GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

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First inventory of the composition and structure of the benthic macrofauna of the San-Pédro port basin's darsine waters (South-West, Côte d'Ivoire)

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GSC Biological and Pharmaceutical Sciences, 2022, 21(03), 157–165

Publication history: Received on 04 November 2022; revised on 15 December 2022; accepted on 17 December 2022

Article DOI: https://doi.org/10.30574/gscbps.2022.21.3.0473

Abstract

Port activities such as ship traffic and dredging of port basin's sediment can impact biological communities such as the benthos, the composition of which remains unknown. Moreover, the knowledge of the ivorian's port basin benthic fauna is of concern to both scientists and port authorities in the development of their activities. This study carried out in July and December 2021, aimed to provide the first data on the composition of San-Pédro's port basin benthic macroinvertebrates communities. For this purpose, four (4) sampling points were defined near the new wharf and in the central channel of this port. The measurements of the physical-chemical parameters of the darsine waters (temperature, salinity, turbidity, dissolved oxygen and lead content) were carried out *in situ* between 6 a.m. and 8 a.m. using a multiparameter. Benthic macroinvertebrates were collected with a Van Veen bucket with the help of two divers. The physical-chemical parameters indicated that the waters were oxygenated and turbid in the construction area of the new wharf. They were salty, warm, and rich in lead in the central channel. 39 species classified in 34 families, 25 orders, 07 classes, and 05 phyla. The phylum of mollusks (with 29 species) was the most preponderant. The distribution of macroinvertebrates was influenced by lead, turbidity, dissolved oxygen, salinity, and temperature. The benthos populations of port basin were lowly diversified and with a fairly balanced organization.

Keywords: Composition and structure; Benthic macrofauna; Port basin; Darsine waters; San-Pédro

1. Introduction

The structure of the port of San Pedro, located in the southwest of Côte d'Ivoire, includes a harbor basin with darsine water trapped by two breakwaters at the entrance of the said port [1]. Port activities such as ship traffic and dredging of the port basin's sediment can have impacts on biological communities among which there are benthic macroinvertebrates. Macroinvertebrates are a very diverse zoological group and occupy a special position in the food webs of aquatic environments. Indeed, they ensure the recycling of detrital organic matter [2]. They act as intermediaries in the transfer of primary production to higher trophic levels [3]. Also, they have variable sensitivities to different stresses such as pollution and habitat modification [4]. In addition, several studies have been carried out on the benthic fauna of the continental shelf of Côte d'Ivoire and have concerned the marine benthos [5, 6, 7]. However, data on San-Pedro port basin's benthic macroinvertebrates composition are almost unavailable to the scientific community. This study aimed to provide the first data on the composition of macroinvertebrate communities in this port basin.

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2. Material and methods

2.1. Study area

San-Pédro's port area is located on the south-western coast of Côte d'Ivoire along the Atlantic Ocean between 4°44'54'' N and 6°38'10'' W [1]. The region is also marked by a very high average hygrometry of 97 % and an average temperature of 25°C to 26°C. The hydrographic network of the city is drained from East to West by five (05) main rivers. These are: the Brimé, the Néro, the Dodo, the Nidia and the San-Pédro. The city also abounds in many small temporary rivers such as the Palabob, the Kré and the Ménégbé [8].

This study was conducted in two sampling campaigns (in July and December 2021). For this purpose, four (04) sampling points were defined in the port basin of San-Pédro: S1 and S2 located near the new ore dock and S3 to S4 located in the extension of the central channel (Figure 1, Table 1)

S1, S2, S3 and **S4**: Sampling site in the port basin

Figure 1 Location of sampling points in the San Pedro's port basin.

Table 1 Geographical coordinates and characteristics of the sampling points

Sites	Geographical coordinates	Depths	Location of sampling points
S1	x=765008 ; y=525003	6	East Basin, near the ore wharf
S2	x=764716 ; y=524612	10	East Basin, near the ore wharf
S3	x=764476 ; y=524323	12	Turning area of the harbour basin
S4	x=764892 ; y=524195	12	At the entrance of the port basin in the main channel

2.2. Sampling procedure

The darsine waters physical-chemical parameters (temperature, salinity, turbidity, dissolved oxygen and lead content) at the sampling points were carried out in situ between 6 a.m. and 8 a.m. using a "*Cobra*" multiparameter.

Benthos sampling was carried out using the armed Van Veen bucket lowered to the bottom. The bucket containing the sediment (surface area of 0.05 m^2 sampled) was raised by two (2) divers in the boat. At each sampling point, six (06) shots of the Van Veen bucket, or a surface area of 0.9 m^2, were made. The collected sediment samples were washed on a 500 µm mesh sieve for pre-sorting, then fixed with 70°C alcohol and preserved in labeled vials. In the laboratory, sorting of different specimens under a binocular loupe at 40X magnification [9]. The identification of different specimens was done with the help of books and publications such as those of: Le Loeuff & Intès [6], Derrien-Courtel

[10], Justine [11], Metral L. & Brisset B. [12], Durand & Levêque [13], Merritt *et al.* [14] et Nelson-Smith *et al*. [15]. The taxonomies of the identified species were confirmed by the Worms [16] and COL [17] databases

2.3. Data analysis

- The Principal Component Analysis (PCA) performed with Statistica Version 7.1 software allowed to characterize the sampling points according to the physico-chemical variables.
- The occurrences of species in the samples of the different sampling campaigns were taken into account to see the regularity of species in the sampling sites.
- Relative abundance was used to identify key macroinvertebrates species representing at least 4% of the total insect population collected at any sampling stations [18].
- The diversity of the communities was made using the Shannon index (H') to quantify the diversity of the benthic macroinvertebrate communities (H = - Σpi*log2pi; With : p representedn the relative abundance of species i in the sample (pi = ni/N) and Piélou's equitability index (E), to evaluate the degree of equilibrium of the benthic macroinvertebrate communities (J = H ' / log 2 S. with S was the number of species in samples) [19, 20].
- The ReDondance Analysis (RDA) performed with the CANOCO 4.5 software, also allowed to establish the relationship between the physicochemical of the darsine waters and the abundances of species [21].
- Spatial variation of physicochemical parameters was evaluated using the Mann-Whitney U-test, and the Kruskall-Wallis test has been used to compare the different average of the parameters between the different sampling sites. A significance level of $p < 0.05$ was considered.

3. Results

3.1. Analysis of the water physico-chemistry

The mean, maximum and minimum values of the physico-chemical variables in the San Pedro harbor basin are recorded in table 2. The highest mean values of temperature (28.93 ± 2°C), salinity (35.76 ± 1 PSU) and lead content (0.31 ± 0.32 NTU) were noted at the entrance to the central channel (point S4). On the other hand, point S1 (near the new pier) recorded the highest average values of dissolved oxygen (4.9 ± 1.01 mg/L) and turbidity (1.58 ± 0.1 mg/L).

Table 2 Average values of physico-chemical variables in the San Pedro's port basin

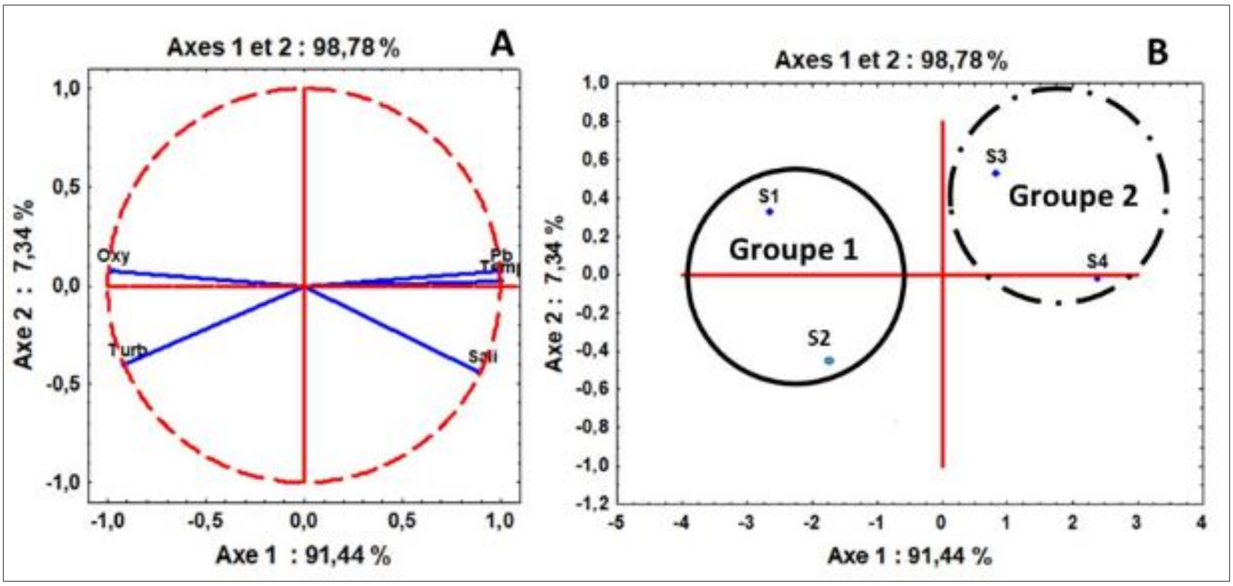
	Sampling points			
Parameters	**S1**	**S2**	**S3**	**S4**
Temperature (°C)	28.48 ± 13.6[a]	28.65 ± 2.86a	28.78 ± 2.9[a]	28.93 ± 2[a]
Salinity (PSU)	35.62 ± 4.1[a]	35.73 ± 2.01[a]	35.71 ± 1[a]	35.76 ± 1[a]
Turbidity (NTU)	1.58 ± 0.1[a]	1.56 ± 1.01[b]	1.49 ± 0.1[a]	0.49 ± 0.07[c]
Dissolved Oxygen (mg/L)	4.90 ± 1.01[a]	3.89 ± 0.20[a]	4.89 ± 0.06[a]	4.88 ± 0.50[a]
Lead (mg/L)	0.29 ± 0.32[a]	0.2 ± 0.02[a]	0.14 ± 0.03[a]	0.31 ± 0.32[a]

3.2. Abiotic typology of sampling sites

The Principal Component Analysis (PCA) also performed from the mean values of the physico-chemical parameters allowed the characterization of the sampling points according to the physico-chemical variables in the San Pedro harbor basin (Figure 2). The first two axes (1 and 2) expressed 91.44% and 7.34% respectively, or 98.78% of the information in the data matrix.

The correlation circle (Figure 3) indicated that axis 1 was positively correlated with temperature, salinity, and lead content. The same axis was negatively associated with dissolved oxygen and turbidity.

The projection of the groups on axis 1 indicated that group I (points S1 and S2) was negatively distinguished by high values of dissolved oxygen and turbidity. On the other hand, group II (points S3 and S4)was positively correlated with the highest values of temperature, salinity, and lead in the positive part.



Temp = temperature, pb = Lead, Sali = Salinity, Oxy = Dissolved Oxygen, Turb = Turbidity.

Figure 2 Principal Component Analysis (PCA) of physicochimical parameters of sampling sites in the San-Pédro's port basin

3.3. Composition of benthic macroinvertebrates

The specific composition and distribution of benthic macroinvertebrates in the San-Pédro harbor basin are shown in table 3. A total of 39 species from 34 families, 25 orders, 7 classes and 5 phyla were collected. The phyla encountered are: Annelids, Arthropods, Cnidaria, Bivalves, Molluscs and Echinodermata.

Table 3 Composition and distribution of benthic macroinvertebrates in the San-Pédro's port basin

Class	Orders	Families	Taxa	S1	S2	S3	S4	
CNIDARIA								
Anthozoa	Alcyonacea	Gorgoniidae	*Eunicella* sp.	x				
ECHINODERMATA								
Asteroidea	Paxillosida	Astropectinidae	*Astropecten* sp.				x	
ARTHROPODES								
Malacostraca	Amphipoda	Leucothoidae	*Leucothoe* sp.	x				
		Gammaridae	*Dikerogammarus* sp.	x	x			
	Décapodes	Cancridae	*Cancer* sp.	x				
ANNELIDS								
Polychètes	Orbiniida	Paraonidae	*Aricidea assimilis*		x	x		
	Phyllodocida	Nereididae	*Nereis sp.*		x			
	Spionida	Spionidae	*Polydora* sp.	x				
	Scolecida	Scalibregmatidae	*Scalibregma* sp.	x				
Clitellata	Haplotaxida	Naididae	*Nais elinguis*			x		

Class	Orders	Families	Taxa	S1	S2	S3	S4	
MOLLUSCS								
Bivalves	Anomalodesmata	Lyonsiidae	*Lyonsia norwegica*				x	
	Cardiida	Tellinidae	*Ameritella versicolor*				x	
	Galeommatida	Lasaeidae	*Bornia sebetia*				x	
	Imparidentia	Lasaeidae	*Lepton* sp.		x	x		
			Lepton trigonale		x	x		
	Mytilida	Mytilidae	*Mytilus galloprovincialis*				x	
	Ostreoida	Ostreidae	*Ostrea edulis*				x	
	Pectinida	Pectinidae	*Chlamys* sp.		x			
	Trigoniida	Trigoniidae	*Neotrigonia margaritacea*		x		x	
	Veneroida	Arcticidae	*Arctica islandica*		x			
		Mesodesmatidae	*Donacilla cornea*		x		x	
		Pisididae	*Pisidium* sp.1				x	
			Pisidium sp.	xx	xx	x	x	
Gastropoda	Architectonicoidea	Architectonicidae	*Pseudotorinia architae*				x	
	Ellobida	Ellobidae	*Melampus* sp.	x				
	Littorinimorpha	Littorinidae	*Littorina obtusata*		x			
			Littorina angulifera				x	
		Rissoidae	*Cingula trifasciata*			x		
	Neogastropoda	Columbellidae	*Parvanachis obesa*		x			
			Parvanachis sp.		x			
		Mitridae	*Mitra sp.*		x			
		Mulicidae	*Nucella lapillus*				x	
		Muricidae	*Muricopsis suga discissus*	x				
			Stramonita haemastoma		x			
		Nassariidae	*Nassaria acuminata*		x			
		Turridae	*Turris nadaensis*		x			
	Patellogastropoda	Patellidae	*Patella* sp.				x	
	Seguenziida	Seguenzioidae	*Granigyra filosa*	x				
	Neotaenioglossa	Thiaridae	*Melanoides* sp.		x			

x= Species collected during one sampling; xx= Species collected during two samplings; - Absence of species ; S1, S2 S3 and S3 : Sampling sites

The phylum of Molluscs (2 classes, 16 orders, 24 families and 29 species) was the most preponderant and diversified. On the other hand, those of Annelids, Cnidaria and Echinodermata, with 1 class, 1 order, 1 family and 1 species each were the least rich in species.

The Bivalve *Dikerogammarus* sp. was only encountered in the vicinity of the new pier (at sites S1 and S2). In addition, the Bivalves *Pisidium* sp. was consistently sampled in the vicinity of the new wharf (points S1 and S2) and once in the turning area in the channel (at sites S3 and S4). *Neotrigonia margaritacea* and *Donacilla cornea* were sampled in the vicinity of the new dock and the channel (at points S2 and S4). As for *Lepton trigonale,* it was only constant at sampling point S2.

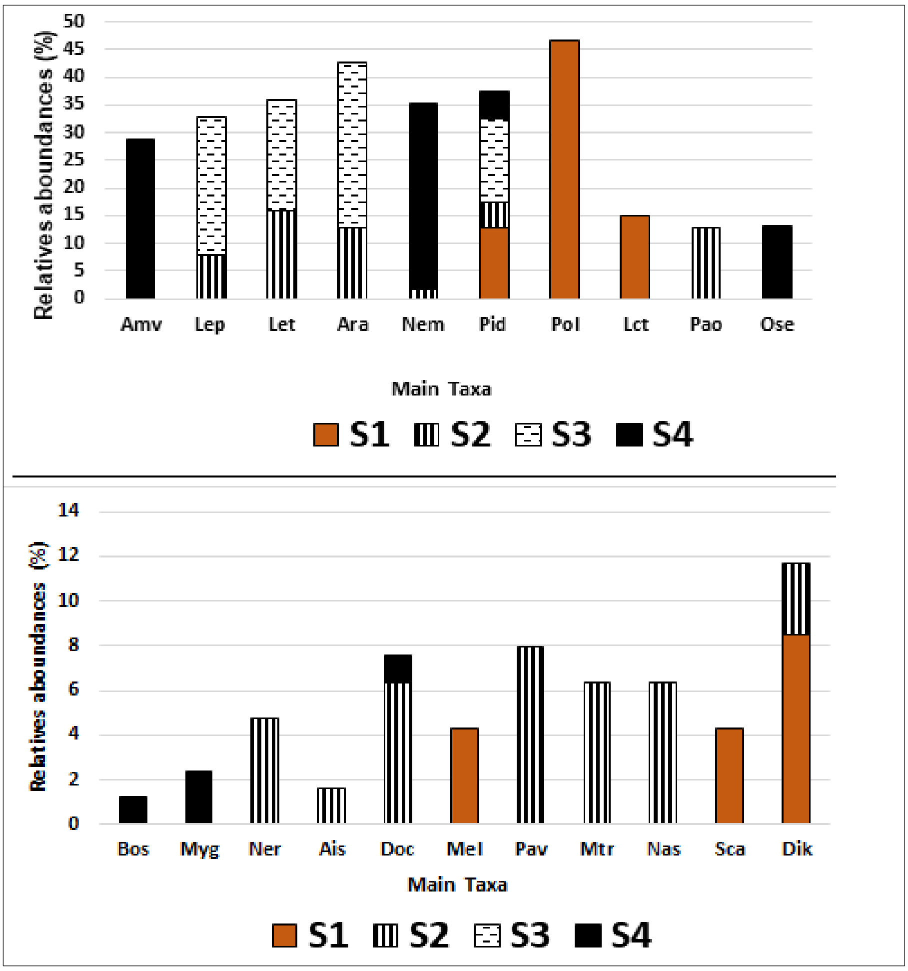
The spatial distribution of benthic macroinvertebrates in the San-Pédro's port area indicated a high specific richness near the new wharf, 27 species (all sites S1 and S2) and a low specific richness, 17 species in the central channel (sites S3 and S4).

3.4. Communities structure

3.4.1. Distribution of abundances of the main taxa

Based on the relative abundances of the collected taxa, 21 major macroinvertebrate taxa populated the Sab-Pédro's port basin sediment (Figure 3). These were: *Ameritella versicolor*, *Bornia sebetia*, *Lepton* sp., *Lepton trigonale*, *Mytilus galloprovincialis*, *Ostrea edulis, Neotrigonia margaritacea, Arctica islandica, Donacilla cornean, Pisidium* sp. *Melampus* sp. , *Parvanachis obesa*, *Parvanachis* sp., *Nassaria acuminata,Leucothoe* sp., *Dikerogammarus* sp., *Aricidea assimilis*, *Nereis* sp., *Polydora* sp. and *Scalibregma* sp.

The spatial distribution of these major taxa is presented in Figure 2 belowing. The analysis shows that *Ameritella versicolor, Bornia sebetia, Ostrea edulis* et *Mytilus galloprovincialis* were most prevalent at station S4. However, S1 was dominated by *Polydora* sp., *Leucothoe* sp, and *Melampus* sp. The taxa *Parvanachis* sp, *Mitra* sp., *Nassaria acuminata, Nereis* sp. and *Parvanachis obesa* were dominant at site S2. Site S3 was dominated by the taxa *Lepton trigonale, Lepton* sp. and *Aricidea assimilis.*



Nem = Neotrigonia margaritacea ; Amv = Ameritella versicolor, Myg = Mytilus galloprovincialis, Ose = Ostrea edulis, , Bos = Bornia sebetia, Dik = Dikerogammarus sp., Mel = Melampus sp., Pid = Pisidium sp., Ara = Aricidea assimilis, Ner = Nereis sp., Ais = Arctica islandica, Doc = Donacilla cornea, Pao = Parvanachis obesa, Pav = Parvanachis sp., Let = Lepton trigonale, Nas = Nassaria acuminata, Sca = Scalibregma sp., Pol = Polydora sp., Lct = Leucothoe sp., Lep = Lepton sp., Mtr = Mitra sp.,

Figure 3 Relative proportions of the main benthic macrofauna taxa in the San-Pédro's port basin

3.4.2. Diversity of communities

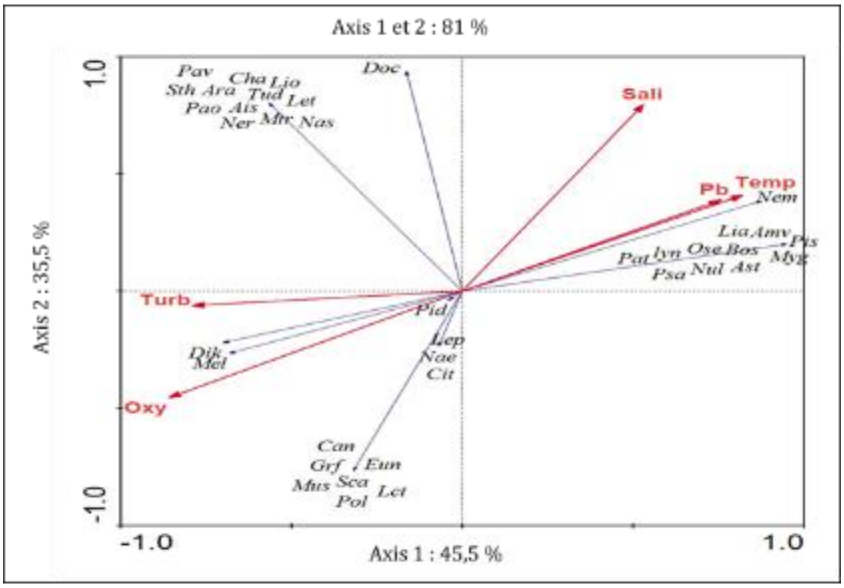
The analysis of the diversity index in the different sampling points showed that the taxon richness of the sampling sites varied from 6 taxa (S3) to 18 taxa (S2) (Table 4). The Shannon index values of three (03) sample points (S1, S3 and S4) were less than 2.5 bits while site S2 recorded a Shannon index of 2.60 bits. The values fluctuated between 1.61 bits (S3) and 2.60 bits (S2). However, the equitability index values were all above 0.5 and fluctuated between 0.70 (S4) and 0.90 (S2 and S3).

Table 4 Statistics of the calculated diversity index

	Sampling points			
Index	**S1**	**S2**	**S3**	**S4**
Taxa_S	10	18	6	14
Shannon_H	1.71	2.60	1.61	1.86
Equitability_J	0.74	0.90	0.90	0.70

3.5. Relationship between water physicochemical parameters and macroinvertebrate distribution

The ReDundancy Analysis (RDA) showed that the first two axes (1 and 2) represented 45.5% and 35.5% respectively, i.e. 81% of the total information (Figure 4). The representativeness of all axes was very significant (*p-value* = 0.0038). Axis 1 was positively correlated with lead and temperature and negatively correlated with turbidity and dissolved oxygen. Axis II was positively associated with salinity.



Temp = temperature, pb = lead content, Sali = Salinity, Oxy = Dissolved oxygen, Turb = Turbidity. Nem = Neotrigonia margaritacea, Pat = Patella sp., Amv = Ameritella versicolor, Lyn = Lyonsia norwegica, Lia = Littorina angulifera, Myg = Mytilus galloprovincialis, Ose = Ostrea edulis, Pis = Pisidium sp.1, Ast = Astropecten sp., Nul = Nucella lapillus, Psa = Pseudotorinia architae, Bos = Bornia sebetia, Dik = Dikerogammarus sp., Mel = Melampus sp., Pid = Pisidium sp., Ara = Aricidea assimilis, Ner = Nereis sp., Cha = Chlamys sp., Ais = Arctica islandica, Doc = Donacilla cornea, Pao = Parvanachis obesa, Lio = Littorina obtusata, Sth = Stramonita haemastoma, Pav = Parvanachis sp., Let = Lepton trigonale, Tud = Turris nadaensis, Nas = Nassaria acuminata, Mtr = Mitra sp., Nae = Nais elinguis, Sca = Scalibregma sp., Pol = Polydora sp., Lct = Leucothoe sp., Can = Cancer sp., Eun = Eunicella sp., Lep = Lepton sp., Cit = Cingula trifasciata, Nul = Nucella lapillus, Mus = Muricopsis sugadiscissus, Mel = Melanoides sp. et Grf = Granigyra filosa

Figure 4 Redundancy Analysis (RDA) highlighting the relationship between physical-chemical parameters and the distribution of benthic macroinvertebrates

The projection of the benthic macrofauna species of the San-Pédro's port basin on the vector axes of the environmental variables (Figure 4), showed that on axis 1, *Neotrigonia margaritacea*, *Patella* sp., *Ameritella versicolor*, *Lyonsia norwegica*, *Littorina angulifera*, *Mytilus galloprovincialis*, *Ostrea edulis*, *Pisidium* sp.1, *Astropecten* sp., *Nucella lapillus*, *Pseudotorinia architae* et *Bornia sebetia* were associated with high values of lead content and temperature. In addition, *Dikerogammarus* sp. and *Melampus* sp. were associated with high values of dissolved oxygen and turbidity. According to axis 2, *Aricidea assimilis*, *Nereis* sp., *Chlamys* sp., *Arctica islandica*, *Donacilla cornea*, *Parvanachis obesa*, *Littorina obtusata*, *Stramonita haemastoma*, *Parvanachis* sp., *Lepton trigonale*, *Turris nadaensis*, *Nassaria acuminata* and *Mitra* sp., were associated with high salinity values. This parameter was opposed to *Scalibregma* sp., *Polydora* sp., *Leucothoe* sp., *Cancer* sp., *Eunicella* sp., *Muricopsis suga discissus* and *Granigyra filosa*.

4. Discussion

The highest mean values for dissolved oxygen (4.9 ± 1.01 mg/L) and turbidity (1.58 ± 0.1 mg/L) were recorded at point S1 near the Mineral Pier. This result could be explained by the movement of waves towards the coast. Indeed, the movement of water would promote its oxygenation [22]. In addition, the return of the waves combined with the sand of the coasts and the effluents of the port activities and works in progress would entrain the suspended matters in the waters of the port basin. This phenomenon would contribute to the high turbidity of the water at this point [23]. In addition, the higher average salinity (35.76 ± 1 PSU) and lead (0.31 ± 0.32 NTU) values noted at the entrance to the central channel (point S4) would be related to the intensity of marine traffic. In addition, the entry of a significant amount of marine water into the central channel would explain the high salinity of sampling point S4.

The benthos of the port basin was dominated by the mollusc phylum (29 species). Martoja [24] estimated that this phylum represents 90% of the marine invertebrates. The consistent collection of *Pisidium* sp. in the vicinity of the new wharf (sites S1 and S2) would indicated its tolerance to disturbance, particularly chemical pollution. For Pellerin & Amiard [22], this organism has the ability to accumulate different chemical compounds. Moreover, ReDondance Analysis (RDA) indicated that this species lives preferentially in low oxygenated areas. The low species richness (17 species) found in the central channel can be explained by the intensity of maritime traffic and the constant inflow of water masses, which would lead to the degradation of benthic macroinvertebrate habitats in this area. Also, the analysis of the community structure from the diversity indices showed that the macroinvertebrate communities of the San-Pédro's port basin were not very diversified and not very balanced [26]. This situation would be related to the sediment dredging activities carried out in this port basin to allow the circulation of ships.

5. Conclusion

This study provided the first data on the composition and structure of the benthos of the San-Pédro's port basin. 39 species from 34 families were recorded. The mollusc phylum was the most diversified in the sediment of the San-Pédro's port basin. *Pisidium* sp., a species tolerant to chemical disturbance, was consistently collected. The distribution of macroinvertebrates was influenced by lead, turbidity, dissolved oxygen, salinity and temperature. The benthos populations in this basin were low diversified and with a fairly balanced organization.

Compliance with ethical standards

Acknowledgments

The authors would like to thank all the institutions that made this work possible, in particular the Autonomous port of San Pedro and the university Jean Lorougnon Guédé authorities.

Disclosure of conflict of interest

No conflict of interest.

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