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Diversity and Spatial Distribution Pattern of Benthic Macroinvertebrates of the Cavally River (Ivory Coast, West Africa)

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Abstract*—Diversity and specific composition of the aquatic Macroinvertebrates of the Cavally River has been studied. The study was carried out considering three sampling zones: upstream, middle stream and downstream from the Ity mine. Macroinvertebrates were collected in four sampling periods between May 2015 and February 2016 using a kick net (mesh size 250 µm)) and a van Veen been. In total 9114 individuals belonging to 115 taxa; 52 families and 16 orders have been identified. The faunistic spectrum consists mainly of insects, Crustaceans, Clitellates, Molluscs, Arachnids and Trombidiformes. Hemiptera are the most diversified. Chironomidae are the most abundant. Downstream stations have the lowest abundance and richness despite the good organization of their stand.*

***Keywords*—** *Macroinvertebrates, Diversity, mining effects, Cavally river, Ivory Coast.*

I. INTRODUCTION

The water resource conditions the development of human activities (health, food, or human activities). However, aquatic ecosystems are threatened by human activities that cause significant anthropogenic effects (Vazquez and Favila 1998, Dokulil *et al.,* 2000, Tazi *et al*., 2001). According to (Moisan and Pelletier, 2008) disturbances of aquatic ecosystems are very often felt at the level of biological communities. The effects of these changes are manifested by dramatic changes in the diversity and species composition of aquatic communities (Bony *et al.,* 2013). The biological communities of a habitat are then considered as a synthetic expression of all the ecological factors that characterize this environment (Mary, 2011). In Côte d'Ivoire, studies on macroinvertebrates are numerous and diverse, including the work of (Lévêque *et al.*, 1983; Stazner *et al*., 1984; Diétoa, 2002; Edia *et al.,* 2007, Diomandé *et al.,* 2009). However, studies on the benthic macroinvertebrates of the Cavally River are very few or rare. The present study aimed at providing a first database on the benthic macrofauna of the Cavally river. Its objectives were to evaluate the diversity of benthic macroinvertebrate communities of the Cavally River and to determine the structure and composition of this fauna.

II. MATERIALS AND METHODS

A. Study Site

Located in western of Côte d'Ivoire, Cavally river covers a catchment area of 30 600 km^2 and 515 km long. The study area is located in the middle course of the Cavally River in the Tonkpi region, specifically in the Department of Zouan hounien (Figure 1). It concerns the section of the river lying between 5° 76' 20.6" and 5° 99' 01" N; 7° 47' 79.8" and 7° 84' 09 " W. This portion of the river crossing the Ity gold mine is under great pressure due to human activities (agriculture, gold washing, fishing, mining effluents, etc.) which significantly deteriorates the aquatic environment. This area is influenced by a mountain climate characterized by two seasons: a long rainy season from april to october corresponding to the rising waters and a short dry season, from november to march for low water (Dieulin, 2008).

B. Sampling Procedure

The study was carried out on 34 stations (S1 to S34) chosen in the watershed of the river according to the accessibility, the morphological characteristics and the presence or not of potential sources of disturbances. Particularly, according to the ecological characteristics of the river, three sampling zones were considered according to the upstream-downstream gradient: 7 stations (S1 to S2) in the upstream with strong current, 21 stations (S8 to S28) in middle stream with high mining activity and the last 6 stations (S29 to S34) in downstream (Fig. 1).

Benthic macroinvertebrates were sampled at each of the 34 sampling sites quaterly (two sampling periods during the rainy season and two sampling periods during the dry season) using a kick net (mesh size 250 µm) following SASS (South African Scoring System) method (Dickens & Graham, 2002). The samples were collected during 2-3 minutes sampling sessions by submerging the kick net and dragging it in the water column over a certain distance. The net also scraped against the bottom substrate to dislodge and collect the sediment organisms. The benthic fauna was also harvested with a Van Veen grab sampler in stainless steel. At each site, three sediment samples corresponding to a total area of 0.15 m² were taken at several depths. The grab was sunk to the bottom of the water at a slow, steady pace. The rope was retained as vertically as possible to ensure the establishment and the lifting of the grab at a right angle in relation to the bottom. As soon as the jaws of the grab touch the bottom, the rope is pulled up to close the jaws trapping sediment. Out of the water, the content of the grab was washed on a 0.5 mm mesh sieve. All samples were fixed in 70% alcohol.

In the laboratory, all the collected samples were screened, and the harvested individuals were sorted using a binocular magnifying glass, and were counted and identified to the lowest taxonomic level as possible by using the appropriate determination keys Déjoux *et al.* (1981); Diomandé *et al.*

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(2000), Mary, 2000; de Moor *et al.*, 2003; Tachet *et al.* (2003), Brown (2005), Bony *et al.* (2008); Moisan (2010), Mary, (2011).

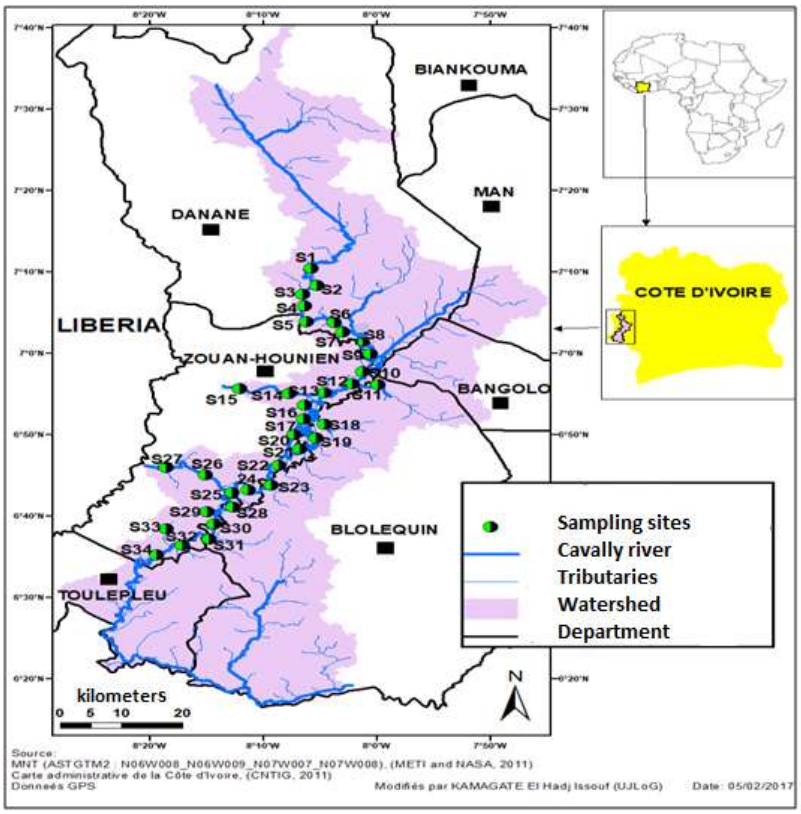

Fig. 1. Location of the study area showing sampling sites.

C. Data Analysis

The data analysis was carried out on the basis of:

- Total taxa richness;
- Faunal density;
- Shannon's diversity index H' (1949): based on the number of species and the regularity of their frequency distribution. H' = - Σ pi log 2 pi where pi is the relative abundance of the species i in the sample (p i = n i /N); H' fluctuates between 0 and log S. A high index of Shannon corresponds to favorable environmental conditions allowing the installation of many species.

Generally, the value of H' is located between 0.5 (low diversity) and 4.5 or 5 (the most diverse communities);

- Pielou regularity or fairness index J; This index is the ratio of the diversity H' to the maximum diversity that can be obtained with the same number of taxa (H'max = log2 S): J = H'/ H'max = H' / log2 S; The fairness index varies between 0 and 1 (when it is close to 0, it means that a species dominates in the benthic community; when it equals to 1, all species have the same abundance). For many ecologists, a high fairness value is equivalent to a balanced community;

Analyses were performed using Past software (PAleontological STatistics, Version 2.16.

III. RESULTS

Taxonomic Composition of Benthic Macroinvertebrates

The taxonomic composition of the benthic communities of the Cavally River is presented in Table 1. 9114 aquatic macroinvertebrates of 115 taxa belonging to 16 orders and 52 families were collected. These macroinvertebrates consist mainly of Insects, Molluscs, Crustacean, Clitellates, Arachnids and Trombidiformes. The community was represented by 38 families of Arthropods, 6 families of molluscs, 2 families of crustaceans, 3 families of Clitellates, 1 family of Trombidiformes and 1 family of Arachnid. Insects are the most dominant with 81.97% of taxa followed by Molluscs (13.66%), Crustaceans (2.36%) and Clitellates (1.55%), the other groups (0.46%) are very poorly represented: Trombidiformes (0, 38%) and Arachnids (0.08%) (Fig. 2).

The insects consist of 7 orders namely the Ephemeroptera (7.28%), Trichoptera (0.42%), Odonata (4.77%), Hemiptera (28.36%), Lepidoptera (0.14%), Coleoptera (21.12%), Diptera (37.87%), 38 families and 90 taxa. The order Hemiptera is the most diversify with 11 families and 24 taxa, followed by Odonata with 19 taxa and 5 families.

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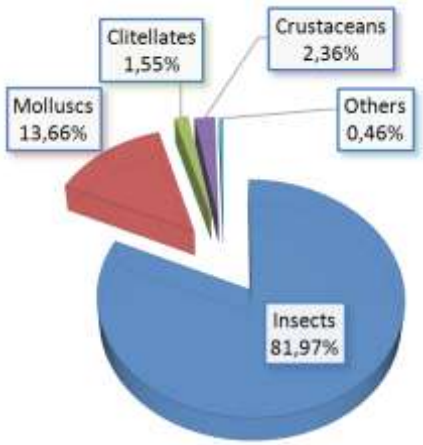

Fig. 2. Relative proportions of main groups of macroinvertebrates collected in the Cavally River.

The order of Diptera displayed 2830 individuals grouped into 17 taxa and 9 families, mainly dominated by Chironomidae with 2319 individuals or 81.94% of all Diptera. Next comes the Coleoptera represented by 1578 individuals grouped into 17 taxa and 5 families (Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae) and the Ephemeroptera with 544 individuals divided into 7 taxa and 3 families (Baetidae, Leptophlebiidae, Oligoneuriidae). The other orders, were very less represented, are Trichoptera with 5 taxa and 4 families (Hydropsychidae, Hydroptilidae, Leptoceridae, Philopotamidae) and Lepidoptera consisting of 1 taxa and 1 family (Piraliddae).

Libellulidae family was most diversifyed of insects with 10 taxa. Molluscs include 15 taxa divided between 6 families (Ancylidae, Lymnaeidae, Planorbidae, Thiaridae, Sphaeriidae, Corbulidae) and 4 orders (Basommatophores, Ceanogasteropods, Veneroid, Eulamellibranch). At the Clitellate level, 6 taxa belong to 3 families (Tubificidae, Glossiphonidae, Salifidae) and 2 orders (Haplotaxida, Rhynchobdellida) have been listed. Crustaceans harvested belong to the order of decapods composed of 2 families (Atyidae Palaemonidae). Arachnids and Trombidiformes contain respectively 1 family (Tetragnathidae and Hydrachnidae) and 1 taxon each (Tetragnatha sp., Hydracarien).

Distribution of Benthic Macroinvertebrates

Of the aquatic macroinvertebrates present in all study areas, 9114 individuals are shared between upstream, middle and downstream with respectively 3395 individuals (37.25%), 5136 individuals (6,40%) and 583 individuals) (6.40 %). The stations of the middle stream have the highest abundance (56,35%) with a predominance of the Diptera (45,15%) and the lowest one at the level of the downstream stations with a dominance of the decapods (33,96%). The highest specific (S) richness was observed at middlestream stations (95 taxa) followed by upstream stations (92 taxa) and the lowest recorded at the downstream station (42 taxa) (Table II).

The Shannon & Weaver (H ') (1949) and equitability (E) indices calculated on the basis of the numerical abundance of species give different values from one medium to another (Table 2). The Shannon diversity index values are higher in the upstream (H '= 3,11) than in the middlestream H' = 2,86 and downstream (H '= 2,73). Piélou's equitability J 'translates the quality of the organization of a stand. Its value is highest at the downstream (E = 0.73), although the taxonomic richness and abundance are the lowest. The upstream and middlestream stations indicate respective fairness values of E = 0.69 and E = 0.63 (Table II).

IV. Discussion

The taxonomic composition of the benthic communities of the Cavally River in the Tonpki region is characterized by Insect, Crustaceans, Clitellates, Molluscs, Arachnids and Trombidiformes grouped into 16 orders, 52 families and 115 taxa, with insect dominance (81.97% of taxa). The order Hemiptera is the most diverse with 11 families and 24 taxa. The most diverse family of insects is that of Libellulidae (10 taxa). This faunistic composition is similar to that of African freshwaters macroinvertebtates communities (Diomandé & Gourène, 2005). In fact, this wildlife structure is similar to that drawn up by some authors (Tchakonté, 2016; Onana *et al*. 2016; Nyamsi *et al*., 2014 ; Foto *et al*., 2011; Diomandé *et al*., 2009) in Anthropized watercourses of tropical African regions. In addition, Chironomidae are present throughout the length of the river, and constitute the most abundant family (25.44%). Similar results (40.72%) were observed by Diomandé *et al*., (2009) in the Agnéby River. The abundance of these so-called polluo-tolerant taxa in these environments would globally indicate that the ecological integrity of the Cavally River would be altered (Barbour et al., 1999). The low percentage of pollo-sensitive taxa (Ephemeroptera (7.28%), Trichoptera (0.42%)) collected, confirms this fact. Foto et al. (2011) noted the emergence of these taxa in heavily anthropogenic urban environments.

The evaluation of the abundance and the specific richness of the river show that the downstream stations are the less rich in taxa. This is understandable since these stations are located downstream of anthropogenic disturbances (Tshijik *et al*., 2016). In addition, middle course stations located in anthropized areas indicate the highest abundance and richness related to unaffected areas of upstream stations. This could probably be explained by an increase in polluting anthropogenic activities in the river's catchment areas, thus favoring a homogenization of macroinvertebrate communities (Maloney *et al*., 2011). Also, the large size of the area and a high degree of habitat heterogeneity can induce a high biological diversity in macroinvertebrate communities (Sankaré *et al*., 1999, Palmer *et al*., 2000). The highest values of Shannon index and equitability are respectively observed in the upstream and downstream stations. This would reflect a good biological quality of the river (Camargo *et al*., 2004, Peterson, 2006). However, this organization of the macroinvertebrate population results essentially from the diversification and proliferation of pollo-tolerant taxa (Chironomidae). This could be related to anthropogenic activities influencing the watercourse. Indeed, the artisanal and industrial mining practiced in the area, as well as the

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domestic discharges in the Cavally river could contribute considerably to the installation of particular conditions favorable to the presence of a diversified population of polluted taxa.

V. CONCLUSION

This study provides a first inventory of aquatic macroinvertebrates of Cavally River in the tonpki region. 115 taxa belonging to 52 families and (16) orders were collected. The stand is diverse with a dominance of pollo-tolerant taxa. The upsream and middlestream stations are most diversified and most abundant. The diversity of taxa considered as pollutants indicates a very strong anthropization of the Cavally River basin. This study provides the basis for future ecological studies of aquatic macroinvertebrates in this region.

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TABLE I. List of benthic macroinvertebrates of the Cavally River with their abundances

				Sampling sites			
Class	**Order**	**Familly**	**Taxa**	**upstream**	**middlestream**	**Downstream**	**Total**
	Arachnid	**Tetragnathidae**	*Tetragnatha sp.*	2	4	1	7
	Trombidiforms	**Hydrachnidae**	*Hydracarien*	5	21	9	35
Clitellates	**Oligocheta**	**Oligocheta**	*Oligochètes*	18	108	4	130
	Haplotaxida	**Tubificidae**	*Potamothrix*	0	4	0	4
	Rhynchobdellida	**Glossiphonidae**	*Glossiphonia sp.*	0	1	0	1
			Helobdella sp.	1	3	0	4
		Salifidae	*Barbonia Weberi*	1	0	0	1
			Salifidae	0	1	0	1
Crustaceans	**Decapoda**	**Atyidae**	*Atyoida serrata*	5	8	185	198
		Palaemonidae	*Macrobrachium vollenhovenii*	1	3	13	17
Molluscs	**Basommatophora**	**Ancylidae**	*Ferrissia fontinalis*	81	3	0	84
		Lymnaeidae	*Lymnaea peregra*	0	155	9	164
		Planorbidae	*Afrogyrus sp.*	1	2	0	3
			Biomphalaria pfeifferi	38	0	12	50
			Bulinus forskali	5	17	0	22
			Bulinus natalensis	4	0	0	4
			Bulinus truncatus	1	49	0	50
			Bulinus sp.	1	0	0	1
			Indoplanorbis exustus	148	91	4	243
			Physa turriculata	0	1	0	1
	Ceanogastéropoda	**Thiaridae**	*Cleopatra sp.*	9	0	0	9
			Melanoides tuberculata	570	20	0	590
			Potadoma sp.	2	1	0	3
	Veneroïde	**Sphaeriidae**	*Pissidium punctifera*	1	5	0	6
	Eulamellibranche	**Corbulidae**	*Corbula sp.*	0	15	0	15
Insects	**Coléoptera**	**Dytiscidae**	*Hydaticus sp.*	7	2	0	9
			Hydrocanthus micans	0	4	0	4
			Hyphydrus sp.	26	160	5	191
			Laccophilus sp.	9	17	1	27
			Neptosternus sp.	0	7	0	7
		Elmidae	*Elmis sp.*	5	1	0	6
			Potamodytes	33	46	1	80
		Gyrinidae	*Aulonogyrus sp.*	37	94	47	178
			Dineutus sp.	45	41	0	86
			Olonogyrus sp.	86	0	0	86
			Orectogyrus sp.	563	18	14	595
		Hydraenidae	*Hydraena borbonica*	114	1	0	115
		Hydrophilidae	*Amphiops sp.*	10	35	8	53
			Coelestoma sp.	12	10	9	31
			Enochrus sp.	9	19	0	28
			Hydrophilus sp.	22	30	1	53
			Laccobius sp.	3	26	0	29

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TABLE II.

				Sampling sites			
Class	**Order**	**Familly**	**Taxa**	**upstream**	**middlestream**	**Downstream**	**Total**
Insects	**Diptera**	**Ceratopogonidae**	*Bezzia sp.*	2	0	0	2
			Ceratopogon	185	227	0	412
		Chaoboridae	*Chaoborus sp.*	1	45	0	46
		Chironomidae	*Ablabesmyia pietipes*	0	1	0	1
			Chironominae	331	1915	17	2263
			Cricotopus sp.	0	3	0	3
			Cryptochironomus sp.	7	0	0	7
			Orthocladiinae	3	37	1	41
			Polydilum Fuscipenne	0	1	0	1
			Tanypodinae	1	1	1	3
		Culicidae	*Aedes sp.*	7	9	1	17
			Culex sp.	3	5	0	8
		Limoniidae	*Eriopterini sp.*	0	0	6	6
		Psychodidae	*Psychodidae*	0	3	0	3
		Simuliidae	*Simulium*	1	12	0	13
		Tabanidae	*Tabanus sp.*	0	3	0	3
		Tipulidae	*Tipula sp.*	0	1	0	1
	Ephéméroptera	**Baetidae**	*Afrobaetodes reitteri*	10	0	0	10
			Baetis sp.	1	9	0	10
			Centroptilum sp.	92	180	0	272
		Leptophlebiidae	*Adenophlebiodes sp.*	14	196	1	211
			Leptophlebiide	0	15	0	15
			Pelocarantha titan	3	17	2	22
		Oligoneuriidae	*Elassoneuria sp.*	0	3	1	4
	Hemiptera	**Belostomidae**	*Amphiops sp.*	3	0	0	3
			Diplonychus sp.	23	113	2	138
		Corixidae	*Micronecta sp.*	1	77	0	78
			Stenocorixa protusa	1	17	0	18
		Dytiscidae	*Bidesus sp.*	0	11	0	11
		Gerridae	*Edrymetropsis carayoni*	18	0	0	18
			Eurymetra sp.	99	25	4	128
			Gerris sp.	14	2	0	16
			Gerrisella sp.	15	22	0	37
			Limnogonus sp.	165	421	34	620
			Rhagadotarsus hutchinsoni	20	17	10	47
		Hydrometridae	*Hydrometra sp.*	5	7	11	23
		Naucoridae	*Laccoris sp.*	1	3	0	4
			Naucoris sp.	2	14	7	23
		Nepidae	*Laccotrephes ater*	1	17	0	18
		Notonectidae	*Anisops sp.*	123	284	69	476
			Notonectidae	6	42	0	48
		perlidae	*Neoperla spio*	0	4	0	4
			Plea sp.	6	0	0	6
	Lepidoptera	**Ranatridae**	*Ranatra sp.*	3	10	30	43
		Veliidae	*Microvelia sp.*	174	11	11	196
			Rhagovelia infernalis	0	42	0	42
			Rhagovelia reitteri	27	85	7	119
			Rhagovelia sp.	3	0	0	3
		Pyralidae	*Pyralidae*	9	2	0	11
	Odonata	**Aeshnidae**	*Anax imperator*	1	14	0	15
		Coenagrionidae	*Ceriagrion sp.*	13	6	3	22
			Pseudagrion punctum	0	6	0	6
			Pseudagrion sp.	9	2	0	11
		Corduliidae	*Phyllomacromia sp.*	8	2	0	10
		Gomphidae	*Ictinogomphus sp.*	4	1	0	5
			Microgomphus sp.	6	1	0	7
			Neurogomphus sp.	1	6	7	14
			Phyllogomphus aethiops	11	3	1	15

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				Sampling sites			
Class	**Order**	**Familly**	**Taxa**	**Upstream**	**Middlestream**	**Downstream**	**Total**
Insects	**Odonata**	**Libellulidae**	*Bradinopyga strachani*	2	5	0	7
			Crocothemis sp.	3	5	0	8
			Libellula	27	79	17	123
			Olpogastra sp.	1	0	0	1
			Orthetrum sp.	8	0	0	8
			Parazyxomma flavicans	0	0	2	2
			Trithemis annulata haematina	3	34	0	37
			Urothemis sp.	0	1	0	1
			Zygonyx sp.	13	0	5	18
			Zygonyx torridus	14	24	9	47
	Trichoptera	**Hydropsychidae**	*Hydropsyche*	3	1	0	4
		Hydroptilidae	*Hydroptila sp.*	6	11	0	17
		Leptoceridae	*Leptocerus sp.*	5	3	1	9
			Parasetodes sp.	1	0	0	1
		Philopotamidae	*Philopotamus sp.*	1	0	0	1
Total	**17**	**51**	**115**	**3395**	**5136**	**583**	**9114**

TABLE IIII. Summary statistics of the data collected on aquatic macroinvertebrates at the different sampling stations of the Cavally River basin

	continuum fluvial		
Index	**Upstream**	**Middlestream**	**Downstream**
Taxonomic Richness_S	92	95	42
Individuals	3395	5136	583
Shannon_H'	3,11	2,86	2,73
Equitability_E	0,69	0,63	0,73

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