Journal of Global Biosciences
ISSN 2320-1355
Volume 7, Number 5, 2018, pp. 5423-5438
Website: www.mutagens.co.in

Research Paper

COMPOSITION AND DISTRIBUTION OF ZOOPLANKTON IN RELATIONSHIP TO ENVIRONMENTAL PARAMETERS IN TROPICAL RIVER (SASSANDRA RIVER BASIN, Côte d'Ivoire)

Kouamé Kouakou Augustin, Raphael N'doua Etilé, Georges Kassi Blahoua, Gouli Goore Bi, Essetchi Koumelan Paul and Valentin N'douba

Laboratoire d'Hydrobiologie,
UFR Biosciences,
Université Félix HOUPHOUËT-BOIGNY de Cocody-Abidjan,
22 BP 582, Abidjan,
Côte d'Ivoire.

Abstract

Zooplankton community is an essential components of aquatic ecosystem where it contributes to transferring energy and organic matter from the primary producers to the higher trophic level taxa. However, changes in some environmental characteristics strongly influence their diversity and abundance. Thirteen sites were sampling in the Lower Sassandra River Basin (Côte d'Ivoire, West Africa) to examine patterns in zooplankton species assemblage structure in relation to some environmental parameters. Zooplankton samples were collected monthly from October 2004 to November 2005 with a cylindro-conical net of 50 µm in mesh opening size. Sampling observation showed of 67 taxa including Rotifera (39 species), Cladoceran (19 species), Copepoda (8 species) and Ostracoda (One species). Sassandra river's zooplankton species richness varied according to the sampling sites, with highest values observed in Buyo Lake (n = 61 species) while lowest diversities were obtained Lobo and Bolo rivers (n = 25-28 species). On average, Sassandra river's zooplankton was numerically dominated by Copepoda (40.37 % of zooplankton total abundance), followed by Rotifera (Mean: 29.51%) and Cladocerans (Mean: 25.67%). Ostracoda, with *Candonocypris multiformis* was less represented in Sassandra river's zooplankton community (Mean: 7.23%). In the lower basin of the Sassandra, seven species dominate the zooplankton community and constitute on average 44% of the total zooplankton abundance: *Thermocyclops consimilis* (9.30%), *Thermocyclops decipiens* (7.62%), *Mesocyclops varicans* (7.61%), *Thermocyclops emimi* (6.73%), *Thermodiaptomus yabensis* (6.23%), and *Keratella tropica* (5.64%). Zooplankton composition, abundance and its spatial variations were

linked to water temperature, conductivity, dissolved solids rate, flow velocity, and Nitrates and nitrites concentrations.
Key words: Sassandra River Basin, environmental parameters, Zooplankton.

INTRODUCTION

Zooplankton is the secondary producer group of the food chain in an aquatic ecosystem, which convert the vegetable product to the animal protein. So, zooplankton is an important link in the transformation of energy from producers to consumers as invertebrates, fish larvae and fish [1]. To this fact, it plays a major role in the functioning and the productivity of aquatic ecosystems through its key position. Zooplankton communities are also sensitive to various substances in water such as nutrient enrichment and pollutants. Thus, they have often been used as indicators to assess the condition and change of the freshwater environment [2]. Consequently, studies on zooplankton are quite important to understand aquatic ecosystem functioning, to contribute to its protection and to permit its rational management in a context of expected eutrophication and pollution of aquatic ecosystem provoked by an increasing anthropogenic activity on the one hand, and of aquatic ecosystem watershed highest human occupation with intense use of agricultural chemical agents on the other hand.

In lotic ecosystems of Côte d'Ivoire, several studies on zooplankton have been achieved. Studies have mainly been performed in Bandama stream basin [3], Agneby and Bia rivers [4], Bagoe river [5], Come river [6], for coastal rivers of south-East (Ehania, Bodoua, Boulo 1 et Boulo 2) [7]. Sassandra river is one of the four mains streams of Côte d'Ivoire, with the main channel stretching on 840 km and watershed of 75 000 km^2 [8]. To date, surveys on this aquatic ecosystem are scares and focused mainly on hydrology [9], water physical and chemical parameters [10], fish community [11] and *Synodontis koensis* Pellegrin, 1933 Feeding [12], morphology and sedimentology of its mouth [13], morphology and hydrology of its estuary [14]. However, no investigation has been carried in the Sassandra river basin to detect patterns in zooplankton communities and their environmental basis. In the present study, our goal was to propose a focus on Sassandra river zooplankton (composition and abundance spatio-temporal variation in relation to environmental variables). This study is a contribution to produce baseline data on biodiversity of this aquatic ecosystem.

MATERIAL AND METHODS

Study Area

The Sassandra River Basin flows through western Côte d'Ivoire to the Atlantic Ocean. It runs for approximately 840 km and drains 75 000 km^2 [8]. The present study was restricted to the lower course of the basin (**Fig. 1**) because an armed conflict has prevented field work in northern Côte d'Ivoire since September 2002. The vegetation of the region is primarily tropical rainforest. Two dry and two wet seasons are recognized in the study area [15]. The long dry season (LDS) extends from December to March and the second one (SDS) from July to September. The long wet season (LWS) occurs from April to June and the short one (SW) from October to November. The study area is divided into four zones: (1) the man-made Lake Buyo (drainage area: 920 km^2) originated from the building of a hydroelectric dam on the main course of the Sassandra River in 1981 [16], (2) the main channel and two major tributaries: (3) Lobo and (4) Davo rivers. The wide main river channel receives less shade from streamside forests than smaller tributaries which are shaded by overhanging canopy of riparian vegetation. The fluctuations in stream level and flow rate are determined by both intensity of precipitation and discharge from the Buyo dam.

Zooplankton and environmental parameters were collected from October 2004 to November 2005, at 13 stations of which 2 stations (Sa1-Sa2) are located on Buyo lake, 4 (stations Sa3–Sa6) on the main channel, 3 (Sa7-Sa9) on the Lobo tributary and 4 (Sa10–Sa13) on the Davo tributary. The stations were selected based on an easy accessibility by the road and a possibility for conducting a sampling program.

Sampling design

The physical and chemical parameters (water temperature, dissolved solids rate (DSR), turbidity, dissolved oxygen concentration, pH, conductivity) were measured in surface, with appropriated technical equipment: an oxymeter WTW DIGI with a built in thermometer, a conductimeter WTW-LF 340, A pH-meter WTW pH-330, and a Secchi disk.

The zooplankton sampling was carried out using a cylindro-conical net of 64 µm in mesh opening size by filtration. Three hundred liters of river subsurface water were collected and filtered through the plankton net of 64 µm mesh size. Samples were preserved in a mixture of river's water and borax neutralized formalin at a final concentration of 5%. Zooplankton organism was identified using the following works: [17-23]. The taxa were identified and counted under a dissecting microscope (magnification: 160, 250 and 400). The least abundant taxa were counted on the entire sample, while the most abundant taxa were counted on subsamples made with wide bore piston Eppendorf pipettes. One or several subsamples were examined until numbering a minimum of 100 individual per taxa. Zooplankton densities, expressed as taxa number per liter, were calculated by dividing the number of organisms estimated in each sample by the volume of water filtered (Three hundred liters).

Analytical procedure:

Zooplankton density, species richness and ecological diversity indices (Shannon: H' and Equitability: E) were used to determine structure and ecological dynamics of zooplankton community. The calculation of Shannon and Equitability indices was made through the formula:

(1) $H = -\sum_{i=1}^{i=S} p_i \times \log_2 p_i$ where S is the total number of species and p_i the proportion of individuals in the i species (i = 1, 2, …, S) [24].

(2) $E = \frac{H}{\log_2 S}$, In which H is the Shannon diversity index and S the species richness [25].

The relationships between the zooplankton species and environmental parameters 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

Qualitative analysis: Taxonomic composition and taxa distribution

During this study in Sassandra river, a total of Sixteen-seven zooplankton species were identified, including four groups: Rotifera (39 species), Cladocera (19 species), Copepoda (8 species), and Ostracoda (1 species) (**Table I**). Rotifera dominate qualitatively the zooplankton community in Sassandra river, with 39 species (58% of total diversity) belonging to 15 families and 20 genuses. Brachionidae was the most diversified family (6 genuses and 15 species), followed by Trichocercidae (4 species, a genus: Trichocerca) and Lecanidae (3 species, with *Lecane* as genus). In Rotifera community, *Brachionus* presented the highest diversity (6 species), followed by *Keratella* and *Trichocerca* (4 species). Cladocera taxa (19 species) belonging to 6 families and 13 genuses. Chydoridae presented the highest diversity (6 genuses and 9 species), followed by Macrothricidae (2 species: *Macrothrix triserialis* and *Macrothrix spinosa*). Copepoda community was represented by one family (Cyclopidae) and undetermined harpacticoid. Cyclopidae regroups 7 species belonging to 3 genuses: *Thermocyclops*, *Mesocyclops* and *Microcyclops*.

Sassandra river's zooplankton species richness and diversity indices varied according to the sampling sites. Zooplankton richness varied between 12 (Sa11) and 55 taxa (Sa1) with a total diversity of 67 taxa. Highest zooplankton richness was observed in Buyo Lake (61 species) while lowest diversities were obtained Lobo and Bolo rivers (25-28 species). Similar spatial pattern was observed for Shannon diversity indice, with on average 3.17 bit.ind^{-1} in Buyo lake and 2.52-2.59 bit.ind^{-1} in Lobo and Davo rivers. Equitability indice spatial variation was characterized by values in Bolo river (0.93) relatively highest than in other sampling sites (0.83-0.87). Zooplankton richness didn't showed significant seasonal variation ($p > 0.05$): 9-50 taxa during the rainy season versus 12 to 55 taxa during the dry season. Similar tendency was also observed for Shannon and Equitability indices.

Species distribution was characterized by 13 species common on all sampling zone (*Brachionus falcatus*, *Keratella lenzi*, *K. cochlearis*, *K. tropica*, *Lecane bulla*, *Trichocerca chattoni*, *T. similis*, *Bosmina tubicen*, *Monospilus dispar*, *Moina micrura*, *Diaphanosoma excisum*, *Thermocyclops decipiens*, *T. consimilis*) while 30 species were specific to Buyo lake (**see table I**). *Horaella brehmi* and *Mytilina mucronata* were only observed in Davo and Lobo rivers.

Quantitative analysis

Community structure and abundance spatio-temporal variation

This study reveals that Sassandra river's zooplankton abundance varied significantly ($p < 0.01$) according to stations, with highest abundances always obtained in Buyo Lake (Mean: 20.59 to 44.83 ind.L^{-1}) (**Fig. 2**).

Excepted in Buyo lake, Sassandra zooplankton abundance didn't showed significant seasonal variation. In Buyo, zooplankton abundance varied from 20.59-22.56 ind.L^{-1} during the rainy season to 43.70-44.83 ind.L^{-1} during the dry season while in the other sampling zones, abundance varied from 2.35-7.32 ind.L^{-1} during the rainy season to 4.39-12.91 ind.L^{-1} during the dry season.

On average, Sassandra river's zooplankton was numerically dominated by Copepoda (40.37 % of zooplankton total abundance), followed by Rotifera (Mean: 29.51%) and Cladocerans (Mean: 25.67%). Ostracoda, with *Candonocypris multiformis* was less represented in Sassandra river's zooplankton community (Mean: 7.23%). The most abundant copepod species of the Sassandra watershed were *Thermocyclops consimilis* (22.02 %), *T. decipiens* (18.04%), and *Mesocyclops varicans* (18.01%). In the Buyo lake, the mains copepod species were *Mesocyclops varicans* (30.31%) and *Thermodiaptomus yabensis* (20.33%) while copepod group was dominated by *Thermocyclops consimilis* in the Sassandra main stream and in the Lobo river (respectively, 36.44% and 49?58%). In the Sassandra tributary Lobo, the main copepod species was *Thermocyclops emini* (30.77%). Rotifer structure was marked by the absence of dominant specie in the Buyo lake. Ten species dominated rotifers, contributing to about 72.44% of total abundance.

In the Sassandra main stream, rotifers were dominated by *Keratella tropica* (29.80%), *K. lenzi* (15.13%), *Mytilina* sp. (9.52%) and *Trichocerca similis* (9.45%) while in tributaries Lobo and Davo rivers, rotifers were dominated by *K. tropica* (31.32% and 24.14% respectively) and *Trichocerca similis* (28.19% and 15.98% respectively). *Diaphanosmona excisum and Monospilus dispar* were the most abundant cladocerans species in the Sassandra main stream and in the tributaries Lobo and Davo rivers. They contribute to 31.10% to 41.94% and 26.68% to 33.45% respectively of total cladocerans abundance. In the Buyo lake, cladocerans were dominated by *Bosmina tubicen* (18.42%), *Diaphanosmona excisum* (17.62%), *Moina micrura* (17.40%) and *Ceriodaphnia cornuta* (16.82%).

In general, in the lower basin of the Sassandra, seven species dominate the zooplankton community and constitute on average 44% of the total zooplankton abundance: *Thermocyclops consimilis* (9.30%), *T. decipiens* (7.62%), *Mesocyclops varicans* (7.61%), *T. emimi* (6.73%), *Thermodiaptomus yabensis* (6.23%), and *Keratella tropica* (5.64%). So, in the Sassandra basin, zooplankton community was dominated by copepods species.

Environmental parameters influence on zooplankton distribution

Canonical Correspondence Analysis (CCA) showed that the first two axes explained 65.10 % of the observed variance in zooplankton community structure, with ≈ 52.10 % for the first axis (**Fig. 3)**. This analysis reveals two main zones in south basin of the Sassandra: lentic system (Buyo lake: stations Sa1 and Sa2) and lotic system regrouping Sassandra main stream (Sa3 to Sa6) and the two main tributaries of Sassandra river (Lobo and Davo rivers: Sa4 to Sa13). Lotic system was positively correlated with the axis I, and its stations were positively correlated with temperature, conductivity, solids dissolved rate (TDS), and transparency. Taxa associated to this lotic zone were the copepods *Thermocyclops decipiens*, *T. consiminis*, *Thermodiaptomus yabensis*, *Mesocyclops dussarti*, *M. varicans* and *Microcyclops linjanticus* ; the rotifers *Keratera* tropica, *Brachionus bidenta, Lecane signifera*, *Epiphanes clavilata*, *Filinia opoliensis*, *Asplanchna brightwelli*, *Monommata grandis, Hexarthra intermedia* ; and cladocerans *Moina micrura, Macrothrix triserialis, Diaphanosoma excisum, Scapholeberis kingi, Chydorus sphaericus* and *Daphnia barbarta*. The second group of stations in the lentic system was negatively correlated to the axis I and with flow velocity, dissolved oxygen rate, nitritres, nitrates and phosphates concentrations. Main taxa associated to this lotic system were the cladoceran *Monospilus dispar*, the ostracoda *Candonocypris multiformis, Rotifer Mytlina* sp. and indeterminated harpacticoids.

DISCUSSION

A total of Sixteen-seven taxa were collected during this study in Sassandra river, belonging to Rotifera (39 species), Cladocerans (19 species), Copepoda (eight species) and Ostracoda (one species). So, Sassandra river's zooplankton diversity was marked by Rotifera qualitative dominance (66% of total diversity, 39 species belonging to 15 families and 20 genuses). Beside Brachionidae was the most diversified family (15 species belonging to six genuses), while *Brachionus* as genus presented the highest diversity (six species: *Brachionus angularis*, *B. calyciflorus*, *B. caudatus*, *B. falcatus*, *B. quadridentatus*, *B. bidentata*). Dominance of the rotifera in Sassandra stream is also linked to genuses *Trichocerca* (four species: *Trichocerca chattoni*, *T. capucina*, *T. Cylindrica*, *T. similis*), *Keratella* (four species: *Keratella cochlearis*, *K. Lenzi*, *K. quadrata*, *K. tropica*), and *lecane* (Three species: *Lecane luna*, *L. bulla*, *L. signifera*). Conversely, if Brachionidae is the most diversified family in tropical and low altitude rivers, lakes, pounds, etc., in the Jesumira river (State of Acre, Brazil) [26] and in the Orogodo river (Nigeria) [27], Lecanidae was the most diversified family with *Lecane* as the genus presented the highest richness. This result marked by qualitative dominance of Rotifera, whith Brachionidae and *Brachionus* as respectively family and genus the most diversified was similar to those commonly reported in freshwater hydrosystem of Cote d'Ivoire: Bia and Agneby rivers [4]; Bagoe rivers [5]; Aby-Tendo-Ehy lagoons system [7]; Aghien lagoon [28]; Ehania, Boullo 1 & 2 and Bodoua rivers in the south-eastern of Côte d'Ivoire [7]. Qualitative dominance of rotifera phylum, Brachionidae and *Brachionus* in zooplankton community is also reported in several other tropical freshwater ecosystems as Tiga lake (Kano, Nigeria) [29], Ekpan river (Nigeria) [30] and Parnaíba River, in the northeastern of Brazil [31]. According to Neves *et al.* [32], this pattern is common in tropical freshwaters, whether in lakes, ponds, reservoirs, rivers, or streams. Nevertheless, these results are in contradiction with studies of Ezekiel et al. [33] and Ikhuoriah et al. [34] in Niger delta, respectively in Sombreiro and Ossiomo rivers, who reported that highest diversity was observed in cladocera and copepoda groups. Qualitative preeminence of Rotifera, Brachionidae and *Brachionus* in tropical freshwater zooplankton composition could be explained by many assumptions. One of the hypotheses could be that Sassandra river water become eutrophic with many anthropogenic activities on its area catchment (palm tree farms and oils industry), discharge of the waste water and waste of palm oils into the stream [11]. Besides, it is broadly admitted that Brachionidae and *Brachionus* taxa are majority and regularly met in eutrophics tropical waters due to their great tolerance to eutrophication, and are associated hyper-eutrophics waters and considered like good bio-indicators of eutrophication [35-38]. Rotifera qualitative dominance in tropical freshwater aquatic ecosystems may also be linked to the fact that rotifera species are a short life cycle, with parthenogenetic reproductive pattern and have a great tolerance to various environmental conditions [39-40], are opportunist organisms and ingest bacteria and organic detritus dominating in eutrophics areas aquatic ecosystem [41]. One of other hypotheses which can explain rotifer qualitative preeminence in tropical freshwater zooplankton composition is that zooplankton consumer as fish predation which exert a selection on the taxa and/or the individuals of big size (as copepods and cladocerans), leading finally in the long term a community dominated by the zooplankton of small size such as the rotifera [39, 42]. In tropical zone, vertebrate predation is essentially the fact of fish larva and juveniles, and due to their continuous recruitment in tropical freshwater it impact may be important [43], and can veritably impacted zooplankton community composition. For Orimono and Oganah [27], the ability of rotifers to undergo vertical migration, which minimizes competition through niche exploitation and food utilization, could be probably the reason for their qualitative dominance in tropical freshwater environment.

In Sassandra streams, crustacean zooplankton community was made up of copepods, cladocerans, and ostracoda. Crustacean zooplankton fauna are typically to traditional one in tropical zone, with cladocerans species as *Ceriodaphnia affinis*, *C. cornuta*, *Moina micrura*, *Diaphanosoma excisum*, *Bosmina tubecen*, and copepods species as *Mesocyclops dussarti*, *M. varicans*, *Microcyclops linjanticus*, *Thermocyclops consimilis*, *T. decipiens*, *T. emini*.

During this study, our results show that zooplankton highest richness (61 species), abundance (Mean: 45 ind.l^{-1}) and diversity indices (Shannon: 3.02 to 3.33 bit.ind^{-1}) were observed in Buyo lake, versus lowest diversity (25 to 31 species), abundance (Mean: 5 to 12 ind.l^{-1}) and diversity indices (Shannon: < 3 bit.ind^{-1}) in the fluvial system (Sassandra stream, Davo and Lobo rivers). This spatial pattern of zooplankton diversity and abundance, with highest values in lacustrine zone and lowest values in the fluvial system, was also observed by Ouattara *et al.* [4] (56 species, 116675 ind.m^3 in the Ayamé lake versus 16-22 species, 9180 to 3580 ind.m^3 in the Bia river). Beside, Ouattara *et al.* [44] reported the same tendency with phytoplankton community, with highest density in Ayamé lake and lowest density in the up and downstream of the Bio river. Similar results were also obtained with fish by Gourène *et al.* [45] in the Bia watershed, with 35 species in the Ayamé lake versus 28 species in the Bia river. In contrast, Nogueira *et al.* [46] observed a significant difference of phytoplankton richness in the fluvial stretches of Paranapanema River (tributaries and main river) when compared with the reservoirs, with highest values in the fluvial system. Besides, no significant difference in abundance either was observed between tributaries and reservoirs. According to Pourriot *et al.* [40], difference of abundance and diversity between fluvial system and lacustrine zone may be linked to the short residence time of water on fluvial (lotic) environments where only organisms with rapid growth and high renewal rate can increase their populations. For Ouattara *et al.* [44], in the fluvio-lacustrine system, highest abundance and diversity phytoplankton community obtained in lacustrine portion is essentially due to an addition and little disappearance of species in this portion on the one hand, and by the fact that in the lacustrine portion, phytoplankton community finds the favorable conditions to its development, with the stagnant state of waters and the increase of the transparency on the other hand. For Baxter and Glaude [47], the increase of diversity and abundance of zooplankton in lake can be attributed by the fact that, when a river is dammed up to form a basin, the reduction of the debit favors the development of a population of phytoplankton which is widened by the contribution increased of nourishing elements carried away by the passage of water on soil and vegetation flooded. It is followed (or accompanied) of an increase of the population of zooplankton, and so forth along the food chain. According to Aoyagui and Bonecker [48], lowest diversity and abundance of zooplankton registered in fluvial zone may be linked to a decrease in the abundance of phytoplankton caused by suspended sediments, diminishing the light penetration in the environment, affect indirectly zooplankton population, limiting growth rates of rotifers population, the main zooplankton community in tropical freshwater. It may also due to by current velocity in the rivers which is reported as the most important factor on population development of rotifers in lotic environment [48].

Quantitative analysis of zooplankton community structure in the Sassandra river show numerical dominance of Copepoda (40.37 % of zooplankton total abundance), followed by Rotifera (Mean: 29.51%) and Cladocerans (mean: 25.67%). The main zooplankton species were *Thermocyclops consimilis* (9.30%), *T. decipiens* (7.62%), *Mesocyclops varicans* (7.61%), *T. emimi* (6.73%), *Thermodiaptomus yabensis* (6.23%), and *Keratella tropica* (5.64%). Numerical dominance of copepod group in tropical freshwater was also reported by others word as in Bia river (Côte d'Ivoire) [4], and in the Comoe river (sector Comoé national park, Côte d'Ivoire) [6], in the Sombreiro River (Niger Delta, Nigeria) [33], in the Ossiomo river (Nigeria) [34]. In contrast, zooplankton community structure was marked by numerical dominance of rotifer group as in the Loumbila lake (Burkina Fasso) [49], in Bagoe river (Niger Basin, Côte d'Ivoire) [5], in Aghien lagoon (freshwater ecosystem, Côte d'Ivoire) [28], in four coastal rivers in the south-East of Côte d'Ivoire (Ehania, Boulo 1 & 2, and Bodoua) [7]. Numerical dominance of copepod the Sassandra river is linked to proliferation of *Thermocyclops consimilis*

(9.30% of total abundance), *T. decipiens* (7.62%), *Mesocyclops varicans* (7.61%), *T. emimi* (6.73%), *Thermodiaptomus yabensis* (6.23%).

In the present study, Canonical Correspondence Analysis (CCA) shows that highest richness, and abundance of zooplankton in the Buyo lake may be attributed to the reduction of water turbulence, to the increase of transparency and temperature in this zone. Positive correlation between transparency and zooplankton community is documented by Neves et al., [32]. Daphniidae and Calanoida copepods are considered as organisms of elevated transparency and mainly associated to limnetics environment while Chydoridae and Harpacticoida are considered as littoral and benthic organisms of high turbidity and organic matter [50]. Zooplankton organisms responded to other physic-chemical variables.

CONCLUSION

This study drawing up first informations on the zooplankton community of the Sassandra basin. Besides, it provides informations on the spatial variation of the zooplankton composition and abundance in relation with Sassandra Bassin environmental factors. Sixteen-seven taxa of zooplankton were collected in the Sassandra river basin. Sassandra river's zooplankton community is marked by numerical dominance of Copepoda (40.37 %), followed by Rotifera (Mean: 29.51%) and Cladocerans (Mean: 25.67%). In the lower basin of the Sassandra river's, seven species dominate quantitatively the zooplankton community (44% of the total zooplankton abundance): *Thermocyclops consimilis* (9.30%), *T. decipiens* (7.62%), *Mesocyclops varicans* (7.61%), *T. emimi* (6.73%), *Thermodiaptomus yabensis* (6.23%), and *Keratella tropica* (5.64%). This study revealed that, in Sassandra basin, zooplankton community was mainly influenced by water temperature, conductivity, solids dissolved rate (TDS) and transparency in lotic system and by flow velocity, dissolved oxygen rate, nitritres, nitrates and phosphates concentrations in the lentic system.

ACKNOWLEDGEMENTS

Authors wish to express their sincere thanks to the staff of Hydrobiology Laboratory of the Félix Houphouët-Boigny University (Côte d'Ivoire) for fieldwork assistance, and to the Belgian Technical Cooperation for providing financial support. Also thanks to anonymous reviewers for their critical reading of the manuscript.

REFERENCES

1. Deksne, R., Škute, A., and Meinerte, A. Seasonal changes in zooplankton community of the Daugava River. Acta Biologica Universitatis Daugavpiliensis, 2011, 11(1): 61-75.
2. Rissik, D., D., van Senden, M., Doherty, T., Ingleton, P., Ajani, L., Bowling, M., Gibbs, M., Gladstone, T., Kobayashi, I., Suthers, and W., Froneman. "'Plankton-related environmental and water-quality issues," in Plankton, a guide to their ecology and monitoring for water quality, 1st Edition, I.M. Suthers, D. Rissik, Eds. Melbourne: CSIRO Publishing, 2009. pp. 39-72.
3. De Ridder, M., and Pourriot, R. Peuplement en Rotifère du bassin du Bandama (Côte d'Ivoire), Revue d'Hydrobiologie Tropical, 1984, 17 : 287-294.
4. Ouattara, N.I., Ouattara, A., Koné, T., N'Douba, V., and Gourene, G. Distribution du zooplancton le long de deux petits bassins côtiers ouest africains (Bia et Agnébi; Côte d'Ivoire). Agronomie Africaine, 2007, 19(2): 197-210.
5. N'da, S.A, Etilé, R.N., N'zi, K.G., Berté, S., and N'douba, V., Composition and Distribution of Zooplankton Relationship to Environmental Factor in a Tropical River: (Bagoe,

Côte d'Ivoire). International Research Journal of Biological Sciences, 2015, Vol. 4(11): 1-11.
6. Yao, S.S., R.N., Etilé, and G.K., Blahoua, Diversity and structure of zooplankton community of Comoé River in relation with environmental factors (Comoé National Park, Côte d'Ivoire). International Journal of Engineering Research and Management (IJERM), 2015, (2): 68-74.
7. Monney, I.A., I.N., Ouattara, R.N., Etilé, M.N., Aka, M., Bamba, and T., Koné, Distribution du zooplancton en relation avec les caractéristiques environnementales de quatre rivières côtières du Sud-est de la Côte d'Ivoire (Afrique de l'ouest). Journal of Applied Biosciences, 2016, 98: 9344-9353.
8. Lemoalle, J., La diversité des milieux aquatiques. In: Lévêque C, D Paugy, Ed. Les poissons des eaux continentales africaines: diversité, écologie, utilisation par l'homme. Editions de l'IRD, Paris, 1999, 11-30.
9. Camus, H., Hydrologie du Bassin du Sassandra (Note Préliminaire), Office de recherche scientifique et technique outremer (ORSTOM), Centre d'Adiopodoumé-Côte d'Ivoire, N°5/68, 1969, 60p.
10. Iltis, A., and C., Lévêque, Caractéristiques physico-chimiques des rivières de Côte d'Ivoire. Revue d'Hydrohiologie Tropical, 1982, 15(2): 115-130.
11. Kouamé, K.A., S.S., Yao, G., Gooré Bi, E.P., Kouamelan, V., N'Douba, and N.J., Kouassi, Influential environmental gradients and patterns of fish assemblages in a West African basin. Hydrobiologia, 2008, 603: 159-169.
12. Yao S.S., K.A., Kouamé, N.I., Ouattara, G. Gooré Bi, and E.P., Kouamélan, Preliminary data on the feeding habits of the endemic species Synodontis koensis Pellegrin, 1933 (Siluriformes, Mochokidae) in a West African River (Sassandra River Basin, Côte d'Ivoire). Knowledge and Management of Aquatic Ecosystems, 2010, 396(04): 1-12.
13. N'guessan Y.A., E.M., Amani, B.K.F., Koffi, L., Adopo, B.E., Diangone, S., Monde, and A., Kouadio, Caractérisation morphologique et sédimentologique de l'embouchure du fleuve Sassandra (Côte d'Ivoire). Afrique Science, 2014, 10(2): 277-288.
14. N'guessan, Y.A., T., Wango, K.E., Konan, A., Adingra, E.M., Amani, S., Monde, K., Affian, and K., AKA, Hydrologie et morphologie de l'estuaire du fleuve Sassandra, Basse Côte d'Ivoire. Afrique Science, 2015, 11(2): 161-172.
15. Eldin, M., Le climat. *In*: Avenard JM, Eldin M, Girard G, Sircoulon J, Touchebeuf P, Guillaumet JL, Adjanohoun E, Perraud A. Ed. Le milieu naturel en Côte d'Ivoire, ORSTOM, Paris, 1971, 77-108.
16. Traoré, K.L., Caractéristiques physico-chimiques du Lac de Buyo. Rapport de Recherche, Institut d'Ecologie Tropicale (IET), Côte d'Ivoire, 1989.
17. Durand, J.R., and Lévèque, C., Flora et faune aquatiques de l´Afrique Sahelo-Soudanienne Tomme 1, Paris, 1980, 189pp.
18. Jeje, C.Y., A revision of the Nigerian species of the genera *Mesocyclops* Sars, 1914 and *Thermocyclops* Kiefer, 1927 (Copepoda: Cyclopoida). Hydrobiologia, 1988, 164: 171-184.
19. Boxshal, G.A., and Braide, E.I., The freshwater cyclopoids copepods of Nogeria, with an illustrated key to all species. Bulletin of Museum of Natural History (Zool.), 1991, 57(2): 185-212.
20. Koste, W., and R.J., Shiel, Rotifera from Australian Inland Waters. II. Epiphanidae and Brachionidae (Rotifera: Monogononta). Znvertebr. Taxon, 1987, 7: 949-1021.
21. Shiel, R.J., A quide to identification of rotifers, cladocerans and copepods from Australian inland waters. Murray-Darling Freshwater Research Center, Co-operative

Research Centre for freshwater Ecology, Identification guide N°3, Ellis Street, 1995, 144p., ISSN 1321-280X, ISBN 0 646 224107.
22. De Mannuel, J., The rotifers of Spanish reservoirs: ecological, systematical and zoogeographical remarks. Liinnetica, 2000, 19: 91-167.
23. Khan, R.A., Faunal Diversity of Zooplankton in freshwater wetlands of Southeastern West Bengal. Records of the zoological survey of India, , 2003, Occasional paper N° 204: 1-107. (Published by the Director, Zoological Survey of India, Kolkata, ISBN 81-85874-84-0).
24. Shannon, E.C, and Weaver W., The mathematical theory of communication. University of Illinois press, 1963, 117 p.
25. Hill M.O., Diversity and evenness: A unifying notation and its consequences. Ecology, 1973, 54: 427-432.
26. Da Silva, E.S., E.C., Keppeler, and J.F, Silvério, Composition of zooplankton of the small river Jesumira, located in a cleared in area at the Park National Serra do Divisor, State of Acre, Brazil. Ciências Biológicas e da Saúde, Londrina, 2010, 33(2): 201-210.
27. Arimono, F.O., and A.O., Oganah, Zooplankton Community Responses in a Perturbed Tropical Stream in the Niger Delta, Nigeria. The Open Environmental & Biological Monitoring Journal, 2010, 3: 1-11.
28. Aka, N.M., Etilé, R.N., Konan, F.K., Bony Y.K., Zooplankton composition and distribution in relationship to environmental parameters in a tropical coastal lagoon (Ebrié lagoon: Aghien, Côte d'Ivoire). International Research Journal of Biological Sciences, 2016, 5(12): 1-12.
29. Akindele, E.O., Relationships between the physico-chemical water parameters and zooplankton fauna of Tiga lake, Kano, Nigeria. Bayero Journal of Pure and Applied Sciences, 2013, 6(1): 95-100.
30. Iloba, K.I., and Ruejoma, M.G.O., Physico-chemical characteristics and zooplankton of Ekpan river, delta state, Nigeria. International Journal of Applied Biological Research (IJABR), 2014, Vol.6(1): 8-30.
31. Lucena, L.C.A., Melo, T.X., Medeiros, E.S.F., Zooplankton community of Parnaíba River, Northeastern Brazil. Acta Limnologica Brasiliensia, 2015, 27(1): 118-129.
32. Neves, I.F., D. Rocha, K.F. Roche, and A.A. Pinto. "Zooplankton community structure of two marginal lake of river (Cuiaba) (Mato, Grosso, Brazil) with analysis of rotifer and Cladocera diversity." Brazilian Journal of Biology, 2003, 63(2): 329-343. http://dx.doi.org/10.1590/S1519-69842003000200018.
33. Ezekiel, E.N., Ogamba E.N., and Abowei J.F.N., The Zooplankton Species Composition and Abundance in Sombreiro River, Niger Delta, Nigeria. Asian Journal of Agricultural Sciences. 2011, 3(3): 200-204.
34. Ikhuoriah S.O., Oronsaye C.G., and Adebanjo I.A., Zooplankton communities of the river Ossiomo, Ologbo, Niger delta, Nigeria. Animal Research International, 2015, 12(3): 2249-2259.
35. Arcifa, M.S., E.A.T., Gomes, A.J., Meschiatti, Composition and fluctuations of the zooplankton of a tropical Brazilian reservoir. Archiv für Hydrobiologie, 1992, 123: 479-495.
36. Branco, C.W.C., Rocha, M.I.A., Pinto, G.F.S, Gômara, G.A., De Filippo, R., Limnological features of Funil Reservoir (R.J., Brazil) and indicator properties of rotifers and cladocerans of the zooplankton community. Lakes & Reservoirs: Research and Management, 2002, 7: 87-92.

37. Lucinda, L.L.H., Melao M.G.G., Matsumura-tundisi, T., Rotifers in freshwater habitats in the upper Tietê river basin, Sao Paulo State, Brazil. Acta Limnologica Braziliana, 2004, 16(3): 203-224.
38. Leitao, A.C., Freire R.H.F., Rocho O., Santaella, S.T., Zooplankton community composition and abundance of two Brazilian semiarid reservoirs. Acta Limnologica Braziliana, 2006, 18(4): 451-468.
39. Brooks, J.L., and Dodson S.I., Predation, body size and composition of plankton. Science, 1965, 150: 28-35.
40. Pourriot, R., C., Rougier, and A. Miquelis, Origin and development of river zooplankton: example of the Marne. Hydrobiology. 1997, 345: 143-148.
41. Badsi, H., Ali, O.H., Loudiki, M., El Hafa, M., and Aamari, A., 2010. Ecological factors affecting the distribution of zooplankton community in Massa Lagoon (Southern Morocco). African Journal of Environmental Science and Technology. 4(11): 751-762.
42. Post, J.R., and Mcqueen D.J., The impact of planktivorous fish on the structure of a plankton communily. Freshwater Biology. 1987, 17: 79-89.
43. Lazzaro, X., A review of planktivorous fishes: their evolution, feeding behaviours, selectivities, and impacts. Hydrobiologia, 1987, 146: 283-293.
44. Ouattara, A., N. Podoor, and G. Gourene, Études préliminaires de la distribution spatio-temporelle du phytoplancton dans un système fluvio-lacustre africain (Bassin Bia ; Côte d'lvoire). Hydroécologie Appliquée, 2001, 13(1): 113-132.
45. Gourène, G., G.G., Teugelsb, B., Ugueny, and D.F.E., Thys Van Den Audenaerde, Evaluation de la diversité ichtyologique d'un bassin ouest-africain après la construction d'un barrage. Cybium, 1999, 23(2): 47-160.
46. Nogueira, M.G., Ferrareze, M., Moreira, M.L., Gouvêa R.M., Phytoplankton assemblages in a reservoir cascade of a large tropical – subtropical river (SE, Brazil). Brazilian Journal of Biology, 2010, 70(3): 781-793.
47. Boxter, R.M., and P., Glaude, Les effets des barrages et des retenus d'eau sur l'environnement au Canada : expérience et perspectives d'avenir. Canadian Bulletin of Fisheries and Aquatic Sciences, 1980, 205F: 36 p.
49. Aoyagui, A.S.M., and C.C. Bonecker, The art status of rotifer studies in natural environments of South America: floodplains. Acta Scientiarum. Biological Sciences, 2004, 26: 386-406.
50. Ouéda, A., Guenda, W., Kabré ,A.T., Zongo, F., and Kabré, G.B., Diversity, abundance and seasonal dynamic of zooplankton community in a south-Saharan reservoir (Burkina Fasso). Journal of Biological Sciences, 2007, 7(1): 1-9.
51. Perbiche-Neves, G., J.L., Portinho, R.A.R., Ferreira, and M.G., Nogueira, Increases in microcrustaceans (Cladocera and Copepoda) associated with phytoplankton peaks in tropical reservoirs. Tropical Ecology, 2016, 57(3): 523-532.

Table I: List of zooplankton species and distribution of taxa collected in the Sassandra rivers

Groupes	Families	Taxons	Codes	Buyo Lake	Main channel	Lobo	Davo
Rotifera	Brachionidae	*Anureopsis fisa* (Gosse 1851)	Afis	+	+		+
		Anureopsis navicula Green, 1960	Anav	+			
		Ascomorpha ecaudis Perty, 1850	Aeca	+			
		Brachionus angularis Gosse, 1851	Bang	+		+	+
		Brachionus bidentata Anderson, 1889	Bbid	+			
		Brachionus calyciflorus Pallas, 1766	Bcal	+	+	+	
		Brachionus caudatus Barrois and Daday, 1894	Bcau	+			
		Brachionus falcatus Zacharias, 1898	Bfal	+	+	+	+
		Brachionus quadridentatus Hermann, 1783	Bqua	+			
		Keratella lenzi Hauer, 1953	Klen	+	+	+	+
		Keratella cochlearis (Gosse, 1851)	Kcoc	+	+	+	+
		Keratella quadrata (Müller, 1786)	Kqua	+			
		Keratella tropica (Apstein 1907)	Ktro	+	+	+	+
		Plationus patulus (O.F. Muller, 1786)	Ppat	+			
		Platyias qudricornis (Ehrenberg, 1832)	Pqua	+			
	Asplanchnidae	*Asplanchna brightwelli* Goss, 1853	Abri	+			
		Asplanchna girodi de Guerne, 1888	Agir	+			
	Chonochilidae	*Conochilus dossuarius* Hudson, 1885	Cdos	+			
	Dicranophoridae	*Dicranophorus claviger* (Hauer, 1965)	Dcla	+			
	Epiphanidae	*Epiphanes clavulata* (Ehrenberg, 1813)	Ecla	+	+		
	Filiniidae	*Filinia longiseta* (Zacharias, 1898)	Flon	+	+	+	
		Filinia opoliensis (Zacharias, 1898)	Fopo	+			
	Hexarthridae	*Hexarthra intermedia* (Wiszniewski, 1929)	Hint	+			
		Hexarthra mira (Hudson, 1871)	Hmir	+			
	Trochoshaeridae	*Horaella brehmi* Donner, 1949	Hbre			+	+
	Lecanidae	*Lecane bulla* (Gosse, 1851)	Lbul	+	+	+	+
		Lecane lunaris (Ehrenberg, 1813)	Llun	+	+		+
		Lecane signifera (Jennings, 1896)	Lsig	+			
	Colurellidae	*Lepadella patella* (Müller, 1786)	Lpat	+			
	Notommatidae	*Monommata grandis* Tessin, 1890	Mgra	+			
		Scarridium longicaudum O.F.Muller	Slong	+			+
	Mytilinidae	*Mytilina mucronata* (O.F.Muller, 1773)	Mmuc			+	+
		Mytlina sp.	Mytsp		+	+	
	Synchaetidae	*Polyarthra vulgaris* Carlin, 1943	Pvul	+	+		+
	Proalidae	*Proales decipiens* (Ehrenberg 1830)	Pdec	+			
	Trichocercidae	*Trichocerca chattoni* (de Beauchamp, 1907)	Tcha	+	+	+	+
		Trichocerca capucina (Wierzejski & Zacharias, 1893)	Tcap	+			
		Trichocerca cylindrica Imhof, 1891	Tcyl	+			
		Trichocerca similis (Wierzejski, 1893)	Tsim	+	+	+	+
Cladoceran	Bosminidae	*Bosmina tubicen* Brehm, 1953	Btub	+	+	+	+
	Chydoridae	*Alona monacantha* Sars, 1901	Amon	+			

		Alona pulchella King, 1853	Apul	+			
		Acroperus elongatus (Sars, 1862)	Aelo	+			
		Chydorus eurynotus Sars, 1901	Ceur	+	+	+	
		Chydorus barroisi (Richard, 1894)	Cbar	+	+		+
		Chydorus sphaericus (O.F. Müller, 1785)	Csph	+			
		Kurtzia longirostris(Daday, 1898)	Klon		+	+	
		Monospilus dispar (Sars 1861)	Mdis	+	+	+	+
	Daphnidae	*Ceriodaphnia affinis* Lilljeborg, 1901	Caff	+		+	+
		Ceriodaphnia cornuta Sars, 1885	Ccor	+	+	+	+
		Daphnia barbarta (Weltner, 1897)	Dbar	+			
		Daphnia longispina O.F.M., 1785	Dlon	+			
		Scapholeberis kingi Sars, 1903	Skin	+			
	Moinidae	*Moina micrura* Kurz, 1820	Mmic	+	+	+	+
	Sididae	*Diaphanosoma excisum* Sars, 1886	Dexc	+	+	+	+
	Ilyocriptidae	*Ilyocryptus spinifer* Herrick, 1882	Ispi	+	+		
	Macrothricidae	*Macrothrix triserialis* Brady, 1886	Mtri	+	+	+	
		Macrothrix spinosa King, 1853	Mspi	+			
Copepoda	Undetermined	Harpacticoides	Harp		+	+	+
	Diaptomidae	*Thermodiaptomus yabensis* (Wright & Tressier, 1928)	Tyab	+	+		
	Cyclopidae	*Mesocyclops dussarti* Van de Velde, 1984	Mdus	+	+	+	
		Mesocyclops varicans (Sars, 1863)	Mvar	+			
		Microcyclops linjanticus (Kiefer, 1928)	Mlin	+	+		
		Thermocyclops consimilis (Kiefer, 1934)	Tcon	+	+	+	+
		Thermocyclops decipiens (Kiefer, 1929)	Tdec	+	+	+	+
		Thermocyclops emini (Mrazek, 1895)	Temi	+		+	
Ostracoda	Cyprididae	*Candonocypris multiformis* Kiss, 1960.	Cmul		+	+	+
Total 4	**24**	**67**	**-**	**61**	**31**	**28**	**25**

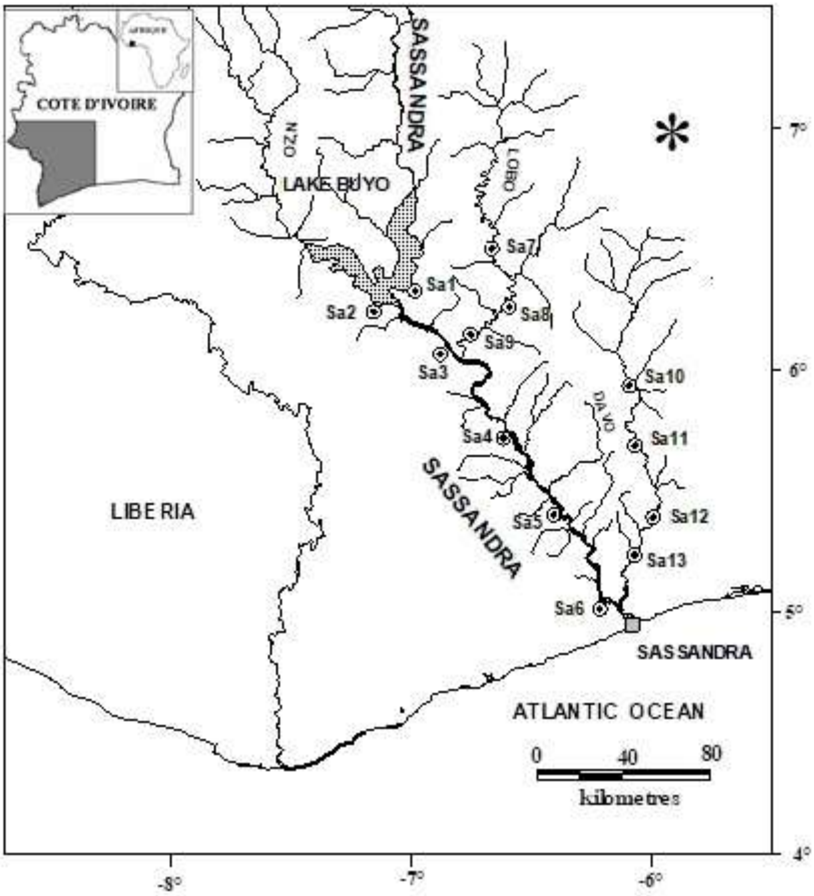

Fig. 1: Map of the Lower Sassandra River Basin with indication of the sampling sites (Sa1-Sa13)

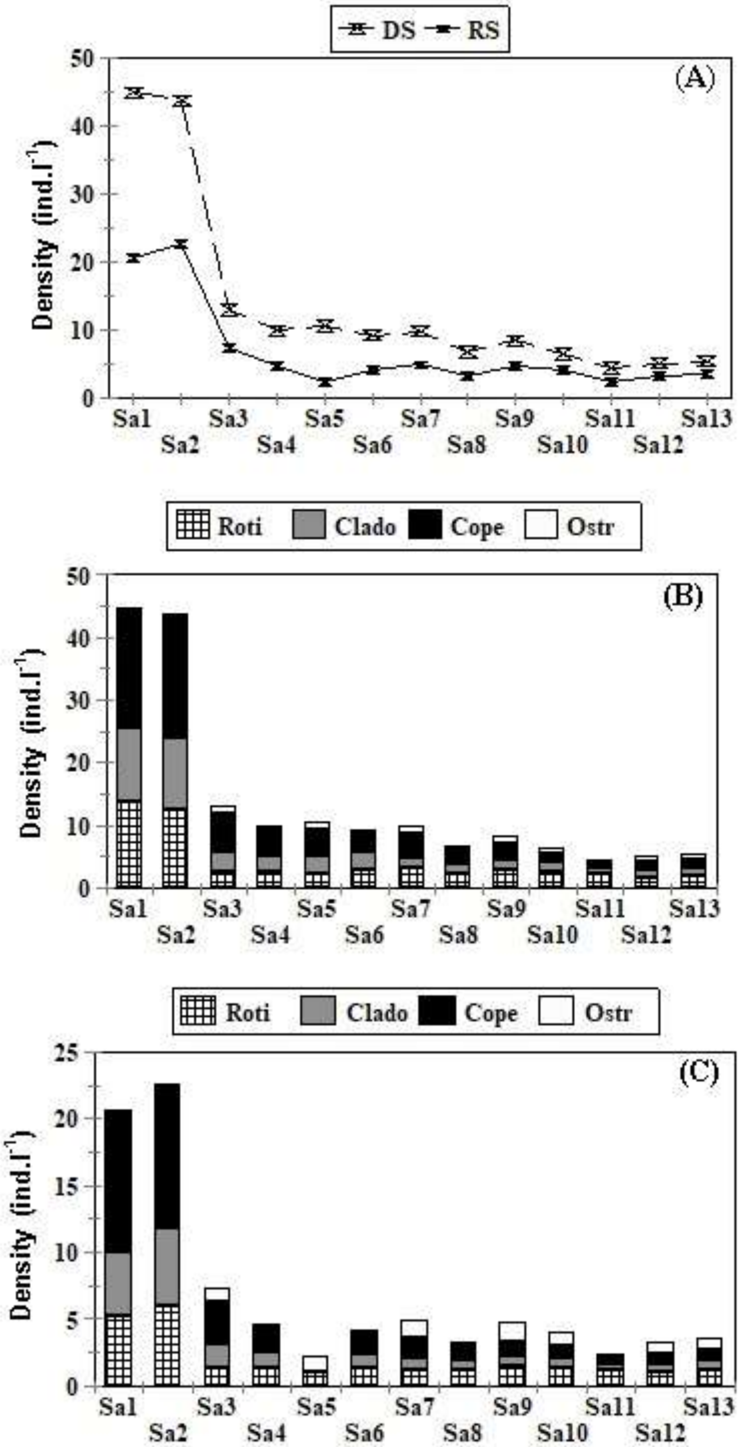

Figure 2: Spatial variations of the total zooplankton abundance (A) and of the relative abundance of the main zooplankton groups collected during the dry (B) and the rainy (C) seasons in the Sanssandra rivers (Roti: Rotifera, Clado: Cladoceran, Cope: Copepoda, Ostr: Ostracoda).

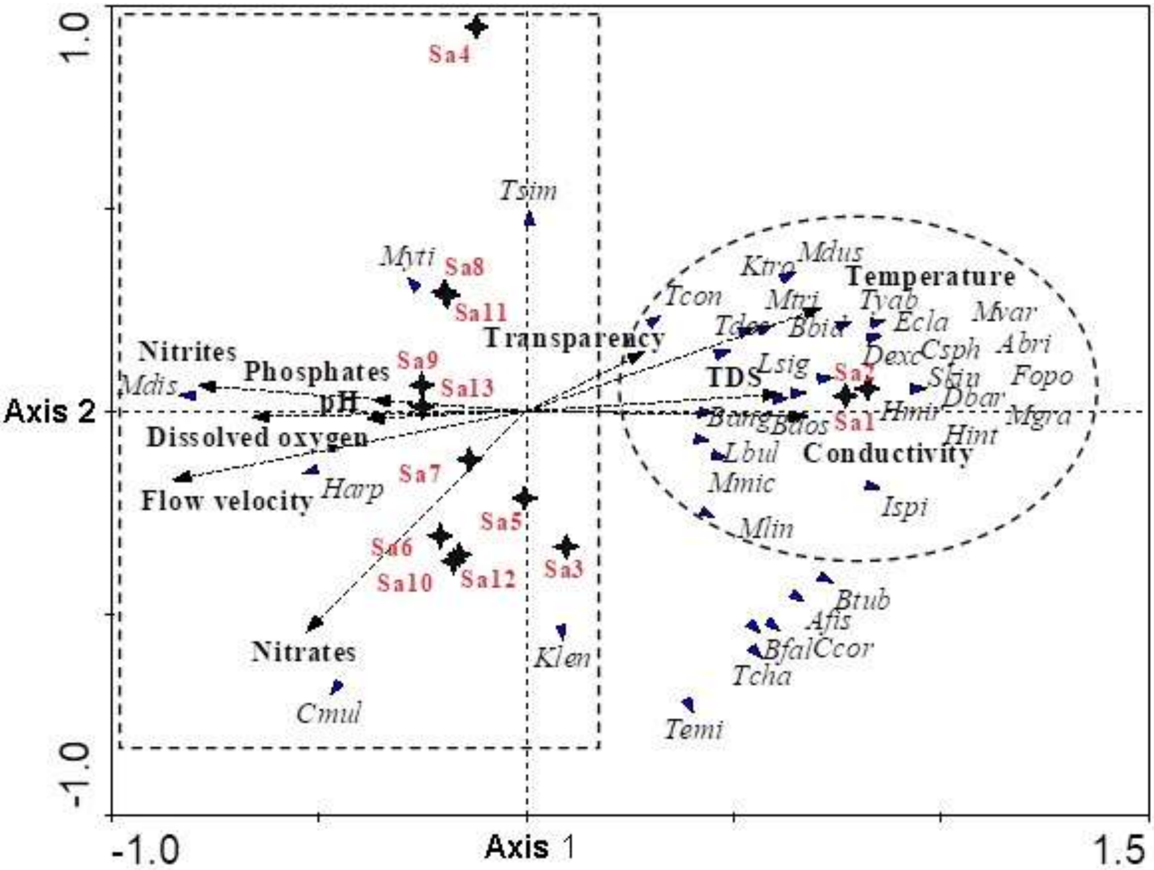

Fig. 3 : CCA of data from environmental factors and zooplankton species collected in the Sassandra river (Afis: *Amuaeospis fissa*, Mdus: Bang: *Brachionus angularis*, Bbid: *Brachionus bidentacus*, Cdos: *Chonochilus dossuarius*, Lbul: *Lecane bulla*, Fopo: *Filinia opoliensis*, Tsim: *Trichocerca* similis, Klen: *Keratella lenzi*, Ktrop: *Keratella tropica*, Bfal: *Brachionus falcatus*, Lsig : *Lecane signifera*, Hint: *Hexarthra intermedia*, Hmir: *Hexarthra mira*, Mgra: *Monommata grandis*, Mdis: *Monospilus dispar*, Mytisp: *Mytilina sp.*, Btub: *Bosmina tubicens*, *Ceriodaphnia curnuta*, Csph: *Chydorus sphaericus*, Dbar: *Daphnia bartbata*, Dexc: *Diaphanosoma excisum*, Ispi: *Ilyocriptus spinifer*, Mtri: *Macrothrix triserialis*, Skin: *Scapholaberis kingi*, *Mesocyclops dussarti*, Ther: *Thermocyclops decipiens*, Harp: Harpacticoids, Mvar: *Mesocyclops varicans*, Mlin: *Microcyclops linjanticus*, Tcon: *Thermocyclops consimilis*, Temi: *Thermocyclops emini*, Tyab: *Thermodiaptomus yabensis*, Cmul: *Condonocypris multiformis*).