

Composition and Distribution of Zooplankton Relationship to Environmental Factor in a Tropical River: (Bagoe, Côte d'Ivoire)

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Abstract

The relation between zooplankton and environmental parameters were studied in Bagoe river in thirteen stations the dry (March-April 2012) and rainy (October-November 2012) seasons. Thirty-eight taxa of zooplankton were identified in Bagoe river, including Copepoda, Cladocera, Rotifera and others zooplankton. Rotifera was the richest group with 26 taxa belonging to 15 families and 18 genuses. Zooplankton abundance varied significantly (p < 0.01) according to station and season. Abundance seasonal variation was marked by dry season values (1 to 233 ind.L⁻¹) highest than those observed during wet season (0 to 6 ind.L⁻¹). Spatially, the highest zooplankton abundance was generally obtained in southern part of the river in both the dry and the wet (with the exception of station B11) seasons. Rotifera was the most abundant group with, in average 57 % of total abundance in the wet season and 91% over the dry season. During the dry season, the most abundance taxa of Rotifera, were Trichocerca sp. (mean: 24%), Polyharthra sp. (23%) and Lecane sp. (20%). During the wet season, Polyharthra sp., was the most abundant Rotifera (70%). Zooplankton composition and abundance and its spatial and seasonal variations were linked to water temperature, Turbidity, conductivity, flow velocity, dissolved oxygen concentration, and dissolved solids rate.

Keywords: Bagoe River, zooplankton composition and abundance, spatio-temporal variations.

Introduction

Zooplankton is ecologically an important group of aquatic organisms that occupy a wide range of habitats. It is a important biotic component of an aquatic ecosystem. It influences they functionality and contributes to the energy flow, food chain, food web and cycling of organic matter¹⁻³. Zooplankton actively grazing alga and consumes suspended matter and involving in the transfer of primary productivity to fish and other consumers⁴. Zooplankton organisms offer also several advantages as indicators of environmental quality (pollution, water quality, and eutrophication) in aquatic $ecosystem^{5,6}$. Therefore, zooplankton survey can help to manage aquatics ecosystems. In freshwaters ecosystems of Côte d'Ivoire, several studies on zooplankton have been achieved. Studies have mainly been performed in ponds⁷⁻⁹, lakes of hydroelectric dams¹⁰⁻¹⁵, agro-pastoral lakes¹⁶, Bandama stream basin¹⁷ and, Agneby and Bia rivers^{18,19}. Surveys on the zooplankton of the others freshwaters ecosystems of Côte d'Ivoire are scares or inexistent. Bagoe River is an aquatic ecosystem in the north of the Côte d'Ivoire and presenting 83 variety species of fish belonging to 43 genera, 19 families and 8 orders²⁰. To date, zooplankton community of this hydrosystem remains unknown. In the present study, our goal was to propose a focus on Bagoe River zooplankton, its specific composition and spatio-temporal variation in relation to environmental variables.

Material and Methods

Study area and data collection: The Bagoe River, tributary in the Niger stream, is situated in the North of Côte d'Ivoire between $9^{\circ}15'$ and $10^{\circ}50'$ N and $5^{\circ}40$ and $7^{\circ}10'$ W (figure-1). It is 350 km long and with a watershed of 33 430 km^{2 (21)}. The Bagoe river's watershed undergoes the influence Soudanoguineen climate characterized by one rainy season (May-October) and one dry season (November-April). Zooplankton and environmental variables were collected during the dry (March-April 2012) and the rainy (October-November 2012) season in 13 sampling sites (figure-1).

The physical and chemical parameters (water temperature, dissolved solids rate (DSR), turbidity, dissolved oxygen concentration, pH, conductivity) were measured in surface, with a portable multi-parameter probe, TURO T-611. Water turbidity was measured using a Secchi disk. The zooplankton sampling was carried out using a cylindro-conical net of 64 μ m in mesh opening size by filtration. Hundred liters of subsurface water were collected and filtered through the plankton net of 64 μ m mesh size. Samples were preserved with formalin at a final concentration of 5%.

Zooplankton organism was identified using the following works $^{22-26}$. The taxa were identified and counted under a dissecting microscope.



Figure-1 Map of the Bagoe River in Côte d'Ivoire with sampling position sites

Analytical procedure: The relationships between the zooplankton species and environmental parameters of the Bagoe were assessed by using a Canonical Correspondence Analysis (CCA). Kruskal-wallis test was use for zooplankton density comparison between stations and season. All steps of this method were computed using Statistica 7.1 software.

Results and Discussion

Environmental parameters: Figure-2 shows spatial variation of environmental variables of Bagoe River, during the rainy (October-November) and dry (March-April) seasons. Water temperature varied between 23.1 and 32.5 °C according to the station and the season. Highest temperatures were always obtained during the dry season. Turbidity, pH, conductivity and dissolved solids rate presented a spatio-temporal variation similar to that of water temperature (figure-2). Dissolved oxygen concentration varied between 3.97 to 6.77 mg.L⁻¹ during rainy season versus 0.75 to 5.62 mg.L⁻¹ during dry season. Flow velocity varied between 0.1 to 0.6 m.s⁻¹ during the rainy season versus 0.02 to 0.3 m.s⁻¹ during the dry season. All environmental variables studied showed significant seasonal variations (p < 0.001).

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during dry and rainy seasons in the Bagoe River (DS = Dry Season, RS = Rainy Season)

Taxonomic composition spatio-temporal pattern: A total of Thirty-eight taxa of zooplankton were identified in Bagoe river including four groups: Copepoda, Cladocera, Rotifera and others zooplankton (table-1). Copepods were represented by one family (Cyclopidae) and two genus plus unidentified copepod nauplii. *Mesocyclops* sp. and unidentified copepods nauplii presented highest occurrence (> 50%). Cladocera taxa belonging

to 4 families and 7 genuses. Daphnidae presented the highest diversity (3 taxa: Ceriodaphnia cornuta, Moina micrura and Moinodaphnia sp.) followed by Bosminidae (2 taxa: Bosmina longirostris and Bosminopsis dietersi). All cladocerans taxa have occurrences \leq 30%. Rotifera dominate qualitatively the Bagoe zooplankton with 26 taxa (68% of total diversity) belonging to 15 families and 18 genuses. The most frequent taxa of the Rotifera group (occurrence $\geq 50\%$) were *Trichocerca* sp. (83%), Asplanchna sp. and Lecane sp. (58% each), Keratera tropica (50%) and Polyharthra sp. (50%). Bagoe river zooplankton species richness and diversity indices varied according to stations and seasons. During the dry season, zooplankton richness varied between 2 (Ba9) and 18 taxa (Ba3) with a total diversity of 35 taxa. During the rainy season, species richness varied between 0 (station Ba9) and 12 taxa (station Ba12) with a total diversity of 22 taxa. In Bagoe river, zooplankton richness was significantly more important during the dry season (p < 0.01). Similar seasonal pattern was observed for Shannon diversity indice, with values in dry season (Mean: 2.2 bit.ind⁻¹) higher than during the rainy season (Mean: 1.84 bit.ind⁻¹). Shannon's diversity indice spatial variation was characterized by highest values at stations Ba1 and Ba3 to Ba7 $(1.30-2 \text{ bit.ind}^{-1})$ and lowest value at station Ba9 (0 bit.ind⁻¹).

Zooplankton structure and abundance spatio-temporal variation: Bagoe river zooplankton abundance varied significantly (p < 0.01) according to stations and seasons. Abundance seasonal variation was marked by dry season values (1 to 233 ind.L⁻¹) highest than during rainy season (0 to 6 ind.L⁻¹) (figure-3). Bagoe river's zooplankton was dominated by Rotifera (mean: 57-91%), followed by Copepoda (8-27%) (figure-4 A, B). Rotifera and Copepoda presented highest abundance at Ba3 to Ba6 and B11 (\approx 101 to 233 ind.L⁻¹ in the dry season) and at Ba11 (\approx 4 ind.L⁻¹ in the rainy season) (figure-4 A, B).



Figure-3 Spatial and seasonal variations of the total zooplankton abundance in the Bagoe river (DS: Dry Season and RS: Rainy Season)

During the dry season, 5 taxa of Rotifera collected accounted for 89% of total abundance: *Trichocerca* sp. (24%), *Polyharthra* sp. (23%), *Lecane* sp. (20%), *Keratella tropica* and *Filinia opoliensis* (8% each). *Trichocerca* sp. and *Lecane* sp. were more abundant at stations Ba4 (112 and 74 ind.L⁻¹ respectively) and Ba6 (42 and 64 ind.L⁻¹ respectively). *Keratella tropica* presented the most abundance at station Ba3 (31 ind.L⁻¹) while *Filinia opoliensis* highest abundance were observed at stations Ba3-Ba5 (10 to 22 ind.L⁻¹) (figure-4C). Copepoda were represented by 3 taxa during the dry season: nauplii stage (86%), *Mesocyclops* sp. (10%) and *Thermocyclops* sp. (4%). Highest abundances of these taxa were observed at stations Ba4 to Ba11 (figure-4E).

During the rainy season, Rotifera comprised mainly *Trichocerca* sp. (43%), *Filinia opoliensis* (17%), *Lecane* sp. (11%) and *Polyharthra* sp. (9%) (figure-4D). Copepods were mainly constituted by *Thermocyclops* sp. (50%), nauplii stage (39%) and *Mesocyclops* sp. (11%) (figure-4F).

Environmental parameters influence on zooplankton: Canonical Correspondence Analysis (CCA) showed that the first two axes expressed the variance percentage more than 60%, with $\approx 40\%$ for the first axis. During the dry season (DS), CCA showed a clear discrimination of 2 two zones (figure-5A). The first group, positively correlated with the axis II, comprised stations B1 to B4 and B6 located at the southern part of the Bagoe river's watershed, and were opposed to stations B7 to B13 and B5, corresponding to the northern part of this river's watershed.

The first group of stations was positively correlated axis II and with dissolved oxygen and conductivity. Taxa associated to this zone were the copepods *Thermocyclops decipiens*, nauplii and the rotifers *Filinia opoliensis*, *Filinia therminalis*, *Brachionus falcatus*, *Keratela tropica*, *Filinia* sp., *Keratera* sp. and *Lecane* sp.. The second group of stations was negatively correlated to the axis II and with pH, dissolved oxygen rate, temperature, conductivity, and flow velocity.

Taxa mainly associated to this part were Mesocyclops sp., *Moina micrura, Trichocerca* sp., *Synchaeta* sp., *Ascomorpha* sp., *Asplanchna* sp., *Hexarthra* sp., *Filinia longiseta, Brachionus caudatus, Polyahrthra* sp.. The analysis performed on the rainy season data doesn't show clear spatial discrimination (figure-5B). However, let's observe that the main environmental factors controlling taxa distribution during the rainy season were dissolved oxygen, turbidity, pH and conductivity.

Discussion: Zooplankton community, is common to the traditional ones in tropical and sub-tropical freshwater : Bia and Agneby rivers (Côte d'Ivoire)¹⁹, Lake Guier (Senegal)²⁷, Niger delta (Nigeria)²⁸, Paraguay river (Paraguay)²⁹, Paranapanema³⁰ and Jesumira rivers³¹ (Brazil).

	Table-1	
Distribution of zoo	plankton taxa collected in the Bagoe River; + : tax	a presence

Groups	Families	Таха	Stations												
			Ba1	Ba2	Ba3	Ba4	Ba5	Ba6	Ba7	Ba8	Ba9	Ba10	Ba11	Ba12	Ba13
Copepoda	Cyclopidae	Mesocyclops sp.	+		+		+	+	+			+	+		
	"	Thermocyclops decipiens	+	+		+		+			+		+	+	
	unidentified	Nauplii	+	+	+	+	+	+	+		+	+	+	+	+
Cladoceran	Chydoridae	Alona spp.					+	+					+		
	Bosminidae	Bosmina longirostris		+											+
	"	Bosminopsis dietersi											+		
	Sididae	Diaphanosoma excisum										+	+	+	
	Daphnidae	Ceriodaphnia cornuta											+		
	"	Moina micrura		+								+	+	+	
	"	Moinodaphnia sp.	+										+		
Rotifera	Gastropidae	Ascomorpha sp.					+								
	Asplanchnidae	Asplanchna sp.			+	+	+		+	+			+		+
	Brachionidae	Brachionus angularis						+							+
	"	Brachionus calyciflorus					+	+							
	"	Brachionus caudatus			+		+	+					+		+
	"	Brachionus falcatus	+	+	+	+	+	+	+						
	"	Keratella javana			+			+							
	"	Keratella tropica	+	+	+		+		+	+			+	+	+
	"	Keratella sp.			+										+
	"	Platyias quadricornis					+						+		
	Colurellidae	Colurella sp.													+
	Lepadellidae	Lepadella sp.			+								+		
	Conochilidae	Conochilus sp.			+				+						
	Epiphanidae	Epiphanes sp.						+	+				+		
	Euclanidae	Euchlanis sp.					+								
	Filiniidae	Filinia longiseta			+		+	+							+
	"	Filinia opoliensis			+	+	+						+		+
	"	Filinia terminalis	+		+	+									

Groups	Families	Taxa	Stations												
			Ba1	Ba2	Ba3	Ba4	Ba5	Ba6	Ba7	Ba8	Ba9	Ba10	Ba11	Ba12	Ba13
	"	Filinia spp.			+					+			+		
	Hexarthridae	Hexarthra sp.					+	+					+		+
	Lecanidae	Lecane sp.	+		+	+	+	+		+		+	+		+
	Notommatidae	Monommata sp.			+										
	Synchaetidae	Polyarthra sp.			+		+	+				+	+		+
	"	Synchaeta sp.							+				+		
	Testudinellidae	Testudinella sp.						+	+						
	Trichocercidae	Trichocerca sp.	+	+	+	+	+	+	+	+	+	+	+	+	+
Others	unidentified	Insect larvae	+		+							+	+		
Zooplankton	"	Ostracodes										+	+		
Total taxa		38	10	7	20	8	17	16	10	5	3	10	24	6	14







Ba2

Ba4

Ba6

Ba10 Ba12

100

50

0

Ba1



Figure-4

Spatial variations of the total zooplankton abundance (A and B) and of the abundance of the main rotifera (C-D) and copepoda (E-F) taxa obtained during the dry (left) and the rainy (right) seasons in the Bagoé river (Clado: Cladoceran, Cope: Copepoda, Roti: Rotifera, Others: others zooplankton / rotifers, Ncop: Copepods nauplii, Meso: *Mesocyclops* sp., Ther: *Thermociclops decipiens*, Fopo: *Filinia opoliensis*, Tricho: *Trichocerca* sp., Leca: *Lecane* sp., Poly : *Polyathra* sp., Ktro: *Keratella tropica*





CCA of data from environmental factors and zooplankton species collected in the Bagoe river during the dry season (A) and the rainy season (B) Meso: Mesocyclops sp., Ther: Thermociclops decipiens, Fopo: Filinia opoliensis, Tricho: Trichocerca sp., Poly: Polyathra sp., Ktrop: Keratella tropica, Fter: Filinia terminalis, Bfal: Brachionus falcatus, Fil spp.: Filinia spp., Kera sp.: Keratella sp., Mmic: Moina micrura, Ncop : Copepods nauplii, Meso : Mesocyclops sp., Ther : Thermociclops decipiens, Fopo : Filinia opoliensis, Tricho : Trichocerca sp., Leca : Lecane sp., Poly : Polyathra sp., Ktrop : Keratella tropica, Sync: Synchateta sp., Asco: Ascomorpha sp, Aspl: Asplanchna sp., Hexa: Hexarthra sp., Flong: Filinia longiseta, Bcaud: Brachionus caudatus, Dexc: Diaphanosoma excisum, Epip: Epiphanes sp

Total zooplankton richness (38 taxa) recorded in Bagoe River is relatively low compared to other tropical and subtropical rivers as Bia and Agneby rivers in Côte d'Ivoire (68 taxa)¹⁹, Orogodo river in Nigeria (79 taxa)²⁸, Okhuo river in Nigeria (51 taxa)³², Ikpa river in Nigeria (53 taxa)³³. In contrast, zooplankton richness in Bagoe river is relatively higher that those reported in Sombreiro river (Nigeria)³⁴, Calabar river (Nigeria)³⁵. The difference in richness in this study and studies cited below could be explained by several factors among which we can mention conditions of study environment, sampling duration, the catchment area of the aquatic ecosystem, activities performed on the watershed, etc.. According to Ezekiel *et al.* (2011)³⁴, reported by FAO (2006)³⁶ zooplankton distributions vary in space and in the time in relation to the aquatic systems functioning.

This study showed that, in Bagoe River, the great diversity was observed among Rotifera, with 26 taxa (68% of total diversity). This observation was similar to those observed in others freshwaters hydrosystem as : Bia and Agnebi rivers (Côte d'Ivoire)¹⁹, Lake Guier (Senegal)²⁸, Ovia river (Benin city, Nigeria)³⁷. In contrast, in Sombreiro River (Nigeria), copepoda and cladoceran presented high diversity (29% of total diversity each)³⁴. Branchionidae presented high family diversity with 8 taxa. The most representative genus belonged to the Rotifera Phylum, were Brachionus (4 species), Filinia (4 species) and Keratella (3 species). Similar observation was also found in others tropical and subtropical freshwater ecosystems as Lake Guier ²⁷, Paraopeba River³⁸, Cuiaba river³⁹, the Jacuí Delta floodplain⁴⁰. According to Borges and Pedrozo⁴⁰, these genuses are typically dominate in large floodplain rivers. Our results show that zooplankton of Bagoe River differ markedly between

hydrological phases, with high diversity in the dry season (2 to 19 taxa according sites, total diversity: 35) versus 1 to 13 taxa during the rainy season (total diversity: 22). This result was similar to those found in other tropical and subtropical rivers as Paraguay Rivers (Brazil)²⁹.

In Bagoe river, rotifers was the most abundant zooplankton group (57% to 91% of total abundance according season). This situation characterizes the tropical freshwater ecosystems as lakes and rivers^{31,43} and may be explained by their parthenogenetic reproductive pattern, short generation time under favorable conditions^{41,42,43}, adaptation to turbulence and high concentrations of suspended solids⁴⁴. According to Lampert⁴⁵, the dominance of smaller zooplankton species as rotifers in rivers may possibly be due to predation pressure from planktivorous fishes that selectively prey on larger sized zooplankton.

In Copepoda populations, the nauplii predominance found in this study is also observed in different tropical freshwater habitats^{38,36}. According to Edmondson⁴⁶ reported by Neves et al.³⁹, high densities of copepod immature stages are generally attributed to their continuous reproduction in tropical regions. This can also be explained by intense predation on adult stages by invertebrates and vertebrates⁴⁷. The Highest abundances values of zooplankton obtained during the dry season confirms the results of previous studies in Orinoco River (Venezuela)⁴⁸, in Parana River (Argentina)⁴⁴, in Paraguay River (Paraguay)²⁹. However, this result contrasts with several other studies where highest abundances were obtained during the rainy season^{28,33,49}. Zooplankton abundance seasonal variation could be explained by several factors as changes in runoff, current velocity, turbidity^{41,44}, water environmental characteristics, predation, quality and quantity of food and competition⁵⁰.

Conclusion

This study provides for the first time the composition of the zooplankton population of the Bagoe river. In addition, it provides information on the spatial and seasonal variation of the zooplankton composition and abundance in relation with environmental factors. A total of Thirty-eight taxa were identified in Bagoe River divided including Copepoda, Cladocera, Rotifera and others zooplankton. Rotifera was the richest group with 26 taxa (68% of total diversity) belonging in 15 families and 18 genuses. Rotifera was also the most abundant group, with 57% to 91% of the total population abundance according season. Our survey also showed that abundance and the diversity of zooplankton in Bagoe River vary significantly according seasons, with the most important values in the dry season.

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