithmetic mean (UPGMA) (Crisci and López, 1983).

To determine the relationship between biological variables (species richness, abundance of organisms and Shannon-Weaver diversity) and physical variables (salinity and pH), a principal component analysis (PCA) was performed with numerical resolution. Due to the differences in the units of the variables, it was necessary to standardize the data by Z-transformation (Santamaría-del-Ángel *et al*., 2011).

Furthermore, to identify the spatio-temporal distribution of the community, regions of community distribution within the bay were identified by calculating the first standardized empirical orthogonal function (SEOF) of the matrix of biological and physical data, according to the criteria of Santamaría-del-Ángel *et al*. (2011).

Results

Physicochemical variables

Salinity and pH values did not vary greatly between stations of the same survey or depth, with the exception of salinity at B19 for surface samples, which had values for October 2018 and June 2019 of 14.9 and 12.7 respectively (Table 2). The pH ranged between 8.08 and 8.47, with a higher surface average recorded in June 2019. As for salinity, the highest values occurred in June 2019 at the bottom, with an average of 26.94.

Table 2. Values of the physicochemical variables at each station in the survey.

Parameter	B8	B12	BPB01	B19	B39	G3	B48
October 2018 (MI)							
pH	8.08	8.21	8.11	8.187	8.34	-	-
Salinity	15.8	22.3	23.3	14.9	19.2	-	-
June 2019 Surface (MIIS)							
pH	8.371	8.385	8.393	8.227	8.414	8.478	8.417
Salinity	21.3	19.2	19.9	12.7	20	18.5	20.6
June 2019 Bottom (MIIF)							
pH	8.273	8.346	8.308	8.297	8.447	8.369	8.42
Salinity	30.1	23.8	30.5	28.9	27.6	24.6	23.1

The values for this study were within the range reported by others in this area, such as Gavilán-Murcia, Cañón-Paéz and Tous-Herazo (2005), in which the salinity in the rainy season ranged from 12.0 to 34.0 and the pH was between 7.86 and 8.55, with an average of 8.09.

Biological component

A total of 57 taxa were identified, including 27 species, 11 genera and 19 morphotypes distributed among 33 families, 21 orders and 9 classes belonging to the Mollusca, Arthropoda, Chordata, Cnidaria, Platyhelminthes, Sipuncula, Nemertea and Porifera phyla. There was a total of 9563 individuals, in addition to the presence of organisms that due to their colonial growth form (Cnidaria-Hydrozoa and Porifera) are not included in this figure.

Mollusca was the most abundant phylum (56.6%), including the most abundant family (Mytilidae), which had one species and one morphotype; followed by Arthropoda (41.4%); while the phyla Chordata, Cnidaria, Platyhelminthes, Sipuncula and Nemertea had low abundances (<1%) (Figure 2). *Mytella charruana* (see supplementary material) was the dominant species with 30.75% of the total abundance, followed by the group of barnacles *Amphibalanus amphitrite, Amphibalanus retivulatus* and *Amphibalanus eburneus* with 29.76%, and morphotype 1 of the Mytilidae family with 18.78%.

In terms of spatial distribution, the mollusc and arthropod groups exceeded 78% abundance (Figure 2); in 11 of the 19 samples taken, the mollusc group was the most representative, exceeding 90% of the total individuals found in the surface sample of B08 in June 2019, as well as the bottom samples of PBP01 and B19 in the same month. On the other hand, in the B12 and G3 samples for June 2019, at the bottom and surface respectively, the dominant group was that of arthropods. Cnidarians were not recorded in October 2018 at B08, nor in June 2019 at the surface of B12, B39 and B48, nor the bottom for B08 and B12. In the case of platyhelminths, sipunculids and nemertines were only present at B39 in October 2018; while, for their part, porifera were not found at BPB01 in October 2018, nor at BPB01 and B39 surface or B48 bottom in June 2019.

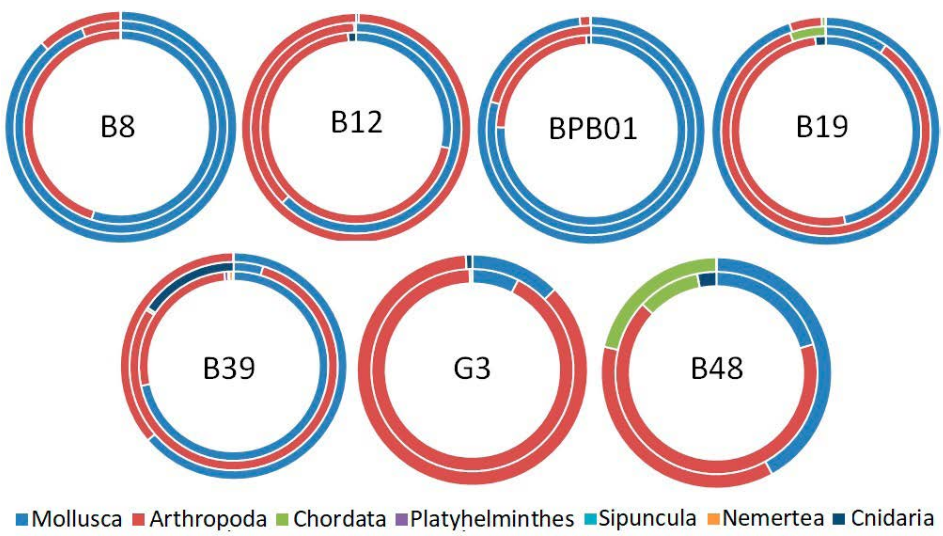

Figure 2. Percent abundance of each phylum of macroinvertebrates at the 7 stations analyzed. The two surveys of 2018 (MI) and 2019 (MII) at the surface "S" and bottom "F" are differentiated as follows: MI - inner ring; MIIS - middle ring; and MIIF - outer ring. Organisms belonging to the phylum Porifera and the class Hydrozoa of the phylum Cnidaria are not included.

Of the 22 orders recorded, (92%) of the total abundance found at the seven stations in the two surveys corresponded to Mytilida and Sessilia. The less abundant orders were: Ostreida (1.9%), which was not found at B12 in October 2018, nor the B8, B12 and B39 bottom samples in June 2019, and was represented by four morphotypes, of which *Crassostrea sp*., had the highest abundance (1.83%); Decapoda (1.8%, 16 morphotypes), which was found in all 19 samples taken, with abundances between 0 and 5.5%; and Amphipoda (1.5%, 5 morphotypes), which was present in 12 of the samples taken, with abundances between 0.3 and 8.9%.

The decapod group was represented in three infraorders (Caridea, Brachyura and Anomura) in which 16 morphotypes were recorded. The infraorder Brachyura was the most abundant, represented by the families Grapsidae, Pilumnidae, Panopeidae and Menippidae, followed by the family Porcellanidae belonging to the infraorder Anomura, and the family Alpheidae of the infraorder Caridea, with low abundance. The orders Myida, Neogastropoda, Isopoda, Stomatopoda, Ascidiacea, Polycladida, Phascolosomatida and Actiniaria, as well as the phylum Nemertea, also had low abundance (less than 1%).

Regarding Cnidaria, the order Leptothecata was present in 10 of the samples taken, and its specimens were mainly found on shells of the family Balanidae; the genera recorded were *Clytia*, Obelia and a morphotype of the family Plumularioidea. Organisms of the phylum Porifera were also observed on individuals of the Balanidae family, as well as directly attached to the substrate. We highlight the presence of seven orders from this phylum, of which Poecilosclerida and Haplosclerida were the most predominant, since they were found in eight and six respectively of the 19 samples taken (Table 3). In October 2018, the highest richness of species from this group was found in sample B12.

The analysis of the ecological diversity indices indicated that species richness in each the 19 samples taken was represented by 10 to 22 taxa, noting that in October 2018 the highest numbers were found with between 20 and 22 taxa present. The same was true for the abundance of organisms: the highest quantity was present at four of the stations in October 2018 (B39, B19, G3S and B12) with densities between 1.3 ind/m² and 3.28 ind/m², while for the other stations in June 2019, it ranged from 0.12 ind/m² to 1.1 ind/m².

Organism diversity for the two samplings was represented by values between 0.86 bits and 2.08 bits (Figure 3); B48 and B39 bottom and BPB01 surface in June 2019 had the highest values, with low correlations of dominance and high correlations of evenness. Diversity was highest at the bottom stations analyzed in June 2019, as they showed the highest values with an average of 1.6 bits, followed by those obtained in October 2018 with an average value of 1.56 bits.

Table 3. Presence and absence of organisms belonging to the phylum Porifera found at the seven stations in October 2018 (MI) and June 2019 (MII: "S" at the surface and "F" at the bottom).

		Stations	Poecilosclerida	Haplosclerida	Desmacellida	Clionaida	Axinellida
MI		B08	0	X	0	0	0
		B12	0	X	X	X	0
		BPB01	0	0	0	0	0
		B19	0	X	0	0	0
		B39	X	0	0	0	0
MII	S	B8S	0	X	0	0	0
		B12S	0	0	0	0	X
		BPB01S	0	0	0	0	0
		B19S	X	0	0	0	0
		B39S	0	0	0	0	0
		G3S	X	0	0	0	0
		B48S	X	X	0	0	0
	F	B8F	0	X	0	0	0
		B12F	X	0	0	0	0
		BPB01F	0	0	X	0	0
		B19F	X	0	0	0	0
		G3F	X	0	0	0	0
		B39F	X	0	0	0	0
		B48F	0	0	0	0	0

Figure 3. Diversity indices: H′ - Shannon-Weaver Diversity (log2); λ - Simpson Dominance; and J′ - Pielou Uniformity. Stations analyzed: MI (B08, B12, PB01, B19 and B39), and MII surface "S" and bottom "F" (B08, B12, PB01, B19, G3, B39 and B48).

Regarding the Bray-Curtis Similarity Index, the classification analysis showed that the 19 samples taken are directly related to one another or small sub-groups, exceeding 50% similarity. For the first survey, in October 2018, a direct relationship was found between B12, B19, B08 and B39, with similarity levels above 60%; in the second survey in June 2019, the stations located at the bottom of the water column at B12, BPB01, B19 and B39 shared over 50% similarity, and among those located at the surface, the strongest relationship was between B39, B12, B8 and G3 (Figure 4a); a single station, B48, was also identified with a direct relationship in June 2019 (MII) of 49% similarity, indicating for this case a connection between the surface and bottom.

A similar association can be seen in the nMDS (Figure 4b), where the differentiation between monitoring in October 2018 (MI) and June 2019 (MIIS and MIIF) is evident. There is a greater dispersion of data in the bottom data from June 2019, and the surface level community in both October 2018 and June 2019 is clearly different to that of the bottom sample from June 2019.

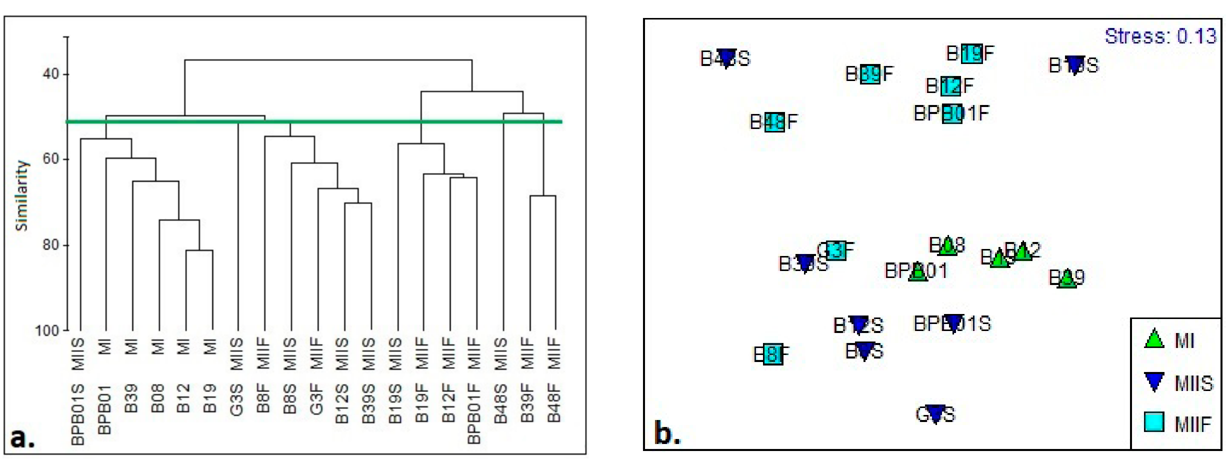

Figure 4.a. Dendrogram of the Bray-Curtis similarity index (similarity threshold 50%) and **b.** multidimensional scaling (nMDS) (stress value: 0.13) for the seven stations, during the two surveys: MI (B08, B12, PB01, B19 and B39), and MII (B08, B12, PB01, B19, G3, B39 and B48) at the two depths (surface "S" and bottom "F").

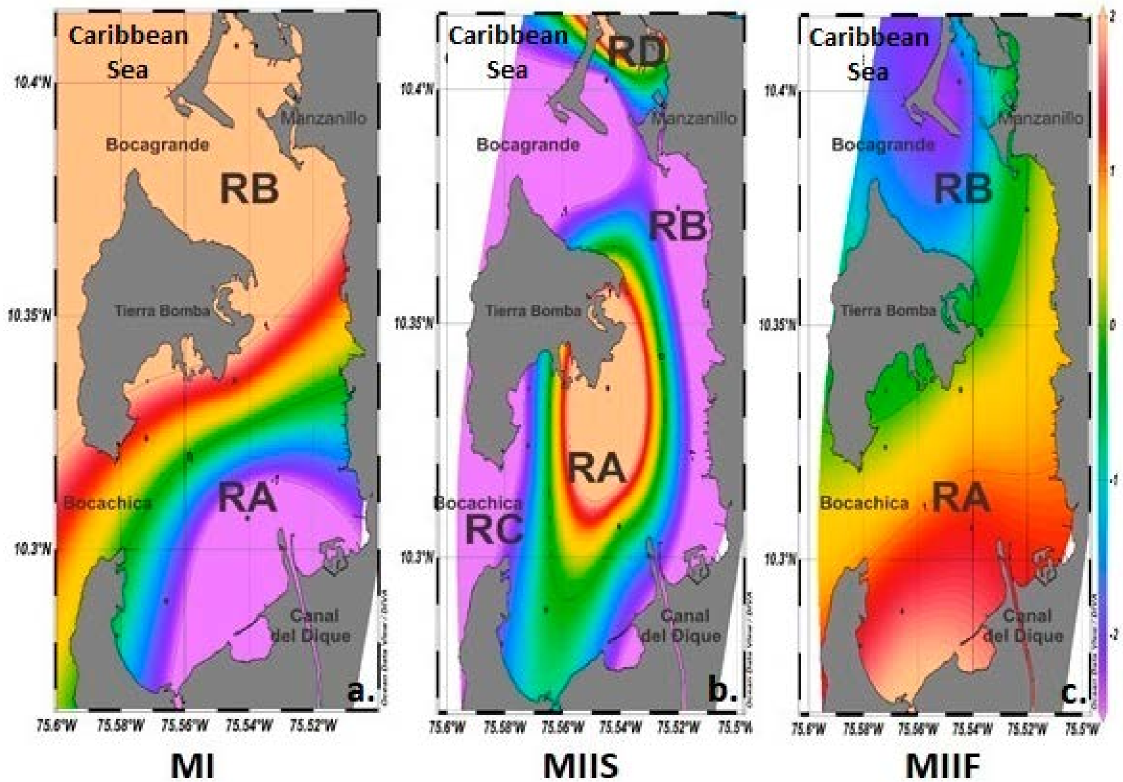

Figure 5. Regions identified based on the relationship between biological and physical variables based on the PCA and the first empirical orthogonal function (EOF): **a.** for MI (RA and RB), **b.** MIIS (RA, RB, RC and RD) and **c.** MIIF (RA and RB).

In order to identify the spatial distribution of the macroinvertebrate community, two to four regions (Figure 5) were identified by the EOF analysis of the correlation between biological variables (species richness, abundance of organisms and Shannon-Weaver diversity) and physical variables (salinity and pH).

For the case of October 2018, the EOF explained 87% of the data association, identifying two distribution regions (Figure 5a): RA located in the south of the bay under the direct influence of the Canal del Dique, and the larger RB from the center to the north of the bay. Bearing in mind that the zero isoline is where the average variables are found, this is what separates the identified regions.

For the case of the second survey, in June 2019, the distribution analysis was performed after separating the surface from the bottom (Figures 5b and 5c respectively); at the surface, it was found that the model accounts for 78% of data variation and identified four regions, two more than in October 2018, generating new regions around buoys B12 (RC) and B48 (RD) and modifying the pattern of the RA and RB regions; there was also a more homogeneous pattern compared to October 2018.

For its part, the distribution of the sea bottom data from June 2019 (90%) was in the same two regions as in October 2018, although the RA region extended further towards the center-north, and in terms of variability the pattern was reversed with negative anomalies in the north (RB) and positive ones in the south (RA).

Discussion

The macroinvertebrate community at the sampling sites was composed of sessile and mobile organisms with euryhaline characteristics that prefer estuarine environments and can easily inhabit hard structures, either natural or artificial, available at the intertidal level. They are mostly filter feeders, which facilitates their establishment in this type of environment (Masterson, 2007; Curelovich and Calcagno, 2014; Martín *et al*., 2013).

The groups of cnidarians, platyhelminths, sipunculids, nemerteans, ascidians and porifera, which are common in most marine ecosystems (Flórez, 1983; González-Muñoz *et al*., 2016; Quiroga, Bolaños and Litvaitis, 2004; Quiroz-Ruíz and Londoño-Mesa, 2015; Díaz and Zea, 2008), made up a minority of the abundance and taxa richness of this community.

According to Crooks (1998), estuarine ecosystems are the most vulnerable in the world in terms of anthropogenic marine introductions, as these areas are constantly influenced by maritime transport, the construction and operation of port areas, the discharge of ballast water and sediments, as well as the influence of organisms attached to the structures of ships. As mentioned earlier, Cartagena Bay is an area classified as estuarine, making it a very suitable place for the introduction of foreign organisms.

The characterization of the organisms found included the mussel Perna viridis, which was first recorded in the Colombian Caribbean in 2009 (Cañón-Páez, López-Osorio and Arregocés-Silva, 2010; Da Costa and Coatanroch 2009), and has been reported to be established in other Caribbean countries, such as Trinidad and Tobago, Venezuela and the Florida coast of the United States (Agard, Kishore and Bayne, 1992; Ingrao, Mikkelsen and Hicks, 2001).

This species is recognized for its high establishment capacity due to its high reproductive rate, planktonic dispersal and rapid growth (Baker *et al*., 2007). They attach strongly by the byssus, colonizing submerged substrates such as rocks, wood, concrete, metal, boats, PVC pipes, ropes, muddy bottoms, algal mats and mangrove roots (Vakily 1989; Agard, Kishore and Bayne, 1992; Rajagopal *et al*. 1998).

Mytella charruana was also identified with high abundances within this study. This species has also been considered as an invasive species in different studies (Gillis, Walters, Fernandes and Hoffman. 2009; Puyana, Prato and Diaz, 2012); although it is normally distributed in the Caribbean area, only recently are there official records that show a high dominance within communities associated with rocky coastlines and specifically in Colombia (Puyana, Prato and Diaz, 2012). Usually attached as epibionts, they also adhere to natural hard substrates such as oyster shells and artificial ones such as water pipes (Masterson, 2007). These authors identified the species, describing it as having a high capacity for dispersal and colonization in different environments, as it competes for space and other resources with other benthic organisms. According to the study carried out by Prato (2009), it adheres to a wide variety of hard artificial submerged substrates such as steel plates, PVC pipes, ropes and plastic moorings.

In terms of arthropods, the highest abundance was of the barnacle group (order Sessilia) *Amphibalanus spp*., which included the species *A. amphitrite, A. reticulatus* and *A. ebuneus.* According to Curelovich and Calcagno (2014), these organisms in many cases are the first invertebrates to colonize a substrate, modifying it and facilitating the recruitment of other groups, including mytilid bivalves, which take advantage to settle on or inside the shells of barnacles, as well as other invertebrate groups.

Other representative groups of considerable abundance were the orders Amphipoda and Decapoda, which were present at most sample points. Amphipods were organised into five morphotypes, are usually widely distributed in different marine environments due to their reproductive success and gregarious patterns (Thomas, 1993a), and have been used as indicators in reef ecosystems (Thomas, 1993b). The families reported are common for the Caribbean zone (Martín *et al*., 2013).

Decapods are commonly abundant and widely distributed in marine ecosystems. Those belonging to the infraorder Brachyura tend to be the most numerous, as they comprise the largest number of families, genera and species (Sánchez and Sandoval, 2005), while the family Porcellanidae is common on hard substrates in the littoral zone and depend to some degree on substrates formed by sessile organisms such as coral reefs and mollusc aggregations (Werding, 1984).

According to the results obtained through the ACP and EOF, the main sources of changes in the composition of the macroinvertebrate community along the bay probably respond to the influence of the exchange of oceanic waters at the Bocagrande (B39 and B48) and Bocachica (B8 and B12) stations, as well as the discharge of freshwater in the sector near the mouth of the Canal del Dique (PB01).

In the case of the October 2018 sampling, two zones are identified that divide the bay into a southern region (RA) and a northern region (RB), where the stations located in the northern part (B39 and B19) tend to have a more stable distribution of the community. In the central-southern section, the influence of a greater exchange of waters originating from the freshwater discharges of the Canal del Dique, and the greater depth that occurs on this side of the bay (CIOH, 2004b), are factors that determine the structure of the community in this region.

The surface map for June 2019 shows a different distribution, in which a less defined pattern is evident in the distribution of the communities. Here, four regions were identified, including two representing only one site each: zone RC around buoy B12 and zone RD for buoy B39, both influenced by the entry of marine waters; at PB01 a different distribution pattern was evidenced, generating a region closer to the coastline, while the others showed a homogeneous pattern of distribution from south to north.

In contrast, the distribution from June 2019 at the bottom of the water column maintained a similar pattern to that of October 2018, but its temporal variability was reflected in the extension of the RA zone towards the north and a change in the variability of the pattern that could indicate the influence of the seasonality of the area on the structure of the community. Alternatively, the factors of the water column could mean that the distribution of the community on the bottom is more stable compared to at the surface.

As a consequence of these more marked changes in the RA zone, the stations in this region show a lower richness and abundance of organisms, although the composition is very similar to the other stations. According to some studies, there is a direct relationship between physicochemical factors and benthic populations. Among the different physicochemical characteristics of the water, salinity is one of the determining parameters in the presence and stability of certain organisms. It directly influences the osmosis processes of organisms, such as the maintenance of osmotic equilibrium and buoyancy (Pérez and Stupak, 1996; Tait, 1971), and is an important factor in places that exerience considerable variations, as occurs in areas where the waters are under the effect of freshwater, such as in the case of the stations located in the discharge zone of the Canal del Dique (RA), or oceanic waters (RC).

In the Colombian Caribbean, 4 annual climatic periods can be identified, including the minor rainy season (May-June) and the major rainy season (September-November) (Bula-Meyer, 1990; Franco-Herrera, 2005). Water exchange and consequently variations in freshwater flow determine the distribution of salinity and other physical and chemical characteristics of the water within the bay (Rueda-Bayona, 2010).

The temporal variation in freshwater discharges and the particularity of the bay, whose physical shape makes it a protected place, thereby limiting the exchange of oceanic waters, gives it estuarine characteristics, and allows the establishment of species with mostly euryhaline characteristics, as is the case of barnacles of the genus *Amphibalanus* and bivalves of the Mytilidae family, which made up the majority of the abundance of organisms in the 19 samples taken.

Organisms' capacity to adapt can limit their presence, growth or even wide coverage in these ecosystems. A greater stability in the water conditions favors, in this case, a greater diversity of organisms, as evidenced at stations B39 and B48 due to the lack of influence of the freshwater discharges from the Canal del Dique. In contrast, buoys PB01 and B19 receive these discharges directly, and there are important changes in the diversity of organisms depending on the climatic season and water depth.

Conclusions

In general terms, the composition of the macroinvertebrate community associated with hard substrates in Cartagena Bay is similar to that commonly found in marine environments influenced by freshwater; there are also organisms that are normally associated with places with high anthropogenic intervention and which are characterized by being highly tolerant to changes in the environment, as is the case of the most abundant taxa, belonging to the orders Mytilida and Sessilia, which were collected at all seven stations during the two monitoring periods.

Freshwater discharges throughout the annual climatic cycle allow us to see significant changes in the composition and abundance of the macroinvertebrate community in Cartagena Bay. The influence of different seasons generates differential distribution and stability between surveys (October 2018 and June 2019) and depths (surface and bottom in June 2019), showing that the characteristics of the water can modify the diversity of organisms.

Baseline information is provided on changes in the macrofaunal community due to the effect of port operations, in order to provide information to the entities responsible for the design and development of tools to strengthen the control of maritime traffic and its influence on marine fauna and flora communities.

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Supplementary Material

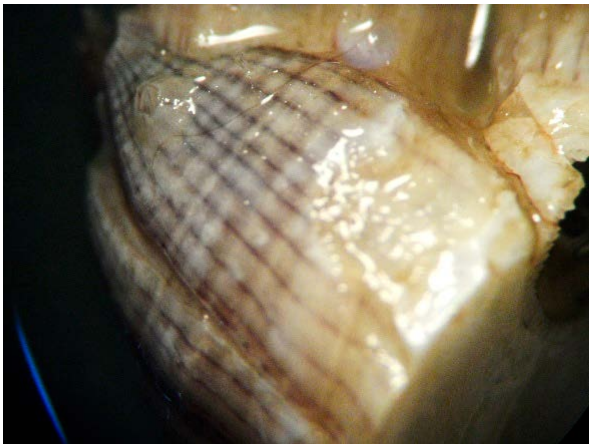
Mollusca

Mytella charruana

Perna viridis

Crustacea

Amphibalanus amphitrite



Amphibalanus reticulatus

Amphibalanus eburneus

Petrolisthes galathinus

Pachygrapsus transversus

Menippe nodifrons