E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2018; 6(6): 285-291

www.fisheriesjournal.com
Received: 11-09-2018
Accepted: 13-10-2018

Antoine Chikou
Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University Abomey-Calavi, 01 BP: 526 Cotonou, Bénin

Thierry Matinkpon Agblonon Houelome
Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University Abomey-Calavi, 01 BP: 526 Cotonou, Bénin

Delphine Adandedjan
Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University Abomey-Calavi, 01 BP: 526 Cotonou, Bénin

Ibrahim Imorou Toko
Laboratory of Research in Aquaculture and Aquatic Ecotoxicology, Faculty of Agronomy, University of Parakou, 03 BP: 61 Parakou, Bénin

Issaka Youssao Abdou Karim
Laboratory of Animal Biotechnology and Meat Technology, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, 01 BP: 2009 Cotonou, Bénin

Philippe Laleye
Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University Abomey-Calavi, 01 BP: 526 Cotonou, Bénin

Correspondence
Antoine Chikou
Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University Abomey-Calavi, 01 BP: 526 Cotonou, Bénin

Structural organization of the macroinvertebrates communities of the Alibori River during the rainy season (Northern Benin)

Antoine Chikou, Thierry Matinkpon Agblonon Houelome, Delphine Adandedjan, Ibrahim Imorou Toko, Issaka Youssao Abdou Karim and Philippe Laleye

Abstract
The impact of cotton activities on the structuring of the macroinvertebrates communities of the Alibori River was evaluated. Samplings were carried out at 15 sites from June to September 2015 during the rainy season. The benthic macrofauna inventory revealed 53 taxa of aquatic invertebrates belonging to 33 families, 13 orders and 7 classes. Insects composed 70% of species identified with 6 orders, 23 families and 40 species. Molluscs comprised 12% of species identified. Analysis of the structure with the Self-Organizing Map (SOM) revealed a zonal distribution upstream-downstream which indicates that the various sampling sites had in common a great part of benthic fauna and that their differences are a limited number of taxa which were specific to each sampling sites. The zonal distribution of organisms reveals an anthropogenic disturbance along the River. The redundancy analysis carried out between the physico-chemical variables and the main taxa, showed that nitrates, phosphates, conductivity, Total Dissolved Solids (TDS) were the important parameters which influenced the distribution of macroinvertebrates.

Keywords: Macroinvertebrates, structure, disturbances, Alibori River

1. Introduction

Agricultural activities are the major cause of aquatic ecosystems degradation in rural areas [1, 2]. The use of chemical pesticides and fertilizers affects aquatic biological communities. Agricultural runoff due to rain or from irrigation water introduces pesticides and fertilizers into the natural aquatic environment, where it poses significant toxicological risks to resident organism. Only 0.1% of the sprayed pesticides reaches the target pests, the rest being distributed into the ecosystems where it contaminates the land, water and air [3]. All these pollutants finally reach to aquatic ecosystems.

In Benin, chemical aggression of the environment is a serious threat to aquatic biodiversity, particularly in the sections of north Benin, where the most cotton is produced (up to 90% of national production according to the [4]. Cotton production requires the use of large quantities of pesticides and fertilizers [5, 6].Thus, these products pollute the aquatic ecosystems of the Benin cotton basin and affect their biological integrity [3].

But nowadays, it is recognized that surface water quality assessment systems must use biological indicators [7]. Macroinvertebrates are the most widely used as bioindicators of ecological quality [8-10]. The structure of macroinvertebrates communities is function of various environmental factors which influence the habitats in both space and time [11]. Their studies ensure the impact assessment of pollution and the alteration of aquatic habitats [12]. The presence or absence and abundance of benthic macroinvertebrates have been shown to be a good indicator of both chronic and episodic impact of human disturbance to river condition and other aquatic environment [13]. The complex relationships between community variations and environmental disturbances can be studied through composition and structure of the macroinvertebrates community.

The present study aims to determine the characteristics of the macroinvertebrates community structure during the rainy season and assess its degree of disturbance in Alibori River.

2. Materials and methods

2.1 Description of study area

The Alibori River is an ecosystem located in the Sudanian zone between 10° 30 ' and 12° north latitude and 1° 32' and 3° 50 'east longitude (Figure 1). The climate of this region corresponds to a dry semi-arid Sudanian zone with a rainy season and a dry season. The area is watered with a pluviometry which fluctuates between 700 mm and 1200 mm per year. The Alibori River (length 338 km) is the most important freshwater river crossing in the six largest cotton-producing (Malanville, Karimama, Banikoara, Kandi, Gogounou, Sinendé), with Banikoara being the greatest cotton-producing municipality at 40% of national production [3]. Therefore, the Alibori River collects the drainage from most of the agricultural areas in the cotton-producing basin. The river originates in the central plateau of Benin and moves northwards into the Niger River.

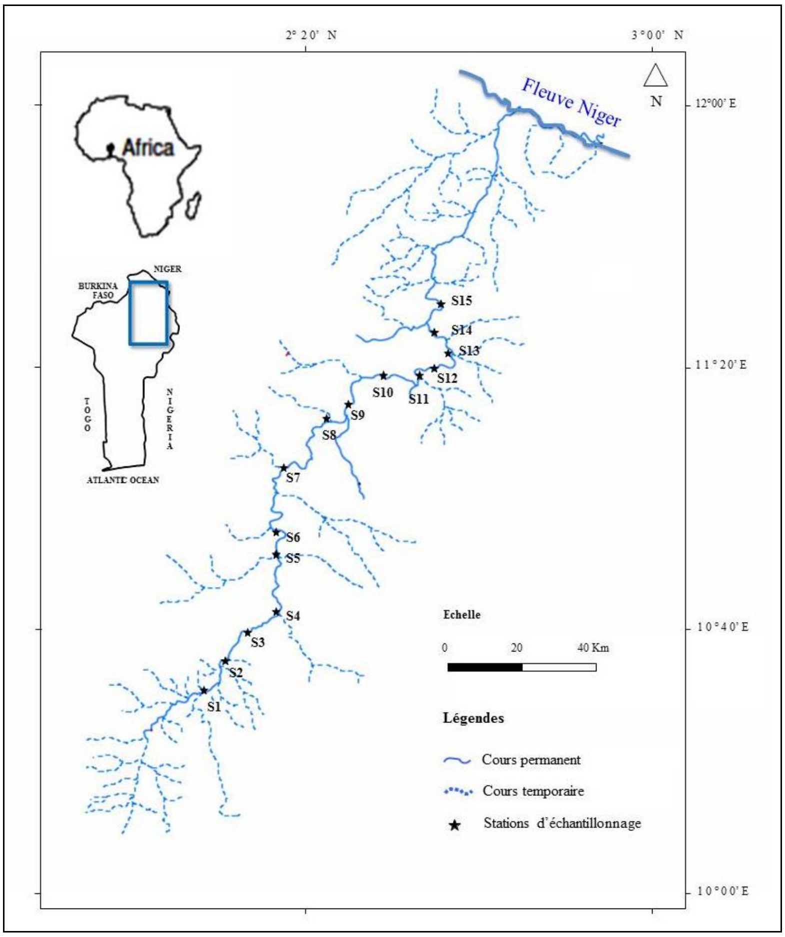

Fig 1: Map of Albori River Showing sampling sites. S1= Yanningourou (Yan), S2= Lougou (Lou),S3= Ganroukoro (Gan), S4= Diadia1(Dia1), S5= Diadia2 (Dia2), S6= Dawonga (Daw), S7= Kpeborogou (Kpe), S8= Bourin, S9= Biowerekourou, S10= Alibori k1 (Al1), S11= Alibori k2 (Al2), S12= Alibori B1 (Al3), S13= Alibori B2 (Al4), S=14 Alibori B3 (Al5), S15= Angaradebou (Ang).

2.2 Physico-chemical parameters

Samples were collected monthly during rainy season from the June, 2015 to September, 2015 at 15 different sites usually between 6:00 am and 10:00 moon. The water transparency and water depth were determined using a Secchi disk. The pH, conductivity, temperature, dissolved oxygen (DO) and Total Dissolved Solids (TDS) were measured using a multiprocessor conductimeter. The surface velocity (Vs) of the water was measured using a float and a decametre. A stopwatch was used to measure the time taken by a float to travel a distance of 1 m measured with decametre. The current velocity (Vc) is obtained according to the relation: $Vc = 0.80 \times Vs$ [14]. It is expressed in cm / s. Water sampling was collected at each station for the determination of dissolved salts. At the laboratory, the nitrites, nitrates and total phosphorus concentration were measured using a SHIMADZU UV-1205 spectrophotometer.

2.3 Collection of benthic macroinvertebrates

Benthic samples were collected from 15 sampling sites of the study area (Figure 1) using an Ekman grab sampler of 225 cm² at a depth of approximately 10 cm. For each sampling site, 10 hauls were made by sending the grab down into the bottom. Each sample was sieved through two sieves of 500 µm and 1 mm mesh size in the river water and the collected organisms were cleaned under River water and preserved separately in labelled bottles containing 4% formaldehyde solution. Once in the laboratory, the invertebrate specimens from each site were sorted out into different groups and preserved in 70% alcohol. They were counted and identified under microscope using appropriate identification guides.

2.4 Statistical analyses

Analysis of variance (ANOVA) was used to test for significant differences between the means of the physico-chemical parameters of sampling sites. This test was carried out using STATISTICA 4.5.

The spatial variations of the benthic assemblages were determined using the artificial non supervised neuron networks, the "Self Organizing Maps (SOM)" or Kohonen

maps [15]. This method was used to order sampling stations according to species assemblages. 20 neurons were chosen (4 lines × 5 columns) because the configuration obtained presented minimum values for both quantification and topographic errors, which are used to appreciate the classification quality [16]. The SOM algorithm calculates the connection intensities between input and output layers by using an unsupervised competitive learning procedure [15]. This classifies samples in each node according to their similarity in the environment. The relevant groups or sample clusters which characterize the sampling sites assemblages were determined by performing a hierarchical classification analysis (Ward's linkage and the Euclidean distance method). The analysis was carried out using the SOM toolbox for Matlab (version 2).
The multivariate technique redundancy analysis (RDA) was used to assess the correlations between abiotic parameters and main species (abundance > 5%) of the macrofauna of the River. The analysis relevance was verified by a Monte-Carlo permutation test performed on 499 random permutations. This analysis was done with CANOCO 4.5 (CANOnical Community Ordination version 4.5).

3. Results
3.1 Physico-chemical parameters
Table 1 shows the eleven environmental parameters investigated in this study. For water transparency, dissolved oxygen, TDS, nitrites, nitrates and total phosphorus mean values, significant differences were noted (ANOVA, p<0.01). The highest values of conductivity and TDS were measured at downstream. In particular, phosphates, nitrites and nitrates have also exhibited their high values at downstream sites of the river. On the other hand, upstream sites showed high values of water transparency and dissolved oxygen concentrations.

Table 1: Synthesis of environmental values and analysis of variance.

Parameters	H	p	Significance
Transparency (cm)	36,68	0,001	**
Depth (m)	17,15	0,248	NS
T°C	0,91	0,823	NS
pH	1,50	0,185	NS
Conductivity (µS.cm^{-1})	4,88	0,181	NS
Dissolved Oxygen (mg.l^{-1})	30,82	0,006	**
TDS (mg.l^{-1})	37,35	0,001	**
Curent Velocity (cm.s^{-1})	6,93	0,937	NS
NO_3^- (mg.l^{-1})	37,34	0,001	**
NO_2^- (mg.l^{-1})	33,55	0,002	**
PO4 (mg.l^{-1})	40,47	0,000	***

p= probability, * = Significant difference (** = p<0, 01; *** = p<0,001), NS= No Significant

3.2 Composition
The different taxa of benthic macroinvertebrates collected during the study and classified into the different taxonomic groups are presented in Table 2. Altogether, 53 taxa (genus and species) belonging to 33 families, 13 orders and 7 classes were inventoried. Insects composed 70% of species identified with 6 orders, 23 families and 40 species. Molluscs comprised 12% of species identified (3 orders, 5 families and 8 species). Other groups of invertebrates such as the Achaeta (1 order, 1 family, 1 species), Oligochaeta (1 order, 2 families, 2 species), Polychaeta (1 order, 1 family, 1 species) and Crustaceans (1 order, 1 family, 1 species) were collected. The Molluscs with 97.68% of total abundance were the main group. The Gastropoda represented 41.24% and the Bivalvia (20.16%). It was following by the Insects (36.28%).

Table 2: List of macroinvertebrates organisms collected in the River Alibori during the study.

Classes	Orders	Families	Species
Insects	Coleoptera	Dytiscidae	*Hydrovatus* sp.
			Rhantus exsoletus
			Dytiscus sp.
			Hydaticus sp.
			Hydaticus aruspex
			Undetermined 1
			Undetermined 2
		Hydrophilidae	*Berosus infuscatus*
			Berosus peregrinus
			Berosus sp.
			Hydrochara caraboides
			Hydrochara obtusata
			Amphios senegalensis
			Enochrus sp.
			Laccobius sp.
		Hydropsychidae	*Hydrochus elongatus*
			Clivina fossor
		Chrysomelidae	*Donacia* sp.
		Helophoridae	*Helophorus* sp.
		Gyrinidae	*Orectochilus* sp.
		Elmidae	*Potamophilus* sp.
		Noteridae	*Noterus* sp.
		Spercheidae	Undetermined 3
	Heteroptera	Corixidae	*Corixa* sp.
			Corixa punctata
		Mesoveliidae	Undetermined 4
		Nepidae	*Nepa rubra*
		Aphelocheiridae	*Aphelocheirus aestivalis*
		Notonectidae	Undetermined 5

	Ephemeroptera	Baetidae	*Baetis* sp.
	Plecoptera	Leuctridae	*Euleuctra geniculata*
	Diptera	Tabanidae	*Haematopota* sp.
		Chironomidae	*Chironomus* sp.
			Critocopus sp.
		Limoniidae	*Dicranata* sp.
		Indéterminé	Undetermined 6
	Odonata	Gomphidae	*Gomphus* sp.
			Paragomphus sp.
		Cordulegasteridae	*Cordulegaster* sp.
		Corduliidae	*Cordulia* sp.
Gastropoda	Mesogastropda	Ampullaridae	*Lanistes ovum*
			lanistes variscus
		Thiaridae	*Melanoides tuberculata*
			Melanoides sp.
	Basomatophora	Lymnaeidae	*Lymnaea sp.*
		Planorbidae	*Bulinus forskalii*
			Bulinus globosus
Bivalvia	Unionoida	Unionidae	*Anodonta* sp.
Achaeta	Gnathobdelliformes	Hirudidae	*Hirudo medicinalis*
Oligochaeta	Haplotaxida	Tubificidae	*Tubifex tubifex*
		Lumbricidae	*Eisenilla tetraedra*
Polychaeta	Nereidiformia	Nereidae	*Nereis sp*
Crustacean	Myriapoda	Undetermined	Undetermined 7
Total	13	33	53

3.3 Spatial assemblage structures

Figure 2 (A) shows the result of the hierarchical classification analysis which allowed regrouping the 20 cells of the Kohonen map into three groups (I to III). Each group identified on the map (Figure 2B) with the same pattern, was constituted of samples having similar taxonomic compositions. This analysis of the presence-absence of taxa obtained through SOM revealed a zonal distribution upstream-downstream which indicates that the various sampling sites had in common a great part of benthic fauna and that their differences are a limited number of taxa which were specific to each sampling sites. Group I comprised a great part of sample from the downstream and is isolated from groups II and III, which are poor in taxa. Group I comprised 28 samples (85.7% of downstream sites). Group II comprised 12 samples of which 66% from the upstream part of River. As for the third, it was composed of 20 samples of which 65% of the upstream.

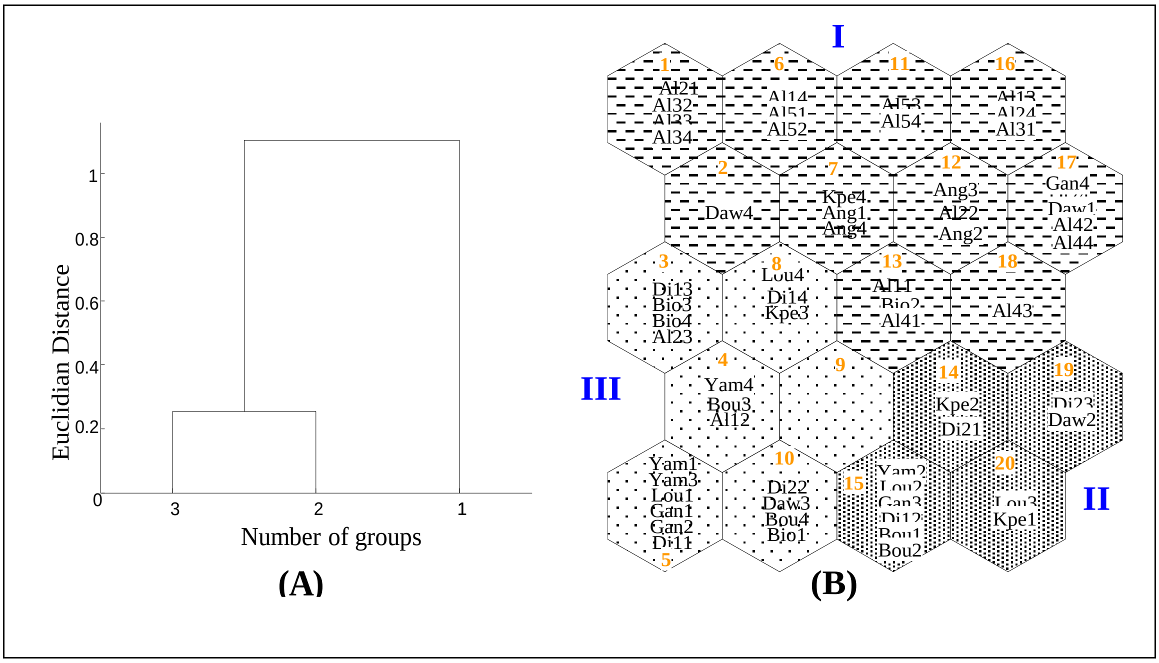

Fig 2: Hierarchical clustering of the SOM cells with a Ward linkage method and a Euclidian Distance (A) and SOM map of the samples classification on the basis of presence-absence matrix (B)

Yam, Lou, Gan, Al1, Al2…and so on are the samples sites, the second number near the samples sites is the number of the sampling and the numbers (1 to 20) in each cell are numbers of the cells of Kohonen map.

3.4 Influence of environmental variables on the distribution of macrofauna taxa

The results of the redundancy analysis performed between the physicochemical parameters and the main families at the different sites are presented in Figure 3. The Monte-Carlo permutation test showed that the result of this analysis is

significant (p = 0.04 and total variance = 1). This analysis reveals that the first two axes expressed 89.8% of the information.
The axe 1 is highly and positively correlated with high values of conductivity, TDS, depth, phosphorus and nitrites. It is negatively correlated with dissolved oxygen concentrations and transparency value. The axe 2 is negatively correlated with the nitrates contents. It is these parameters of axe 1 that influenced the distribution of a great proportion of benthic macrofauna.
Thiaridae highly correlated with axe 1, were determined by conductivity and depth in August at site Ang. The Unionidae were highly and positively correlated with axe 1 and found in August and September at downstream sites (Al1, Al3 and Al4). The species in this family, therefore, were determined by a high depth and high levels of nitrites and phosphates becoming abundant to the detriment of other species. To these families are opposed Hydrophilidae and Hydropsychidae which were found at the upstream sites.
Hydrophilidae were negatively correlated with transparency at Yam, kpe, Bio, Daw during the months of June and July. Hydropsychidae, on the other hand, were characterized by high oxygen value at the upstream sites. Ampulariidae were distinguished by high nitrates value, on the axe 2, during the months of July and August at downstream sites (Al2, Al3 and Al5)

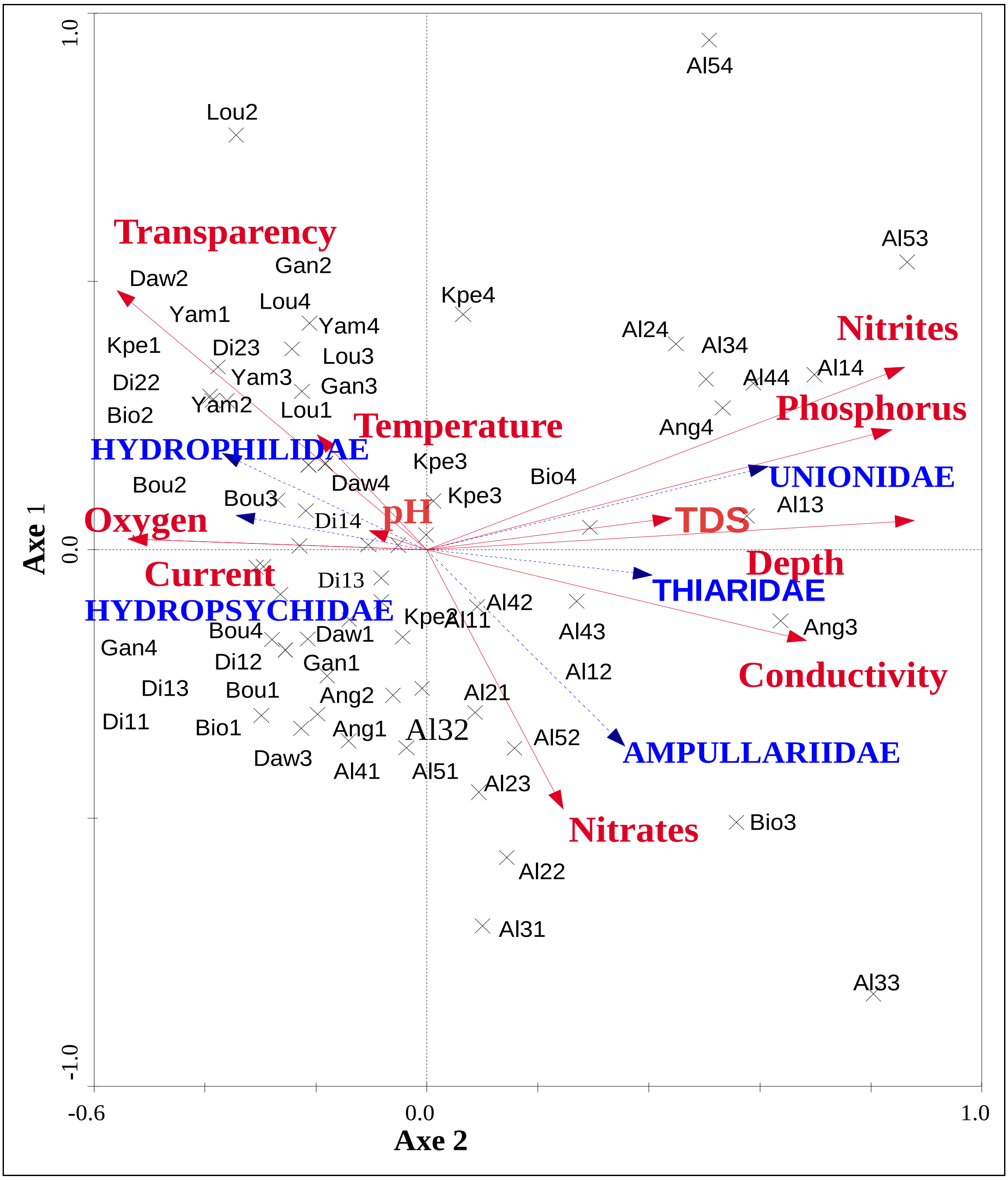

Fig 3: Redundancy analysis biplot showing the correlation between macroinvertébrés families and physico-chemical parameters in Alibori River.

4. Discussion
The entomofauna was constituted 70% of species identified the Alibori River. Coleoptera with 23 staxa, represented 27.24% of the families and 43.39% of the total species identified. This high abundance of the Coleoptera to the detriment of the Ephemeroptera and Trichoptera, whose

presence is indicator of good quality water, show a disturbance environment [17, 18]. Similar work in rivers indicated that the specific richness of Ephemeroptera and Plocoptera decreases with pressure of anthropogenic activities [19, 20, 21]. Molluscs represented 62% of the total abundance and show the enrichment of organic matter in downstream sites. Thus, the downstream sites favored the development of species like *Melanoides tuberculata, Lanistes variscus* and *Anodonta* sp. which are opportunist species. Also, the presence of Chironomidae and Chrysomelidae at downstream sites in the area of high agricultural production reveals an accumulation of residues from agricultural inputs [22]. The establishment of agricultural activities close to aquatic ecosystems disturbs benthic communities and contributes to the reduction and the distribution of species [23, 24]. The structure analysis of the macrofauna communities obtained through SOM revealed a zonal distribution upstream-downstream which indicates that the various sampling sites had in common a great part of benthic fauna and that their differences are a limited number of taxa which were specific to each sampling site. The community of groups II and III formed of upstream sites samples and far from agricultural areas is rich. This community is made up of less polluted sites [25, 26]. In contrast, the community of group I was composed of downstream samples with low diversity. These sites were the most disturbed and located in areas of intense agricultural activities. The decrease of diversity at these sites is connected at the accumulation of nutriments and organic matter observed at downstream [27]. Indeed, redundancy analysis indicated a high correlation between TDS, conductivity, nitrites, phosphates and molluscs. This result explains the proliferation of molluscs and the low diversity at the sites enriched with organic matter and nutrients [28]. On the other hand, the high transparency and concentration of dissolved oxygen were associated with a high richness at upstream. This observation supports the hypothesis of the pollution gradient that evolves from upstream to downstream.

5. Conclusion
The present study allowed to inventory in Alibori River 53 taxa of invertebrates divided into 7 classes. Transparency, dissolved oxygen, conductivity, Total Dissolved Solid, nitrites, nitrates and phosphates are the parameters which influenced the distribution of macroinvertebrates. Analysis of the macrofauna structure reveals an upstream-downstream zonal distribution in relation with the abiotic typology of the River. The presence of pollution indicators such as Chironomidae and Chrysomelidae, high abundance of molluscs in the basin is an expression of a disturbance. Detailed study of macroinvertebrates community will help in future to assess the impact of cotton activities on ecological integrity of Alibori River.

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