



(RESEARCH ARTICLE)



Preliminary data on the structure of macroinvertebrate communities and the physicochemical conditions of the Toumanguié and Bosso rivers under the influence of agricultural activities in the Aboisso department (south-east, Côte d'Ivoire)

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GSC Biological and Pharmaceutical Sciences, 2024, 26(01), 001–009

Publication history: Received on 18 November 2023; revised on 29 December 2023; accepted on 01 January 2024

Article DOI: <https://doi.org/10.30574/gscbps.2024.26.1.0542>

Abstract

The Toumanguié agricultural zone in the Sud-Comoé region of south-eastern Côte d'Ivoire contains several agricultural plantations and a dense and varied hydrographic system including the Bosso and Toumanguié rivers. However, knowledge of the ecological status of these two rivers is almost unavailable to the scientific community to assess the impact of agricultural activities. The purpose of this one-off study, carried out in March 2023, was to provide initial data on the physicochemical state and composition of macroinvertebrate communities in these two rivers. Four (4) sampling points were defined on these rivers. Measurements of the water physicochemical parameters (temperature, dissolved oxygen transparency, conductivity and pH) were taken *in situ* between 06:00 and 08:00 in the morning using a multiparameter, and some water samples were taken for the determination of nutrients. Macroinvertebrates were collected using a Van Veen bucket and a dip net. Analysis of the physicochemical parameters showed that the water in the Toumanguié agricultural zone was of relatively good quality and conducive to the survival of aquatic macroinvertebrates. However, the nutrient values indicated that the water was slightly polluted as a result of the degradation of organic matter. 34 taxa belonging to 26 families and 11 orders were identified, with a predominance of insects. Diptera were predominant. The taxa commonly collected in these rivers were: *Cricotopus kisantuensis*, *Polypedilum fuscipenne*, *Chironominae* and *Diplonychus* sp. The macroinvertebrate communities in these two rivers were not very diversified but were relatively balanced in terms of diversity index values.

Keywords: Macroinvertebrate communities; Physicochemical conditions; Toumanguié and Bosso rivers; Agricultural activities; Aboisso department

1. Introduction

The Toumanguié agricultural zone is located in the south-east of Côte d'Ivoire in the Sud-Comoé region, which contains several agricultural plantations such as oil palm, rubber, cocoa, etc. This region also has a dense and varied hydrographic network with lakes, rivers and lagoons. This vast hydrographic network includes the Bosso and Toumanguié rivers, located in the Toumanguié agricultural zone, where the pressure of human activity is clearly marked by the extent of the plantations. Discharges such as factory effluents, pesticides and fertiliser residues from these plantations can run off into these two rivers, degrading their physico-chemical quality and hence their ecological quality. These agricultural activities can therefore have repercussions on the diversity and structure of biological communities, including benthic macroinvertebrates. Macroinvertebrates are good bioindicators because of their sedentary nature and ecological plasticity. They also play an important role in the food webs of aquatic environments, acting as intermediaries in the transfer of primary production to higher trophic levels [1]. Their structure also reflects the variables that modify their habitat [2, 3]. Studies have also been carried out on macroinvertebrates in several aquatic environments in the region, such as the Bia [4], Soumié, Eholié, Ehania and Noé rivers [5]. However, data on benthic macroinvertebrate community

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composition the Bosso and Toumanguié rivers water's are virtually unavailable to the scientific community. The aim of this study was to provide the first data on the composition of macroinvertebrate communities in these two rivers.

2. Material and methods

2.1. Sampling sites

The data collection campaign took place from 10 to 13 March 2023 in the rivers located in the Toumanguié agricultural zone. The area of direct interest considered during this study comprises the rivers in and around the Toumanguié agricultural zone. To this end, data on the diversity of aquatic macroinvertebrates was collected at four (04) sampling points in aquatic environments affected by agricultural activities in the Toumanguié area. The sampling sites were distributed as follows :

- One site on the Bosso river before an oil mill in the Toumanguié farm area (bout);
- One site on the Toumanguié river after the oil mill inside the Toumanguié farm (tov3);
- One site on the Toumanguié river at the entrance to the agricultural zone (toka);
- One site on the Toumanguié river at the exit of the agricultural zone towards the village of Toumanguié (tovil). Table 1 below shows the geographical coordinates of these stations.

Table 1 Geographical coordinates of data sampling stations

Sampling site	Longitude	Latitude
BoUT	N='05.33331°	W= 03.39381°
ToV3	N='05.36566°	W= 03.38295°
ToKa	N='05.36097°	W= 03.35333°
ToVil	N='05.31795	W= 03.32511°

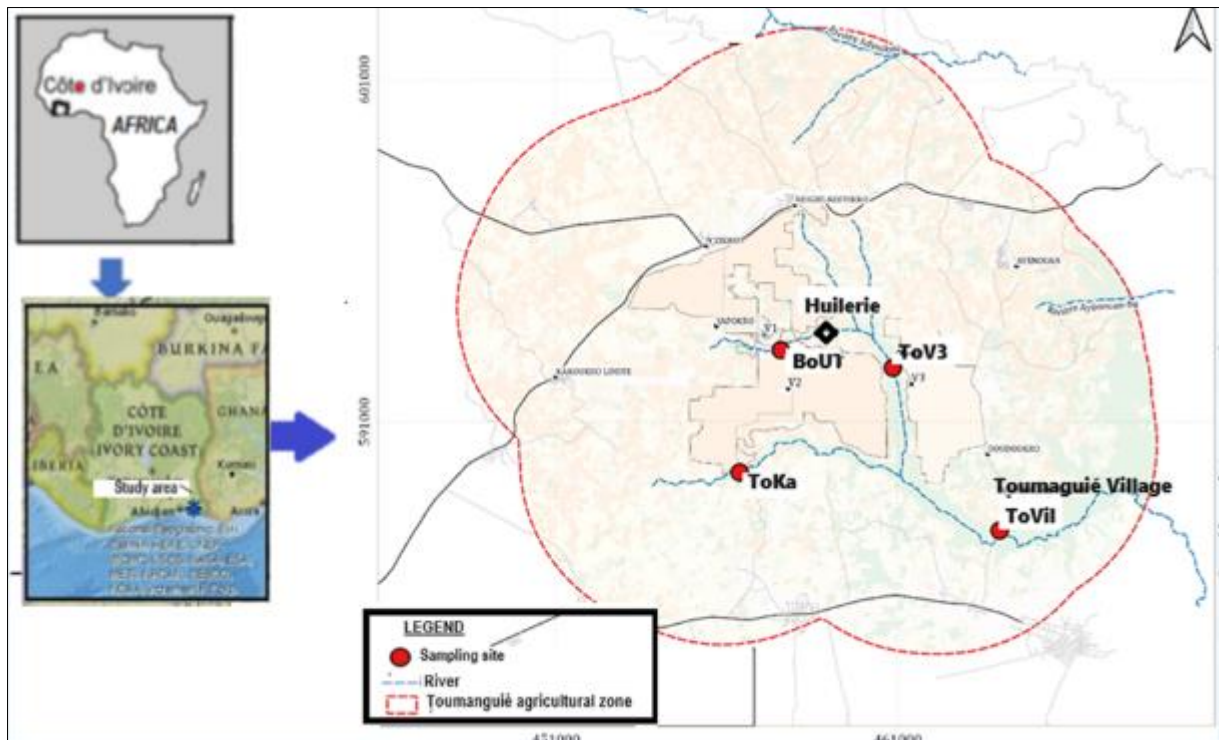


Figure 1 Map showing the location of data sampling points in the Toumanguié agricultural zone

2.2. Measurement of physico-chemical parameters

At each sampling point, the physicochemical parameters of the water were measured *in situ* using a multiparameter and a portable pH-meter. These measurements covered temperature, conductivity, dissolved oxygen and pH. Transparency was estimated using a Secchi disc [2].

2.3. Collection of water samples and laboratory analysis

Water samples were taken in 1 L glass bottles at each sampling site in the various rivers. They were transported to the laboratory in coolers containing ice packs, where they were kept in the refrigerator at 4 °C before being analysed. These water samples were used to measure nitrite (NO_2^-), nitrate (NO_3^-), ammonium (NH_4^+) and phosphate (PO_4^{3-}) ions using a spectrophotometer, in accordance with the standard protocols of the Association Française de Normalisation (AFNOR). To this end, the previously sampled volume of 500 mL of water was filtered using filter membranes (Whatman - Membrane Nitrate cellulose: 0.45 μm) and a suction pump. NH_4^+ cation measurements were carried out on the unfiltered raw samples.

2.4. Sampling of submerged macroinvertebrates

Benthic macroinvertebrates were sampled at each of the eight (08) sites defined in the area of interest using a dip net (250 μm mesh) following the SASS (South African Scoring System) method [6]. Samples were collected for 3 minutes by submerging the turbid net and dragging it through a water column over a distance of 5 meters. The net was also struck against the substrate to dislodge and collect organisms from the sediment.

2.5. Sampling of the benthos

Benthic macroinvertebrates were sampled using a stainless steel Van Veen grab. At each site, three sediment samples corresponding to a total surface area of 0.15 m^2 were taken. The contents of the bucket were washed on a 0.5 mm mesh sieve after removal from the water. In the laboratory, the macroinvertebrates were sorted under a binocular magnifying glass at 40 x magnification, then identified using the keys and works of Déjoux *et al.* [7], De Moor *et al.* [8], Tachet *et al.* [9] and Brown [10].

3. Results

3.1. Physicochemical status and water quality of rivers

The values of the physicochemical parameters measured during the data collection campaign for the hydrobiological study are presented in Table 4 below.

Water temperatures in this interest zone range from 26.8°C (BoUT) to 29.7°C (ToV3). The pH values range from 6.12 (ToKa) to 7.15 (ToVil). Dissolved oxygen values fluctuated between 3.98 mg/L (ToV3) and 4.13 mg/L (ToVil). Water transparency varied from 37.5 cm (BoUT) to 65 cm (ToKa). Conductivity values fluctuated between 24 $\mu\text{S}/\text{cm}$ (ToKa) and 104 $\mu\text{S}/\text{cm}$ (ToV3).

Table 2 Physicochemical characteristics of sampling sites on rivers in the Toumanguié area

Paramètres	ToKa	BoUT	ToV3	ToVil
pH	6.12	6.7	6.64	7.15
Transparency	65	37.5	54.5	50
Conductivity	24	58	104	32
Temperature	29.2	26.8	29.7	29
Dissolved oxygen	4.05	4.12	3.98	4.13

BoUT = Bosso River, before huilerie, **ToV3** = Toumanguié rivers after huilerie ; **ToKa** = Toumanguié river after agricultural zone ; **ToVil** = Rivière Toumanguié river in downstream of the agricultural zone

3.2. Nutrients

The nutrient concentration values (Table 3) for nitrite (0.2 to 0.4 mg/L) and phosphate (0.22 to 0.92 mg/L) are respectively above the 0.2 mg/L threshold, while those for nitrate (0.0 to 0.004 mg/L) and ammonium (0 to 0.02 mg/L)

are below this threshold. These values above the 0.2 mg/L threshold indicated slight water pollution, which would be inherent in a process of degradation of organic matter from animal and plant residues. In addition, these high orthophosphate values in the water analysed can also be explained by eutrophication of the environment following an accumulation of phosphorus compounds from agricultural activities in the Bosso and Toumanguié river catchment areas.

Table 3 Nutrient content of sampling sites in the Toumanguié area

Parameters	ToKa	BoUT	ToV3	ToVil
NO ₂ (mg/L)	0	0	0.004	0.038
NO ₃ ⁻ (mg/L)	0.25	0.4	0.2	0.3
NH ₄ ⁺ (mg/L)	0.018	0.02	0	0.09
PO ₄ ³⁻ (mg/L)	0.2	0.22	0.92	0.98

BoUT = Bosso River_before huilerie, ToV3 = Toumanguié rivers after huilerie ; ToKa = Toumanguié river after agricultural zone ; ToVil = Rivière Toumanguié river in downstream of the agricultural zone

3.3. Composition of rivers macroinvertebrate communities

Table 4 shows the spatial distribution of benthic macroinvertebrate taxa encountered at the sampling sites located in the Toumanguié agricultural zone. Across the four sampling sites, 34 taxa belonging to 26 families and 11 orders were recorded. The macroinvertebrates collected belonged to 03 phyla, namely Molluscs, Annelids and Arthropods. These species belong to 06 classes, namely Insects, Gastropods, Clitellates, Arachnids and Malacostracans.

The Insects class was the best represented with 31 taxa in 06 orders and 22 families (72% of taxa), followed by Gastropods (12% of taxa) with 05 taxa in 03 orders and 04 families. The orders of insects represented are: Coleoptera, Diptera, Ephemeroptera, Hemiptera, Hymenoptera and Odonata.

The Hemiptera order was the most diverse, with 07 taxa (Figure 2). The hemipteran taxa recorded are: *Aphrodes* sp., *Diplonychus* sp., *Cicadella viridis*, *Micronecta scutellaris*, *Limnogonus chopardi*, *Laccocoris* sp. and *Anisops* sp.. (Cf. Table 4). This result highlights the preponderance of Hemiptera, which are known to be pollutant-tolerant taxa in the waters of the area of interest. A single taxon of Ephemeroptera (*Labiobaetis* sp.) was collected.

Analysis of the spatial distribution of macroinvertebrates shows that 07 species was unique to the ToKa site located at the entrance to the Toumanguié agricultural zone. These are : *Thalassius* spp., *Tetragnatha* sp., *Tomichia ventricosa*, *Laccobius* sp., *Chaoborus cristallinus*, *Mansonia* sp. and *Solenopsis* sp. Ephemeroptera *Labiobaetis* sp., Hemiptera *Cicadella viridis* and *Anisops* sp. and Diptera *Corynoneura* sp. were uniquely encountered at the BoUT site on the river Bosso. The taxa *Chironomus formosipennis* and *Alboglossiphonia* sp. were only encountered at station ToV3. Last but not least, *Pseudasphondylia* sp. and *Neurigona squamifera* were only collected at the ToVil site. Analysis of the occurrences shows that 04 taxa constantly appeared in the samples taken at the various sampling sites. These were *Cricotopus kisantuensis*, *Polypedilum fuscipenne*, *Chironomini* sp. and *Diplonychus* sp. (cf. Table 4).

Table 4 List of macroinvertebrate taxa collected in the Toumanguié area

Orders	Famiies	Species	ToKa	BoUT	ToV3	ToVil
Haplotaxides	Turbificidae	<i>Ophidonais serpentina</i>			1	2
Rhynchobdellides	Glossiphonidae	<i>Alboglossiphonia</i> sp.			1	
Trombidiformes	Pisauridae	<i>Thalassius</i> spp.	6			
	Tetragnathidae	<i>Tetragnatha</i> sp.	1			
Décapodes	Atyidae	<i>Caridina Nilotica</i>		1		1
Basommatophores	Planorbidae	<i>Bulinus natalensis</i>				1
	Tomichiidae	<i>Tomichia ventricosa</i>	2			
Coléoptères	Dytiscidae	<i>Dineutus</i> sp.	2	1	1	6

		<i>Hygrotus</i> sp.	2	3		
	Hydrophilidae	<i>Amphiops</i> sp.	3			1
		<i>Enochrus</i> sp.	1	3		
		<i>Laccobius</i> sp.	1			
Diptères	Cecidomyiidae	<i>Pseudasphondylia</i> sp.				2
	Chaoboridae	<i>Chaoborus cristallinus</i>	1			
	Chironomidae	<i>Chironomus formosipennis</i>			4	
		<i>Corynoneura</i> sp.		1		
		<i>Cricotopus kisantuensis</i>	2	45		8
		<i>Polypedilum fuscipenne</i>	3	1	1	
		<i>Chironomini</i> sp.	12	3		4
		<i>Procladius</i> sp.		2		
	Culicidae	<i>Mansonia</i> sp.	2			
Dolichopodidae	<i>Neurigona squamifera</i>				1	
Ephéméroptères	Baetidae	<i>Labioaetis</i> sp.		3		
Hémiptères	Aphrophoridae	<i>Aphrodes</i> sp.	2			
	Belostomatidae	<i>Diplonychus</i> sp.	5	1		10
	Cicadellidae	<i>Cicadella viridis</i>		1		
	Corixidae	<i>Micronecta scutellaris</i>	1	1	1	
	Gerridae	<i>Limnogonus chopardi</i>	1	2		
	Naucoridae	<i>Laccocoris</i> sp.	1			2
	Notonectidae	<i>Anisops</i> sp.		3		
Hyménoptères	Formicidae	<i>Solenopsis</i> sp.	3			
Odonates	Coenagrionidae	<i>Pseudagrion</i> sp.	1		1	
	Libellulidae	<i>Zygonyx torridus</i>	2	1		
	Macromiidae	<i>Phyllomacromia</i> sp.	1	4		
Total = 11	26	34	22	17	7	11

BoUT = Bosso River_before huilerie, **ToV3** = Toumanguié rivers after huilerie ; **ToKa** = Toumanguié river after agricultural zone ; **ToVil** = Rivière Toumanguié river in downstream of the agricultural zone

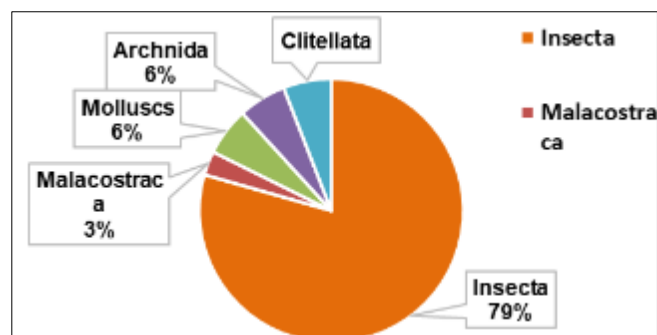


Figure 2 Proportions of macroinvertebrate classes collected in the Toumanguié area

3.4. Structure and organisational quality of macroinvertebrate communities

Table 5 presents the macroinvertebrate statistics for the rivers in the Toumanguié agricultural zone. A total of 179 individuals were collected. ToKa has the highest species richness (22 taxa), with 55 individuals. The ToV3 site located downstream of the Toumanguié oil mill is the least diverse, with 07 taxa and 10 individuals collected.

The community structures indicated that the macroinvertebrate communities were dominated by the order Diptera. This order had a total of 92 individuals collected, representing 51.39% of the total number of individuals collected (*cf.* Table 5). It was followed by the order Hemiptera with 31 individuals.

Analysis of community diversity using Shannon index calculated for the sites indicated that the ToKa site was the most diversified (2.767 bit), while the ToV3 site was the least diversified (1.748 bit).

Table 5 Summary of statistical data for aquatic macroinvertebrates found at the various sampling sites

Index	Sampling sites			
	ToKa	BoaUT	ToV3	TouVil
Taxonomic Richness_S	22	17	7	11
Individuals	55	76	10	38
Shannon index_H	2.767	1.751	1.748	2.056
Equitability index_J	0.8952	0.6179	0.8983	0.8572

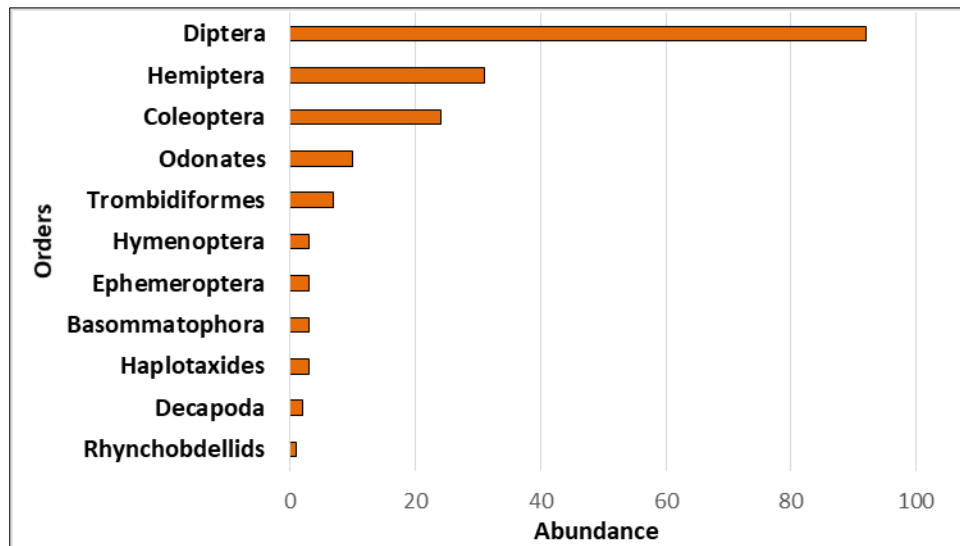


Figure 3 Abundance of macroinvertebrates orders collected in the Toumanguié area

4. Discussion

4.1. Physicochemical state of the water

These values reflect a strong thermal variation within the hydrographic system of the area of interest. These results are attributable to the heterogeneity of the water and variations in the rate of sunshine in the Toumanguié area. This result may also be related to the period during which the temperature was measured in this study. Measurements at some sites were taken in the morning, with relatively high levels of sunshine at times. These measured temperature values (all below 30°C) are included in the margin, providing good quality water conducive to the life of aquatic organisms [11].

These values show that the pH of the water in the area of interest was close to neutral. This indicates that the water was neither basic nor acidic. These pH values were within the range indicative of good water status, between 6 and 9, as indicated by Bernard *et al.* [11]. The quality of the water in the rivers in the Toumanguié agricultural area therefore posed no major threat to local human populations or to the survival of aquatic species.

This range of values is consistent with those recorded in several freshwaters in Côte d'Ivoire, such as Buyo and Taabo, as reported by Yapo [12] and Aliko [13]. For these environments, the dissolved oxygen level is between 2 and 11 mg/L. Furthermore, fluctuations in this parameter are essentially influenced by the preponderance of suspended matter and the extent of photosynthetic activity by algae and aquatic plants. Low concentrations of less than 3 mg/L would indicate heavy pollution of the water due to an increase in the solubility of suspended matter [14].

The water transparency values indicated that the water is relatively less turbid. These values were attributable to the richness of the water in suspended matter, the depths of some of the sampling sites and the mixing of river water with wastewater and runoff rich in suspended matter.

The majority of conductivity values were below 100 $\mu\text{S}/\text{cm}$, which means that the water was of relatively good quality in terms of this parameter. However, the relatively high values observed in the water could be explained by the fact that our sampling took place during the rainy season. This period leads to the precipitation of runoff water in the river beds [15].

4.2. Macroinvertebrate community diversity and structure

A total of 34 taxa were recorded at all the sampling sites, with insects dominating, accounting for 27 taxa. The species collected in this study are typical of those found in several Ivorian rivers [5, 16, 17]. The composition of the environments by order is dominated by Diptera, with 10 taxa. This order is followed by Hemiptera with 07 taxa. This structure is similar to those obtained in several Ivorian and African rivers, such as that reported by Masifwa *et al.* [18] in Lake Victoria in Uganda, Allouko *et al.* [19] and Camara [17] in the Banco River. On the one hand, this observed dominance of insects is linked to their preponderance in macroinvertebrate communities in aquatic environments due to their great ecological plasticity [19]. However, the number of species collected is relatively low compared with those reported by Edia [5] on three rivers in the same region. The difference between the results could be explained by the sampling effort and the intensity of the impact of agricultural activities on these rivers.

Analysis of the results on the composition and distribution of macroinvertebrate taxa shows that the sampling sites located before the Toumanguié agricultural zone (BoUT and ToKa), with 22 and 17 taxa respectively, have relatively high numbers of species compared with the two sites located after the agricultural zone. This finding could be the result of the impact of agricultural activities on the watercourses. This situation is confirmed by the preponderance of Diptera.

With the exception of the ToKa site, the other sites host communities that are less diverse (because $H' < 2.5$ bit) and relatively well balanced in view of the reported equitability index values, which are almost all above 0.5.

Furthermore, the preponderance of Hemiptera and Diptera, which are reputed to be pollutant-tolerant taxa in the waters of the study area, and the presence of a single taxon of Ephemeroptera (*Labiobaetis* sp.) with an absence of taxa from the orders Trichoptera and Plecoptera, which are pollutant-sensitive organisms in the waters, show that these waters are of poor ecological quality.

5. Conclusion

This study provided the first data on the composition and structure of the macroinvertebrate community in the rivers of the Toumanguié agricultural zone. Analysis of the physico-chemical parameters shows that the water in the Toumanguié agricultural zone is of relatively good quality and conducive to the survival of aquatic macroinvertebrates. However, the nutrient values indicate that the water is slightly polluted as a result of the degradation of organic matter. 34 taxa belonging to 26 families and 11 orders were identified, with a predominance of the insect class. The distribution of macroinvertebrate communities were low diversified and with a fairly balanced organisation with a slight impact of agricultural activities on their structure.

Compliance with ethical standards

Acknowledgments

We would like to thank the authorities of the agro-industrial companies operating in the Toumanguié area and TACIS for the opportunity to collect the data for this study.

Disclosure of conflict of interest

No conflict of interest.

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