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Kressou Armand
Laboratory of Biodiversity and Tropical Ecology, University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire

Bony Kotchi Yves
Laboratory of Biodiversity and Tropical Ecology, University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire

Allouko Jean-Renaud
Laboratory of Biodiversity and Tropical Ecology, University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire

Djene Kouakou Roland
Laboratory of Biodiversity and Tropical Ecology, University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire

Corresponding Author:
Kressou Armand
Laboratory of Biodiversity and Tropical Ecology, University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire

Biosedimentary index (IBS) and biological quality of the water courses in the upper Bandama fauna and flora reserve (North-center Côte d'Ivoire)

Kressou Armand, Bony Kotchi Yves, Allouko Jean-Renaud and Djene Kouakou Roland

Abstract
This study aimed to assess the biological quality of the Bamdama watercourse in the Upper Bandama Fauna and Flora Reserve. Macro-invertebrates were sampled between January 2018 and February 2019 using a kick net and Van Veen grab on twelve stations. A total of 3922 individuals of 199 taxa belonging to 8 classes, 27 orders and 87 families were collected. Insects appeared most abundant and diverse with 80.40% of the taxonomic richness and 66% of the different classes represented. Based on the values of the Biosedimentary Index (IBS), the station (MS) located at the middle stream in the pond has water of «fair» biological quality. On the other hand, all other stations have «good» organic quality water.

Keywords: Biosedimentary index, diversity, biological quality, upper bandama fauna and flora reserve, Ivory Coast

Introduction
The hydrosystems of the Upper-Bandama fauna and flora reserve (RFFHB) are subject to strong anthropogenic pressures, including the location of agro-food industries upstream of the reserve, intensive agriculture, artisanal fishing at the site. The use of pesticides and traditional gold panning [1, 2]. Moreover, the unstable socio-political situation that prevailed in Côte d'Ivoire between 2002 and 2011 accentuated the clandestine settlement of populations. Hence the increase in the invasion of these media by aquatic plants and algae, inducing their enrichment in suspended matter [3].

Today, with the Ivorian State taking over this reserve through the Ivorian Office of Parks and Reserves (OIPR), it is gradually setting up, quality monitoring systems water from the reserve. These systems include methods based on monitoring biological communities, including the aquatic macro-invertebrates that live there. These organisms are used as indicators of the quality of aquatic environments because of their sedentary nature, their great diversity and their variable tolerance to pollution and habitat degradation [4]. In addition, they reflect particularly well the ecological status and integrity of aquatic environments by reacting very quickly to changes in their environment. Finally, they are an essential component of the food web of aquatic ecosystems [5, 6] and actively participate in the transformation of organic matter. The presence or the absence of a species, the richness and the specific diversity, are thus indices of a good or bad quality of the waters. The reserve has benefited from very few studies, especially those concerning its benthic macrofauna. There fore, the implementation of such a monitoring system relies entirely on the knowledge of this aquatic component necessary to assess the state of biological integrity of the aquatic environments of this reserve.

This assessment using biological indices is based on the presence or absence of some bioindicator taxa and the extent of changes observed in them. These indices apply to both lotic and luteal facies systems. They provide complementary information since they aim to characterize disturbances by their effects on living communities (benthic macroinvertebrates) in place. They are also more integrated because they reflect both the characteristics of the water.

Thus, the purpose of this publication is to assess the biological quality of the water at the sampling stations of this reserve through the biological index IBS (the biosedimentary index).

Materials and Methods

Study Site

Established by decree N ° 73-133 of the 21/03/73, the Upper-Bandama fauna and flora reserve (RFFHB) covering 123 km² is located in the North-center of Côte d'Ivoire, between, 8° 10' 25,3" and 8° 38' 25,01" N and 5° 12' 14,1" and 5° 37' 55.3" W. The RFFHB is crossed from north to south by the white Bandama River for a distance of 160 km, or 15% of its total length. This zone is subject to a sub-humid tropical climate, sometimes referred to as sub-Sudanian transition [7]. It is characterized by two seasons, one dry, from November to March, accented by the harmattan between January and February and the other rainy, covering the period from April to October. Heavy rainfall and a larger flood recorded in September with a flow of 300 m^3/s. The average annual rainfall is about 1230 mm. Other climates characteristics are relatively large thermal amplitudes are of the order of 26.6 °C and a humidity ranging from 35 to 79%.

Sampling Procedure

During this study, eight (8) seasonal sampling campaigns were conducted between January 2018 and February 2019 in the reserve, at the frequency of four (4) sampling campaigns per season. A total of twelve (12) sampling stations were visited, of which eight (8) are arranged along the Bandama River longitudinal gradient, two (2) of which are outside the reserve respectively upstream under the influence of anthropogenic activities and downstream in a relatively well-preserved area. Of the four (4) other stations, two (2) are located in the Nambyon River and two (2) ponds (Fig. 1).

All stations were sampled with a kick net and Van Veen Grab. Overall, 36 sampling sites were defined. The samples were collected at each site for two to three minutes by submerging the kick net and dragging it into the water column. The net has also been banged against the bottom substrate to dislodge and collect sediment organisms. The survey was also done using a Van Veen grab.

At each site, three (03) sediment samples corresponding to a total area of 0.15 m² were taken. *In situ*, the samples were washed on a 500 µm mesh vacuum screen and fixed with 5% formalin. In the laboratory, the organisms were sorted, identified and counted. The identification was made at the lowest taxonomic level by combining the appropriate literature [8-17, 6].

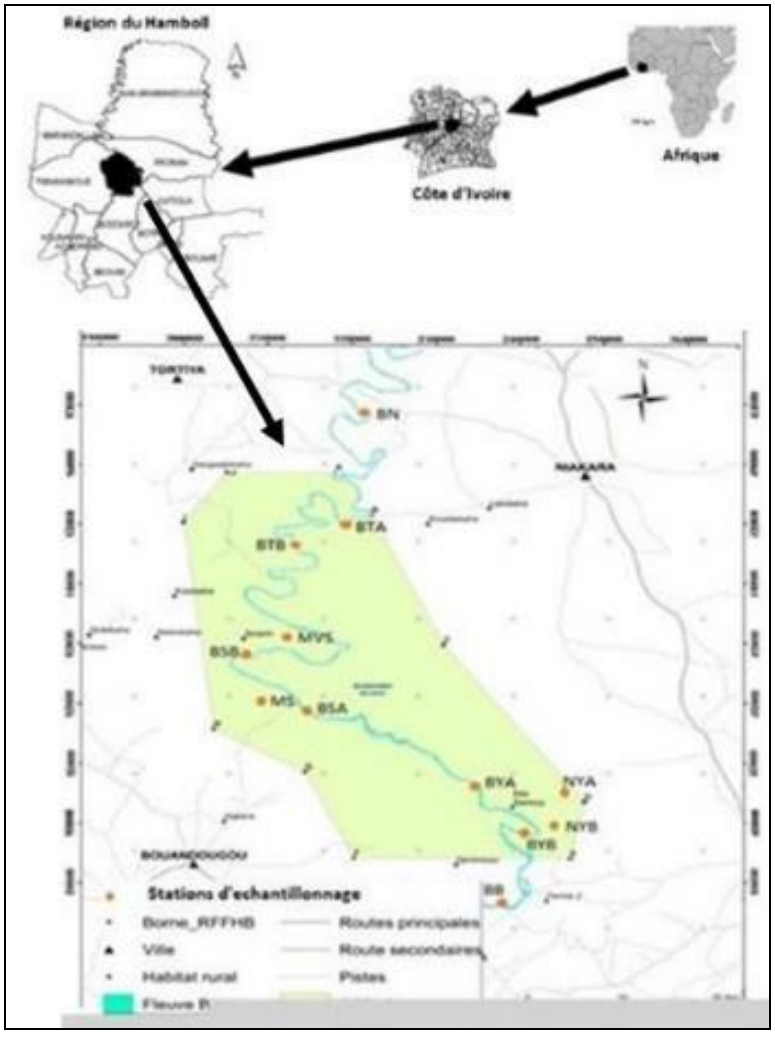

Fig. 1: Location of the sampling stations in the Upper-Bandama Fauna and Flora Reserve (RFFHB). pond (MS and MVS); River (NYA and NYB); Bandama - (BTA, BTB; BSA; BSB; BYA; BYB (located in the reserve), BN and BB stations (located outside the reserve).

Biosedimentary Index (IBS)

The Biosedimentary Index (IBS) was performed to assess mechanical-type disturbances generated by fine sedimentary particles (sand, silt, clay) in streams draining ultra-basic-dominant land observed on New Caledonia [18]. The method refers to a set of indicator taxa to which a score has been assigned based on their sensitivity to their presence. The biosedimentary index (IBS) on a station is obtained by dividing the sum of the scores of the indicator taxa present by the total number of indicator taxa.

$$IBS = 1/n \sum_{I=1}^{I=n} S_i$$

With n: number of indicator taxa; Si: taxon i score for the calculated index.

The scores values of this index are between 1 and 10, with the most sensitive taxa having maximum scores. The index score theoretically varies between 0 (no indicator taxon present) and 10 (all indicator taxa present have a score of 10). In reality, the biosedimentary index rarely exceeds the value of 7, 5. The scores currently used for this index are listed in Table I.

Table 1: Biosedimentary Index Indicator Taxa Sensitivity Scores (IBS) [19].

Indicator Taxa		Score	Scores		Score
Insects		Isostictidae	9	Némertiens	6
Lépidoptera	4	Lestidae	5	Oligochètes	7
Collemboles	4	Libellulidae	4	Crustaces	
Ephemeroptera		Argiolestidae	8	Amphipodes	3
Baetidae	5	Synthemistidae	8	Isopode	3
Leptophlebiidae		Diptèra		Atyidae	7
Amoa	9	Blephariceridae	8	Grapsidae	5
Celiphlebia	7	Ceratopogonidae	2	Hymenosomatidae	5
Coula	10	Forcipomyiinae	5	Palaemonidae	9
Fasciamirus	6	Chironomini	3	Heteroptera	
Kariona	10	Chironomus	4	Belostomatidae	5
Kouma	10	Corynoneura	6	Corixidae	5
Lepegenia	4	Harrisius	4	Gerridae	9
Lepeorus	7	Orthocladiinae	2	Hebridae	5
N. genre 4	9	Pseudochironomini	5	Hydrometridae	7
N. genre A	10	Tanypodinae	3	Leptopodidae	5
N. genre B	10	Tanytarsini	4	Mesoveliidae	4
Notachalcus	8	Cecidomyiidae	3	Notonectidae	10
Oumas	4	Culicidae	9	Ochteridae	5
Ounia	8	Dixidae	5	Pleidae	5
Papposa	10	Dolichopodidae	5	Saldidae	5
Paraluma	4	Empididae	4	Veliidae	9
Peloracantha	10	Ephydridae	6	Planipennes	5
Poya	9	Limoniidae	6	Molluscs Gastropodes	
Simulacala	7	Muscidae	5	Gyraulus	10
Tenagophila	7	Psychodidae	8	Physastra	10
Tindea	7	Rhagionidae	5	Physa	3
Trichoptèra		Simuliidae	5	Pseudosuccinea	3
Ecnomidae	4	Stratiomyidae	4	Melanoides	4
Helicophidae	10	Syrphidae	3	Melanopsis	9
Helicopsychidae	9	Tabanidae	6	Thiara	3
Hydrobiosidae	7	Tanyderidae	5	Hydrobiidae	4
Hydropsychidae	5	Coléoptèra		Microbenthos	
Hydroptilidae	2	Cucurlionidae	7	Ostracodes	9
Kokiriidae	9	Dytiscidae	3	Copépodes	5
Gracilipsodes	8	Gyrinidae	5	Hydracariens	4
Oecetis	6	Hydraenidae	5		
Symphitoneuria	6	Hydrophilidae	8		
Triplectides	7	Noteridae	5		
A. genr. Leptoceridae	7	Scirtidae /Helodidae	3		
Philopotamidae	7	Staphylinidae	3		
Polycentropodidae	8	Haliplidae	5		
Odonatoptèra		Cnidaires (Hydres)	3		
Aeshinidae	5	Plathelmintes	9		
Coenagrionidae	5	Achètes	10		
Corduliidae	10	Nématodes	3		

The biological quality classes of the waters recorded in Table II are proposed [19], to assess the water quality at each station. In addition, color classes are assigned to each water quality class to make it easier to read the representation on a quality map [19].

Table 2: Biosedimentary Index Quality Classes (IBS).

IBS Values	**Quality**	**Colors**
IBS > 6,50	Excellent	Blue
5,75 < IBS ≤ 6,50	Good	Orange
5,00 < IBS ≤ 5,75	Fair	Yellow
4,25 < IBS ≤ 5,00	Bad	Green
IBS ≤ 4,35	Very bad	Red

Results

Global Community Analysis

In this study, 3922 aquatic macro-invertebrates individuals belonging to 08 classes, 27 orders, 87 families and 199 taxa were counted in the twelve sampling sites. Of the eight classes of macro-invertebrates inventoried, Insects, Gastropods and to a lesser extent Clitellates appeared the most abundant and diverse. Insects account for 160 taxa, or 80.40% of the total taxonomic wealth and 2590 individuals, or 66% of the total number of organisms collected. Gastropods comprise 19 taxa, or 9.55% of the total number of taxa and 657 individuals, or 17% of all organisms. Clitellates with 6 taxa and 268 individuals account for 3.02% of total taxonomic wealth and 7% of the abundance of organisms, respectively. Insects dominate by *Anisops* sp. (Hemiptera), Gastropods by *Melanoides tuberculata* (Thiaridae) and Clitellates by *Ophidonais serpentina* (Haplotaxida) (Fig 2).

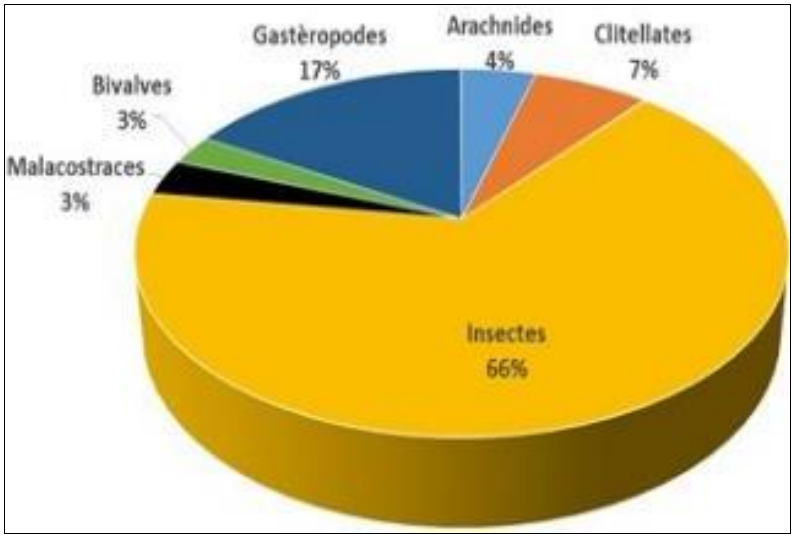

Fig 2: Relative abundance of macro-invertebrates classes harvested from the Upper Bandama Fauna and Flora Réserve.

Biological quality of water at sampling stations in Upper Bandama Fauna and Flora Reserve

Table II illustrates the breakdown by indicator of the taxa considered in the calculation of the biosediment index (IBS) and the biological quality of the water at these stations. Of the 199 taxa inventoried in this study, ninety-seven (97) proved to be indicators for the IBS index. The largest numbers of indicator taxa were found at the middle course in the Bandama River at the BSA station and the upper stream of Nambyon River (NYA). These stations displayed 50 and 48 indicator taxa respectively. On the other hand, the downstream station (BYA) on the Bandama River has the lowest number of indicator taxa (24 taxa). Over all, the values of the biosedimentary index (IBS) between 5.71 in the pond (MS station) and 6.27 on the Bandama river (BTB station) indicate that the waters of the stations prospected in the different courses of water are of « good » biological quality. With the exception of the median course of the pond (MS) whose minimum value (5.71) of the IBS index shows that it has a water of «Fair » biological quality.

Table 2: IBS Index Data for Sampling Stations.

	Bandama River								**Pond**		**River**	
	Up Stream			**Middle Stream**		**Down Stream**			**Middle Stream**		**Down Stream**	
	BN	**BTA**	**BTB**	**BSA**	**BSB**	**BYA**	**BYB**	**BB**	**MS**	**MVS**	**NYA**	**NYB**
Total indicator taxa	36	37	35	50	46	24	31	43	31	47	48	38
Total scores	113	130	138	152	134	97	95	123	137	149	140	139
IBS Index	5,95	6,19	6,27	5,85	5,83	6,06	5,94	5,86	5,71	5,96	6,08	5,79
Quality Classes	B	B	B	B	B	B	B	B	P	B	B	B

Pond = MS and MVS stations; Nambyon River = NYA and NYB Stations; Bandama River= BTA stations; BTB; BSA; BSB; BYA and BYB (located inside the reserve), BN and BB stations (located outside the reserve). IBS indices = Biosedimentary indices. B = «good» biological quality; P = «Fair» biological quality.

Discussion

In general, the faunistic composition of aquatic macro invertebrates of the Upper Bandama Fauna and Flora Reserve was dominated by Insects. This observation has also been made by some authors [20-25] in anthropogenic water courses of Africa tropical regions.

The high diversity and abundance of Insects and Gastropods may be related to the coverage of reservoirs by aquatic plants and to the presence of bedrock on the Bandama River and the Nambyon River. In fact, aquatic plants and rocky substrates are an important component of the ecology of Insects and Gastropods at several levels. In the sense that they serve as sources of food and support for the growth of the periphyton, main food source of gastropods. In addition, they provide well-oxygenated pawning sites for breeding and provide shelter for various predators [26].

Regarding the biosedimentary index (IBS), the reference indicator taxa scores were used to determine the biological quality of the water at the different stations of the reserve. The number of reference indicator taxa recommended by Mary, 2015 [19] for the calculation of this index is 56 taxa. During this study, 97 indicator taxa were recorded in all stations. This difference in numbers of indicator taxa could be due to sampling methods, sampled substrates, and environmental conditions. In all stations this index is between 5.71 (MS station) and 6.27 (BTB station). These values generally suggest that the waters of the sampling stations in the reserve are of «good» biological quality. However, on the middle course ponds the station (MS) which records the minimum value of the IBS index at a water of «fair» biological quality. The «fair» biological quality of the water in this pond could be explained by its stagnation, it slow coverage by the surrounding canopy (0 to 5%). Indeed by **(**Barendregt & Bio (2003); Gonçalves Jr. *et al*. (2006)) [27, 28] the speed of the current of the water favors the oxygenation of the water. For these authors, the canopy, by shadowing a body of water causes a drop in temperature which in turn leads to a decrease in the solubility of the gases and thus maintains oxygenation. Each of these variables plays a direct or indirect role in the entomological composition and quality of wetlands. As these conditions were not met at this station (MS), this could explain the development and proliferation of pollutant-resistant indicator taxa such as Chironomidae and Naididae. This to the detriment of pollen-sensitive taxa such as individuals of the complex (ET) and Coleoptera, who preferred running waters [29]. These organisms are sensitive to water pollution.

In addition, the «fair» biological quality of the water in this pond is related to the rapid decline in dissolved oxygen that occurs during the dry season (November to March) when salinity reaches its maximum. This phenomenon is the result of the degradation of the organic matter produced by the strong phytoplanktonic surge of the wet season (April to October) which is linked to the nutrient in take in this environment. Thus, the benthic organisms that live on the sediment of this pond are well adapted to desiccation phenomena. They are able to survive three to five months of dewatering [30]. The colonization and recolonization of pools by these benthic organisms can be explained as much by their ability to resist adverse conditions [31] as by their possible migrations (active and passive) between environments [32].

This observation has already been made by Oyenekan, 1979 [30] in the Lagos Lagoon, where the Gastropod *Melaniidé pacbyneania* able to survive three to five months of drying out. In addition, the «good» biological quality of the water at the stations on the Bandama River and the Nambyon River was due to the constant renewal of their waters.

Conclusion

Given current and future mining operations (gold and diamonds) in the region. It would bewise to extend the characterization of water quality to the entire hydrographic net work of this reserve in order to take stock of aquatic macro-invertebrates present. These are essential for the assessment of the ecological health of these aquatic environments. Also, in the long term, it would bead visable to set up a program of bio-surveillance of these rivers to allow the design of a local biotic index, based on the populations of macro-invertebrates specific to Ivory Coast. Moreover, this will make it possible to better control the different impacts of pollution on the wetlands of this reserve.

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