

COMMUNITY STRUCTURE OF BENTHIC POLYCHAETE FROM MÁNAMO CREEK, DELTA ORINOCO RIVER, VENEZUELA

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ABSTRACT: Structure of the benthic polychaetes community, collected on soft bottoms of Mánamo creek, was analyzed. Samples were taken with an Eckman dredge and sifted on a sieve of 0.5 mm mesh size. Four hundred-ten specimens were examined and twenty-four polychaete species were identified. Families with the greatest number of organisms were Capitellidae and Spionidae with four species each, *Nephtys buceru* was the dominant species throughout the study and was present at all sampling stations. Diversity index values ranged between 1.17 and 3.44 bits.ind⁻¹. Polychaeta's community was significantly different among areas ($F= 3.37, p<0.05$) and it also varied significantly among sites of these areas ($F= 2.90, p<0.05$). Despite having found low richness values, this work is a significant contribution to the knowledge of species diversity in the Orinoco delta region and on the dynamics of this community, based on their distribution throughout the system, being in this case mainly driven by a salinity gradient.

Key words: Estuarine system, benthos, multivariate analysis, soft sediments, ecology

RESUMEN: Se analizó la estructura comunitaria de macrofauna bentónica recolectada en fondos blandos de caño Mánamo. Las muestras fueron tomadas con una draga Eckman y el material fue tamizado en un tamiz de 0,5 mm de apertura de malla. Se examinaron 410 especímenes, identificándose 24 especies. *Nephtys buceru* fue la especie dominante a lo largo de todo el estudio y común a todas las estaciones. Los valores promedio del índice de diversidad estuvieron comprendidos entre 1,17 y 3,44. La comunidad de poliquetos fue significativamente diferente entre las áreas ($F = 3,37, p < 0,05$) y también varió significativamente entre los sitios de estas áreas ($F = 2,90, p < 0,05$). A pesar de la baja riqueza de especies encontradas, este trabajo representa un gran aporte al conocimiento de la diversidad de especies presentes en la región del delta del Orinoco, así como sobre la dinámica de estas comunidades, referida a su distribución a lo largo del sistema, estando en este caso regido principalmente por un gradiente salino.

Palabras clave: Sistema estuarino, bentos, análisis multivariado, sedimentos blandos, ecología.

INTRODUCTION

The estuarine system is considered as a dynamic ecosystem with fluctuating hydrographic conditions that influence the distribution and abundance of aquatic organisms. These conditions mean that estuaries are considered areas of low diversity of benthic organisms respect to freshwater systems and / or marine. Being salinity and the physico-chemical sediment composition and its stability the parameters related to the distribution of the abundance of organisms and species richness (CARRIKER 1967; WILDISH & KRISTMANSON 1979; DÍAZ-DÍAZ *et al.* 2013)

In 2002, Conservation International (CI) and Fundación La Salle did a quick study of aquatic biodiversity (AquaRAP) in the Gulf of Paria and Orinoco river delta areas, in which a large number of fish (106) and invertebrate (96) species were identified. CAPELO *et al.* (2004, 2008) reported that for the Gulf of Paria and Orinoco river delta at least 350 species of invertebrates are known, and they refer to 29 mollusks, 18 crustaceans, three macroalgae, one scyphozoan, one aquatic phanerogam species, and colonies bryozoan associated with *Melongena melongena* and *Pugilina morio*, but could not identify the species of polychaetes collected and refer to only four families. LASSO *et al.* (2004), LIÑERO-ARANA *et al.* (2010) y DÍAZ-DÍAZ *et al.* (2013) noted that information about the biota of the area, particularly related to aquatic invertebrates, is scarce. In relation to Polychaeta class, only a few taxonomic studies have been

developed (DELGADO-BLAS *et al.* 2010; LIÑERO-ARANA *et al.* 2010; BALZA *et al.* 2013; DÍAZ-DÍAZ *et al.* 2013) but about the community structure of these organisms, information has not been generated so far yet.

In this study the benthic polychaetes community of Caño Mánamo was analyzed based on some ecological indicators and the role that some environmental parameters have on the distribution of abundance and richness of these organisms.

METHODOLOGY AND STUDY AREA

Field and Laboratory Methods

For this study, 8 stations were established (TABLE 1, Fig. 1), distributed in three zones or regions following the proposal of CANALES (1985), who considering the height above sea level and the influence of the tides, proposed a division for the Orinoco river delta into three regions: upper (upper delta), middle (middle delta) and lower (lower delta). Therefore, the stations were distributed as follows: Upper delta: San Rafael, Caño La Iglesia and El Garcero; Middle delta: El Guamal, Las Bonitas and Guinamorena; Lower delta: Isla Misteriosa and El Cidral.

Sediment samples were taken for granulometric analysis and determination of organic matter were made following the methodology described by SEGNINI DE BRAVO *et al.* (2013). Silicates, ammonium, nitrites, nitrates, oxygen dissolved and BOD were determined as described by MARTÍNEZ *et al.* (2013a). Temperature, conductivity, salinity and pH were measured *in situ* with a multiparameter meter Thermo Fisher Model 5 Star.

Quarterly samplings were carried out between March 2011 and January 2012 on eight stations from Mánamo creek (Fig. 1), using a 0.09 m² Eckman dredge. Samples were sieved using a 0.5 mm open mesh. Specimens were fixed in 10 % formaldehyde and preserved in 70 % ethanol. They were examined and structures with taxonomic value were dissected and observed using compound and stereoscopic microscopes. Polychaetes identification was done following the methodology described by DÍAZ-DÍAZ *et al.* (2013), Specimens are deposited in the reference collection of the Laboratorio de Biología de Poliquetos (LBP-Family N°cat./n°specimens) at the Instituto Oceanográfico de Venezuela.

Species richness, density, Shannon-Weaver diversity index (H'), evenness (J'), the biological abundance index (McCLOSKEY 1970), as community parameters, were estimated. VARESCHI index (VARESCHI 1969) was calculated to determine the degree of heterogeneity of the community (DÍAZ-DÍAZ *et al.* 2014)

Data analysis

Bray-Curtis dissimilarity matrix was constructed from the squared root transformed data of abundance by species. Three-factor permutational multivariate analysis of variance (PERMANOVA, ANDERSON 2001)

TABLE 1. Geographic location of sampling stations in the Mánamo canal.

Station	Common name	Lat. N/Long W
S1	San Rafael	09°04'03.53" – 62°05'03.9"
S2	Caño La iglesia	09°11'18.0" – 62°18'17.6"
S3	El garcero	09°17'16.21" – 62°20'15.6"
S4	El guamal	09°23'54.20" – 62°23'25.4"
S5	Las bonitas	09°37'21.20" – 62°22'15.4"
S6	Guinamorena	09°40'07.4" – 62°21'01.8"
S7	Isla misteriosa	09°52'28.9" – 62°21'77.1"
S8	El Cidral	09°56'76.0" – 62°18'56.0"

tested the null hypotheses of no difference among areas (fixed factor, 3 levels: superior delta, medium delta, inferior delta), months (fixed factor, 4 levels: March'11, January'12) June'12, September'12, and sample sites (nested in factor area, 3 sites for each area) for species abundance and richness (using at least 9900 permutations). When differences were found, a Pairwise test was also applied. The probability distribution for the statistics of the Pairwise

test was constructed using Monte Carlo simulations. Nonmetric multidimensional scaling (nMDS) was done on the Bray-Curtis dissimilarity matrix. SIMPER analysis was performed to estimate which species contributed the most to the similarity within each area. Also, we used BIOENV (with permutations) to identify which environmental variables best explain the temporal and spatial pattern of the community. These analyses were performed using the Primer V6.0 software.

RESULTS AND DISCUSSION

Ecological studies on polychaetes in Venezuela are very scarce and particularly in continental waters even more so. Prior to this study, only two works led ecological aspects of the structure and composition of the polychaetes community at the mouth or area of influence of the Orinoco River (LIÑERO-ARANA *et al.* 2010; BONE *et al.* 2011; BALZA *et al.* 2013; DÍAZ-DÍAZ *et al.* 2013; LIÑERO-ARANA & DÍAZ-DÍAZ 2013) so this study constitutes the first contribution to the knowledge of the biodiversity of polychaetes in one of the most important effluents of the Orinoco River. In the referred works it has been pointed out that the communities of polychaetes associated with soft bottoms in this region are characterized by high richness of species but a low density of organisms in relation to coastal marine environments.

Abiotics variables

The results for the abiotic variables shown in the present work correspond to those obtained by MARTINEZ *et al.* (2013a, 2013b) and SEGNINI DE BRAVO *et al.* (2013), they are presented in a summarized way. Salinity ranged from 0.01 to 15.50 ups with an average of 1.39 ± 0.7 ups; the highest values were found at stations near the river mouth (Isla Misteriosa and El Cidral). The percentages of variance provided by this parameter to the dissimilarity between stations is considerably outperforming in most cases 50%. Salinity decreased in all stations in June due to the increased flow of water produced at the beginning of rainy season. However, in El Guamal and Las Bonitas, BOD had higher percentage of contribution to the variance; that could be explained by the increase of organic matter in water with the onset of the rainy season, as well as contributions due to human activity in some sectors of the margins of the creek. This variable has been referred to as one of the most important parameters to be used for determining organic contamination (HENRY & HEINKE 1999). While in

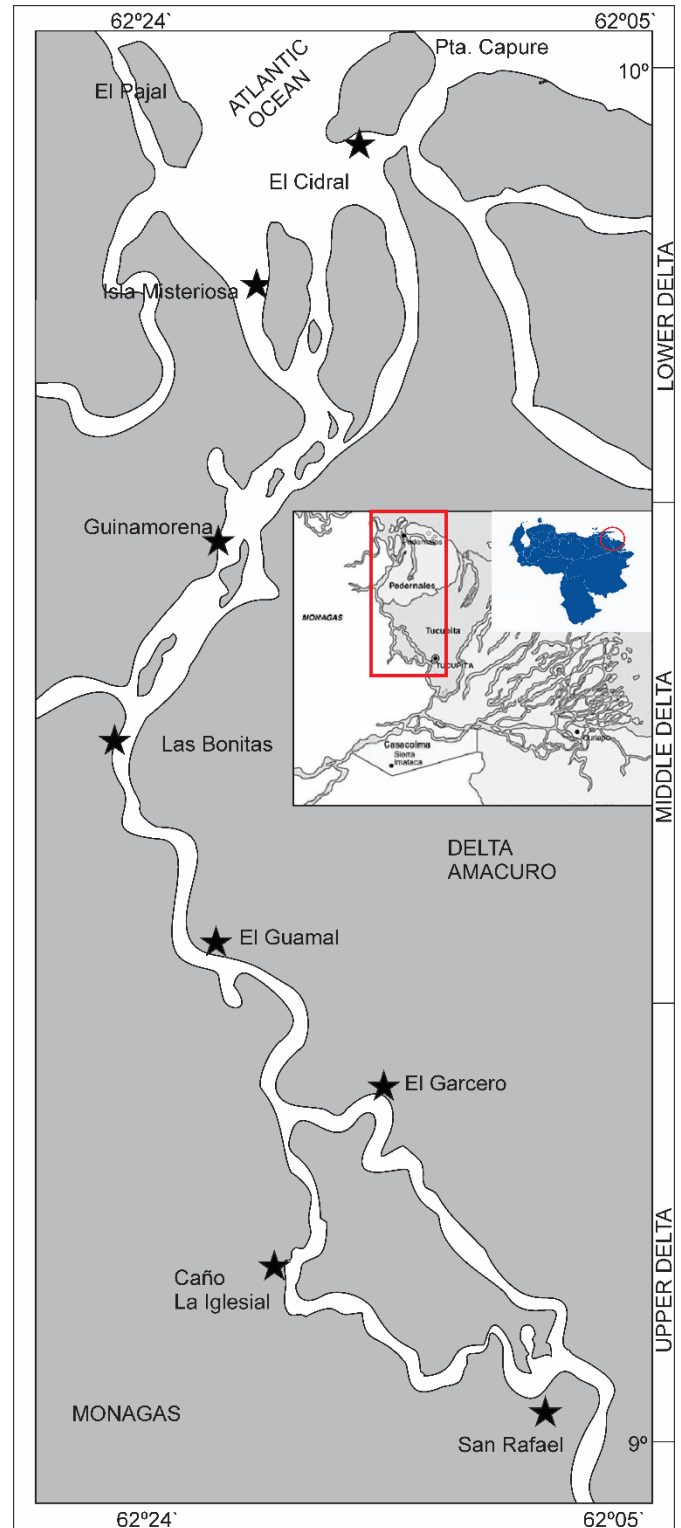


Fig. 1. Geographic location of sampling stations in Manamo Creek, Orinoco Delta.

San Rafael the highest percentage of the variance was due to silicates ($\text{SiO}_4 \text{H}_4$: 87.23%), which is possibly related to some work and drilling extraction of sand in that station. The pH presented fluctuations during all samples and is influenced by heterotrophic bacterial activities and primary productivity in the waters of the channel. Lower pH values were observed during the month of June 2011, associated with the rainy season, when it increases the content of organic matter in the water, while the higher (> 7.20 unid.) were observed during October between the area of San Rafael and Isla Bonita. The dissolved oxygen ranged between 2.84 to 9.37 mg / L with an average of 5.82 ± 1.89 mg / L, the highest concentrations were found in March and the lowest in October, possibly due to increased organic matter caused by the rains (June-September). The temperature fluctuated between 26 °C (El Guamal, November 2011) and 30.3 °C (El Cidral, July 2011), the highest values were found near the mouth. The lowest temperatures were found in Guamal and Isla Bonita, possibly due to a greater depth of the creek (MARTÍNEZ *et al.* 2013a).

The ammonia ranged from 0.003 to 0.086 mg / L with a mean value of 0.016 ± 0.01 mg / L, the highest values were observed in June, at the stations near the sea, indicating a strong heterotrophic activity mainly decomposing organic matter (MARTÍNEZ *et al.* 2013b). NH_4 concentrations increased San Rafael possibly because downloads of untreated domestic sewage from Tucupita city. The concentrations of ammonium (NH_4^+) in rivers usually vary between 0.01 and 0.04 mg / L (MEYBECK 1982), and in coastal waters are unpolluted values usually less than 1 mmol / l (SENIOR, 1994). In the aquatic environment, components of both zooplankton, benthos and nekton excrete ammonia, being they responsible for this, due to the mineralization of organic nitrogen; that is used by the autotrophic organisms as a source of nitrogen and is oxidized by nitrifying bacteria (GARDNER *et al.* 1991, 1993). Similarly, it is found in large concentrations in urban effluent, which is the main source of nitrogen (LAPOINTE & CLARK 1992; LEON *et al.* 1997).

Nitrite values (NO_2^-) were very low, ranging from N.D. 8.00×10^{-3} mg/L to an average value of 2.00×10^{-3} mg/L, the highest NO_2^- values were on stations close to the marine region. These values are those expected in natural waters, which are generally very low. The nonparametric Kruskal-Wallis analysis indicated that the median NO_2^- values showed highly significant differences ($p < 0.0001$) between the samples, identifying, according to the Steel-Dwass-Critchlow-Fligner a posteriori test, three homogeneous groups of medians (March-Apr, Jun and Oct-Jan), with the highest concentrations in the months of October (median: 2.20×10^{-3} mg/L) and January (median: 2.30×10^{-3} mg/L), intermediate NO_2^- values were in June (median: 1.90×10^{-3} mg/L), while the lowest were in March and April (median: 9.00×10^{-4} mg/L), corresponding to the drought period (MARTÍNEZ *et al.* 2013a). The highest concentrations occur towards the mouth of the canal, during the month of October and towards the San Rafael sector, upstream of the canal, during the month of January. MONENTE & COLONNELLO (1997) reported NO_2^- values below 20×10^{-3} mg/L for this region with somewhat higher NO_2^- values during the low water season (drought).

Nitrate values were between 0.01 to 0.41 mg / L with an average of 0.09 ± 0.03 mg / L; the highest concentrations were found on June (median: 0.19 mg / L). The lowest median NO_3 values (March-April: 0.038 mg / L, Oct: 0.035 mg / L and Jan: 0.043 mg / L). The higher NO_3 values in the water may be due to the arrival of the rainy season, during which the accumulated nutrients and pollutants are carried into the rivers and streams of the Orinoco River Delta, Very similar values were reported by MONENTE & COLONNELLO (1997) for this sector Orinoco river delta, although these authors found lower values of NO_3 during the April to June period and intermediate values in the months July and October (0.36 and 0.46 mg / L, respectively). Total nitrogen ranged from 0.16 to 1.12 mg/L with an averaged 0.51 ± 0.16 mg/L; with the highest during the month of June, as the nitrates. An increase in total nitrogen concentrations has been observed towards the mouth of the creek, possibly due to the resuspension of sediments due to the salt wedge and the influence of the tides (MARTÍNEZ *et al.* 2013a).

Granulometric analysis of surface sediments showed a predominance of silty and bioclastic sands, with an average of 65.66% sand, and 21.84% 11.93% silt clay. The largest amount of sand was found in San Rafael and Caño Iglesias stations, these showed the lowest values of richness and abundance. The

content of organic matter in surface sediments ranged from 0.12 to 14.92% and an average value of 2.54% with the highest concentration in Güinamorena station. The remaining stations showed values below 5%. Similar results were reported in rivers of Lithuania (KLAVIŅŠ & VIRCAVS 2001) with concentrations between 1.15 and 12.99% (MARTÍNEZ *et al.* 2013b).

Polychaeta's community structure

Polychaeta's community was represented by 23 species belonging to 12 families (TABLE 2). Capitellidae and Spionidae, were the families with the highest species richness, with four species each one; followed by Ampharetidae and Nereididae with three and two species respectively. *Nephtys bucera*, Nereididae sp. A, *Alitta succinea* and *Capitella cf. capitata* were the most abundant species.

The Vareschi index, was low (8.33%), which indicates the great heterogeneity among the stations, similar results were reported by DÍAZ-DÍAZ & LIÑERO-ARANA (2006) and DÍAZ-DÍAZ *et al.* (2013). In this study only *Nephtys bucera* were common to all stations, follow by Nereididae sp. A, the last one was present in six stations; both species appear to tolerate salinity differences between areas of the creek. The differential distribution of richness and abundances and diversity in the three areas suggest that the physico-chemical water and sediment characteristics play a role, but the anthropogenic activities near of the stations should not be excluded it (DE VOOGD & CLEARY 2008), as it observed in San Rafael and Caño Iglesia, stations located near human settlements, where the lowest values were observed in ecological indicators, throughout the study. These values were higher in the nearest sea stations, suggesting few dominant species

TABLE 2.- Relative abundances and species-specific constancy of the species identified in this study. 1=Caño La Iglesia; 2=El Garcero, 3=El Guamal; 4= El Cidral; 5= Winamorena; 6=Isla misteriosa; 7= Las Bonitas; 8=San Rafael. C: Constant, Acc: Accessory, A: Accidental

Species	1	2	3	4	5	6	7	8	Constance
<i>Nephtys simoni</i>				5		3			A
<i>Nephtys bucera</i>	16	12	18	6	34	11	43	53	C
<i>Sigambra wassi</i>						1			A
<i>Sigambra grubei</i>				1					A
<i>Lepidonotis sublevis</i>						1			A
<i>Alitta succinea</i>		6	5	3	5	6		10	C
Nereididae sp. A	24	12		9	12	13	6		C
Nereididae sp. B				1		3	14		ACC
<i>Isolda pulchella</i>				3	2	1			ACC
<i>Hobsonia floridana</i>				6	3	1			ACC
<i>Leitoscoloplos robustus</i>				3					A
<i>Glycinde solitaria</i>				6					A
<i>Cossura soyeri</i>				2		1	1		ACC
<i>Capitella cf. capitata</i>			9	8	2	13			C
<i>Rhasgua lobatus</i>				1	3	2			ACC
<i>Mediomastus californiensis</i>				6		6			A
<i>Heteromastus filiformis</i>				4	5	4	8		C
<i>Pectinaria gouldi</i>				1		1			A
<i>Dipolydora socialis</i>				4					A
<i>Polydora cf. websteri</i>				1		4			A
<i>Paraprionospio yocoyamai</i>				3	1	2	1		C
<i>Spiophanes sp.</i>				1	1				A
<i>Aphelochaeta sp.</i>				1					A

and therefore a homogeneous distribution of which reflect the abundances probability that two randomly chosen individuals in a community are of the same species. While those stations in the middle and upper area had the lowest values of diversity, richness and / or dominance of one or two species (TABLE 2).

The stations from lower delta (Isla misteriosa and El Cidral) had the greatest species richness average (12 and 15 species), density (294 and 369 ind.m⁻²) and diversity (3.10 and 3.44). Whereas San Rafael and El garcero had the lowest (S: 3.75 and 2.50; D: 36.82 and 32.20 ind.m⁻²; H: 1.56 and 1.17, respectively) (TABLE 3).

Polychaeta's community was significant different among areas (F= 3.37, $p<0.05$) and it also varied significantly among sites inside these areas (F= 2.90, $p<0.05$) (TABLE 4). Furthermore, pairwise test revealed that the community of the first two areas was similar, but there were differences between areas 1 and 3 ($t= 2.38$, $p<0.05$), and area 2 and 3 ($t= 1.79$, $p<0.05$) (TABLE 5).

In terms of richness, the factor sites within area varied significantly and there was also a significant interaction between month and area (F=3.96, $p<0.05$), what means that the temporal dynamics of the polychaetes richness is not the same for each area (TABLE 6). The Pairwise test was made in order to test how this difference in richness among areas for each month was distributed (TABLE 7), finding differences for the first month between area 1 and 2 ($t=3.28$, $p<0.05$), area 1 and 3 ($t=6.86$, $p<0.05$); for the second month between all areas; for the third month between area 1 and 3 ($t=6.01$, $p<0.05$), area 2 and 3 ($t=3.02$, $p<0.05$); for the fourth month only between area 1 and 3 ($t=3.15$, $p<0.05$).

The communities of each one of the three areas were clearly distinguished within the ordination presented in the nMDS (Fig. 2), in which it seems to be an organization of samples (they grouped together in terms of the area in which they belong). Furthermore, there was a gradient of richness visualized in the same ordination, with the lowest richness in area 1, getting higher for the third area, possibly due to the salinity that varies throughout the day due to the cyclical mixture of fresh and salt water in the channel as a result of the rhythm of the tides (high and low), and that to a certain extent each of the areas (high, medium, low) could be characterized by certain species, but it could also show which species are adapted to survive these frequent changes. Among the most abundant species, *N. bucera*, Nereididae sp. A and *A. succinea* were found in all sections of the creek, while *Capitella cf. capitata* and *H. filiformis* were present in the middle and lower Delta and *Polydora cf. websteri* was present only in the lower Delta (Fig. 3).

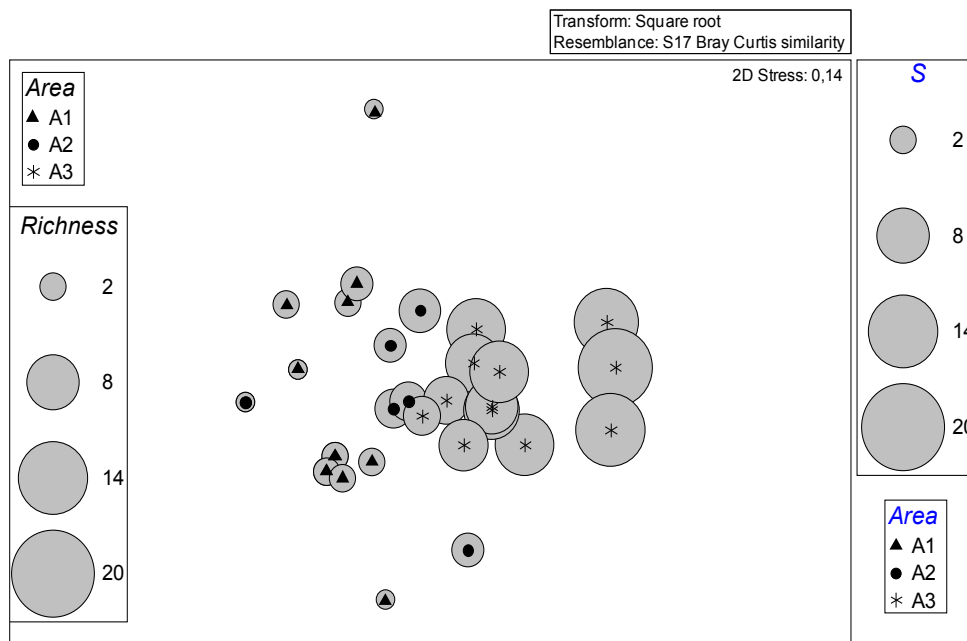


Fig. 2. Nonmetric multidimensional scaling (nMDS) ordinations of samples from the three areas of Mánamo creek using the polychaeta data matrix. Bubble size represents the value of richness for each specific sample (A1: upper; A2: middle; A3: lower).

As for the species that contributed to the similarity by area, *Nephtys bucera* and Nereididae sp A characterized the first area; *N. bucera*, Nereididae sp. B and *Heteromastus filiformis* were characteristic of the second area; while Nereididae sp. A, *N. bucera*, *Hobsonia floridana*, *Capitella cf. capitata* would be responsible for the similarity in the lower delta (TABLE 8). TABLE 9, shows the dissimilarities values between studied zones, with up to 9 species contributing to these values, being El Guamal y Guinamorena the most dissimilar (75.0) and Caño la Iglesia and El Guamal the most similar (38.30).

On the other hand, salinity, NO₃, NT and organic matter, were the environmental variables which best explained the pattern observed in the spatial and temporal characterization of polychaeta community of Caño Mánamo (Rho=0.526; p<0.001). QUADROS *et al.* (2009) obtained similar results, at least for some parameters, BIO-ENV analysis indicated the strong influence of nitrate (NO₃⁻), total nitrogen and clay on the distribution patterns of polychaetes. However, the goal of that study was to examine the effect of this increasingly stressed environment on polychaetes that form an important biotic component of the creek. The hypothesis proposed was to test is that intertidal hydro-sedimentological parameters (salinity, DO, PO₄, NO₃⁻, sand, silt, clay, C.org, TN, and TP) of the creek have changed significantly over the years due to anthropogenic pressure and that they impacted the polychaete populations seriously.

The analysis of the composition and spatial distribution of the polychaete community Mánamo creek, allowed to recognize that this is a stratified stream. Results showed spatial differences in the structure and composition of this community, suggesting the existence of three different communities along the creek, possibly determined by the presence of the salt wedge. Thus, the polychaetes present in the upper delta

TABLE 3.- Ecological indicators for each season and campaign. 1=San Rafael; 2=Caño La Iglesia; 3=El Garcero, 4=El Guamal; 5= Las Bonitas; 6= Winamorena; 7=Isla misteriosa; 8= El Cidral.

	Campaign	1	2	3	4	5	6	7	8
Richness	C1	5	6	0	5	8	12	12	8
	C2	4	6	3	3	6	12	11	18
S	C3	3	6	4	4	6	7	12	11
	C4	3	6	3	4	7	8	12	14
	Ave.	3.75	6.00	2.50	4	6.75	9.75	11.75	15.25
	SD	0.96	0.00	1.73	0.82	0.96	2.63	0.50	3.40
Density	C1	53.03	151.52	0.00	60.61	128.79	250.00	272.73	500.00
	C2	83.33	75.76	53.03	30.30	113.64	204.55	174.24	234.85
(ind.m ⁻²)	C3	45.45	75.76	53.03	37.88	113.64	166.67	356.06	303.03
	C4	45.45	75.76	22.73	37.88	151.52	234.85	371.21	439.39
	Ave.	36.82	94.70	32.20	41.67	126.89	214.02	293.56	369.32
	SD	18.03	37.88	25.78	13.12	17.90	36.79	90.57	121.74
Diversity	C1	2.24	2.08	0.00	2.25	2.59	3.22	3.26	3.91
	C2	1.49	2.32	1.45	1.50	2.20	2.87	2.98	3.95
H'	C3	1.25	2.45	1.66	1.92	1.87	2.11	3.11	2.76
	C4	1.25	2.45	1.58	1.92	2.32	2.54	3.05	3.15
	Ave.	1.56	2.32	1.17	1.90	2.24	2.68	3.10	3.44
	SD	0.47	0.17	0.79	0.31	0.30	0.47	0.12	0.59
Evenness	C1	0.96	0.80	0.00	0.97	0.86	0.90	0.91	0.94
	C2	0.75	0.90	0.91	0.95	0.85	0.80	0.86	0.95
J	C3	0.79	0.95	0.83	0.96	0.70	0.75	0.87	0.80
	C4	0.82	0.95	1.00	0.96	0.83	0.85	0.85	0.83
	Ave.	0.82	0.90	0.69	0.96	0.82	0.82	0.87	0.88
	SD	0.10	0.07	0.46	0.01	0.06	0.06	0.03	0.08

were composed primarily of freshwater taxa and some euryhaline taxa. In contrast, the lower delta featured a community typical of shallow marine environments. The transition between these communities fits the ecotonal model. Greater abundance, richness, and diversity were recorded at the lower delta stations, especially near the mouth; however, the lowest values were recorded at stations adjacent to the end of the salt wedge. The results are relevant considering the limited knowledge on ecological patterns have on benthic polychaete in the area.

The presence of 12 families with 23 species was like that recorded by LIÑERO-ARANA & DÍAZ-DÍAZ (2013) who recorded 13 families and 23 species, of which 15 turned out to be new records for Venezuela, however much lower than that reported for Venezuelan coastal waters (DÍAZ-DÍAZ *et al.* 2017), where more than 500 species have been recorded. The most important polychaetes families at the study site were Spionidae and Capitellidae with four species each. DÍAZ-DÍAZ & ROZBAZYLO (2021) report that these families together with Cirratulidae are common in soft sediment environments, regardless of the organic content of the sediment. The authors explained that this may be related to a very similar functional structure between these communities, dominated by detritivorous polychaetes and which in this case represent more than 70% of the species present along the effluent.

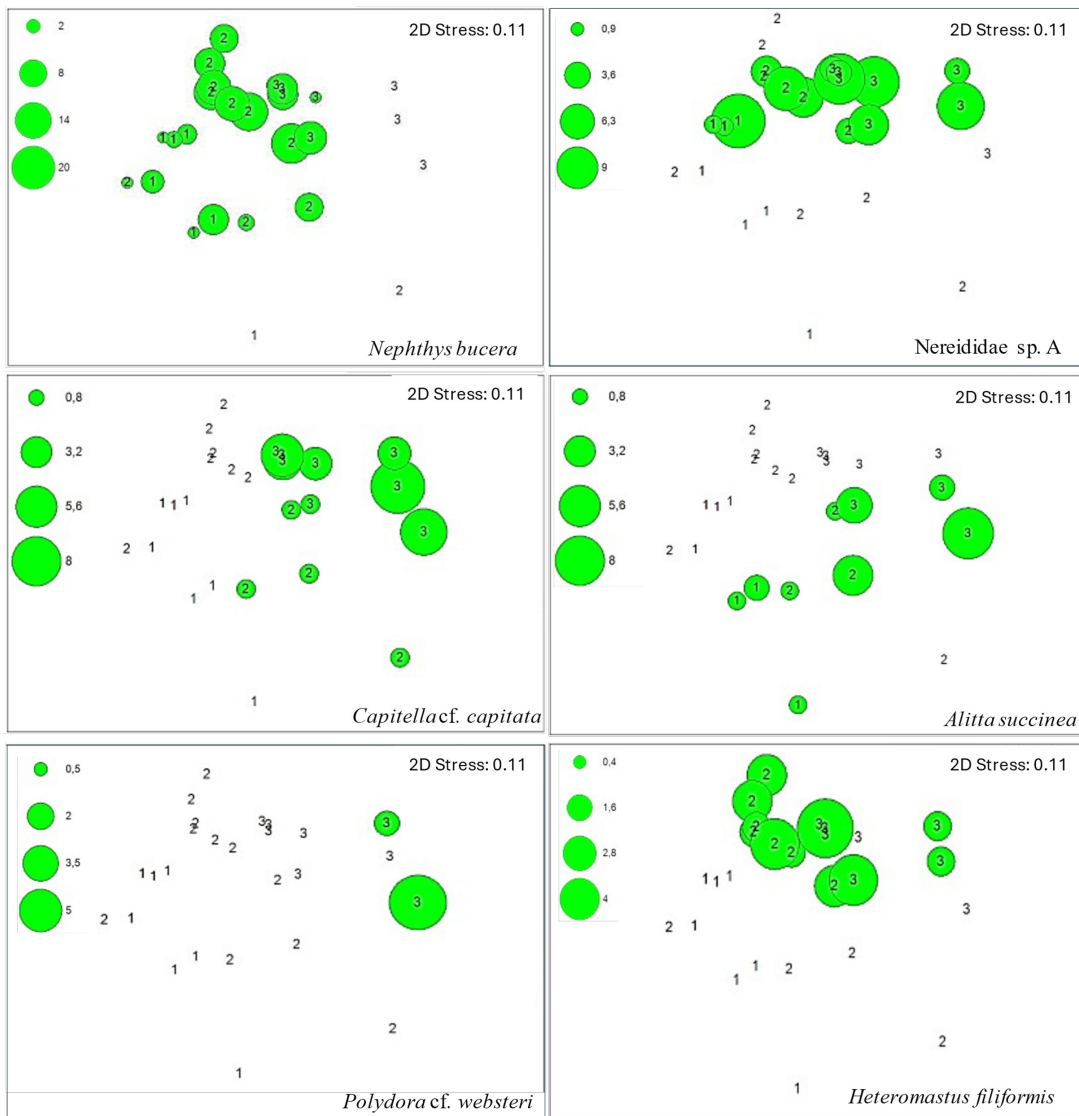


Fig. 3. Nonmetric multidimensional scaling (nMDS) ordinations for the most abundant species from the three areas of Mánamo creek using the polychaeta data matrix. Bubble size represents the value of their respective abundance (1: upper; 2: middle; 3: lower).

TABLE 4. PERMANOVA based on the Bray-Curtis dissimilarities (squared root transformed) of the multivariate data (polychaete's community) of abundance for species, considering a three factors (month, area and site) mixed design.

Source	df	SS	MS	Pseudo-F	P(perm)	P(MC)	%CV
Month	3	6301.5	2100.5	1.89	0.07	0.07	5.19
Area	2	20018	10009	3.37	0.01	0.01	30.94
Sites(Area)	6	19388	3231.3	2.90	<0.001	<0.001	23.19
Month x Area	6	6471.3	1078.5	0.97	0.51	0.51	0
Residuals	14	15596	1114				40.68
Total	31	73889					

TABLE 5. Pairwise test for levels of the area factor, considering the multivariate data of abundance for polychaete species (using Monte Carlo simulations).

Groups	t	P(MC)
Area1, Area2	1.018	0.4048
Area1, Area3	2.3807	0.0066
Area2, Area3	1.7938	0.0589

TABLE 6. PERMANOVA based on the Euclidean distance of the univariate data (polychaete community) of richness, considering a three factors (month, area and site) mixed design.

Source	df	SS	MS	Pseudo-F	P(perm)	P(MC)	%CV
Month	3	23.26	7.7532	5.3383	0.013	0.0107	3.581
Area	2	334.2	167.1	22.917	0.0054	0.0016	75.905
Sites(Area)	6	48.667	8.1111	5.5847	0.0036	0.0041	7.8825
Month x Area	6	34.571	5.7619	3.9672	0.016	0.0146	6.9007
Residuals	14	20.333	1.4524				5.7311
Total	31	554.97					

TABLE 7. Pairwise test between areas for each month considering the univariate data of richness (using Monte Carlo simulations).

Areas	t	P(MC)
Month 1		
Area1, Area2	3.2863	0.0431
Area1, Area3	6.8694	0.0011
Area2, Area3	2.1733	0.1598
Month 2		
Area1, Area2	3.0984	0.0529
Area1, Area3	5.9696	0.0027
Area2, Area3	4.0567	0.0286
Month 3		
Area1, Area2	0.69561	0.5378
Area1, Area3	6.0104	0.0035
Area2, Area3	3.029	0.0575
Month 4		
Area1, Area2	0.69561	0.5347
Area1, Area3	3.1568	0.0319
Area2, Area3	1.9053	0.1488

TABLE 8. Polychaeta species contribution to the mayor average of similarity within each area, for Caño Mánamo during the study.

Groups 1 & 2						
Average dissimilarity = 73,05						
Species	Group 1 Av.Abund	Group 2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Nephtys bucera</i>	2,17	6,08	33,89	1,64	46,39	46,39
Nereididae sp. A	1,17	1,42	12,94	0,89	17,72	64,11
Groups 1 & 3						
Average dissimilarity = 86,28						
Species	Group 1 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nereididae sp. A	1,17	4,25	13,76	1,19	15,95	15,95
<i>Capitella</i> cf. <i>capitata</i>	0	4	12,62	2,79	14,62	30,57
<i>Nephtys bucera</i>	2,17	3,25	10,95	1,25	12,69	43,26
<i>Mediomastus californiensis</i>	0	2,25	7,88	2,39	9,13	52,39
Groups 2 & 3						
Average dissimilarity = 74,77						
Species	Group 2 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Nephtys bucera</i>	6,08	3,25	12,56	1,42	16,8	16,8
Nereididae sp. A	1,42	4,25	10,8	1,1	14,45	31,24
<i>Capitella</i> cf. <i>capitata</i>	0,33	4	9,33	2,12	12,48	43,72
<i>Mediomastus californiensis</i>	0	2,25	6,37	2,16	8,53	52,24

TABLE 9. Polychaeta species contribution to the mayor average of dissimilarity within each station/area, for Caño Mánamo.

Area 1						
Groups SR & EG						
Average dissimilarity = 55,30						
Species	Group SR Av.Abund	Group EG Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Nephtys bucera</i>	1,36	0,67	22,31	1,07	40,34	40,34
Nereididae sp. A	0	0,67	17,39	1,32	31,45	71,79
Groups SR & CI						
Average dissimilarity = 45,89						
Species	Group SR Av.Abund	Group CI Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nereididae sp. A	0	1,18	27,78	4,8	60,54	60,54
Groups CI & EG						
Average dissimilarity = 38,30						
Species	Group CI Av.Abund	Group EG Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Nephtys bucera</i>	1,17	0,67	14,25	0,91	37,21	37,21
Nereididae sp. A	1,18	0,67	13,99	0,85	36,52	73,73
Area 2						
Groups Egu & G						
Average dissimilarity = 75,00						
Species	Group Egu Av.Abund	Group G Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nereididae sp. A	0	1,06	13,14	1,45	17,52	17,52
<i>Nephtys bucera</i>	0,8	1,74	11,37	1,66	15,17	32,68

<i>Heteromastus filiformis</i>	0	0,88	10,66	1,5	14,22	46,9
<i>Rhasgua lobatus</i>	0	0,75	9,1	1,56	12,13	59,03

Groups LB & IM

Average dissimilarity = 58,98

Species	Group LB	Group IM	Av.Diss	Diss/SD	Contrib%	Cum.%
	Av.Abund	Av.Abund				
<i>Capitella cf. capitata</i>	0	1,45	9,39	8,4	15,92	15,92
<i>Mediomastus californiensis</i>	0	1,17	7,66	5,58	12,98	28,91
Nereididae sp. A	0,58	1,14	5,76	1,31	9,76	38,67
<i>Rhasgua lobatus</i>	0	0,75	5,21	1,66	8,84	47,51
<i>Heteromastus filiformis</i>	1,09	0,6	3,98	1,42	6,75	54,26

Groups LB & G

Average dissimilarity = 51,55

Species	Group LB	Group G	Av.Diss	Diss/SD	Contrib%	Cum.%
	Av.Abund	Av.Abund				
Nereididae sp. B	1,23	0	10,06	6,51	19,51	19,51
Nereididae sp. A	0,58	1,06	6,64	1,22	12,89	32,4
<i>Rhasgua lobatus</i>	0	0,75	6,31	1,61	12,25	44,65
<i>Hobsonia floridana</i>	0	0,75	5,87	1,63	11,39	56,04

Area 3

Groups IM & IC

Average dissimilarity = 49,54

Species	Group IM	Group IC	Av.Diss	Diss/SD	Contrib%	Cum.%
	Av.Abund	Av.Abund				
<i>Magelona pettibonea</i>	0	0,8	3,59	1,59	7,26	7,26
<i>Hobsonia floridana</i>	0,3	1	3,31	1,33	6,69	13,94
<i>Nephtys bucera</i>	1,06	0,75	3,24	1,3	6,54	20,49
<i>Alitta succinea</i>	0,42	0,65	2,89	1	5,84	26,33
<i>Rhasgua lobatus</i>	0,75	0,3	2,87	1,34	5,78	32,11
<i>Isolda pulchella</i>	0,25	0,85	2,77	1,31	5,59	37,7
<i>Nephtys simoni</i>	0,58	0,67	2,75	1,14	5,56	43,26
<i>Heteromastus filiformis</i>	0,6	1,13	2,7	1,28	5,44	48,71
Nereididae sp. B	0,8	0,25	2,69	1,29	5,43	54,13

Compared to other works, the results are relatively similar, such as those obtained by MARTIN *et al.* (2004) identified two low diversity faunistic assemblages in the Rio de la Plata estuary (Argentina) the first one was related with a high clay and organic matter contents and dominated by a species of Nereididae family (*Laeonereis culveri*) and presented as secondary species belonging to Capitellidae, Nephtyidae and Spionidae families. The other assemblage was related to the salinity, lower organic matter content and fine sand (sediment dominant fraction), with *L. culveri* and *Capitella capitata* as dominant species, being secondary species belonging to Capitellidae, Nereididae and Spionidae families. Concluding that the abundance of some species of polychaete was positively correlated with mud and organic matter content in the sediment and negatively correlated with the water salinity. Similar results were found by TOMIYAMA *et al.* (2008) who pointed out that the salinity gradient is the main factor responsible for the distribution of polychaetes and molluscs in Natori River, Japan. NEBRA *et al.* (2011), in the Ebro River estuary (in the sense that polychaetes were the dominant group, occupying 49.64% of the total abundance and more than 33% of the richness. Otherwise, ONWUTEAKA (2016) found a strong relationship between polychaetes and salinity along a longitudinal gradient on Bonny River (Nigeria); this gradient is critical salinity ranges which define the characteristic composition and distribution of polychaete fauna within and between stations. This study

also provided important information about the diversity of the salinity gradient and the distribution of species, pointing out the necessity to increase the researches about the physiology and distribution of polychaetes in saline estuaries habitats in the tropics. While DÍAZ-DÍAZ *et al.* (2013) reported 59.33% of the total abundance and 65.71% of the total richness corresponded to polychaetes. Regarding distribution of polychaetes in the effluent, it increases from the upper to the lower delta, which coincides with that reported by BONE *et al.* (2003), who indicated that the distribution of abundance and richness increased towards the mouth area. Despite the low species richness found, this work represents a significant contribution to knowledge of the diversity of species in the Orinoco delta region and the dynamics of this community, based on their distribution throughout the system, being in this case mainly driven by a salinity gradient.

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