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ARTÍCULO DE INVESTIGACIÓN/RESEARCH ARTICLE

POLYCHAETES FROM RED MANGROVE (*Rhizophora mangle*) AND THEIR RELATIONSHIP WITH THE WATER CONDITIONS IN THE GULF OF URABÁ, COLOMBIAN CARIBBEAN

Poliquetos de manglar rojo (*Rhizophora mangle*) y su relación con las condiciones acuáticas en el golfo de Urabá, Caribe Colombiano

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ABSTRACT

Polychaetes play a significant role in benthic communities' ecology; they dominate the infauna, recycle nutrients from the water column and are commonly used as biological indicators. Along the Gulf of Urabá (Colombian Caribbean), particularly for the zones of the Marirrío Bay and the Rionegro Cove, there are no reports about ecological aspects of polychaete species; only a few taxonomic studies have been conducted. In this research we evaluate the relationship between polychaete species associated with red mangrove roots, *Rhizophora mangle,* and some physicochemical variables of the water column; also, we made some notes about the spatial distributions of polychaetes species within the two study areas. We found that the environmental variables that best explain polychaetes community segregation are the dissolved oxygen and electrical conductivity; temperature seems to have not a significant effect. In terms of spatial distribution, we found that *Alitta succinea, Capitella* cf. *capitata* and *Ficopomatus miamiensis* occupied the inner, middle and outer zones for both study area and seasons, while *Stenoninereis* sp. 1 (rainy and dry season) and the exotic polychaete *Ficopomatus uschakovi* (rainy season) were found just in Rionegro Cove. Finally, the species *Nicolea modesta* is registered by first time for the Gulf of Urabá, Colombian Caribbean.

Keywords: *Capitella* cf. *capitata,* estuaries, exotic species, *Ficopomatus uschakovi*, polychaetes ecology.

RESUMEN

Los poliquetos tienen un papel importante en la ecología de las comunidades bénticas, dominan la infauna, reciclan nutrientes de la columna de agua y son comúnmente usados como indicadores biológicos. En el Golfo de Urabá (Caribe Colombiano), específicamente para las zonas de Bahía Marirrío y Ensenada de Rionegro no existen estudios sobre la ecología de los poliquetos, solo se han desarrollado algunos estudos taxonómicos. En esta investigación se evaluó la relación entre algunas variables fisicoquímicas y las especies de poliquetos encontradas. Adicionalmente, se realizaron algunas observaciones sobre las distribución espacial de estas especies en las dos zonas de estudio. Se encontró que las variables que mejor explican las segregación de las especies de poliquetos fueron el oxígeno disuelto y la conductividad eléctrica; la temperatura no tuvo un efecto significativo. En términos de distribución espacial se encontró que las especies *Alitta succinea, Capitella* cf. *capitata* y *Ficopomatus miamiensis* ocuparon las zonas interna, media y externa de las dos áreas de estudio en las dos temporadas de muestreo; mientras que *Ficopomatus uschakovi* (temporada de lluvia*)* y *Stenoninereis* sp. 1 (ambas temporadas) fueron registradas solamente la Ensenada de Rionegro en diferentes temporadas. Finalmente, las especies *Nicolea modesta* es registrada por primera vez para el Golfo de Urabá.

Palabras clave: *Capitella* cf. *capitata,* ecología de poliquetos, estuarios, especies exóticas, *Ficopomatus uschakovi*.

INTRODUCTION

Polychaetes play an important role in benthic communities' ecology; they are commonly used as biological indicators of marine pollution due to their food habits, nutrient recycling in the water column, and their strategic position in food webs (Garay *et al.*, 2002). These organisms are mainly benthic, dominating numerically the infauna, and responding easily to the environmental disturbance; for example, some species increase their abundance while the organic pollution increases, but others species have the opposite behavior (Salazar-Vallejo, 1991; Guerra-García and García-Gómez, 2004).

In the Colombian Caribbean Sea, the polychaetes studies have been restricted to the northern and central coasts. The researchers have focused mainly on taxonomy (see Laverde-Castillo and Rodríguez-Gómez, 1987; Dueñas, 1999; Londoño-Mesa *et al.,* 2002; Báez and Ardila, 2003; Bolaño-Lara *et al.*, 2005; Londoño-Mesa, 2011; Arteaga-Flórez *et al.,* 2014; Arteaga-Flórez and Londoño-Mesa, 2015; Molina-Acevedo and Londoño-Mesa, 2015). However, studies such as Moreno (2002) and Romero-Murillo and Polanía (2008) have presented some ecological aspects in polychaetes, for example, analysis of the taxocenosis process of Polychaeta, Mollusca and Crustacea in red mangrove areas. In particular, Fernández-Rodríguez and Londoño-Mesa (2015) state the need to improve ecological research about polychaetes in Colombia that provides the bases to do more complex studies such as ecotoxicology and bioaccumulation.

Along the Gulf of Urabá, particularly for the zones of the Marirrío Bay and the Rionegro Cove (South Colombian Caribbean), there are no reports about ecological aspects of polychaete species, only a few taxonomic studies have been conducted (Arteaga-Flórez, 2010; Arteaga-Flórez *et al.*, 2014). Thus, this is the first ecological research about polychaetes in the Gulf of Urabá. We focused on the relationship between polychaete species associated with red mangrove roots, *Rhizophora mangle* L*.,* and some physicochemical variables of the water column as temperature, dissolved oxygen concentration, and electrical conductivity, in Marirrío Bay and Rionegro Cove, to evaluate if there is species segregation related to these variables. Also, we made some observations about the spatial distributions of polychaetes within the two study areas. Finally, in this study, variables such as organic matter or grain size are not showed since the data analyzed here belongs to two different projects in which their objectives were also different. Then, we used the common variables from each sampling to do the analysis.

MATERIAL AND METHODS
Study area

The Gulf of Urabá is located in the south end of the Colombian Caribbean (Fig. 1), between Chocó and Antioquia departments. The coastal contour has a shoreline length of 600 km between Tiburón Cape (frontier line with Panamá) and Caribaná Point. It presents a "U"-shaped morphology and it is one of the largest entries of the Caribbean Sea (Blanco-Libreros *et al.*, 2010), forming the second largest estuary in Colombia. Within the Gulf, the high flow of the Atrato River affects the water circulation dynamics, with freshwater from the river flowing in a surface level, and salt water from the gulf entering in a deeper level in the estuarine areas (Blanco-Libreros *et al.*, 2010).

In the Gulf, the coastline is dominated by *Rhizophora mangle* (red mangrove), *Laguncularia racemosa* L. (white mangrove) and *Avicennia germinans* L. (black mangrove) (Blanco-Libreros *et al.*, 2010) forming a diverse mangrove forests that favor biodiversity. Marirrío Bay and Rionegro Cove, two important bays in the Gulf, are considered contrasting in terms of contribution of marine water, freshwater, sediment deposition and industrial or domestic waste (Blanco-Libreros *et al.*, 2010), due to their distance from the river mouths, as well as for their location inside the Gulf. In this region, the economy is based on the banana plantations on a large scale that cover 9607 ha of the territory. The banana production is daily exported abroad from the Colombia Bay Port by international ships; which helps in the dispersion of exotic species (García-Valencia, 2007).

Marirrío Bay is located to the southwestern side of Gulf of Urabá, between Colombia Bay and Pichindí Mouth, close to the area of influence of Leoncito Arm, the southernmost mouth of the Atrato River. There are a few studies about the dynamic of macroinvertebrate communities associated to the red mangrove roots (Ortíz and Blanco, 2012) (Fig. 1A).

Rionegro Cove is already a costal lagoon, located in the northeastern side of the Gulf of Urabá, between Urabalito Mouths, and Arenas Point. It is favored by the refraction of waves at Caribaná Point, making it an important biological region (García-Valencia, 2007) (Fig. 1B).

Fieldwork

Since the data analyzed here belongs to two different projects, the numbers of sampling points are different in each season. Sampling protocols and methods were the same for each survey.

The first sampling was taken in April of 2010, corresponding to dry season. A total of ten stations were sampled: six in Marirrío Bay (Fig. 1A) and four in Rionegro Cove (Fig. 1B). The second sampling was carried out during November 2012, corresponding to rainy season. A total of 12 stations were sampled: six in Marirrío Bay (Fig. 1A) and six in Rionegro Cove (Fig. 1B). Sampling stations were taken in the outer, middle and inner zone of each body of water. Physicochemical variables (temperature, dissolved oxygen and electrical conductivity) were measured at 1 m deep using an YSI multiparameter sensor.

Samplings were conducted according to the following process: (i) Selection of the submerged roots unfixed to the substrate from *R. mangle* trees. Sediment around the roots
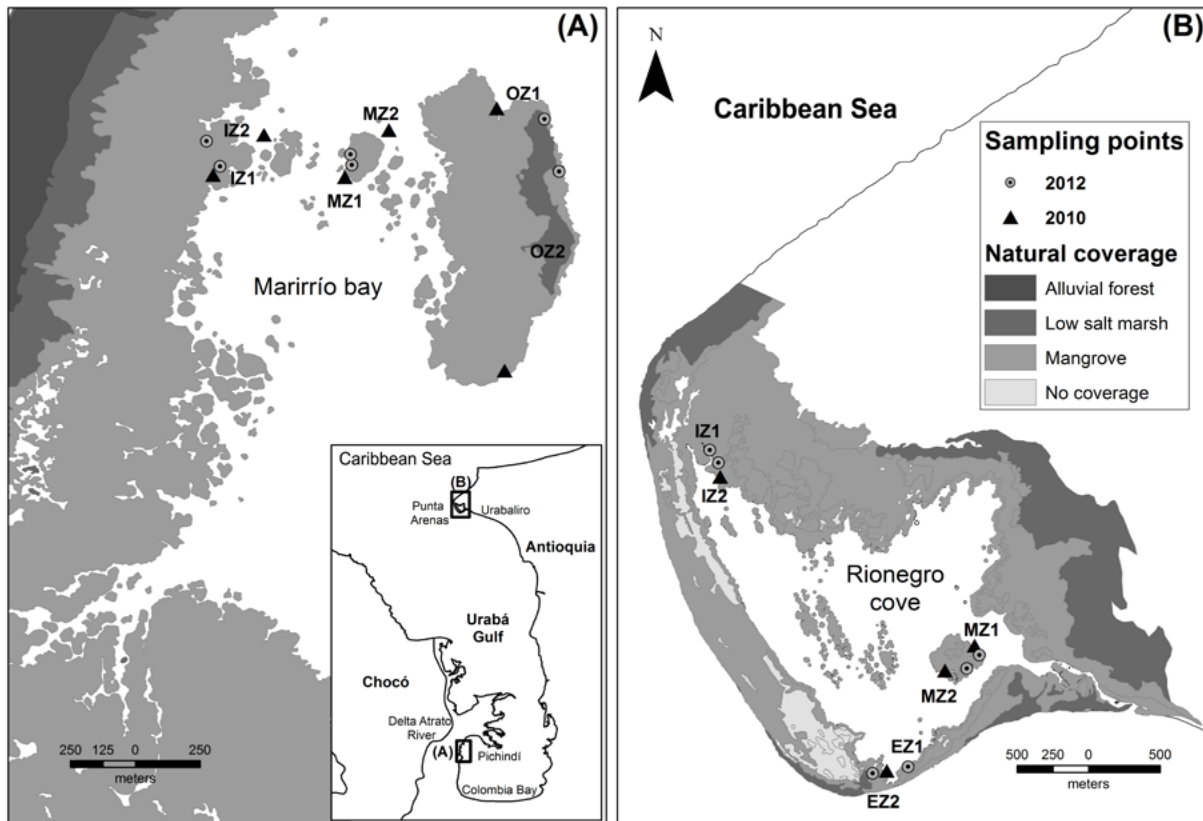
Figure 1. Sampling points in Marirrío Bay (A) and Rionegro Cove (B), Gulf of Urabá, Colombian Caribbean; during raining (2012) and dry (2010) season. Map modified from "*Proyecto Expedición Estuarina-Golfo de Urabá, Fase 1-* Código EA 2013-02-2009".

was not considered. (ii) Cutting of 1–5 roots from different trees. (iii) Roots fixation in formalin-sea water solution 10 %.

Laboratory work

Roots were processed as follows: (i) formalin was removed by multiple freshwater exchanges, using a 250 µm sieve, in order to retain the specimens; (ii) invertebrate specimens were selected and removed from roots bark and solution, using tweezers; (iii) invertebrate specimens were preserved in 70 % ethanol; (iv) invertebrates were separated into higher-level taxa (e.g. phylum, class, family), and (v) polychaetes were identified according to Fauchald (1977) for family and genera, and de León-González *et al*., (2009) for family, genera and species. Finally, all the specimens were properly deposited at the *Colección Estuarina y Marina de la Universidad de Antioquia* (CEMUA).

Data analysis

For the biocenosis analysis, we plot the most abundant species to illustrate the species proportions in three zones of each study area (e.g. inner, middle, outer) for both seasons.

Due to the unbalanced sampling, data could not be compared regarding the spatial-temporal variations. Then,

relationships between environmental variables and the most abundant species were analyzed by a multivariate ordination technique (canonical correspondence analysis, CCA). Considering the small group of environmental variables, we did not use Collinearity or stepwise regression analyses to select the most representative variables used in CCA. We run this analysis for both study areas and seasons using the free software PAST.

RESULTS

Taxonomic comments

A total of 855 polychaete specimens were examined, belonging to six families, nine genera and ten species (Table 1).

The taxonomic identification included the revision of original and/or subsequent redescriptions of every species; names were corroborated according to World Register of Marine Species (WoRMS) or specialized literature.

Seven taxa were identified to species level (Table 1), three taxa were only identified to genus level due to diverse circumstance; for example, the specimen belonging to *Boccardia* sp. 1 had small body size (0.5mm), and specimens belonging to *Stenoninereis* sp. 1 and *Namalycastis* sp. 1 had morphological characters that were not consistent with

literature; thus, new species could be derived from them. In the case of *Capitella* cf. *capitata* (Fabricius, 1780) the morphology of the specimens analyzed agree with Warren (1976) and Frontana-Uribe and Solís-Weiss (2011); however important details of the prostomium noted by Blake *et al.*, (2009) could not be observed due to the small body size of the specimens, thus, in this research our specimens were considered as *Capitella* cf. *capitata*. Finally, in this study we follow the combination *Alitta succinea* (Leuckart, 1847) according to Villalobos-Guerrero and Carrera-Parra (2015) and Read and Glasby (2016).

Biocenosis analysis

For the dry season in Rionegro Cove the most abundant species was *A. succinea* with 49 specimens followed by *Platynereis mucronata* de León-González, Solís-Weiss and Valadez-Rocha, 2001 (14), *Ficopomatus miamiensis* (Treadwell, 1934) (9), *Stenoninereis* sp. 1 (2), *Parasabella lacunosa* (Perkins, 1984) (1) and *C.* cf. *capitata* (1). In particular, *A. succinea* was present in all zones (Fig. 2A) while *P. mucronata, P. lacunosa* and *Stenoninereis* sp. 1 were recorded just in the external zone of Rionegro Cove, and *F. miamiensis* was recorded in the outer and middle zone (Fig. 2A). In the same season, for

Table 1. Polychaete species per family found in Marirrío Bay and Rionegro Cove, Gulf of Urabá.

| Family	Species
Capitellidae Grube, 1862	*Capitella* cf. *capitata* (Fabricius, 1780)
Nereididae Lamarck, 1818	*Namalycastis* sp. 1
Sabellidae Latreille, 1825	*Alitta succinea* (Leuckart, 1847)
	Platynereis mucronata de León-González, Solís-Weiss and Valadez-Rocha, 2001
	Stenoninereis sp. 1
	Parasabella lacunosa (Perkins, 1984)
Serpulidae Rafinesque, 1815	*Ficopomatus miamiensis* (Treadwell, 1934)
	Ficopomatus uschakovi (Pillai, 1960)
Spionidae Grube, 1850	*Boccardia* sp. 1
Terebellidae Johnston, 1846	*Nicolea modesta* Verrill, 1900
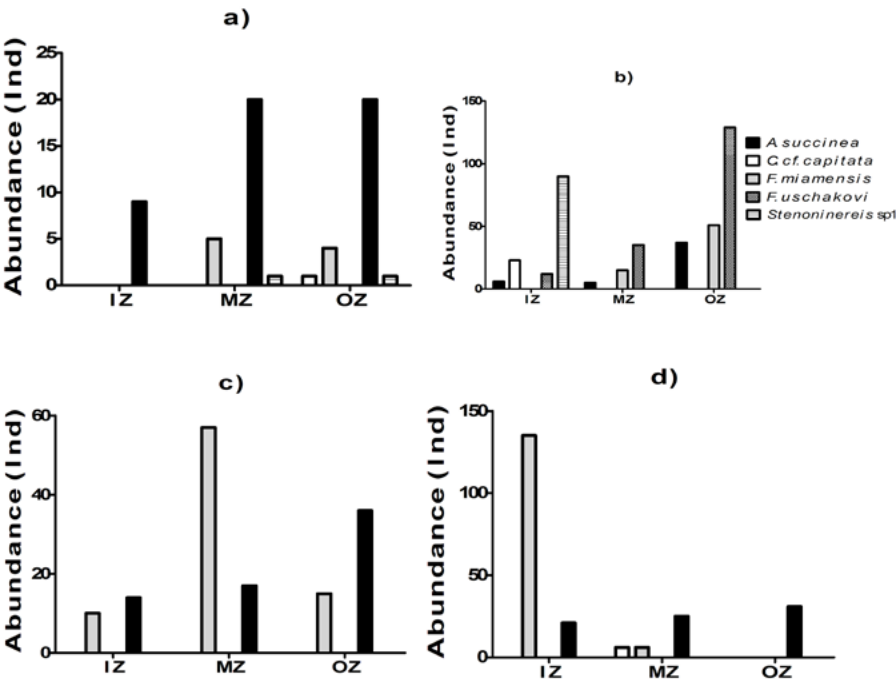
Figure 2. Plot of the most abundant polychaetes species in three zones of Rionegro Cove and Marirío Bay for dry and rainy season. A-B). Rionegro Cove, dry and rainy season, respectively. C-D). Marirrío Bay, dry and rainy season, respectively. Abbreviations: Inner Zone (IZ), Middle Zone (MZ) and Outer Zone (OZ).

Marirrío Bay the most abundant species were *F. miamiensis* and *A. succinea* with 82 and 67 specimens, respectively; these species were present in the whole bay (Fig. 2C). In particular, *F. miamiensis* dominated the middle zone, whereas *A. succinea* dominated in the outer zone (Fig. 2C). Species such as *Boccardia* sp. 1, *Nicolea modesta* Verrill, 1900 and *P. lacunosa* were found in the inner and outer zone of Marirrío Bay with just one specimen per species respectively. Finally, the species *N. modesta* is registered by first time in the Gulf.

For the rainy season in Rionegro Cove, the most abundant species was *Ficopomatus uschakovi* with 176 specimens followed by *F. miamiensis* (66), *Stenoninereis* sp. 1 (90)*, A. succinea* (48), *C.* cf. *capitata* (23). *Ficopomatus uschakovi* (Pillai, 1960) dominated the outer and middle zone while *Stenoninereis* sp. 1 dominated the inner zone (Fig. 2B). It should be noted that when *F. uschakovi* and *F. miamiensis* where found in the same zone and sampling station, *F. uschakovi* was the most abundant species. In the same season, for Marirrío Bay, the most abundant species was *F. miamiensis* with 141 specimens followed by *A. succinea* (77), *C.* cf. *capitata* (6) and *Namalycastis* sp. 1 (1). *Ficopomatus miamiensis* dominated the inner zone and *A. succinea* dominated the middle and outer zone (Fig. 2D). It should be note that just the middle zone presented a greater number of species (*C.* cf. *capitata*, *F. miamiensis, Namalycastis* sp. 1 and *A. succinea*).

Fauna and environmental relationships

The relationship between polychaetes community and environmental variables are shown in the CCA (Fig. 3); only the first axis was statistically significant for polychaetes abundance ($p < 0.05$; eigenvalue: 0.46) and accounted 83.38 % of the total variance. The relationship between environmental variables and the first ordination axis, considering the most abundant polychaetes species, were high for conductivity (R: 0.86) and dissolved oxygen (R: -0.511). From the CCA (Fig. 3), it can be observed that sampling stations are forming two groups. One composed of stations located in Rionegro Cove in the rainy season (Group 1: stations 1-3), and a second group composed of stations located in Rionegro Cove in the dry season and Marirrío Bay for both seasons (Group 2: stations 4-12). Additionally, *F. uschakovi* and *C.* cf. *capitata* show a general affinity for conductivity but with different signs. The same scenario was observed for *A. succinea* and *F. miamiensis* with dissolved oxygen.

DISCUSSION

In this research, the most abundant species were *F. miamiensis, A. succinea* and *F. uschakovi.* In particular, *F. miamiensis* and *A. succinea* were found during the two sampling events in both study areas, which suggest that they are tolerant to a wide range of the physicochemical conditions; for example, *F. miamiensis* showed a significant relationship with dissolved oxygen for the dry season in Marirrío Bay. The behavior of *F. miamiensis* in the Gulf agrees with the observations of Tovar-Hernández and Yáñez-Rivera (2012) in the Mexican Pacific where specimens of *F. miamiensis* presented a wide range of different levels of oxygen, salinity, and temperature.
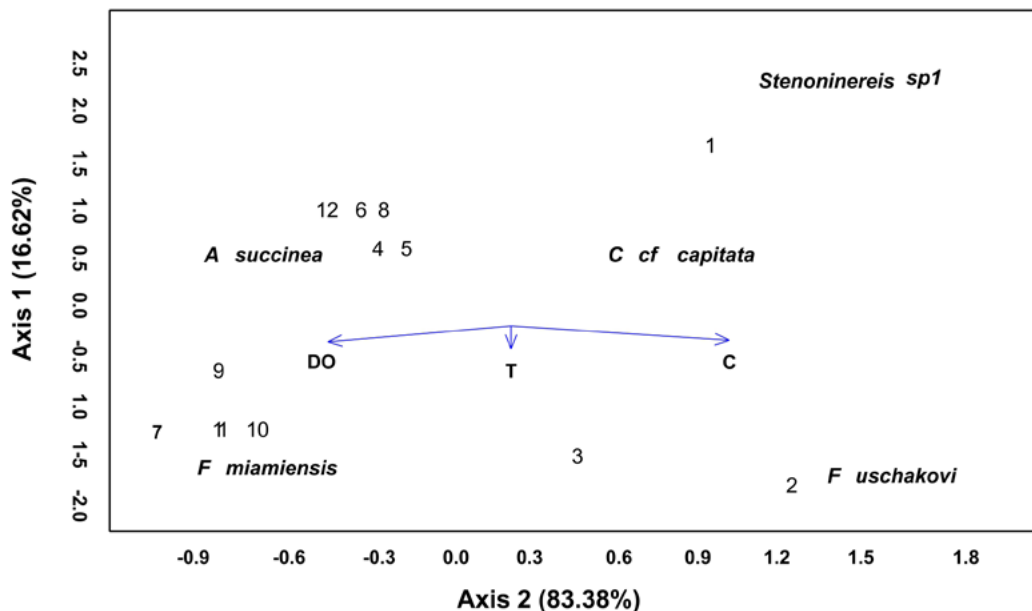
Figure 3. Canonical Correspondence Analysis (CCA) of the most abundant species and environmental variables in Marirrío Bay (MB) and Rionegro Cove (RC), for both seasons. Abbreviations. T: Temperature (°C); DO: Dissolved Oxygen (mg/L); C: Conductivity (mS). Numeration of the sampling stations as follows: **1-2-3** for inner, middle, outer zone of RC in rainy season; **4-5-6** for inner, middle, outer zone of RC in dry season; **7-8-9** for inner, middle, outer zone of BM in rainy season and **10-11-12** for inner, middle, outer zone of BM in dry season, respective.

In the case of *A. succinea*, this species was found in sympatry with all the species recorded in this study; this species has been registered on mangrove roots in the northern Colombian Caribbean in zones with anthropic impact (Londoño-Mesa *et al.,* 2002; Arteaga-Flórez and Londoño-Mesa, 2015). In particular, the high abundance of *A. succinea* in the Gulf could be explain in terms of its optimal reproduction temperature; for example, some authors state that *A. succinea* presents a high mass reproduction events in temperatures >20 °C (Villalobos-Guerrero, 2012); if considering that the mean temperature of the Gulf is 28 °C (García-Valencia, 2007), this scenario could produce frequent reproduction events; however this hypothesis should be proved in future studies.

On the other hand, *F. uschakovi* was only recorded for the rainy season in Rionegro Cove. This species is considered an exotic species, and it was first registered in the Colombian Caribbean by Arteaga-Flórez *et al.,* (2014); given the physicochemical conditions under this species was found, we can consider it as euryhaline and eurythermal. Also, *F. uschakovi* was found in greater proportions in areas with the lowest percentage of dissolved oxygen. This exotic polychaete was observed forming conglomerates of calcareous tubes as reported by de Assis *et al.,* (2008) and in sympatry with *F. miamiensi*s. Probably, these two species are competing for food and space on *R. mangle* roots as was suggested by Arteaga-Flórez *et al.*, (2014).

Capitella capitata is a species known for being an euryhaline species and for its great resistance to living in environments with high organic matter concentration (Méndez, 1993; Méndez, 2006). However, in this research we could not ensure that our specimens are truly *C. capitata* since the key morphological characters suggested by Blake *et al.,* (2009) could not be observed using a traditional microscope, then, determinant conclusions about the ecology of *C.* cf. *capitata* could not be proved.

The two groups of sampling stations observed in the CCA (Fig. 3) could be explained based on the circulation system of each study area. For example, Marirrío Bay and Rionegro Cove have been considered as contrasting areas. In particular, Marirrío Bay has a few water refills; this fact provides to the surface water an oligohaline and/or mesohaline character, due to the action of trade winds from the north and northeast, which exert a force that promotes retention of freshwater solids. In the rainy season, these winds are weaker and blow to the south, so the sediment in the Atrato and other rivers remain confined into Colombia Bay (Ortíz and Blanco, 2012), thus Marirrío Bay remains isolated without water exchange (Group 2 in CCA; Fig. 3). Meanwhile, Rionegro Cove is exposed to seawater from the north of the country due to a background and local wave conditions. In rainy season, Rionegro Cove receives surface runoff into the cove from nearby rivers (e.g. Mulatos River) and swamps (e.g. Marimonda and El Salado) bringing dissolved solids into the cove. Also the outer zone of the cove tends to present an "opening" phenomenon, where the *R. mangle* trees yield to the force of ocean waves increased the entrance area to the cove (Group 1 in CCA; Fig. 3) (Blanco-Libreros *et al*., 2010; Escobar, 2011). However, in dry season this area remains almost isolate without water exchange because *R. mangle* trees occupied the main part of the entrance (Group 1 in CCA; Fig. 3) (Blanco-Libreros *et al*., 2010). These hydrodynamics events affect the diversity and abundance of polychaetes species as noted by Santi and Tavares (2009) and as well as was observed in this research, in where the two study areas present differences in species segregation (Fig. 2).

According to our data, in terms of the environmental preferences, polychaetes species seems to be more related to conductivity and dissolved oxygen levels than temperature, which can be explained by the tropical characteristics of the area, where the surface temperature does not present greater changes throughout the year. Additionally, conductivity and dissolved oxygen are the variables that most varied throughout year in the Gulf (Blanco-Libreros *et al*., 2010; Ortiz and Blanco, 2012), then, is expected that polychaetes species are well adapted to these conditions as observed by Dafforn *et al.*, (2013).

CONCLUSIONS

A major taxonomic resolution and sampling are needed to improve polychaetes species identification; for example, the morphological characters of *Boccardia* sp.1, *Namalycastis* sp. 1 and *Stenoninereis* sp.1 did not matched with literature, then, is possible that new species could be derived from them. Despite of the identification problems of *C.* cf. *capitata*, this species may be key for the right understanding of organic matter dynamics in Rionegro Cove and Marirrío Bay. Then, we suggest increase taxonomical efforts to confirm the identity of these organisms, to use them as biological indicators of high organic matter concentration. Additionally, the species *Nicolea modesta* is registered by first time for the Gulf of Urabá, Colombian Caribbean.

In the case of *A. succinea,* this species was found in sympatry with all the species recorded in this research. Also*,* the exotic serpulid *F. uschakovi* and the native serpulid *F. miamiensis* were found sharing the same roots in the outer zone of Rionegro Cove for the rainy season; but *F. uschakovi* was found in greater proportions than *F. miamiensis,* then, we suggest that these two species are competing for mangrove root resources; however, spatio-temporal analysis should be done to conclude this sentence.

According with the data analyzed in this research, the environmental variables that best explain polychaetes community segregation are the dissolved oxygen and conductivity; temperature seems to have not a significant effect. In terms of spatial distribution, for the most abundant species, we found that *A. succinea, C.* cf. *capitata*

and *F. miamiensis* occupied the inner, middle and outer zones for both study area and seasons, but *F. uschakovi* (rainy season) and *Stenoninereis* sp. 1 (both season) were found just in Rionegro Cove. Finally, it should be considered that this is the first polychaetes ecological approach within the Gulf of Urabá, Colombian Caribbean; therefore, decisive conclusions about the relationship between polychaetes species and water conditions in the Gulf cannot be done. We highlight the need for more research about important ecological aspects of polychaetes such as their relationships with organic matter, grain size, hydrocarboons, heavy metals, its reproduciton patterns, its biological indicator character, its bioaccumulation abillity, as well as their ecological relationships with other benthic fauna associated to *R. magle* in order to improve the knowledge of these animals in the country.

ACKNOWLEDGMENTS

REFERENCES

Arteaga-Flórez C. Poliquetos (Annelida: Polychaeta) asociados a las raíces sumergidas de mangle rojo *Rhizophora mangle*, en el golfo de Urabá, Caribe colombiano. (Tesis de pregrado). Medellín: Instituto de Biología, Universidad de Antioquia, Medellín; 2010. 111 p.

Arteaga-Flórez C, Londoño-Mesa MH. Neréididos (Nereididae, Polychaeta, Annelida) asociados a raíces de mangle rojo, *Rhizophora mangle*, en Islas San Andrés y Providencia, Caribe Colombiano. Invest Mar Cost. 2015;44(1):164-184.

Arteaga-Flórez C, Fernández-Rodríguez V, Londoño-Mesa MH. First record of *Ficopomatus uschakovi* (Pillai, 1960) (Annelida, Serpulidae) in the Colombian Caribbean, South America. Zookeys. 2014;371:1-11. Doi:10.3897/zookeys.371.5588

Assis JE de, Alonso C, Christoffersen ML. First record of *Ficopomatus uschakovi* (Pillai, 1960) Serpulidae (Polychaeta: Annelida) for the Western Atlantic. Rev Nordest Biol. 2008; 9(1):51–58.

Báez DP, Ardilla NE. Poliquetos (Annélida: Polychaeta) del Mar Caribe colombiano.

Biota colombiana. 2003;4(1):89-109.

Blanco-Libreros JF, Londoño-Mesa MH, Bernal G, Osorio A, Polanía JH, Urrego LE, Correa ID. Proyecto Expedición Estuarina Golfo de Urabá Fase 1. Informe Final-Convenio de financiación 2008-ss-120132. Gobernacion de Antioquia-Universidad de Antioquia; 2010. 287 p.

Blake J, Grassle JP, Eckelbarger KJ. *Capitella teleta,* a new species designation for the opportunistic and experimental *Capitella* sp. I, with a review of the literature for confirmed records. Zoosymposia. 2009;2:25-53.

Bolaño-Lara J, Cárdenas-Oliva A, Vásquez-Flórez A. Anélidos poliquetos de fondos blandos de las zonas mesolitoral e infralitoral del Golfo de Morrosquillo y su relación con parámetros físicos durante el período comprendido entre octubre de 2003 y marzo de 2004. (Tesis de pregrado). Barranquilla: Departamento de Biología. Universidad del Atlántico; 2005. p. 34-144.

Dafforn KA, Kelaher BP, Simpson SL, Coleman MA, Hutchings PA, Clark GF, *et al.*, Polychaete Richness and Abundance Enhanced in Anthropogenically Modified Estuaries Despite High Concentrations of Toxic Contaminants. PLoS ONE. 2013;8(9):e77018. Doi:10.1371/journal.pone.0077018

de León-González JA, Bastida-Zavala JR, Carrera-Parra LF, García-Garza ME, Peña-Rivera A, *et al.,* editors. Poliquetos (Annelida: Polychaeta) de México y América Tropical. Monterrey:Universidad Autónoma de Nuevo León; 2009. 737 p.

Dueñas PR. Algunos poliquetos (Annelida) del Caribe colombiano. Rev Milenio Fac Cien Bas Univ de Córdoba. 1999;1:9-18.

Escobar CA. Relevancia de procesos costeros en la hidrodinámica del Golfo de Urabá (Caribe Colombiano). Bol Invest Mar Cost. 2011;40(2):327-346.

Fauchald K. The polychaete worms, definitions and keys to the Orders, Families and Genera. Natural History Museum of Los Angeles Country; 1977. p. 78-146.

Fernández-Rodríguez V, Londoño-Mesa. Poliquetos (Annelida: Polychaeta) como indicadores biológicos de contaminación marina: casos en Colombia. Gestión y Ambiente. 2015;18(1):189-204.

Frontana-Uribe SC, Solis-Weiss V. First records of polychaetous annelids from Cenote Aerolito (Sinkhole and Anchialine Cave) in Cozumel Island, Mexico. J Cave Karst Stud. 2011;73(1):1-10. Doi:10.4311/jcks2009lsc0107

Garay J, Marín B, Vélez AM. Contaminación marino-costera en Colombia. Ospina-Salazar G.H., Acero A, editors. Chapter in: INVEMAR. Informe del estado de los ambientes marinos y costeros en Colombia: año 2001. Santa Marta: Cuartas Impresores; 2002. p. 40-87.

García-Valencia C. Atlas del golfo de Urabá: una mirada al Caribe de Antioquia y Chocó. Instituto de Investigaciones Marinas y Costeras –Invemar– y Gobernación de

Antioquia. Santa Marta: Serie de Publicaciones Especiales de Invemar; 2007. 180 p.

Guerra-García JM, García-Gómez JC. Polychaete assemblages and sediment pollution in a harbour with two opposing entrances. Helgol Mar Res. 2004;58(3):183–191. Doi:z0.1007/s10152-004-0184-4

Laverde-Castillo JJ, Rodríguez-Gómez H. Lista de los poliquetos registrados para el Caribe colombiano, incluyendo comentarios sobre su zoogeografía. An Inst Inv Mar. Punta Betín 1987;17:95-112.

Londoño-Mesa MH, Polanía J, Vélez I. Polychaetes of the mangrove-fouling community at the Colombian Archipelago of San Andres and Old Providence, Western Caribbean. Wetl Ecol Manag. 2002;10(3):227-232. Doi:10.1023/A:1020127814042

Londoño-Mesa MH. Terebélidos (Terebellidae: Polychaeta: Annelida) del Caribe Colombiano. Biota Colombiana. 2011;12(1):17-34. ISSN: 0124-5376

Méndez N. *Capitella capitata* as a biological indicator of organic matter pollution in the littoral of Barcelona. Chapter in: Boudouresque CF, Avon M, Pergent- Martini C, editors. France: Qualité du Milieu Marin: Indicateurs Biologiques & Physico- Chimiques; 1993. p. 161-174.

Méndez N. Life cycle of *Capitella* sp. (Polychaeta: Capitellidae) from Estero del Yugo, Mazatlán, México. J Mar Biol. 2006;86(2):263-269. Doi:10.1017/ S0025315406013117

Molina-Acevedo IC, Londoño-Mesa MH. Terebélidos (Annelida: Polychaeta: Terebellidae) de Isla Fuerte, Caribe Colombiano. Bol Invest Mar Cost. 2015;44(2):253-279.

Moreno P. Taxocenosis Annélida –Mollusca– Crustacea de las raíces sumergidas de *Rhizophora mangle* en Isla San Andrés, Caribe colombiano. (Tesis de pregrado). Bogotá: Programa de Biología Marina, Universidad Jorge Tadeo Lozano; 2002. p. 23-57.

Ortíz LF, Blanco JF. Distribución de los gasterópodos del manglar, *Neritina virginea* (Neritidae) y *Littoraria angulifera* (Littorinidae) en la Ecorregión Darién, Caribe colombiano. Rev Biol Trop. 2012;60(1):219-232.

Read G, Glasby C. *Neanthes succinea* (Leuckart, 1847). World Polychaeta database. 2016. [Accessed 22 February 2016]. Available at: http://www.marinespecies.org/ aphia.php?p=taxdetails&id=130391

Romero-Murillo PE, Polanía J. Sucesión temprana de la taxocenosis Mollusca-Annelida-Crustacea en raíces sumergidas de mangle rojo en San Andrés Isla, Caribe colombiano. Rev Biol Mar Oceanogr. 2008;43(1):63-74.

Salazar-Vallejo SI. Contaminación Marina: Métodos de evaluación biológica. Chetumal, México: Centro de Investigaciones Quintana Roo; 1991. p. 1-54.

Santi L, Tavarez M. Polychaete assemblage of an impacted estuary, Guanabara Bay, Rio de Janeiro, Brazil. Braz J Oceanogr. 2009;57(4):287-303.

Tovar-Hernández MA, Yánez-Rivera B. Ficha Técnica y Análisis de Riesgo de *Ficopomatus miamiensis* (Treadwell, 1934) (Polychaeta: Serpulidae) In: Low-Pfeng AM, Peters- Recagno EM, editors. Invertebrados marinos exóticos en el Pacífico mexicano. Mazatlán, México: Geomare; 2012. p.193-212.

Villalobos-Guerrero TF. Ficha técnica y análisis de riesgo de *Alitta succinea* (Leuckart in Frey & Leuckart, 1847) (Polychaeta: Nereididae) In: Low-Pfeng AM, Peters- Recagno EM, editors. Invertebrados marinos exóticos en el Pacífico mexicano. Mazatlán, México: Geomare; 2012. p 133-165.

Villalobos-Guerrero TF, Carrera-Parra LF. Redescription of *Alitta succinea* (Leuckart, 1847) and reinstatement of *A. acutifolia* (Ehlers, 1901) n. comb. based upon morphological and molecular data (Polychaeta: Nereididae). Zootaxa. 2015;3919(1):15-178. Doi:10.11646/zootaxa.3919.1.7

Warren LM. A review of the genus *Capitella* (Polychaeta:Capitellidae). J Zool Lond. 1976; 180:195-209. Doi:10.1111/j.1469-7998.1976.tb04673.x