IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
October 2017 Vol.:7, Issue:4

Benthic Macroinvertebrates Composition and Spatiotemporal Variation in Relationship with Environmental Parameters in a Coastal Tropical Lagoon (Ebrié Lagoon, Côte D'ivoire)

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Saki Yao APPIAH*, Raphaël N'doua ETILÉ, Augustin Kouakou KOUAMÉ, Paul Essetchi KOUAMÉLAN

Hydrobiology Laboratory, UFR Biosciences, Félix Houphouët-Boigny University, Abidjan-Cocody, 22 BP 582 Abidjan 22, Côte d'Ivoire, West Africa.

Submission: 19 September 2017
Accepted: 29 September 2017
Published: 30 October 2017

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Benthic Macroinvertebrates, abundance, community distribution, environmental variables, sectors IV and V of Ebrié lagoon, Côte d'Ivoire

ABSTRACT

The Benthic Macroinvertebrates is essential components of an aquatic ecosystem where it contributes to transferring energy and organic matter from the primary producers to the higher trophic level taxa. However, changes in some environmental characteristics strongly influence their diversity and abundance. This work aimed at determining the spatial and seasonal distributions of The Benthic Macroinvertebrates fauna in relation to some physicochemical parameters. The Benthic Macroinvertebrates community of sectors IV and V of Ebrié lagoon was studied between August 2015 and July 2016. This study mostly focused on the spatial and temporal distribution, composition and abundance. Ninety-eight taxa belonging to 59 families, 16 orders and 7 classes (Insecta, Gastropoda, Crustaceans, Annelida, Bivalvia, Nematoda and Arachnida) were inventoried in the sectors IV and V of the lagoon during this study. The macroinvertebrates diversity varied according to seasons (20-35 taxa in the dry seasons *versus* 16-28 taxa in the rainy season). Multivariate analyses (RDA) revealed that The Benthic Macroinvertebrates community composition and abundance variations were mainly controlled by Ebrié lagoon environmental parameters especially water conductivity, pH, temperature, Salinity, transparency, TDS and Depth.

1. INTRODUCTION

Coastal lagoons are transition zones serving as ecotones between freshwater, marine and terrestrial biotopes. They contribute to the overall productivity of coastal waters by supporting a variety of habitats, including salt marshes, seagrasses, and mangroves. They also provide essential habitat for many fish and shellfish species. They support a range of natural services that are highly valued by society including fisheries productivity, storm protection, tourism, and others. So, lagoons and estuaries are ecological and social values for riparian population (Antony *et al*., 2009, Trush *et al.*, 2013). This ecological and social role of lagoons means that they are increasingly undergoing an important anthropogenic impact, which can accelerate natural eutrophication, habitat loss and alteration, chemical contamination, and biotic community's diversity and abundance alteration (Kennish, 2016).

In Côte d'Ivoire, coastal lagoons include mainly Grand-Lahou, Ebrié and Aby lagoons. The Ebrié lagoon is a highly productive ecosystem, which has an important economic role for riparian populations (fisheries, aquaculture, transportation, sand extraction, etc.) (Anoh, 2010; Kouassi *et al.*, 1995). It also considered as one of the aquatic environment of Côte d'Ivoire most affected by anthropogenic activities as such domestic, industrial and agricultural waste dumping. These activities can accelerate the natural eutrophication and lead to dystrophic crises due to oxygen depletion (Bartoli *et al*., 2001) provoking mortalities in the benthic and fish communities, causing sometimes-irreversible deterioration of these ecosystems.

The Benthic macroinvertebrates communities have an important role in the structure and functioning of aquatics ecosystems. Macroinvertebrates play an important role as the food source for diversity of fish, amphibians, birds, and other animals (Voshell and Reese, 2002; Tachet *et al*., 2010) and contribute substantially to the nutrient cycling, transformation of matter and energy flow in aquatics ecosystems (Tachet *et al*., 2010). They are direct contact with the sediment, where multiple contaminants tend to accumulate (Pilo, 2011) and have best respond to changing environmental conditions (Benoit-Chabot, 2014). To this fact, benthic macroinvertebrates have been extensively used for the assessment of the ecological integrity and biomonitoring of aquatic habitats (Beauger, 2008). Due to their limited mobility, benthic organisms are sensitive to local disturbance and because of their permanence over seasons, they integrate the recent history of disturbances that might not be detected in the water column (Warwick, 1993). The distribution of the different benthic macroinvertebrates communities is considered one of the important indicators of the surface waters quality (Badea *et al.*, 2010; Kubosova *et al.*, 2010; Simmou *et al*., 2015). In Côte d'Ivoire, previous studies on benthic macroinvertebrates have been mainly performed in Aby lagoon (Kouadio *et al*., 2008), and Ebrié lagoon (Zabi, 1982; Sankaré and Etien, 1991; Le Loeuff & Zabi, 1993; Kouadio *et al*., 2011, Allouko et al., 2016). The purpose of the present study was to know the variability of benthic macroinvertebrate structure and to identify the abiotic variables managing the structure and the functioning in the sectors IV and V of Ebrié lagoon.

2. MATERIAL AND METHODS

2.1 Study area

The Ebrié lagoon (Figure 1) is located between 5°13' and 5°19' N and 4°14' and 4°27' W. It is the largest lagoon (566 km²) of Côte d'Ivoire stretching for 130 km east to west with a maximum width of 7 km (Albaret 1994, Durand and Guiral, 1994). Based on the hydroclimate, and on aquatic primary and secondary production in Ebrié Lagoon have been divided into six sectors (Durand and Skubich 1982). The permanent linkage with the Atlantic Ocean by the Vridi Channel produces typical estuarine characteristics, especially in sectors II to III, which are near the channel. Under the direct influence of both the Atlantic Ocean and the Comoé River outflow, these parts of the lagoon are seasonally variable and heterogeneous with salinity varying from 0 (rainy season) to 35 (dry season). Conversely, sectors IV to VI are oligohaline (salinity 0 to <10), relatively stable and homogeneous throughout the year (Durand and Guiral, 1994). In the sector I, water is all year round almost exclusively of continental origin in Aghien lagoon and by water with salinity < 9 all year round in Potou lagoon (Traoré *et al.,* 2012).

The Ebrié lagoons system is situated in a region under the influence of a subequatorial climate characterized by two rainy seasons, a short (October-November) and a long season (May-July); and two dry seasons, along (December-April) and a short season (August-September) (Kouadio, 2011).

2.2. Benthic macroinvertebrates samples and environment parameter measure

The sampling stations were investigated monthly during 12 months from August 2015 to July 2016. Samples were collected using a Van Veen grabs (0.03 m^2). At each station, ten samples were collected for benthic macroinvertebrates analyses. Each sample was sieved *in situ* through a 1 mm mesh. The organisms retained by the sieve were fixed in formaldehyde 10 % solution for maintenance of the samples. At the laboratory, macroinvertebrates were identified to the lowest possible taxonomic level and counted using the following works: Fauvel (1923, 1927), Intès and Le Loeuff (1975), Durand and Lévêque (1981), Dejoux *et al*. (1981), Tachet *et al.* (2010).

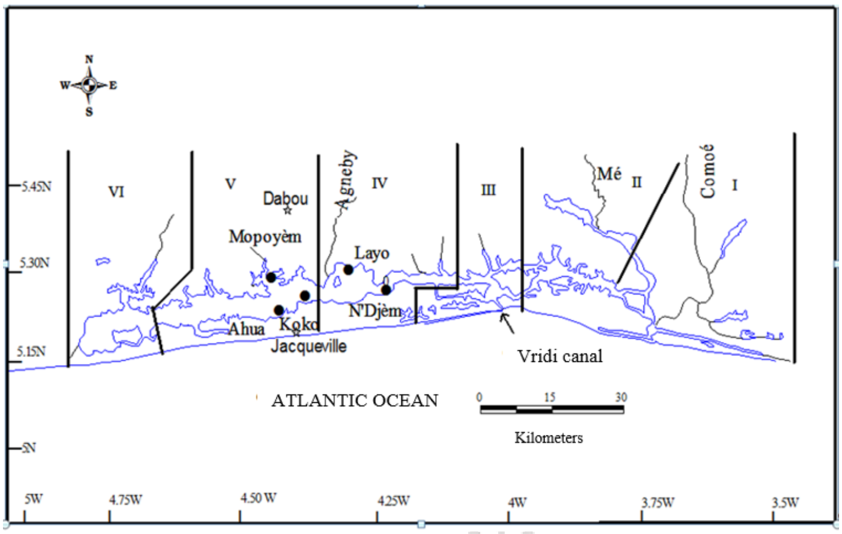


Figure 1: Map of Ebrié Lagoon showing location of the sampling sites (●)

2.3. Measurement of Environmental parameters

During the investigation period, *in situ*, the hydrologic parameters (water salinity, temperature, dissolved oxygen (DO), pH, total dissolved solids (TDS) and electrical conductivity were measured monthly at depth intervals of 10 cm, using a multifunctional probe. *A Secchi* disc was used for water transparency measures.

2.4. Statistical analysis

The species richness (S), the Shannon diversity index (H') and the Pielou evenness index (E) were used to determine the assemblage's structure of benthic macroinvertebrates community. The analyses were carried out using the sub-routine of Paleontological Statistics (PAST) Package version 2.41. The species occurrence percentage (% of) was calculated using the following formula: % of = (Ni/N_{ts}) ×100, with N_i = number of samples containing a given taxa i, and N_{ts} = total number of samples collected. The % of was used to classify species following Dajoz (2000): % of > 50: very frequent taxa; 25 < % of ≤ 50: common taxa; %OF

≤ 25: rare taxa. Redundancy analysis (RDA) was conducted by using the computer program CANOCO, version 4.5 in order to assess the relationships between water physical-chemical parameters and benthic macroinvertebrates species. KruskalWallis and ANOVA test were performed to test the effects of stations and seasons on physicochemical parameters and benthic macroinvertebrates diversity and abundance. A significance level of $p < 0.05$ was considered. Analyses were carried out using the software package Statistica version 7.1. To satisfy the assumption of normality and homogeneity of variance in data, all data were logarithmically transformed before the analyses.

3. RESULTS

3.1. Benthic macroinvertebrates taxonomic structure and composition

98 taxa belonging to 59 families, 16 orders and 7 classes (Insecta, Gastropoda, Crustaceans, Annelida, Bivalva, Nematoda, and Arachnida) have been identified during this study in Ebrié lagoon (Table I). Insecta presented the highest diversity with 51 taxa (52.04% of the total diversity), followed by the Crustacean (19 taxa, 19.4%), Annelida (11 taxa, 11.22%), Gastropoda (10 taxa, 10.20%). Bivalvia Nematoda and Arachnida represented the lowest diversity, with 1 to 4 taxa (< 8% of total diversity).

Insecta taxa belonging to six orders, 24 families, and 43 genuses. Chironomidae family presented the highest diversity (13 taxa) followed by Hydrophilidae (7 taxa), Baetidae (5 taxa) and by Dystiscidae (3 taxa). All others Insecta families recorded in this study are monospecific. The most diversified genuses were *Polypedilum* (4 taxa), *Nilodorum* and *Hydrophilus* (3 taxa each). Crustacea class belonging to 3 orders, 13 families and 15 genuses. Gammaridae presented the highest diversity (4 taxa), followed by Co*+rophiidae, Diogenidae, Potamonidae (2 taxa each). The most diversified genuses were *Gammarus* (3 taxa), *Corophium*, *Clibanarus*, and *Potamonaute* (2 taxa each). Annelida class was represented by 3 orders (Achaeta, Oligochaeta, and Polychaeta) and 11 families. Polychaeta presented the highest family number (5), followed by Oligochaeta (4) and by Achaeta. Oligochaeta family taxa were unidentified in this study. Gastropoda class belonging to two orders (Mesogastropoda and Basommatophora), 5 families and 5 genuses. Neritidae and Thiaridae represented the families the most diversified (respectively 4 and 3 taxa) while *Neritina* and *Pachymelania* genuses presented the highest diversity. Bivalvia was represented by 4 monospecific families (Corbulidae, Dreissenidae, Mytilidae, and Sphaeridae) belong to

Eulamellibranchia order. Arachnida was represented by *Hydracarina* sp. while Nematoda was represented by an unidentified taxon belongs to Mermithidae families. Macroinvertebrates diversity obtained in this study varied according to season and stations. Highest taxonomic richness was observed in Mopoyèm and Layo stations (40 to 47 taxa) while lowest diversities were recorded in Ahua, Koko, and N'Djèm sites (22 to 34 taxa). During the dry season, taxonomic richness varied from 21 (Ahua) to 35 taxa (Layo) while it varied from 16 (N'Djèm) to 27 taxa (Mopoyèm and Layo) during the rainy season. Significant differences in diversity were observed between seasons for all stations ($p < 0.05$). Shannon diversity index spatiotemporal variation was *marked by highest values (> 2 $bit.ind^{-1}$) obtained in all seasons in the sampling sites Mopoyèm, Layo and N'Djèm, and lowest values (< 2 $bit.ind^{-1}$) observed in sampling sites Koko and Ahua. The similar spatiotemporal pattern was observed for Pielou's equitability index, with values in the sampling sites Mopoyèm, Layo and N'Djèm (> 0.5) higher than in the sampling sites Koko and Ahua (≤ 0.5) during the dry and the rainy seasons. Shannon and Pielou's equitability index values were significantly higher in Mopoyèm, Layo, and N'Djèm than in Koko and Ahua ($p < 0.01$).

Table I: List and distribution of benthic macroinvertebrates taxa inventoried in Ebrié lagoon from August 2015 to July 2016 (+ = presence of the taxon at the sampling stations)

Class	Orders	Families	Taxa	Mopoyèm	Layo	N'Djèm	Ahua	Koko	OF
Annelida	**Achaeta**	Branchiobdellidae	*Xironogiton victoriensis*					+	17
		Erpobdellidae	*Erpobdella* sp.				+	+	25
	Oligochaeta	Haplotaxidae	undetermined		+		+		17
		Lumbriculidae	undetermined.	+	+	+	+	+	67
		Naididae	undetermined.		+				25
		Tubificidae	undetermined.		+	+			42
	Polychaeta	Capitellidae	*Capitella capitata*		+	+	+		50
		Glyceridae	*Glycera convoluta*			+			33
		Nephthydae	*Nephthys* sp.		+	+	+		67
		Nereidae	*Nereis* sp.		+	+	+	+	83
		Syllidae	*Syllis* sp.			+			33
Nematoda	undetermined	Mermithidae	undetermined.					+	8
Gastropoda	**Basommatophora**	Planorbidae	*Planorbis* sp.	+	+				17
	Mesogastropoda	Neritidae	*Neritina andansoniana*		+	+	+	+	17
			Neritina glabrata				+	+	100
			Neritina rubricata			+	+	+	17
			Neritina zebra				+	+	8
		Pilidae	*Pila africana*	+					8
		Potamididae	*Tympanotonus fuscatus*			+			33
		Thiaridae	*Pachymelania aurita*		+	+	+	+	100
			Pachymelania fusca		+	+	+	+	100
			Pachymelania fusca quadriseriata		+		+	+	92
Bivalvia	**Eulamellibranchia**	Corbulidae	*Corbula trigona*		+	+	+	+	92
		Dreissenidae	*Dreissena polymorpha*		+	+	+	+	8
		Mytilidae	*Mytilus edulis*			+			8
		Sphaeriidae	*Sphaerium* sp.		+		+	+	50
Crustaceans	**Amphipoda**	Corophiidae	*Corophium acherusicum*	+			+	+	50
			Corophium curvispinum	+	+	+	+	+	75
		Gammaridae	*Echinogammarus* sp.				+		8
			Gammarus chevreuxi	+	+	+	+	+	42
			Gammarus pulex	+			+	+	33
			Gammarus roeseli					+	25
		Talitridae	*Orchestia* sp.				+	+	25

Table I –Continued

Class	Orders	Families	Taxa	Mopoyèm	Layo	N'djèm	Ahua	Koko	OF
	Decapoda	Atyidae	*Caridina* sp.					+	8
		Diogenidae	*Clibanarus africanus*			+			42
			Clibanarus cooki			+		+	42
		Palaemonidae	*Macrobrachium* sp.					+	25
		Penaeidae	*Penaeus notialis*					+	25
		Portunidae	*Callinecte* sp.					+	17
		Potamonidae	*Potamonaute* sp.				+		17
			Sudanonautes sp.				+		8
		Xanthidae	*Panopeus africanus*				+	+	33
	Isopoda	Anthuridae	*Cyathura* sp.				+		25
		Cirolanidae	*Excirolana latipex*			+	+	+	42
		Sphaeromatidae	*Sphaeroma tenebrans*	+			+	+	42
Arachnida	**Trombidiforma**	Hydrachnidae	*Hydracarina* sp.	+					17
Insecta	**Coleoptera**	Curculionidae	*Bagous* sp	+	+				25
		Dytiscidae	*Canthydrus minutus*	+	+				17
			Copelatus sp.		+				8
			Dytiscus sp.		+				8
		Elmidae	*Riolus* sp.		+				17
		Hydrophilidae	*Amphiops* sp.		+				8
			Berosus sp.	+	+				25
			Hydrobius sp.	+					8
			Hydrophilus ricketsi berthod	+					8
			Hydrophilus senegalensis		+				8
			Hydrophilus sp.	+	+				17
			Laccobius sp.		+				8
		Notoridae	*Noterus sp.*		+				8
		Spercheidae	*Sperchus* sp.	+					8
	Diptera	Chaoboridae	*Chaoborus sp.*	+					17
		Chironomidae	*Chironomus sp.*	+	+	+	+	+	92
			Cryptochironomus sp.	+			+	+	33
			Nilodorum brevibucca	+	+				25
			Nilodorum fractilobus	+					25
			Nilodorum rugosum	+	+				17
			Polypedilum abyssinae				+		17
			Polypedilum deletum	+					17
			Polypedilum fuscipenne	+					25

Table I –Continued

Class	Orders	Families	Taxa	Mopoyèm	Layo	N'djèm	Ahua	Koko	OF
			Polypedilum sp.	+	+		+	+	67
			Procladius sp.		+				8
			Stictochironomus sp.		+				17
			Tanypus fuscus		+				17
			Tanytarsus sp.				+	+	25
		Culicidae	*Culex* sp.		+				17
		Stratiomyiidae	undetermined	+	+				25
		Syrphidae	*Eristalis* sp.	+	+				17
	Ephemeroptera	Baetidae	*Baetis* sp.	+	+				42
			Centroptilum sp.		+				8
			Cloeon sp.	+	+				50
			Procloeon bifidum		+				8
			Pseudocentroptilum pennulatum	+					17
	Heteroptera	Belostomidae	*Diplonychus* sp.	+	+				50
		Corixidae	*Micronecta* sp.		+				17
		Gerridae	*Gerrisella* sp.	+					8
			Limnogasus sp.	+					8
		Naucoridae	*Macrocoris* sp.	+	+				17
			Naucoris sp.	+					17
		Nepidae	*Ranatra linearis*	+					8
		Notonectidae	*Notonecta* sp.		+				8
		Pleidae	*Plea* sp.		+				8
		Veliidae	*Velia* sp.		+				8
	Odonata	Coenagrionidae	*Coenagrion pro parte*	+			+		42
			Nehalennia speciosa	+					8
		Corduliidae	*Cordulia aenea*	+					25
		Libellulidae	*Libellula* sp.	+					8
	Tricoptera	Ecnomidae	*Ecnomus* sp.				+		8
Total		**59**	**98**	**40**	**47**	**22**	**34**	**33**	

3.2. Macroinvertebrate community abundance structure and spatiotemporal variation

12.359 individuals were collected during this study in Ebrié lagoon. Macroinvertebrate effective varied significantly according to the sampling sites. Lowest values were obtained in the sampling sites Mopoyèm, Layo and N'Djèm (134 to 465) while highest values were observed in Ahua and Koko sampling sites (1896 to 4313). Except at Koko, there is not the seasonal difference between macroinvertebrate taxa effective obtained during this study (Fig. 2A).

Macroinvertebrate community structure was characterized by Gastropoda order dominance (63% of total abundance), followed by crustacean (18%), insect (8%), bivalvia (6) % and annelida (5%). Nematoda and Arachnida constituted < 0.1% of total abundance (Fig. 2B).

Gastropoda order presented the highest abundances at Ahua (3555 individuals, 86% of total abundance) and Koko (3838 individuals, 59% of total abundance). In these sampling sites, the most abundant gastropoda was *Pachymelania aurita* (80 to 87% according to season). *Pachymelania aurita* was also the most abundant gastropoda at N'Djèm (47%), followed by *Tympanotonus fuscatus* (28%) and by *Neritina glabrata* (18%). At Layo, *Pachymelania fusca* was the most abundant gastropoda (62%), followed by *Pachymelania fusca quadriseriata* (21%) and *Pachymelania aurita* (16%) while *Planorbis* sp. was the most abundant gastropoda at Mopoyèm (80%). During the dry season, *Sphaeroma tenebrans* and *Corophium curvispinum* represented the most abundance crustacean species, with respectively 38 and 36%. During the rainy season, the most abundant crustacean species contributing to about 95% of crustacean were *Corophium acherusicum* (27%), *Corophium curvispinum* (19%), *Excirolana latipex, Sphaeroma tenebrans* and *Gammarus pulex* (14% each). At spatial level, highest abundances of crustacean were observed at Koko (1674 individuals) and Ahua (454 individuals) versus lowest abundances (< 300 individuals) at Mopoyèm, Layo and N'Djèm. At Koko and Ahua, *Corophium acherusicum* and *Sphaeroma tenebrans* were the most crustacean's species, with respectively 29-32% and 29-38%. At Mopoyèm, *Corophium acherusicum* was the most abundant crustacean's species (63%) while *Gammarus chevreuxi* (67%) and *Clibanarus africanus* (57%) were respectively the most abundant crustacean's species at Layo and N'Djèm. Insect order presented highest abundance during the dry season (573 individuals) than during the rainy season (415 individuals). During the dry season, *Polypedilum* sp. and *Nilodorum brevibucca* with respectively 27 % and 25% were the most taxa of insect order, followed by *Chironomus* sp. (11%) and *Beatis* sp. (8%). During the rainy season, insect order comprised mainly *Beatis* sp. (43%), *Nilodorum brevisbucca* (11%), *Diplonychus* sp. (9%) and *Polypedilum* sp. (6%). Insecta order abundance spatial variation was marked by highest values obtained at Mopoyèm (769 individuals, 92% of total macroinvertebrates abundance). In the other sampling site, insecta abundance was relatively low (< 150 individuals, 1 to 21% of total abundance). At Mopoyèm, *Beatis* sp. (28%) and *Nilodorum brevisbucca* (24%) were the most abundant insect species. At Layo, insect order abundance was mainly dominated by *Chironomus* sp. (16%), *Polypedilum* sp. (15%), and by *Beatis* sp. and *Culex* sp. (5% each). *Chironomus* sp. was the only insect's species sampling at

N'Djèm (100%) while *Polypedilum* sp. (42%) and *Chironomus* sp. (30%) constituted the main insect's taxa at Ahua. At Koko, *Cryptochironomus* sp. (53%) and *Chironomus* sp. (40%) were the main insect species.

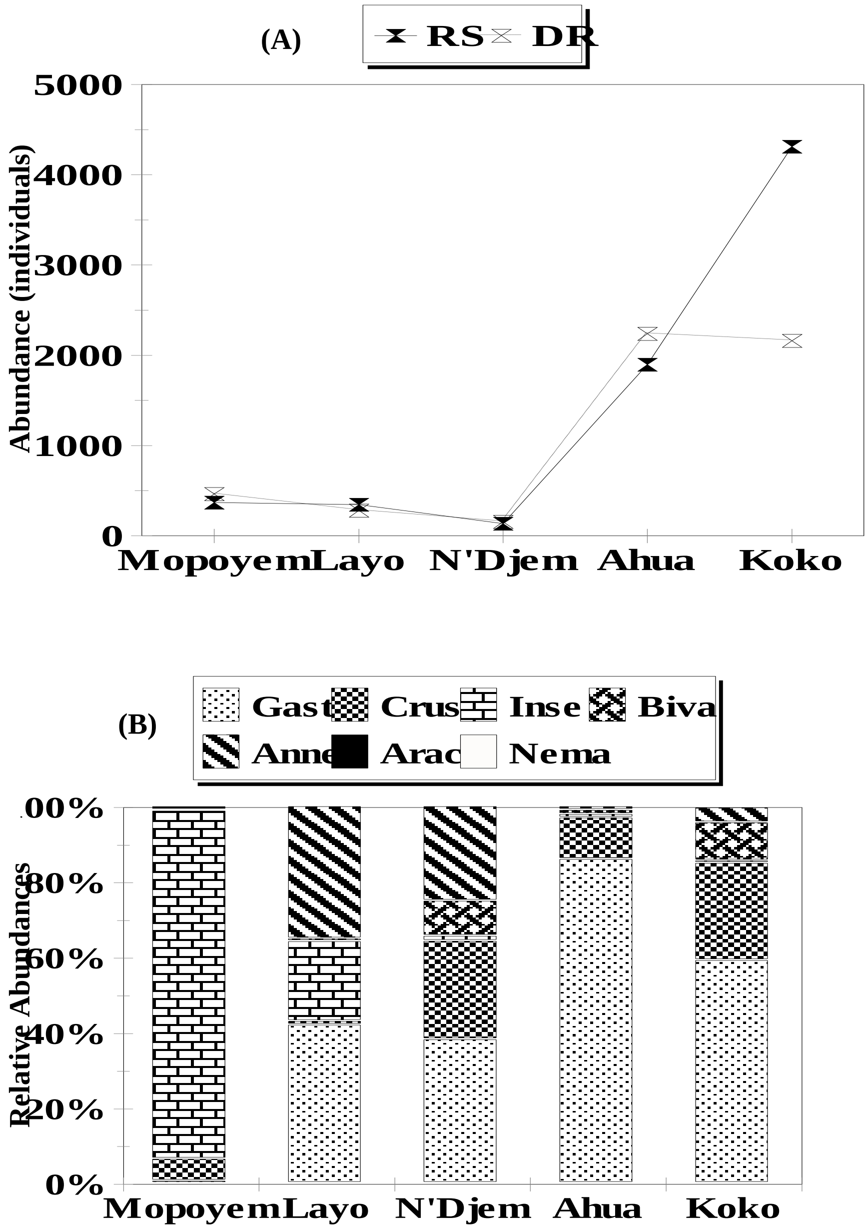


Figure 2: Spatiotemporal variation of benthic macroinvertebrates total abundance (A) and spatial variation of relative abundance of the main benthic macroinvertebrates class (B) inventoried in Ebrié lagoon from August 2015 to July 2016 (Gast: Gastropods, Crus: Crustaceans, Inse: Insecta, Biva: Bivalvia, Anne: Annelida, Arac: Arachnida, Nema: Nematoda).

Highest Annelida abundances were observed at Koko (260 individuals) but highest relative abundances were obtained at Layo (35%) and N'Djèm (25%). *Nereis* sp. was the main annelid species at Koko (92%), while a Tubificidae undetermined taxa (39%), *Nephthys* sp. (22%) and a Lumbriculidae no determined taxa (16%) presented the highest insect's taxa abundance at Layo. At N'Djèm, a Tubificidae undetermined taxa (36%), *Nephthys* sp. (27%) and *Nereis* sp. (19%) were the most abundant insect's taxa. Bivalvia were mainly represented as *Sphaerium* sp. (≈ 80%) at Koko and Layo, while they were dominated by *Corbula trigona* at N'Djèm (70%) and Ahua (84%). *Hydracarina* sp. was the only Arachnida taxa sampling during this study at Mopoyèm.

3.3. Macroinvertebrates and environmental variable

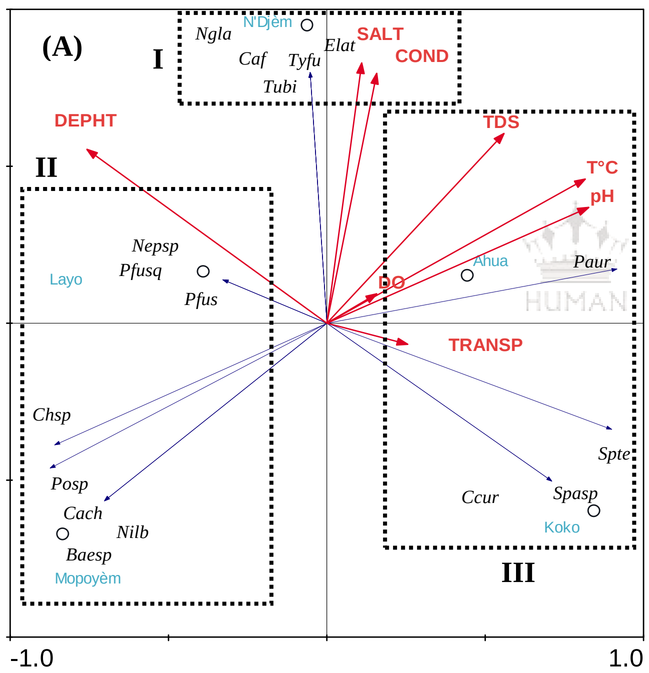
According to the ReDundancy Analysis (RDA), the two axes explained 71.6% of the observed variance in macroinvertebrates community structure. The first represents more than 40.5%. These axes were selected for graphical representation (Fig. 3).

During the dry season, the analysis distinguished also three zones (Fig. 3A). The first zone was defined by N'Djèm, Layo and Mopoyèm. This zone was correlated to the depth. The main taxa associated to the first zone were Tubificidae, *Neritina glabrata*, Tympanotonus *fuscatus*, *Clibanarus africanus*, Excirolana *latipex*, *Pachymelania fusca quadriseriata*, *Pachymelania fusca*, *Nephtys sp*, *Baetis* sp, *Corophium acherusicum*, *Nilodorum brevibucca*, *Polypedilum* sp. and *Chironomus* sp. The second zone (Ahua and Koko) was correlated to temperature, pH, TDS, conductivity and salinity. The main taxa were *Corophium curvispinum Pachymelania aurita*, *Sphaeroma tenebrans*, and *Sphaerium* sp.

During the rainy season, the analysis distinguished, three groups of samples and taxa can be distinguished (fig.3B) (I) samples of stations Mopoyèm and N'Djèm characterized by depth in which *Pachymelania fusca quadriseriata*, *Tympanotomus fuscatus*, *Clibanarus africanus*, *Nereis* sp., *Clibanarus cooki*, *Baetis* sp., *Diplonychus* sp., *Nilodorum brevibucca* , *Pachymelania aurita* and *Corbula trigona* were the most important taxa; (II) samples of stations Koko and Ahua characterized by transparency, temperature, salinity, conductivity, pH and dissolved oxygen in which the dominant taxa were, *Neritina glabrata*, *Sphaeroma tenebrans*, *Sphaerium* sp., *Neritina zebra and Corophium acherusicum;* (III) samples of station Layo essentially composed of Haplotaxidae, Lumbriculidae, Tubificidae, *Nephtys* sp. *Pachymelania fusca* characterized by the TDS.

4. DISCUSSION

The macroinvertebrate species found in this study have been recorded in previous surveys of the macroinvertebrate communities of Ebrié lagoon (Zabi, 1982; Sankaré and Etien, 1991; Le Loeuff and Zabi, 1993; Kouadio *et al*., 2011). 98 taxa were collected in Ebrié lagoon during this study. Taxa diversity in these lagoon is higher than those mentioned by Allouko *et al*. (2016) in sector I of Ebrié lagoon (Aghien lagoon) (Côte d'ivoire) (93 taxa), Kouadio et al. (2011) in sectors I, II and III of Ebrié lagoon (66 taxa) and kouadio *et al*. (2008) in Aby lagoon (Côte d'ivoire) (62 taxa) but is lower than the taxa collected by Adandedjan *et al*. (2013) in the Porto novo lagoon (Benin) (150 taxa). The high number of species may be explained by high variability of environmental and trophic conditions associated to the shallowness of the lagoon and combined low influence of freshwater and marine water



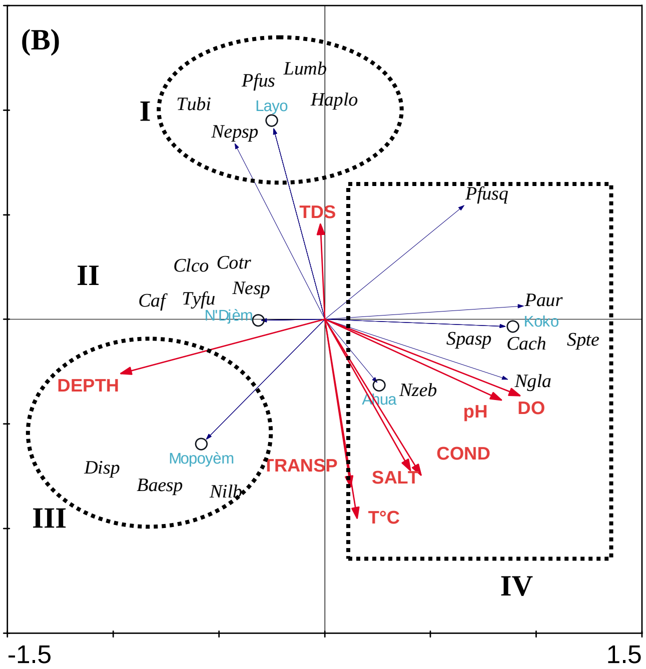


Figure 4: Redundancy analysis ordination diagram applied to environmental variables and benthic macroinvertebrate taxa inventoried in Ebrié Lagoon from August 2015 to July 2016 (A: Dry season, B: Rainy season; Paur: *Pachymelania aurita*; Nepsp: *Nephthys* sp.; Pfus: *Pachymelania fusca*; Pfusq: *Pachymelania fusca quadriseriata*; Tubi: Tubificidae; Lumb: Lumbriculidae; Spasp: *Sphaerium* sp.;Nzeb: *Neritina zebra*; Ngla: *Neritina glabrata*; Nesp: *Nereis* sp.; Caf: *Clibanarus africanus*; Tyfu: *Tympanotonus fuscatus*; Clco: *Clibanarus cooki*; Cach: *Corophium acherusicum*; Disp*: Diplonychus* sp.*;* Nilb: *Nilodorum brevibucca*; Baesp: *Baetis* sp.; Elat: *Excirolana latipex* ; Posp : *Polypedilum* sp. ; Ccur: *Corophium curvispinum* ; Spte : *Sphaeroma tenebrans*; T°C: temperature, TRANSP: transparency, COND: conductivity, DO: dissolved oxygen, SALT: salinity, DO: Disolved oxygen, TDS: Dissolved solids rate)

(Monney *et al*., 2015) and by the difference between the scope settings, the sampling period, and environments nature. In fact, this study showed that the stations near of Agneby Rivers (Mopoyèm and Layo) were characterized by high diversity of macroinvertebrate community. That could be explained by the intrusion of freshwater species to lagoon (Le Loeuff and Zabi, 1993).

The taxonomic composition of benthic macroinvertebrates taxa inventoried in Ebrié lagoon during this study was characterized by highest diversity of insecta with 51 taxa (52.04% of the total diversity), followed by the Crustacean (19 taxa, 19.4%), Annelida (11 taxa, 11.22%), Gastropoda (10 taxa, 10.20%). Bivalva and Arachnida represented the lowest diversity, with 1 to 4 taxa (< 8 % of total diversity). These various listed macroinvertebrate groups are similar with those reported by previous studies in other lagoon ecosystems of Côte d'Ivoire (Kouadio *et al*., 2008, 2011); Nigeria (Uwadiae, 2014) and Benin (Odountan and Abou, 2016). Diversity dominance of insect was also reported in Ebrié lagoons (sector 1: Aghien lagoon) (Côte d'Ivoire) by Allouko *et al*. (2016) (70 taxa, 82% of total diversity), in Lake Nokoue (Benin) by Odountan and Abou (2016) (45 taxa, 63% of total diversity). On the other hand, some other studies report qualitative dominance of Mollusca and/or Crustaceans in Aby lagoon (Côte d'Ivoire) (64% of total taxonomic diversity) (Kouadio *et al*., 2008), in Ebrié lagoon (Côte d'Ivoire) (61% of total taxonomic richness) (Kouadio *et al*., 2011), in Lagos lagoon (Nigeria) (up to 99%) (Nkwoji *et al*., 2010, Uwadiae *et al*., 2012), in Saquarema-Jaconé lagoonal system (Brazil) (Mendes and Soares-Gomes, 2011). In these studies, with Mollusca and/or Crustaceans dominance, Neritidae, and Thiaridae taxa were the most diversified families of mollusca, with within these families respectively *Neritina* and *Pachymelania* as genuses presenting the highest taxonomic richness. Crsutaceans were marked by the qualitative dominance of Corophiidae and Gammaridae, with within these families respectively *Corophium* and *Gammarus* as genuses the most diversified. Our study shows that insecta class with 51 taxa belonging to 6 orders, 24 families, and 43 genuses was the most diversified. Chironomidae family presented the highest diversity (13 taxa), followed by Hydrophilidae (7 taxa) and Baetidae (5 taxa). Insect genuses the most diversified were *Polypedium* (4 taxa), *Nilodorum* and *Hydrophilus* (3 taxa each). This difference in macroinvertebrate qualitative composition and structure may be linked to environment factors as salinity level, with high macroinvertebrate diversity occurring at low salinities, and low diversity occurring at high salinities (Gordon, 2000, Lamptey and Armah, 2008). According to Little (2000) reported by Mendes and Soares-Gomes (2011) salinity influence in the composition and number of species is well known as it imposes severe conditions to organisms, rendering difficulties in maintaining osmoregulation. In this study, salinity fluctuation may be explained taxonomic richness difference between Mopoyèm-Layo sampling sites (40-47 taxa) and Ahua-Koko-N'Djèm sampling sites (22-34 taxa). Mopoyèm and Layo sites were characterized by low salinities (< 3) while the other sites were marked by relative higher salinities (≈ 3 to 6). Lowest salinities observed in Mopoyèm and Layo sites are favorable to insect taxa development (30-31 taxa, versus 1 to 7 taxa in the other sites). On the other hand, relative higher salinity obtained in Ahua, Koko and N'Djèm sites contributed to the flourishing of crustaceans and gastropods taxa, with respectively 5 to 14 taxa and 5 to 7 taxa versus respectively 2-4 taxa and 1-4 taxa in Mopoyèm and Layo sites. Some other factors as Fish predation on macroinvertebrate community (Diomande, 2001); presence or absence of mangroves forest and/or aquatic plants (Jonathan and Lee, 2006) that served as shelters to invertebrates against predators; anthropogenic activity impacts (Azrina *et al*., 2006); pollution (Aggrey-Fynn et al., 2011); redox potential, dissolved oxygen, organic matter and phytopigments (Mendes and Soares-Gomes, 2011); substrate nature and stability (Pererira *et al*., 2017).

Quantitative analyze our data reveals also that macroinvertebrate community structure was characterized by Gastropoda order dominance (Mean: 63% of total abundance), followed by crustacean (18%). The main taxa were *Pachymelania aurita* (43 to 62% of total abundance according to season), followed by *Sphaeroma tenebrans* (2 to 10%) and *Corophium* spp. (2 to 10%). Dominance of Gastropod molluscs in term of macroinvertebrates community abundance was also reported by previous studies in lagoons of Côte d'Ivoire: Aby lagoon (51%) (Kouadio *et al*., 2008) and Ebrié lagoon (71% of total abundance) (Kouadio *et al*., 2011); in Keta lagoon (Ghana) (Lamptey and Armah, 2008) and in Lagos (86-95%) (Nkwoji *et al*., 2010; 2016) and Epe lagoons (98%) (Nigeria) (Uwadiae, 2009). If our study confirms the quantitative dominance of gastropoda in the coastal lagoons of Côte d'Ivoire and as well as of the results of previous studies in tropical zone, the main species changes according the studied lagoons, *Pachymelania aurita* in the present study (Ebrié lagoon, Côte d'Ivoire), in Epe lagoon (Nigeria) (Uwadiae, 2009) and the Lagos lagoon (Nigeria) (Nkwoji *et al*., 2011; Nkwoji, 2016); *Corbula trigona* in Ebrié (Côte d'Ivoire) (Zabi, 1982) and Aby lagoons (Côte d'Ivoire) (Kouadio *et al*., 2008); *Tympanotonus fuscatus var. radula* in an estuarine creek and an artificial pond in Lagos (Southwestern Nigeria) (Ogunwenmo and Osuala, 2004). This variation of the benthic macroinvertebrates main species according to aquatic invertebrates could be linked to the environmental conditions of each ecosystem. Indeed, the suitability of benthic macroinvertebrates as indicator of water quality and environment condition has been demonstrated in a great variety of aquatic ecosystems: Lagos lagoon (Nigeria) (Nkwoji and Igbo, 2010), Lake Figueira (Brazil) (Lima *et al*., 2013), Epe lagoon (Nigeria) (Uwadiae, 2013; 2014), Tallo River estuary (Indonosia) (Saru, 2014), Nokoue Lake (Benin) (Odountan and Abou, 2016). Several species of benthic macroinvertebrates are often considered as good bio-indicators for water quality. The Gastropoda *Pachymelania aurita* is known, as species often associated with relatively clean (no polluted) site and not found in the polluted site while *Tympanotonus* sp. is observed relatively abundant in the polluted sites (Nkwoji *et al*., 2010). *Sangaré signaled P. aurita and Corbula trigona* and Etien (1991) as specie genuseslly collected in brackish water with sandy and muddy fund. It would certainly justify the numeric dominance of *P. aurita* in Koko and Ahua (3119 to 3370 individuals, 52 to 75 of total macroinvertabrates abundance) where the substratum is composed mainly sand and vase. Besides, Gastropods species as *Mytilus edulis* and *M. perna*, and Bivalvia species as *Crassostrea gazar* were known to be intolerant of wide fluctuations in salinity (Uwadiae, 2013). Others of fresh water species as Chironomidae and Chaoboridae taxa have been considered an important indicator of water quality in lakes, and were increasingly used as bio-indicators (Lima *et al*., 2013). So, *Polypedilum* sp. is considered tolerant to organic enrichment and eutrophication (Fusari, 2006 reported by Lima *et al*., 2013) while *Chaoborus* sp. was associated with environments with low oxygen concentration and deeper zones of lakes and reservoirs (Corbi and Trivinho-Strixino, 2002; Jager and Walz, 2002).

In this study, benthic macroinvertebrates richness, diversity and abundance did not present a strong seasonal variation. It may be linked to the relative seasonal stability of hydrological and environment parameters of the survey zone (Durand and Guiral, 1994). On the other hand, these parameters present a strong spatial variation marked by highest taxonomic richness observed in Mopoyèm and Layo sites (40 to 47 taxa) while lowest values recorded in Ahua, Koko, and N'Djèm sites (22 to 34 taxa). Similar spatial variation was also observed with Shannon diversity index with highest values (> 2 $bit.ind^{-1}$) obtained in the sampling sites Mopoyèm, Layo and N'Djèm, and lowest values (< 2 $bit.ind^{-1}$) observed in sampling sites Koko and Ahua. In contrast, abundance spatial variation is marked by highest values in Koko and Ahua sites (1896 to 4313 individuals) and lowest values in the others sites (134 to 465 individuals).

Spatial pattern of taxonomic richness and diversity can be justified by the fact Mopoyèm and Layo sites receive water inputs of Kpapkidjè, Agneby and Layo rivers and present fresh water character, especially during the rainy season while Ahua and Koko site don't communicate with any river, receive only water of precipitation and runoff and present a brackish water character all seasons. Adandédjan et al., 2011 in Porto-Novo lagoon (Benin), also reported this situation of increasing of macroinvertebrate taxa with low salinity observed in the present study. In contrast, in Aby lagoon (Côte d'Ivoire) richness increases from the Bia river mouth in lagoon to the south part towards the point of contact of the lagoon and the sea on the one hand, and from the entrance of Tanoé river in lagoon from the center of the lagoon (Kouadio *et al*., 2008) where salinity was highest. According to authors, it may be explained by the fact that, in the zone near the channel, Aby lagoon is connected to the sea and receives freshwaters from the Bia and Tanoé rivers. So, this zone is favorable to provide a habitat four sea, brackish and freshwater species. Concerning the macroinvertebrate abundance, lowest abundance was obtained in Mopoyèm, Layo and N'Djèm sites may be linked to the fact that water inputs from Kpapkidjè, Agneby and Layo rivers during the rainy season induces collapse of brackish community and favors freshwater community development. On the other hand, in Ahua and Koko sites with the highest abundance, lagoon waters were brackish all seasons and favor constantly brackish community development dominated by *Pachymelania aurita*.

CONCLUSION

A total of ninety-height (98) taxa were recorded in the Ebrié Lagoon in this study. Our study up to date the benthic macroinvertebrate of this ecosystem and showed that the Ebrié Lagoon's benthic macroinvertebrate was composed mainly by taxa commonly found in tropical lagoon. Benthic macroinvertebrate community is marked by the numerical dominance of Gastropoda (62.9% of total abundance) and by the qualitative dominance of insect (52.04% of the total taxa), with Chironomidae as the highest diversified family. This study revealed that, in the part lagoon confined (N'Djèm, Koko, and Ahua) was composed by gastropoda and bivalva and in the part influenced by freshwater Agneby (Mopoyèm and Layo) was composed by insects. Our study showed that the sectors IV and V were exposed to the pollution. Our results contribute to a better understanding of the community structure and biodiversity of the area.

ACKNOWLEDGEMENTS

The authors are grateful to Hydrobiology Laboratory of Félix Houphouët-Boigny University for making available the material for supporting this study. We express our appreciation to anonymous reviewers for their valuable comments and editing of the manuscript.

REFERENCES

1. Adandédjan D., Lalèyè P. Ouattara A. and Gourène G., 2011. Distribution of benthic faune in west African lagoon: the Porto-Novo lagoon in Benin. *Asian Journal of Biological Sciences*: 1-12.
2. Adandedjan D., Montcho A. S., Chikou A., Laleye P., Gourene G. 2013. Use of the self-organizing map (SOM) for the characterization of macrobenthic populations. *Comptes Rendus Biologies*. 336: 244-248

3. Aggrey-Fynn J., Galyuon I., Aheto W. D. and Okyere I., 2011. Assessment of the environmental conditions and benthic macroinvertebrate communities in two coastal lagoons in Ghana. *Annals of Biological Research*, 2 (5) :413-424

4. Albaret J. J., 1994. Biologie et peuplements. *In* Durand JR, Dufour P, Guiral D, Zabi SGF eds, Environnement et Ressources aquatiques de Côte d'Ivoire. Tome II. Les milieux lagunaires. Orstom, Paris: 239-179

5. Allouko J-R., Bony K. Y., Edia O. E. and Konan K. F., 2016. Composition, Distribution and Abundance of Macroinvertebrates in Aghien lagoon (Ivory Coast; West Africa) *International Journal of Innovative Research in Science, Engineering and Technology*. 5: 10104-10111.

6. Anoh K. P., 2010. Stratégies comparées de l'exploitation des plans d'eau lagunaire de Côte d'Ivoire. *Les Cahiers d'Outre-Mer.* Revue de géographie de Bordeaux, 63 (251): 347-363.

7. Anthony A., Atwood J., August P., Byron C., Cobb S., Foster C. and Kellogg D., 2009. Coastal lagoons and climate change: ecological and social ramifications in US Atlantic and Gulf coast ecosystems. *Ecology and Society*, *14*(1): 8.

8. Azrina Z. M., Yap K. C., Rahim Ismail A. Ismail A. and Tan G. S., 2006. Anthropogenic impacts on the distribution and biodiversity of benthic macroinvertebrates and water quality of the Langat River, Peninsular Malaysia. *Ecotoxicology and Environmental Safety* 64: 337-347.

9. Badea B. A., Gagyi-Palffy A., Stoian L. C., Stan G., 2010 Preliminary studies of quality assessment of aquatic environments from Cluj suburban areas, based on some invertebrates bioindicators and chemical indicators. *AACL Bioflux* 3(1):35-41.

10. Bartoli M, Nizzolo D, Viaroli P, Turolla E, Castaldelli, FEA Rossi. 2001. Impact of *Tapes philippiarum farming* on nutrient dynamics and benthic respiration the Cacca di Goro, *Hydrobiologia*, 455: 203-212.

11. Beauger A., 2008. Bio-évaluation de la qualité de l'eau : établissement d'un protocole d'échantillonnage simplifié, basé sur la collecte des macroinvertébrés benthiques sur les seuils des rivières à charge de fond graveleuse. Doctoral dissertation, Université Blaise Pascal-Clermont-Ferrand II; Université d'Auvergne-Clermont-Ferrand I.

12. Benoit-Chabot V., 2014. Les facteurs de sélection des bio-indicateurs de la qualité des écosystèmes aquatiques : élaboration d'un outil d'aide à la décision CUFE – Essais 98p.

13. Corbi J. J. and Trivinho-Strixino S., 2002. Spatial and bathymetric distribution of the macrobenthic fauna of the Ribeirão das Anhumas reservoir (Américo Brasiliense-SP, Brasil). *Acta Limnologica Brasiliensia*, (14) 1, 35-42.

14. Dajoz R., 2000. Précis d'Ecologie. 7ème édition, Dunod, Paris, 615 p.

15. Dejoux C., Elouard J. M., Forge P. & Justin J. M., 1981.-Catalogue iconographique des insectes aquatiques de Côte d'Ivoire. Rapport ORSTOM, 42 : 179 p.

16. Diomandé D., 2001. Macrofaune benthique et stratégies alimentaires de Synodontis bastiani Daget, 1948 et S. schall (Bloch and Schneider, 1801) (Bassins Bia et Agnébi, Côte d'Ivoire. Thèse de Doctorat, Université d'Abobo-Adjamé, 260 p.

17. Durand J. R. & Guiral D., 1994. Hydroclimat et hydrochimie. *In* Durand JR, Dufour P, Guiral D, Zabi SGF eds, Environnement et ressources aquatiques de Côte d'Ivoire. Tome II. Les Milieux lagunaires. Orstom, Paris : 129-136.

18. Durand J. R. & Lévêque C., 1981.- Flore et Faune Aquatiques de l'Afrique Sahélo Soudanienne, Tome I et Tome II. ORSTOM, Paris : 873 p.

19. Durand J. R. & Skubich M., 1982. - Les lagunes ivoiriennes. *Aquaculture*, 27 : 211-250.

20. Fauvel P., 1923. Polychètes errants. Faune de France, 5 : 1-491, 181 figures.

21. Fauvel P., 1927. Polychètes sédentaires. Addenda aux errantes, archi-annélides, Mysostomaires. Faune de France, 16 : 1-497, 152 figures.

22. Fusari M. L., 2006. Estudo das Comunidades de Macroinvertebrados Bentônicos das Represas do Monjolinho e do Fazzari no Campus da UFSCar, Município de São Carlos, SP. São Carlos : Universidade Federal de São Carlos. 80 p. [Dissertação de mestrado].

23. Gordon C., 2000. Hypersaline lagoons as conservation habitats : macro-invertebrates at Muni Lagoon, Ghana. *Biodiversity & Conservation*, 9 (4) : 465-478.

24. Intès A. and Le Loeuff P., 1975. Les Annélides Polychètes de Côte d'Ivoire I. Polychètes errantes, compte rendu systématique. *Cahier ORSTOM, série Océanographie*, 13 (4): 267-321.
25. Jager I. S. and Walz N., 2002. *Chaoborus flavicans* (Diptera) is an oxyregulator. Archiv fuer *Hydrobiologie*, 155: 401-411.
26. Jonathan H. P. and Lee A. F., 2006. Aquatic invertebrate responses to fish presence and vegetation complexity in Western Boreal wetlands, with implications for water bird productivity. *Wetlands*, 26: 1-12.
27. Kennish M. J., 2016. Anthropogenic impacts. In Encyclopedia of estuaries, Kennish M. J., (Ed.) 2016, XXIX, 760 p. 330
28. Kouadio K. N., 2011. -Diversité et structure des peuplements de macroinvertébrés benthiques des lagunes de Côte d'Ivoire : Aby, Ebrié et Grand-Lahou. Thèse de Doctorat de l'Université d'Abobo-Adjamé, Abidjan, Côte d'Ivoire, 145 p.
29. Kouadio K. N. Diomandé D., Koné Y. J. M., Bony K. Y. Ouattara A. Gourène G., 2011. Distribution of benthic macroinvertebrate communities in relation to environmental factors in the Ebrié Lagoon (Ivory Coast, West Africa). *Vie et milieu-life and environment*, 61(2) : 59-69.
30. Kouadio K. N., Diomandé D., Ouattara A., Koné Y. J. M., Gourène G. 2008. Taxonomic diversity and structure of benthic macroinvertebrates in Aby lagoon (Ivory Coast, West Africa). *Pakistan Journal of Biological Sciences* 11(18): 2224-2230.
31. Kouassi A. M., Kaba N. and Métongo B. S., 1995. - Land-based sources of pollution and environmental quality of the Ebrié lagoon waters. *Marine Pollution Bulletin*, 30 (5): 295-300.
32. Kubosova K., Brabec K., Jarkovsky J. & Syrovatka V., 2010. Selection of indicative taxa for river habitats: a case study on benthic macroinvertebrates using indicator species analysis and the random forest methods. *Hydrobiologia* 651: 101-114.
33. Lamptey E. and Armah K. A., 2008. Factors Affecting Macrobenthic Fauna in a Tropical Hypersaline Coastal Lagoon in Ghana, West Africa. *Estuaries and Coasts*, 31:1006 – 1019. DOI 10.1007/s12237-008-9079-y.
34. Le Loeuff P. and Zabi S. G. F., 1993. Revue des connaissances sur la faune benthique des milieux marginaux-littoraux d'Afrique de l'Ouest. 3e partie : discussion et conclusion *Revue Hydrobiologie Tropicale* 26(1) : 19-51.
35. Lima F. B., Schäfer E. A. and Lanzer M. R., 2013. Diversity and spatial and temporal variation of benthic macroinvertebrates with respect to the trophic state of Lake Figueira in the South of Brazil., *Acta Limnologica Brasiliensia*, vol. 25, no. 4, p. 429-441.
36. Little C., 2000. The Biology of Soft Shores and Estuaries. New York, Oxford University, 252p.
37. Mendes C. L.T and Soares-Gomes A., 2011. Macrobenthic community structure in a Brazilian chocked lagoon system under environmental stress. *Zoologia* 28 (3): 365–378, doi: 10.1590/S1984-46702011000300011
38. Monney A. I., Etilé N. R., Ouattara N. I and Kone T., 2016. Seasonal distribution of zooplankton in the Aby-Tendo-Ehy lagoons system (Côte d'Ivoire, West Africa). *International Journal of Biological and Chemical Sciences* 9(5): 2362-2376.39. Nkwoji J. A., 2016. Impact of Hypoxia on the Community Structure of Benthic Macroinvertebrates of Lagos Lagoon, Nigeria. *J. Appl. Sci. Environ. Manage*. Vol. 20 (1): 121 – 130.
40. Nkwoji J. A. and Igbo J. K., 2010. Comparative study of Benthic macroinvertebrate in the Eastern and Western parts of Lagos lagoon, Nigeria. *Environmental research journal*, 4(2): 182-186.
41. Nkwoji J. A., Igbo J. K., Adeleye A. O., Obienu J. A., and Tony-Obiagwu M. J., 2010. Implications of bioindicators in ecological health: study of a coastal lagoon, Lagos, Nigeria. *Agricultural and Biological Journal of Natural Animals*, 1(4): 683-689.
42. Nkwoji J. A., Igbo J. K., Adeleye A. O., Obienu J. A. and Tony-Obiagwu M. J., 2011. Implications of bioindicators in ecological health: study of a coastal lagoon, Lagos, Nigeria. *Agriculture and biology journal of north America*: 1(4): 683-689.
43. Odountan H. and Abou Y., 2016. Structure and Composition of Macroinvertebrates during Flood Period of the Nokoue Lake, Benin. *Open Journal of Ecology*, 6, 62-73.
44. Ogbeibu A. E. and Oribhabor B. J., 2002. Ecological impact of river impoundment using benthic macro-invertebrates as indicators. *Water Research* 36:2427-2436.
45. Ogunwenmo C. A. and Osuala I. A., 2004. Physico-chemical parameters and macrobenthos of an estuarine creek and an artificial pond in Lagos, southwestern Nigeria. *acta Satech* 1(2): 128-132.

47. Pereira T. S., Gomes Pio F. J., Calor R. A. and Copatti E. C., 2017. Can the substrate influence the distribution and composition of benthic macroinvertebrates in streams in northeastern Brazil? *Limnologica*, 63: 27-30.
48. Pilo D., Leitao F., Ben-Hamadou R., Range P., Chicharo M., and Chicharo L., 2011. Macrobenthic response to sewage discharges in confined areas from coastal lagoons: Implication on the Ecological quality status. *Vie Milieu* 61 (2) : 107-118.
49. Sankaré Y. and Etien N. 1991. Analyse des effets de l'ouverture du chenal de Grand-Bassam (estuaire du fleuve Comoé, lagune Ebrié) sur le macrofaune benthique lagunaire. *J Ivoir Oceanol Limnol* 1(2): 81-90.
50. Saru A., 2014. Contribution of environmental parameter on stability ecosystem of habitat of Molluscs. *International Journal of Marine Science*, Vol.4, No.67, 1-6.
51. Simmou Y. J., Bamba M., Konan Y. A., Kouassi K. P., Koné T., 2015. Impact des Activités anthropogéniques sur la Distribution des Macroinvertébrés Benthiques et la qualité des eaux de quatre petits cours d'eaux de Côte D'ivoire. *European Journal of Scientific Research* 136 (2): 122-137.
52. Tachet H., Richoux P., Bournaud M., Usseglio-Polatera P., 2010. Invertébrés d'eau douce : systématique, biologie, écologie. CNRS Editions, Paris, ISBN: 978-2-271-06945-0, 607p.
53. Thrush S. F., Townsend M., Hewitt J. E., Davies K., Lohrer A. M., Lundquist C. and Cartner K., 2013. The many uses and values of estuarine ecosystems. In Dymond JR ed. Ecosystem services in New Zealand conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand, pp 226-227.
54. Traoré A., Soro G., Kouadio E. K., Bamba B. S., Oga M. S., Soro N. et Biémi J., 2012. Evaluation des paramètres physiques, chimiques et bactériologiques des eaux d'une lagune tropicale en période d'étiage : la lagune Aghien (Côte d'Ivoire). *International Journal of Biological and Chemical Sciences* (IJBCS), 6(6) :7048-7058.
55. Uwadiae R. E., 2009. Response of Benthic Macroinvertebrate Community to Salinity Gradient in a Sandwiched Coastal Lagoon: *Report and Opinion*, 1(4): 45-55.
56. Uwadiae R. E., 2013. Spatial Patterns in Diversity and Distribution of Benthic Molluscs in a Weak Tidal Tropical Lagoon. *International Journal of Marine Science*, Vol.3, No.14, 111-120.
57. Uwadiae R. E., 2014. Environmental Characteristics and Community Structure of Benthic Macroinvertebrate of Epe Lagoon, Nigeria. *International Journal of Environmental Sciences*, 3, 36-44.
58. Uwadiae R. E, O. Oni, O.E. Egue, T. Idowu, F.E. Ezekwe, A. Afor, T. Sotomi, A. Mayungbe, 2012. Patterns and determinants of benthic macroinvertebrate functional assemblages: function-environment interrelationship in a lagoon ecosystem. World Journal of Biological Research, vol.5 Issue 2: 67-73.
59. Voshell J. and Reese J. 2002. A Guide to freshwater invertebrates of North America. Mc Donald and Woodward Publishing Co.: Blacksburg VA. Lae R. *Aquatic Living Resources*, 1994, 7: 165–179.
60. Warwick R. 1993. Environmental impact studies on marine communities: Pragmatical considerations. *Aust J Ecol* 18 : 63-80.
61. Zabi S. G. F., 1982. Les peuplements benthiques lagunaires liés à la pollution en zone urbaine d'Abidjan (Côte d'Ivoire). *Oceanol Acta* Suppl 4 : 441-455.