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Taxonomic Diversity and Structure of Benthic Macroinvertebrates in Aby Lagoon (Ivory Coast, West Africa)

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Abstract: The benthic macroinvertebrates of Aby lagoon (West Africa: Ivory coast) was studied during four seasons (high dry season, high rainy season, low dry season and low rainy season, respectively) from June 2006 to March 2007. The distribution of the benthic macroinvertebrates species was recorded at 13 stations on the whole of the lagoon. A total of 62 taxa of benthic macroinvertebrates belonging to 28 families and 10 orders were listed. The molluscs and crustaceans dominate qualitatively by adding up 51 and 24%, respectively of the total number of organisms. Five taxa (*Corbula trigona* (20%), *Pachymelania aurita* (12%), *Clibernhardius cooki* (7%), Oligochaeta (7%) and *Crassostrea gasar* (6%) accounted for 52% of total abundance. Classification analysis used to perform the characterisation of the lagoon on the basis of benthic macroinvertebrates showed the existence of four main clusters in which the seasonal pattern in benthic macroinvertebrates were very similar in the four seasons. In contrast the species richness and diversity indices were significantly different. Furthermore these indices where higher in the stations closer to the sea and surrounded by mangrove trees (southern area) compared to the inland ones.

Key words: Benthic macroinvertebrates, taxonomic diversity, structure, Aby lagoon, Ivory Coast

INTRODUCTION

Littoral ecosystems such as lagoons and estuaries environments serve as important nursery habitats for host of fisheries species, including other vertebrates and invertebrates, many of which feed on benthic macrofauna (Bazaïri *et al*., 2003). Because of such ecological characteristics there are many literatures on benthic ecology (Mistri *et al*., 2002; Marzano *et al*., 2003; Sconfietti *et al*., 2003). In Ivory Coast, such ecosystems are rather well represented. Indeed, three large lagoons in communication with the Atlantic Ocean can be noticed. It is about the Ebrié lagoon, the vastest (566 km^2) localised in the central part of the littoral frontage, the Aby lagoon (424 km^2) in the eastern and the Grand-Lahou lagoon (190 km^2) in the west. To date, most of the studies on the benthic macrofauna were only devoted to the Ebrié lagoon. Among these studies, the most recent (Zabi and Leloeuf, 1993) is approximately 15 years old. The benthic macroinvertebrates of the two other lagoons remains unknown. According to Albaret (1994), the Aby lagoon for example, is known for its high halieutic productivity. However, it is subjected to natural variations of the climatic conditions (lowers pluviometry) and of the increasing of anthropic disturbances (Sankaré *et al*., 1999). What could have an influence on the faunistic composition in general and particularly the benthic macroinvertebrates often used like good indicator of pollution and water quality (Borja *et al*., 2000; Inglis and Kross, 2000).

The present study fills the gap by making an inventory, examining the population structures (abundance and diversity) of benthic macroinvertebrates through seasons and spaces in order to appreciate the medical state of the Aby lagoon.

MATERIALS AND METHODS

Study area: The Aby lagoon (Fig. 1) located in the far east of Ivory Coast, forms a natural boundary with Ghana and is composed primarily of 3 lagoons which are Aby, Ehy and Tendo. The lagoon covers an area of 424 km^2 and stretches for 24.5 km north to south and 56 km east to west with a maximum width of 15.5 km (Avit *et al*., 1996). The maximum depth is 17 m in its broadest part. The lagoon is connected to the sea in its southern part by an artificial channel and receives freshwater primarily of Bia and Tanoe rivers in the north and the east, respectively.

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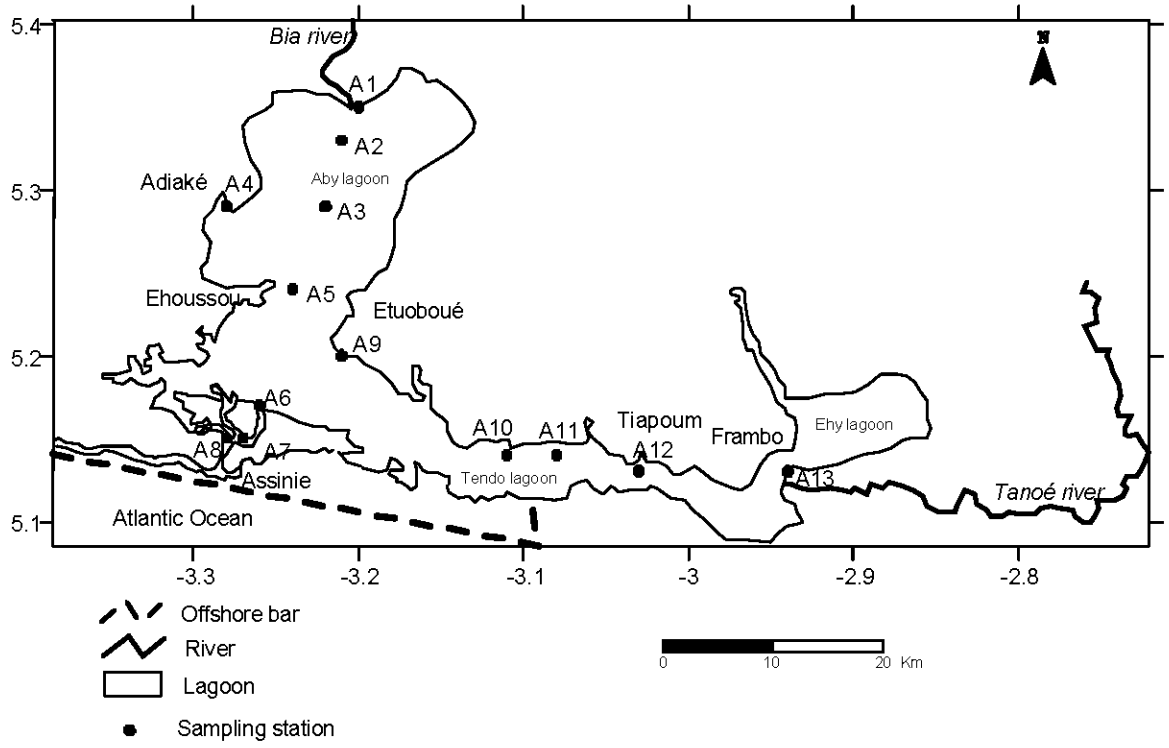

Fig. 1: Map of Aby lagoon showing the sampling stations

Bottom sediments are mostly composed by sand towards the banks and mud with high organic content and shell fragments in the central part of the basin (Sankaré *et al*., 1999).

The vegetation around this lagoon is dominated by a mangrove forest (*Rhizophora racemosa*, *Avicennia germinans*, *Conocarpus erectus*), the palm tree (*Elaeis guineensis*) and coconut (*Cocos nucifera*) cultures.

The climate is an equatorial type with an annual rainfall ranged between 1500 to 1800 mm. It is characterised by two rainy seasons and two dry seasons (Durand and Skubich, 1982). The High Rainy Season (HRS) extends from April to July, the Low Dry Season (LDS) from August to September, the Low Rainy Season (LRS) from October to early December and the High Dry Season (HDS) from December to March.

Sampling and data analysis

Sampling: Thirteen stations abbreviated A1 to A13 (Fig. 1) were sampled seasonally from June 2006 to March 2007 (June 2006, September 2006, November 2006 and March 2007). Soft bottoms were collected using a Van Veen grab and each sample had a surface area of 0.30 m^2. The samples were sieved *in situ* through a 1 mm mesh. The materiel retained on the mesh was fixed in formaldehyde 10%. In the laboratory, the macroinvertebrates were sorted, identified at the lowest taxonomic level possible and counted.

Water parameters (dissolved oxygen, salinity, temperature and transparency) were recorded on field at each site.

Data analysis: The macroinvertebrates structure was described through the species richness (S), the Shannon-Weaver diversity index (H') and abundance (A).

The taxonomic similarity between stations was elucidated by cluster analysis based on the faunal composition (Ward linkage method, Euclidian distance) using the abundance matrix. The abundances were square root transformed to limit the influence of the most dominant taxa. Significant differences in species richness and diversity indices were performed using Kruskal-Wallis test followed by Rank multiple comparison tests. All these analysis were carried out using the STATISTICA 7.1 software computer.

RESULTS

Abiotic parameters: The average values of the abiotic water variables measured on the surface during the study

were mentioned in Table 1. Temperature ranged between 26.3 (station A8, LDS) and 32.0°C (station A5, HDS), salinity between 0 PSU (stations A10 to A13, HRS; A1, A12, A13, LDS; A1, A2, A10 to A13, LRS) and 12.3 PSU (station A8, HDS), dissolved oxygen between 2.89 mg L^{-1} (station A13, LDS) and 13 mg L^{-1} (station A7, HDS) and transparency between 30 cm (station A13, HDS) and 110 cm (station A9, LDS).

Taxonomic composition: A total of 62 taxa of benthic macroinvertebrates belonging to 28 families and 10 orders were collected during this study (Table 2). The orders are: Mesogastropoda and Eulamellibranchia for the Mollusca, Amphipoda, Isopoda and Decapoda for the Crustacea, Diptera, Coleoptera and Trichoptera for the Insecta, Nereidiformia and Capitelliformia for the Polychaete. Molluscs and Crustaceans with 64% of the taxonomic richness dominate qualitatively this biotic structure.

The dominance of both classes also appears on the quantitative level by adding up, respectively 51 and 24% of the total number of organisms. Five of the taxa collected accounted for 52% of total abundance. This group comprised *Corbula trigona* (20%), *Pachymelania aurita* (12%), *Clibernhardius cooki* (7%), Oligochaeta (7%) and *Crassostrea gasar* (6%). Only a species (*Corbula trigona*) is common to all the stations.

Spatial and seasonal pattern: Species richness and diversity indices have great variability between the stations (Fig. 2). The species richness and diversity indices displayed two gradients. The first gradient from the north (mouth of Bia river in the lagoon) to the south

Table 1: Average data of temperature, water salinity, oxygen percentage saturation and transparency (Secchi disk) measured on the surface during the sampling campaigns

	Temperature (°C)			Salinity (PSU)			Dissolved oxygen (mg L^{-1})			Transparency (cm)		
Seasons	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
HRS	29.18	27.70	31.00	1.08	0.00	2.10	6.60	4.00	9.90	0.62	0.30	82.00
LDS	26.72	26.30	27.30	1.87	0.00	10.00	5.21	2.89	7.23	0.63	0.35	80.00
LRS	30.05	28.30	31.10	1.18	0.00	5.80	7.63	5.90	10.40	0.75	0.40	110.00
HDS	30.81	29.30	32.00	6.05	1.50	12.30	8.13	6.20	13.00	0.52	0.40	60.00

HRS: High Rainy season; LDS: Low Dry season; LRS: Low Rainy Season; HDS: High Dry Season

Table 2: Taxonomic list of benthic macro invertebrates found at the thirteen stations in Aby lagoon during the present investigation

					Stations											
Class	Order	Family	Taxon	Acronym	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Mollusca	Mesogastropoda	Neritidae	*Neritina afra*	Nafr				+	+	+					+		
			Neritina andansoniana	Nand				+	+		+						
			Neritina cristata	Ncri				+	+	+							
			Neritina glabrata	Ngla				+	+	+	+			+		+	+
			Neritina kuramoensis	Nkur				+	+		+	+					
			Neritina oweniana	Nowe				+	+								
			Neritina rubricata	Nrub				+	+								
		Thiaridae	*Melanoides tuberculata*	Mtub		+			+	+							+
			Pachymelania aurita	Paur	+			+	+	+	+	+		+			+
			Pachymelania byronensis	Pbyr	+	+		+	+		+	+					
			Pachymelania fusca	Pfus				+	+	+	+	+			+		+
			Pachymelania fusca quadriseriata	Pfuq				+	+	+	+	+					
			Potadoma freethii	Pfre				+	+			+					
		Potamididae	*Tympanotomus fuscatus*	Tfus		+		+	+						+		+
			Tympanotomus fuscatus radula	Tfur					+	+							
	Eulamellibranchia	Corbulidae	*Corbula trigona*	Ctri	+	+	+	+	+	+	+	+	+	+	+	+	+
		Donacidae	*Iphigenia delesserti*	Idel				+			+	+					
			Iphigenia laevigata	Ilae						+	+	+	+				
		Ostreidae	*Crassostrea gasar*	Cgas						+	+	+					
		Tellinidae	*Tellina ampullacea*	Tamp								+					
Crustacea	Amphipoda	Corophiidae	*Corophium acherusicum*	Cach					+	+	+	+					
			Corophium curvispinum	Ccur				+	+	+	+						
			Corophium orientale	Cori					+		+	+					
			Corophium sp.	Cosp			+		+	+	+	+					
		Gammaridae	*Echinogammarus* sp.	Ecsp						+	+						
			Gammarus chevreuxi	Gche			+				+						
			Gammarus pulex	Gpul			+	+		+	+			+			
			Gammarus roeseli	Groe					+	+	+	+					
			Gammarus sp.	Gasp					+	+	+	+					
	Isopoda	Cirolanidae	*Excirolana latipes*	Elat					+	+	+	+					

Table 2: Continued

					Stations												
Class	Order	Family	Taxon	Acronym	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
		Ligiidae	*Ligia exotica*	Lexo					+	+	+	+					
		Sphaeroma-tidae	*Sphaeroma terebrans*	Ster					+	+	+	+					
	Decapoda	Alpheidae	*Potamalpheops monodi*	Pmon					+	+	+	+					
		Palaemonidae	*Nematopalaemon hastatus*	Nhas						+	+						
		Penaeidae	*Penaeus notialis*	Pnot				+		+	+						
		Gecarcinidae	*Cardiosoma armatum*	Carm					+	+	+						
		Portunidae	*Callinectes* sp.	Casp					+	+	+	+					
		Potamidae	*Potamon* sp.	Posp				+			+						
		Diogenidae	*Clibernhardius africanus*	Cafr					+	+	+	+	+	+			
			Clibernhardius cooki	Ccoo	+			+	+	+	+	+	+	+	+	+	+
Insecta	Coleoptera	Elmidae	*Parasetodes* sp.	Pasp													+
	Diptera	Chironomidae	*Ablabesmya dusoleili*	Adus	+				+							+	
			Ablabesmya pictipes	Apic	+											+	
			Chironomus imicola	Cimi	+	+										+	
			Nilodorum brevipalpis	Nbre	+				+					+		+	+
			Nilodorum rugosum	Nrug	+											+	+
			Polypedilum deletum	Pdel	+	+			+					+		+	+
			Polypedilum fuscipenne	Pfus	+				+					+		+	+
			Stenochironomus sp.	Stsp	+	+										+	+
			Stictochironomus caffrarius	Scaf	+	+			+								
			Stictochironomus puripennis	Spur	+					+						+	+
	Trichoptera	Leptoceridae	*Potamodytes* sp.	Ptsp													+
Oligochaeta				Oligo	+	+	+	+	+	+	+		+	+	+	+	
Polychaeta	Nereidiformia	Amphin-omidae	*Hermodice carunculata*	Hcar							+	+					
		Eunicidae	*Marphisas anguinea*	Msan						+							
		Glyceridae	*Glycera gigantea*	Ggig						+							
		Nephtidae	*Nephthys inermis*	Nine							+	+					
			Nephthys polybranchia	Npol					+	+		+	+				
		Nereidae	*Nereis diversicolor*	Ndiv		+				+	+	+	+			+	
			Nereis indica	Nind	+						+	+	+		+		
			Perinereis cultrifera	Pcul						+		+	+				
	Capitelliformia	Phillodocidae	*Eulalia viridis*	Evir							+						
5	10	28	62		16	10	5	22	41	34	38	28	5	10	7	14	15

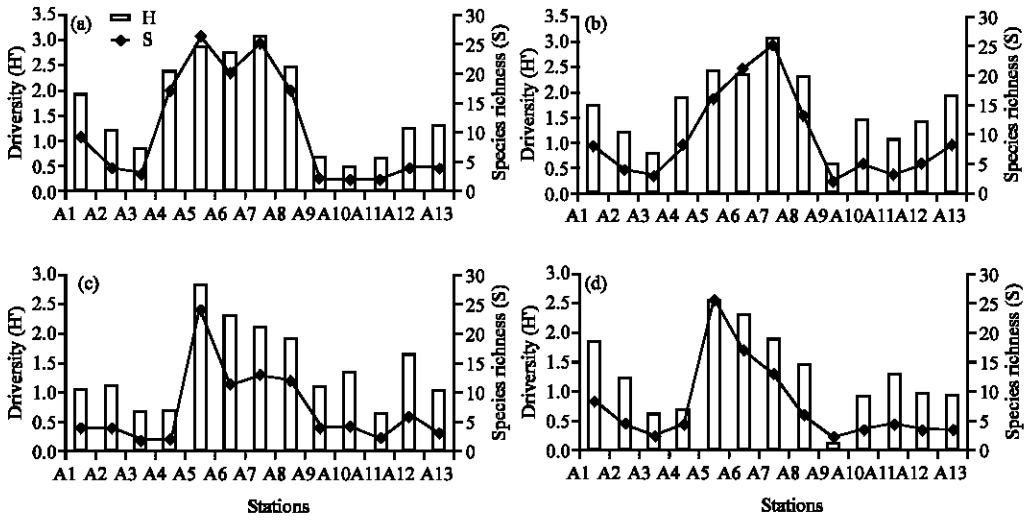

Fig. 2: Community indices of benthic macroinvertebrates in the thirteen stations and the four sampling campaigns in Aby lagoon, (a) HRS: High Rainy Season, (b) LDS: Low Dry Season, (c) LRS: Low Rainy Season and (d) HDS: High Dry Season

towards the point of contact of the lagoon and the sea. The second is from the eastern part (entrance of Tanoe river in the lagoon) to the centre of the lagoon. In both cases, species richness and diversity indices increase. Stations A2, A3 in the north and A9, A10, A11 in the east displayed the low values of the species richness and diversity indices. In several cases the highest average species richness and diversity indices were recorded in station A5. In addition, these indices have a similar pattern in the four seasons.

Cluster identification: The cluster analysis (Fig. 3) showed 4 main groups (Euclidian distance of 30). Cluster I is mostly consisted of samples of the southern stations in the south of the lagoon. This part of the lagoon is influenced by seawater and the shoreline is fringed by mangrove forest. Only two stations (A4, A5) constituted Cluster II. Both stations were closed to the town of Adiaké and the village of Ehoussou respectively. In Cluster III, except the sample of station A4 in the high dry season ($A4_4$), all the other samples ($A9_4$, $A10_3$, $A10_2$, $A3_3$, $A3_4$, $A9_1$, $A9_3$, $A2_3$, $A3_1$ belonged exclusively to the stations found in the central part of the lagoon. These stations were characterised by high deep and muddy substrate. Finally, in Cluster 4, stations were mostly located at the mouths of freshwaters and the lagoon in its northern and eastern part. These stations were shallow and floating macrophytes such as *Eichhornia crassipes* and *Pistia stratiotes* were present. Overall, the species richness and diversity indices were significantly different between clusters (Kruskal-Wallis test, $p<0.001$). Species richness was significantly higher in cluster 1 and 2 compared to cluster 3 and 4 (Rank Multiple Comparison Test, $p<0.001$) (Fig. 4). In the same way, the diversity indices were significantly lower in the clusters 3 and 4 compared to the two ones (Rank Multiple Comparison tests, $p<0.001$) (Fig. 4).

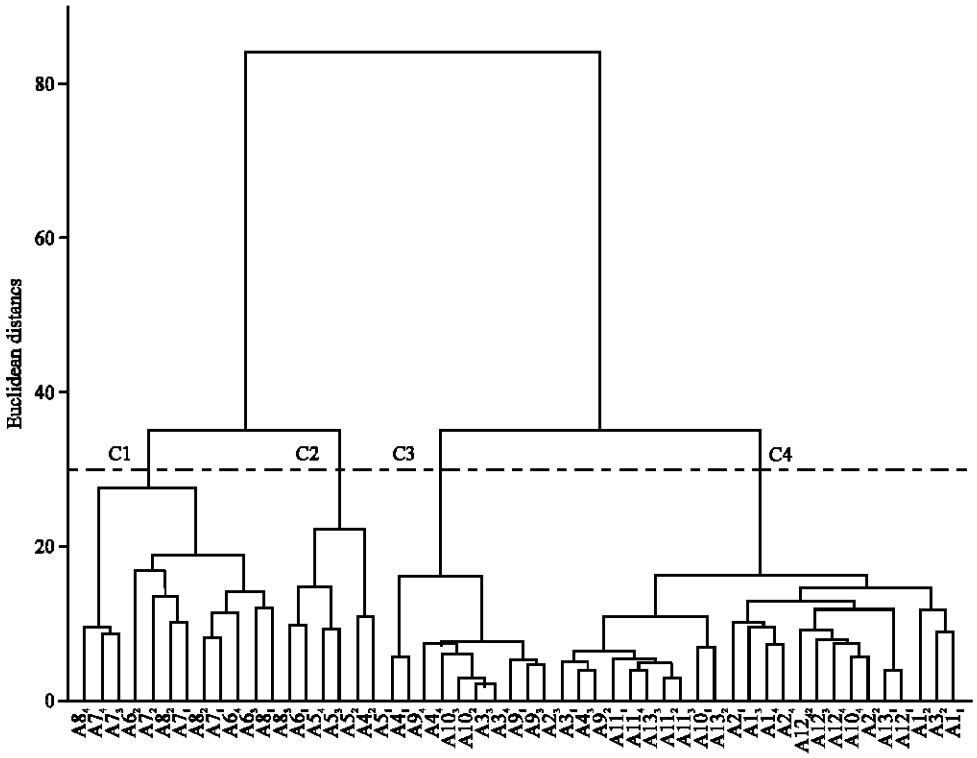

Fig. 3: Cluster analysis of benthic macroinvertebrates showing similarities between the sampling stations in Aby lagoon. C1: Cluster 1, C2: Cluster 2, C3: Cluster 3, CIV: Cluster IV; A1 to A13: stations; in index: 1 = HRS (High Rainy Season), 2: LDS (Low Dry Season), 3: LRS (Low Rainy Season), 4: HDS (High Dry Season)

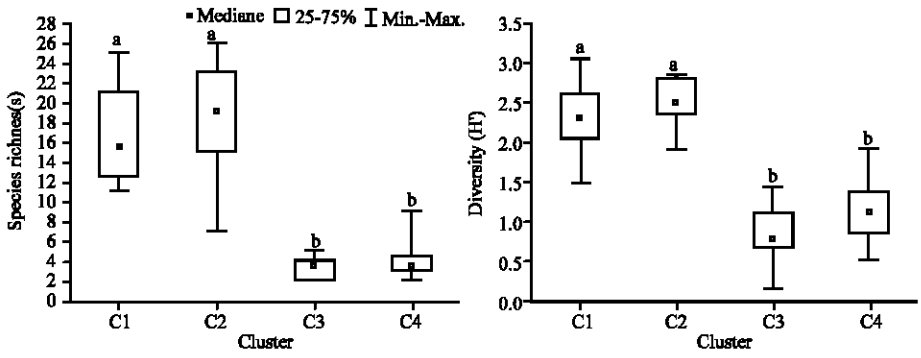

Fig. 4: Box-plots showing differences in species richness and diversity indices between the clusters. The box is corresponding to 50% of the values, the point in the box to the median and vertical bars to the minimum/maximum values. The various alphabetical letters on the box-plots indicate a significant difference ($p<0.05$; multiple comparison test) between clusters; there is no significant difference between the box having an alphabetical letter in common ($p>0.05$)

DISCUSSION

The taxonomic structure of benthic macroinvertebrates of Aby lagoon is characterised by the gastropoda, the bivalvous, the amphipoda, the isopoda and the polychaetes. This taxonomic list is common to the traditional ones in the lagoons environment as suggested by Mistri *et al.* (2002) and Bazaïri *et al.* (2003). In addition to the traditional groups, insects and oligochaetes were listed in Aby lagoon.

The taxonomic list obtained (62 taxa) is the first of the kind in the Aby lagoon. Compared to the list of other lagoons (Mergaoui *et al.*, 2003; Munari *et al.*, 2003; Marchini *et al.*, 2004; Chaouti and Bayed, 2005), the Aby lagoon appears rich in benthic macroinvertebrates. The high number of species may be explained by the fact that the Aby lagoon is connected to the sea and receives freshwaters from the Bia and Tanoé rivers. According to Zabi and Leloeuf (1993), such a lagoon is favourable to provide a habitat for the three groups of organisms in a lagoon. They are sea, brackish and freshwater species.

The spatial distribution of these macroinvertebrates is variable according to the sectors of the lagoon. The southern part of the lagoon (cluster 1) is characterised by a more diversified settlement of macroinvertebrates. That could be explained by the presence of the mangroves forests used as habitats and nurseries for many species (Sankaré *et al.*, 1999) and the influence of seawater from where, the lagoon receives salt by the surge of the waves. Indeed, according to Menif and Ben Hassine (2003), the influence of the sea results in high species richness following the intrusion of the marine species such as fishes, polychaetes, moulds and crabs in the lagoon.

The highest abundances were obtained at the stations A4 and A5 (cluster 2) during the high rainy season. That could be due to a disturbance dependent in the vicinity of the agglomerations. As shown by Marzano *et al.* (2003), a moderate disturbance can favour the growth of a complex community to the profit of another.

The high depths and the substrate primarily characterised by the mud in the central part of the lagoon (cluster III) could explain the low values of the species richness and the diversity indices observed in this sector. Indeed, Chantraine (1980) and Metongo (1985) showed that water at the bottom of these places is not renewed and remains anoxic all the year. In addition, the substrate primarily composed of mud is not favourable for the transfer of certain groups to another place.

The stations of the northern sector and the east of the lagoon (Cluster 4) revealed low species richness and an abundance of stagnant water species such as the larvae of Diptera (chironomidae). That could be explained by the influence of freshwaters. According to Menif and Ben Hassine (2003), these organisms support significant variations of salinity, dissolved oxygen and temperature. In addition, they are remarkably resistant to significant rates of pollution (Diomandé *et al.*, 2000).

In conclusion, this study on the taxonomic diversity and structure of benthic macroinvertebrates in Aby lagoon is the first of the kind. It has contributed to identify 62 taxa of benthic macroinvertebrates dominated by Molluscs and Crustaceans. Compared to the taxonomic list of other lagoons, the Aby lagoon appears rich. However, the increasing of anthropic disturbances on this lagoon should affect the benthic fauna at long term. Therefore, some investigations should be performed in order to know the ecology of the taxa for a conservation program.

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