

# **Detecting Environmental Stress of Tropical Lagoon Using Abundance-Biomass Curve of Benthic Macroinvertebrate Assemblages (Ebrié lagoon, Côte d'Ivoire, West Africa)**

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors YSA and YAK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RNE and ZMG managed the analyses of the study. Author EPK managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Sectors IV and V of the Ebrié lagoon are increasingly experiencing fish mortality. The abundance biomass comparison (ABC) is graphical method use to assess the level of environmental disturbance in this area. The aim of the study were to detect the environmental changes caused by anthropogenic activities using ABC curve of benthic macroinvertebrate assemblages presented in the studied areas. Results of the ABC analyses indicated that stations L, K and M are less stressed with biomass curve above abundance curve. Stations N and A recorded a stressed environment with abundance curve above biomass curve. The ABC plots showed that N and A stations could be classified as moderately disturbed and polluted. The Clarke's W index to the benthic macroinvertebrates data, confirmed this situation; it ranged from -0,129 (N) to 0,224 (L). The results

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of the present study can be extrapolated to other tropical wetland systems to predict the levels of disturbance and to identify characteristic organisms to predict the environmental conditions in the wetland health assessment program.

**Keywords:** *Benthic macroinvertebrate; abundance biomass ABC method; sectors IV and V; Ebrié lagoon; Côte d'Ivoire.*

## 1. INTRODUCTION

Coastal lagoons are important on account of their biological, geological, physical and chemical characteristics. Man makes them useful for transportation, food supply, mining, recreation and preservation activities. Their diversity of fauna and flora, and biomass productivity, have made them a focus of interests since several decades [1]. Lagoons are often exposed to various types of threats such as pollution and the decline of biodiversity due to human population growth and industrialization [2]. This is the case of Ebrié lagoon in Côte d'Ivoire where fish die-off were frequently observed in some recurring areas [3,4,5]. Indeed, the watershed of these areas is dominated by many cities (e.g. Dabou and Jacqueville) and a wide range of human activities, such as agriculture, and industries [6]. These activities have introduced without treatment fertilizers, pesticides, garbage, sewage and other forms of excreta, and industrial effluents into the Ebrié Lagoon and its adjacent marine environment. Massive mortalities are linked to water quality because changes in the environment can respond to changes in fauna and flora composition and abundance [7].

Water quality studies are of several types, including the use of biological organisms such as macroinvertebrates of multiple interest. These organisms are differentially sensitive to many biotic and abiotic factors in their environment and are commonly used as indicators of the condition of aquatic systems [8,9]. Graphical methods, such as abundance biomass comparison (ABC), have been introduced and applied to assess the level of environmental disturbance [10,11]. The ABC method is generally used as an impact indicator for different types of physical, biological and anthropogenic disturbances on benthic communities. This method is based on the assumption that increasing disturbance shifts communities from dominance by large-bodied species with low turnover rates toward dominance by small-bodied species with high turnover rates. The ABC method measures this effect by comparing the ranked distributions of abundance and biomass within a given

community [12]. Several studies in Ebrié lagoon focused on physicochemical quality [13,6] and aquatic macroinvertebrate distribution [14,15]. However, the use of macroinvertebrates to assess the level of ecological stress are limited. The aim of this study was to detect the environmental stress caused by activities anthropogenic using ABC curve of benthic macroinvertebrate assemblages.

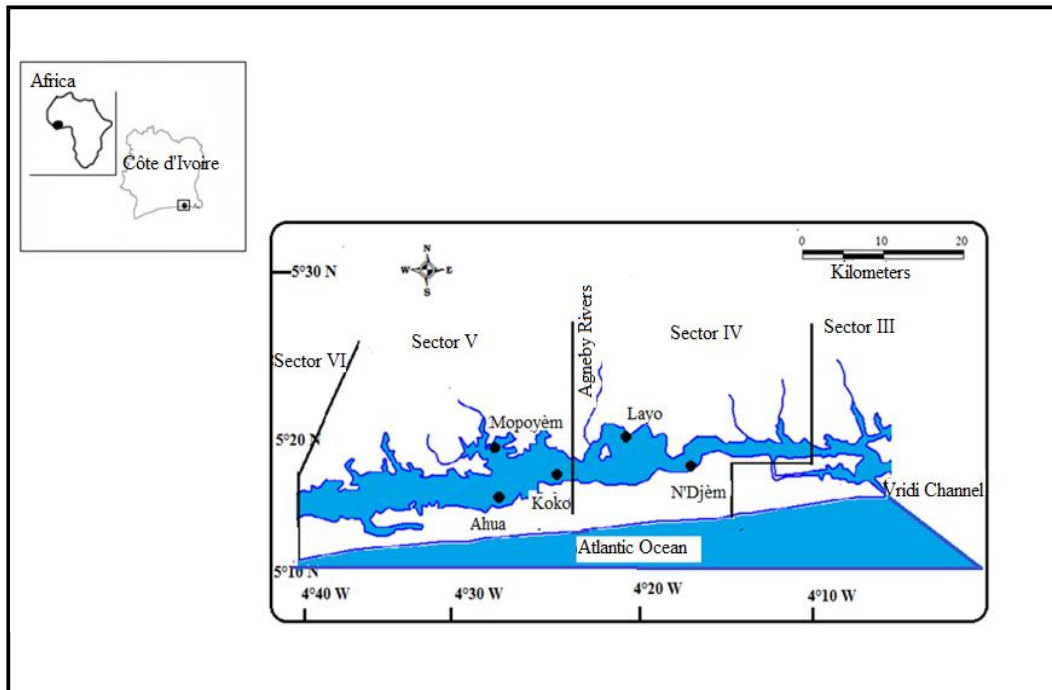
## 2. MATERIALS AND METHODS

### 2.1 Study Area

The Ebrié lagoon with a total length of 130 km and an area of about 566 km<sup>2</sup> is in permanent communication with the Atlantic Ocean through an artificial channel. So it is influenced by the waters of the ocean. It is fed by several rivers such as Comoé, Agneby and Mé Rivers.

Ebrié Lagoon is divided into six sectors based on hydrochemical criteria. Sectors I and II are located in the eastern region of the lagoon, sector III is in the central region and sectors IV, V and VI in the western region.

The eastern region are dominated by continental waters flows. It is a natural mouth of Comoé River. The central region is influenced by the Atlantic Ocean and by the discharge of human wastes, while the western regions are relatively isolated from these sources [16]. Sectors IV and V (Fig. 1) located in western regions (between 5°13'-5°19' N and 4°14'- 4°27' W) are under the influence of two seasons: a dry season (December-April and August-September) and a raining season (May-July and October-November). Salinity is controlled by its exchange with the ocean, freshwater inputs and rainfall. It is 20–29 during the dry season and 0–5 during the raining season [17]. Since October 1999, massive fish die-off have been observed in sectors IV and V of this lagoon, located in the departments of Dabou and Jacqueville. In May 2013, this cyclical phenomenon intensified, leading to the closure of fishing and many aquaculture farms in these lagoon areas.



**Fig. 1. Geographical location of study sites**  
*The black dot indicated the sampling sites*

## 2.2 Data Sampling

According to previous situation, five sampling stations Mopoyèm (M), Layo (L), N'Djèm (N), Ahua (A) and Koko (K) were selected along these sectors. Codes and geographical location of sampling sites are marked in Table 1.

Influenced by Agneby River, station (L) were located in an area surrounded by an industrial banana plantation where swimming, defecation and household activities were practiced. Station (N) were located near the Jacquville Bridge. It were characterized by sanitary installations on stilts. In station (A), samples were taken near the growth pens located in the lagoon. Station (M) were located in a bay. It was characterized by the presence of a fish breeding station and by the practice of fishing activities with the acadja.

Several rubber tree plantations surrounded the resort. This station received water from rivers and runoff. Located near the village of Koko, the station (K) received only runoff water.

Macroinvertebrates were collected monthly (August 2015 to July 2016), using a Van Veen grab (0.03 m<sup>2</sup>). In all the stations of sectors IV and V, ten replicates samples were sieved in situ and the organisms retained by the sieve were fixed in formaldehyde 10% solution. Macroinvertebrates were identified to the lowest possible taxonomic level in laboratory according several studies [18-21], and all taxa were counted and weighed. Briefly, sampled macroinvertebrate families were assigned to three groups, namely pollution intolerant, moderately tolerant, and tolerant. Each category was then scored with a sensitivity factor; a factor

**Table 1. Geographical coordinates of sampling stations**

Stations	Codes	Geographical location	
Mopoyèm	M	N 05°18'54.846"	W 004°27'47.268"
Layo	L	N 05°19'25.45"	W 004°18'56.268"
N'Djèm	N	N 5°16'22.645"	W 004°14'24.930"
Ahua	A	N 05°13'51.444"	W 004°26'24.967"
Koko	K	N 05°15'37.523"	W 004°23'43.303"

of 3 was given to the pollution sensitive (intolerant) group, a factor of 2 to the facultative or moderately tolerant group, and a factor of 1 to the pollution tolerant group. Sensitivity factors of macroinvertebrate families, as defined by Ghosh and Biswas [22]. Abundance (number of individual per m<sup>2</sup>), Biomass (g/m<sup>2</sup>), diversity (Shannon-Wiener, H') were calculated. For each station, dominance curves for abundance and biomass were obtained following the ABC method [23]. In the method, species are ranked in order of importance based on percent dominance of abundance or biomass. The plots were produced using PRIMER 6.1 statistical software. The area between the abundance curve and the biomass curve is called W-statistic [24]. Biomass dominance and an even abundance distribution gives a value of +1 for undisturbed, and the reverse case a value of -1 for grossly disturbed. The W-statistics [25] also were computed for each case by applying the equation:

$$W = \sum_{i=1}^S \frac{(B_i - A_i)}{[50(S - 1)]}$$

Where B<sub>i</sub> is the relative biomass of i species, A<sub>i</sub> is the relative abundance of i species and S is the number of species. Kruskal-Wallis and Mann-Whitney were calculated using Statistica 7.1 software to compare biomass and abundance distribution.

### 3. RESULTS AND DISCUSSION

#### 3.1 Community Structure

Fifty-nine (59) families including Achaetes (1 family), Oligochaetes (5 families), Polychaetes (5 families), Crustacean (13 families), Gastropod (5 families), Bivalve (4 families), Insect (24 families), Arachnid (1 family) and Nematode (1 family) have been identified in Ebrié lagoon. (L) had the highest richness value (47 species) and the lowest value (22 species) was in (N) station. The range of Shannon diversity index was 1.2 bits/ind in A station to 2.8 bits/ind for (L) station. Kruskal-Wallis test based on richness and Shannon index values, showed only significant differences for Shannon index values ( $P < 0.05$ ). Taxonomic richness was higher in stations N (77%), A (70%) and K (76%) for tolerant taxa (Fig. 2). The number of sensitive taxa varied between 11% and 15% in all sampling sites. Tolerant species strongly dominated the biomass and abundance distributions at the N and K sites.

In addition, the total species richness and the richness in sensitive species were higher at the L and M sites. Their high value of tolerant taxon in stations N, A and K can be attributed to hydrodynamics of lagoon. These stations were confined environments where horizontal circulation and vertical exchanges are slowed down. At these stations, human waste, food inputs and discharges of metabolites from captive fish accumulated in the sediments, increasing the level of organic matter and siltation, resulting in acute pollution. These results support the hypothesis that the low water turnover were a major source of disturbance for communities with soft bottom. On the basis of the values of the diversity index (H'), the stations of sectors IV and V of the Ebrié lagoon are classified in a mediocre and declining ecological state. According to Borja et al. [26], the values of diversity index (H') less than 3 bits / ind are classified as mediocre ecological state.

#### 3.2 Abundance and Biomass

Average values of abundance and biomass species are shown in Table 2. Seven tolerant species Nereidae, Nephtyidae, Chironomidae, Sphaeromatidae, Cirolanidae, Tubificidae and Lumbriculidae dominated density distributions in all sampling sites.

Chironomidae dominated the tolerant taxa in M site while Polychaeta (Nereidae and Nephtyidae) was abundant in K site. The domination of tolerant taxa was higher in A, K and M locations (Fig. 3A). Two sensitive taxa Corophiidae and Baetidae dominated density distribution in all five sites. Density of sensitive taxa was higher in M, A and K stations (833 to 3183 individuals per m<sup>2</sup>) while it was lower in L and N stations (27 to 70 individuals per m<sup>2</sup>). Tolerant/sensitive abundance ratios were significantly higher in N and L sites. Significant differences were noted between A and K, L and N stations in the density of sensitive species (Mann-Whitney test,  $P < 0.05$ ).

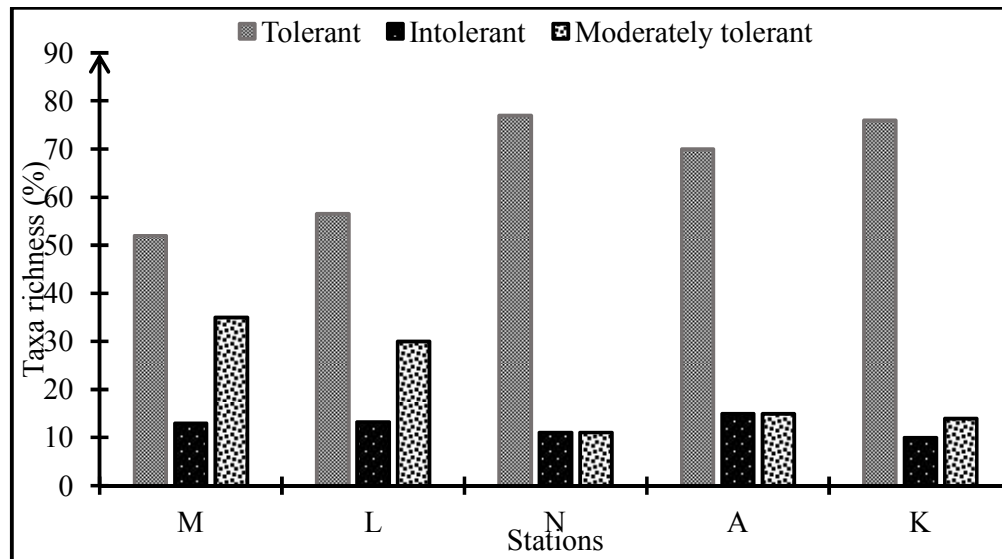
Biomass distributions (Fig. 3B) were characterized by a large contribution of Gastropod. Thiaridae was the most biomass taxa in K and A stations. Significant differences were noted between N and K stations (Mann-Whitney test,  $P < 0.05$ ). Biomass of tolerant species was higher in N and K stations (2447.5 to 4327.13 g per m<sup>2</sup>) and was lower in M station (33.3 g per m<sup>2</sup>). Corbulidae and Potamididae were tolerant species with high biomass.

**Table 2. Abundance (ind/m<sup>2</sup>) and biomass (wet weight in g/m<sup>2</sup>) of species from sectors IV and V in Ebrié lagoon**

	Abundance					Biomass				
	M	L	N	A	K	M	L	N	A	K
<b>Tolerant</b>										
Anthuridae				40	13				1,11	0,22
Atyidae					10					0,83
Branchiobdellidae					13					1,06
Capitellidae		53	7	7			0,56	0,11	0,17	
Chaoboridae	17					0,28				
Chironomidae	1383	187	13	127	143	14,19	93,22	0,06	0,42	0,44
Cirolanidae			33	43	663			0,33	0,61	72,19
Coenagrionidae	60			3		9,44			0,17	
Corbulidae		3	63	127	420		1,11	95,92	126,39	3921,53
Culicidae		20					0,28			
Diogenidae			193		10			777,64		0,50
Dreissenidae			7					4,97		
Erpobdellidae				3	20				0,78	6,33
Gerridae	10					0,92				
Glyceridae			13					2,61		
Haplotaenidae		60		7			13,33		0,06	
Libellulidae	13					3,81				
Lumbriculidae	7	117	3	3	37	0,11	1,94	0,11	2,78	1,78
Mytilidae			20					179,69		
Naididae		30					1,08			
Nephtyidae		160	67	3			1,78	0,58	0,11	
Nepidae	7					2,61				
Nereidae		27	47	110	797		4,58	1,11	2,58	59,44
Notonectidae		10					0,08			
Notoridae		13					0,14			
Palaemonidae					20					21,94
Penaeidae					3					0,58
Planorbidae	13	7				0,11	0,08			
Pleidae		3					0,03			
Portunidae					17					6,25

	Abundance					Biomass				
	M	L	N	A	K	M	L	N	A	K
Potamididae			103					1380,61		
Potamonidae				20					2,67	
Spercheidae	13					0,17				
Sphaeromatidae	3			573	1623	0,33			42,31	180,86
Stratiomyiidae	3	7				0,33	1,50			
Syllidae			20					0,31		
Syrphidae	3	7				1,03	0,31			
Talitridae				3	27				0,03	0,11
Tubificidae		287	87				51,64	3,44		
Veliidae		10					0,11			
Xanthidae				3	10				0,08	53,06
<b>Moderately tolerant</b>										
Belostomidae	120	17				18,00	2,72			
Corduliidae	17					3,86				
Corixidae		10					0,14			
Curculionidae	7	7				0,69	0,89			
Dytiscidae	7	53				0,08	0,56			
Hydrachnidae	27					1,44				
Hydrophilidae	40	43				1,00	0,78			
Naucoridae	43	3				3,94	1,31			
Neritidae		7	83	1390	927		5,67	43,11	993,08	1917,78
Pilidae	3					206,31				
Sphaeriidae		13		23	1767		4,31		9,81	2865,61
Thiaridae		870	183	10460	11867		9308,92	792,28	143212,17	108715,53
<b>Intolerant</b>										
Baetidae	820	37				16,89	32,31			
Corophiidae	113	7	13	580	2650	2,31	0,06	0,08	7,00	25,11
Ecnomidae				3					0,03	
Elmidae		13					2,14			
Gammaridae	47	13	13	250	533	0,50	0,36	0,31	3,17	6,03

M: Mopoyèm; L: Layo; N: N'Djèm; A: Ahua; K: Koko



**Fig. 2. Taxa richness variation (in percentage) of tolerant, sensitive and tolerant macroinvertebrates from M, L, N, A and K stations in Ebríe lagoon**

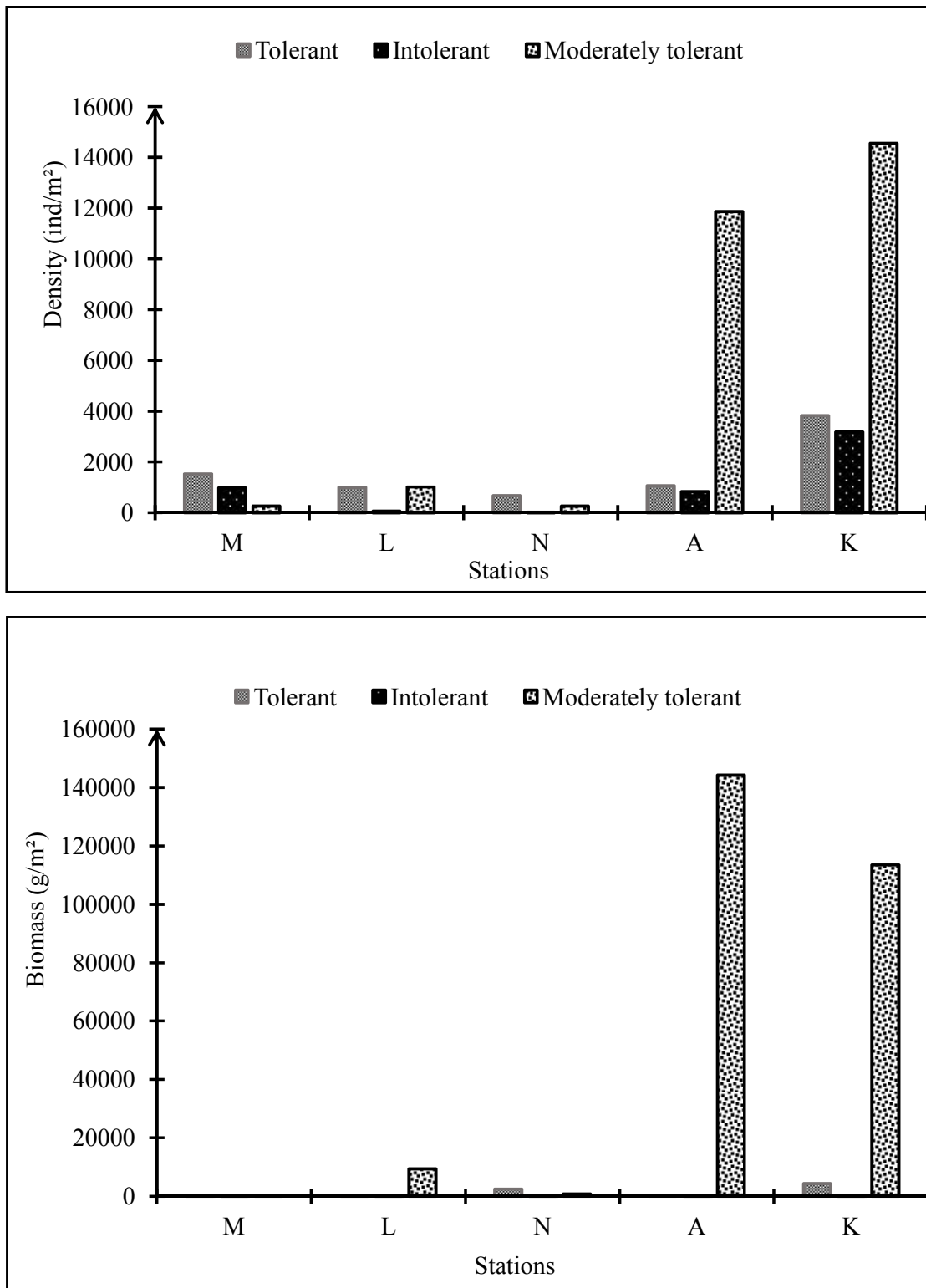
Biomass of the sensitive species was higher in K and L stations (31.14 to 34.9 g per m<sup>2</sup>) and lower in N station (less than 1 g per m<sup>2</sup>). Corophiidae and Baetidae were the important biomass of the sensitive taxa. Tolerant/sensitive biomass ratios were significantly higher in N and K sites.

Benthic macroinvertebrates are known as key species for the functioning of bottom habitats in water ecosystems [27]. They can react to stress or disturbance regimes by modifying their population and the structure of their community [28].

The benthic community seems to be influenced in sectors IV and V by anthropogenic activities such as metabolic waste from farmed fish, aquaculture activities on the water and cages floating. According to Yoboué et al. [29], the exploitation of water by floating cages could lead to the appearance of a structural imbalance in the population of macroinvertebrates at the level of floating cages with the regression of sensitive taxa such as Odonates, Ephemeroptera, Beetles [30,31], and the proliferation of taxa tolerant to organic pollution such as Tubificidae and Chironomidae and Molluscs [32]. The high densities of the tolerant taxa in this study would be explained by the high organic loads resulting from the decomposition of metabolic waste from farmed fish.

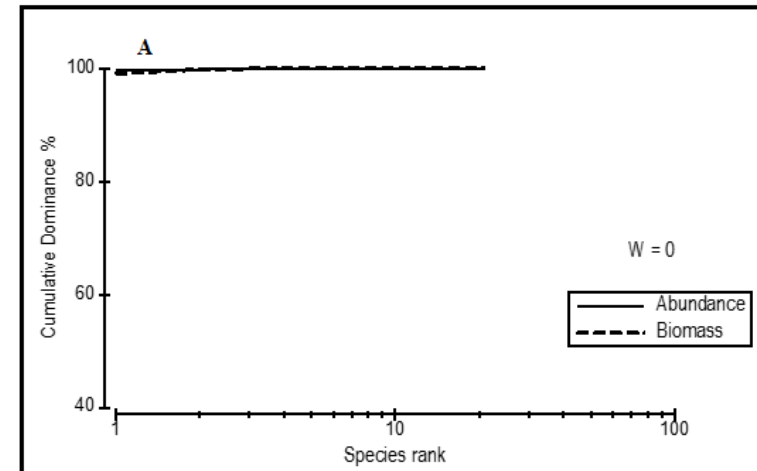
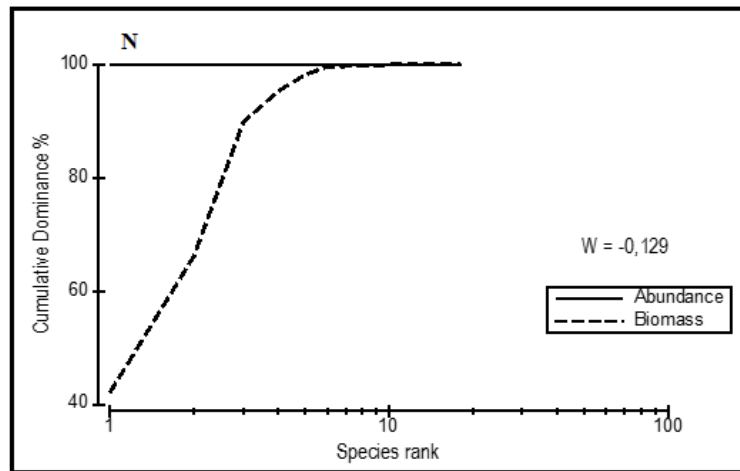
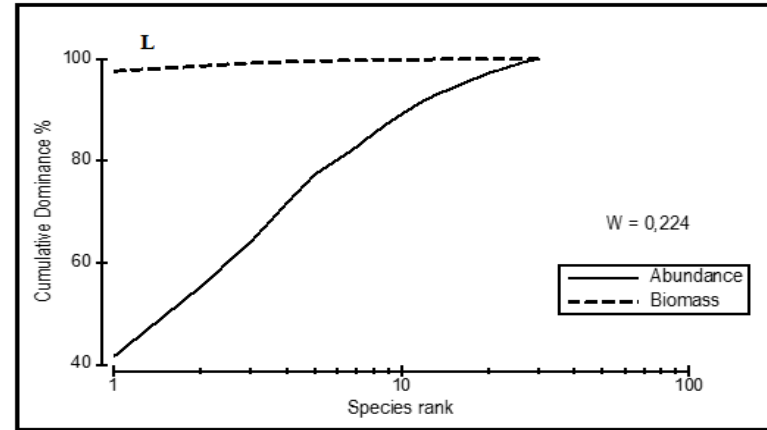
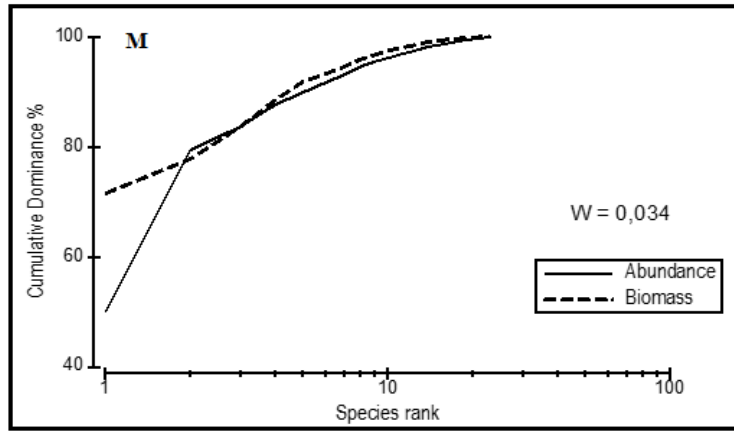
L, K and M sites showed undisturbed patterns with the biomass curve above the abundance

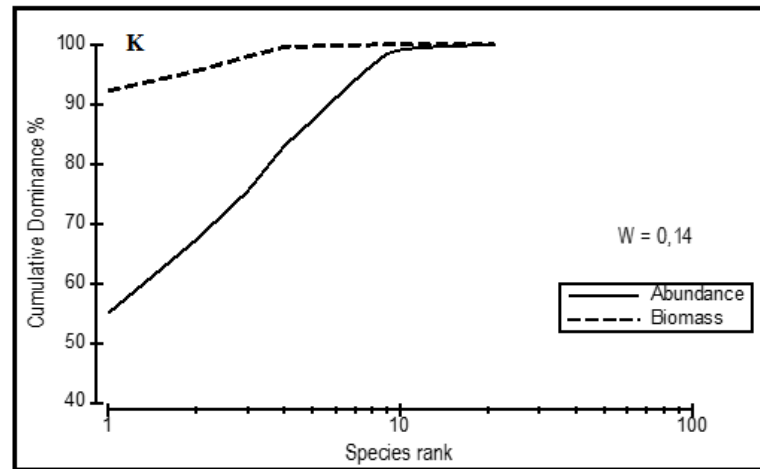
curve in Ebríe lagoon (Fig. 4). Conversely, the abundance curve at N site appeared as disturbed community with the abundance curve lies above the biomass curve. At A site, the biomass curve closely coincident with the abundance, indicating a moderately disturbed area. W statistic of the sites ranged from -0,129 to 0,224. The ABC curves show that the macrofaunal communities closest to the mouths of the rivers (L and M) were moderately disturbed during the sampling periods while those that are distant are more disturbed (N and A). In particular, the low abundance of amphipods and sensitive taxa in the stations could confirm the influence of the fluvial input on the macrofaunal assemblages [33,34]. According to the W statistic all the sites were minus values indicating moderate to a severe disturbance at these sectors. The ABC curves confirmed the results of the W statistic. According to the ABC curves, sites L, K, and M stations indicated partially disturbed environmental conditions and site N showed a typical disturbed condition environmental. Most studies in polluted environments have shown that a decrease in density and diversity can be seen as a measure of the environmental stress on macroinvertebrate communities caused by pollution. Increased pollution has also been reported to be the cause of a high number of individuals belonging to a few opportunistic species [35]. This situation has been also observed on N station.



**Fig. 3.** Density (number of individuals per m<sup>2</sup>) (A) and biomass (wet weight in gram per m<sup>2</sup>) (B) of macroinvertebrates in Ebrié lagoon







**Fig. 4. Abundance and biomass comparison curves for the study sites of Ebrié lagoon**  
*M = Mopoyèm ; L = Layo ; N = N'Djèm ; A = Ahua ; K = Koko ; W= Clarke index*

#### 4. CONCLUSION

This study revealed the environmental stress in sectors IV and V of the Ebrié lagoon. It indicated the disturbance of A and N stations. These stations presented a high specific richness of opportunistic taxa with the proliferation of Molluscs and Annelids due to aquaculture activities, captive fish waste discharges and domestic waste. The abundance curve was above the biomass curve. M, L and K stations presented a less stressful environment. The biomass curve is above the abundance curve. These stations registered the highest richness of sensitive taxa. However, the low Clarke W Index scores (-0.129 to 0.224) recorded at all stations referred to disturbed environments.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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