Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 13, No. 3, p. 1-16, 2018
http://www.innspub.net

INNSPUB
RESEARCH PAPER

OPEN ACCESS

# Zooplankton diversity and its relationships with environmental variables in a West African tropical coastal lagoon (Ebrié lagoon, Côte d'Ivoire, West Africa)

**Yao Saki Appiah***, **Raphaël N'doua Etilé, Kouakou Augustin Kouamé, Essetchi Paul Kouamélan**

*Hydrobiology Laboratory, UFR Biosciences, Félix Houphouët-Boigny University, Abidjan-Cocody, 22 BP 582 Abidjan 22, Côte d'Ivoire, West Africa*

Article published on September 13, 2018

**Key words:** Zooplankton, Community distribution, Environmental parameters, Ebrié lagoon, Côte d'Ivoire.

**Abstract**

Interesting dynamics in the community structure of zooplankton after mortalities of the organism have been recently reported from Côte d'Ivoire. This study was carried out to examine the distribution and assemblage structure of zooplankton in relation to environmental parameters of Ebrié lagoon. Zooplankton samples were collected monthly from August 2015 to July 2016 in five sampling sites with a cylindro-conical net of 64 µm in mesh opening size in sectors IV and V near Dabou and Jacqueville department. Sampling observation showed of 59 taxa including 31 taxa of Rotifer (52.5 %), 11 Copepods (18.6 %), 3 taxa Cladocerans (5.08 %), 13 taxa of other zooplankton 22.03 %) and 1 taxa of Rhizopod (2 %). Copepod was the most abundant group (58.7 % of the total zooplankton abundance), followed by Rotifer (36.8 % of the total abundance) and other zooplankton (4.5 % of the total abundance). The main zooplankton specie was *Acartia clausi* (30.1 % of the total abundance). The seasonal variations of temperature, salinity, conductivity, TDS, pH, dissolved oxygen and phosphates influenced the abundance of species during the dry and rainy seasons. Zooplankton assemblages and composition were primarily due to change in water quality dependent on hydroclimatic changes and probably to anthropogenic actions. This suggests the need for real investigation of the Zooplankton biological capacity when formulating conservation and protection strategies for the sectors IV and V of Ebrié lagoon.

***Corresponding Author:** Yao Saki Appiah ✉ emmanuelsaki@gmail.com

## Introduction

Coastal lagoons are highly productive environments and, due to the high availability of natural resources, preferential areas for human exploitation (Castel *et al.,* 1996).They represent a relevant site for several economic activities such as fisheries, aquaculture and sand extraction (Kouassi *et al.,* 1995, Anoh, 2010). Unfortunately, throughout the World, and in Africa particularly, aquatic ecosystems are continuously altered by human activities such as domestic, industrial, and agricultural waste dumping; crab and shrimp catching and farming (Kouamélan *et al.,* 2003).

In aquatic ecosystems, zooplankton plays a pivotal role and global biogeochemical cycles (Keister, 2012). They contribute to transferring energy and organic matter from the primary producers to the higher trophic level taxa of the aquatic system, including various fish species of commercial value (Naz *et al.,* 2015).

They make excellent indicators of environmental conditions and aquatic health within ponds (Etilé *et al.,* 2009, Abdul *et al.,* 2016). Characterizing the temporal and the spatial variations of zooplankton assemblage becomes indispensable for knowing the structure of the communities on the one hand and seasonal change of these assemblages on the other hand.

The Ebrié Lagoon receives agricultural, urban, and industrial wastes containing contaminants that have proven to be damaging to aquatic habitats and species, mainly through the drainage and the streaming of non-treated effluents (Coulibaly *et al.,* 2010).

This alteration is thought to play an important role in the fish community structures and in the other aquatic organisms (Kress *et al.,* 2002). Massive mortality of fishes has been often observed in sectors IV and V of Ebrié Lagoon, located in the Departments of Jacqueville and Dabou. In May 2013, the reoccurrence of fish mortality resulted in human fish consumption advisory in these areas. Protection of the Ebrié lagoon is one of the conditions for preservation and conservation of living species (Lévêque and Paugy, 1999). Interesting dynamics in the community structure of zooplankton after mortalities of the organism have been recently reported from Côte d'Ivoire. Previous works on zooplankton communities were limited mainly to biological aspects (Kouassi *et al.,* 2001; 2006; Pagano *et al.,* 2003; 2004). The only real inventory study of Ebrié lagoon zooplankton was from Aka *et al.* (2016a; 2016b)who limited their study on the sectors I, II and III of Ebrié lagoon.

The present study is the attempt to record the changes in the community structure of zooplankton in the sectors IV and V of Ebrié lagoon and the objectives are to update the inventory of the zooplankton species composition, to identify potential factors which may in the future threaten organism biodiversity and to determine the main environmental variables that were associated to species distribution.

## Materials and methods

*Study area*

The Ebrié lagoon is the largest lagoon (566 km²) of Ivory Coast stretching for 130 km east to west with a maximum width of 7 km (Durand and Guiral, 1994). Based on the hydroclimate, and on aquatic primary and secondary production, the fisheries in Ebrié Lagoon have been divided into six sectors (Durand and Skubich, 1982).

The sectors IV and V were located in the west of Ebrié lagoons (Fig. 1). These sectors were situated between 5°13'N and 5°19' N and 4°14' W and 4°27' W. The sector IV situated near the Vridi channel is permanent linkage with the Atlantic Ocean and receives Agneby river outflow. This part of the lagoon is seasonally variable and heterogeneous with salinity varying from zero in the rainy season to 35 in the dry season.

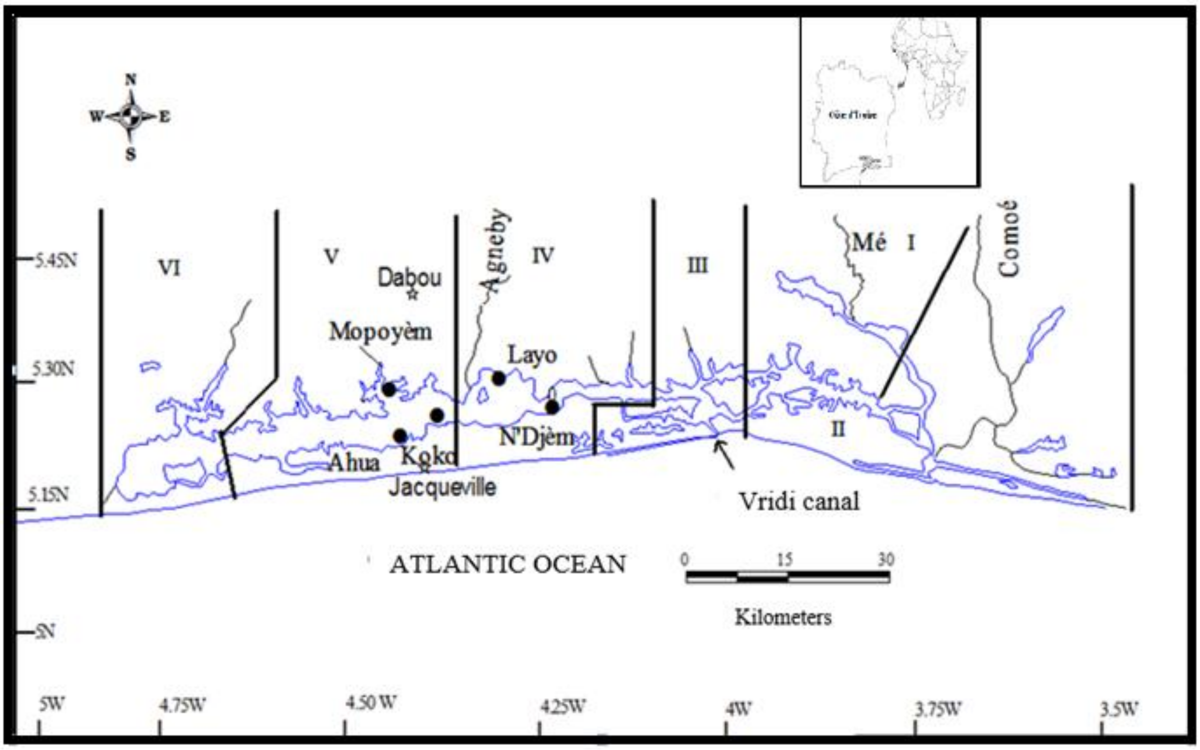


**Fig. 1.**Map showing the localization of sampling stations (●) in the Ebrié Lagoon (Côte d'Ivoire, West Africa).

The sector V is oligohaline (salinity 0–3), stable and homogeneous throughout the year (Durand and Guiral, 1994).

The sectors IV and V are situated in a region under the influence of a subequatorial climate characterized by two rainy seasons, a short (October-November) and a long season (May-July); and two dry seasons, a long (December-April) and a short season (August-September).

A total of five sampling stations were selected, distributed along these sectors of Ebrié Lagoon according to size of fish mortality. Thus, fish mortality investigation allowed to select Ahua and Mopoyèm (massive mortality); Koko and Layo (little mortality) and N'Djèm (very little mortality).The sampling stations were investigated monthly from August 2015 to July 2016 during 12 months. The zooplankton sampling was carried out using a cylindro-conical net of 64 µm in mesh opening size by filtration. Samples were immediately preserved in a mixture of lagoon's water and borax neutralized formalin at a final concentration of 5%. Zooplankton organisms were identified using the following works (Dussart and Gras, 1966; Rey and Saint-Jean, 1968; 1969; Pourriot, 1980; De Ridder, 1981). 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 of 1 and 5 ml. One or several subsamples were examined until numbering a minimum of 100 individuals per taxa, in order to minimize sub-sampling errors and to reduce the coefficient of variation to a maximum of 10% (Cassie, 1968).

*Environmental parameters*

During the investigation period, *in situ*, the hydrologic parameters (water salinity, temperature, dissolved oxygen, pH, TDS and conductivity were measured monthly at depth intervals of 10 cm, using a multifunctional probe. A Secchi disc was used for water transparency measures. *Ex-situ*, Phosphate ($PO_4^{3-}$) analyses were carried out using a molecular absorption spectrophotometer (UV Type 2700) according to Murphy and Riley (1962**),** nitrite ($NO_2^-$ )

nitrate ($NO_3^-$ ) and ammonium ($NH_4^+$) analyses were carried out using a calorimetric assay according to Amino and Chaussepied (1983). Phosphates, nitrites, nitrates, and ammonium were measured at 885 nm, 543 nm, 415 nm, and 630 nm wavelengths, respectively.

*Zooplankton community structure analysis*

The species richness (S), the Shannon diversity index (H') and the Pielou evenness index (E) were used to determine the assemblage's structure of zooplankton community. The analyses were carried out using the sub-routine of Paleontological Statistics (PAST) Package version 2.41. Redundancy analysis (RDA) was conducted by using the computer program CANOCO, version 4.5 in order to assess the relationships between water physical-chemical parameters and zooplankton species. To satisfy the assumption of normality and homogeneity of variance in data, all data were logarithmically transformed before the analyses.

Kruskal-Wallis and ANOVA test were performed to test the effects of stations and seasons on physico-chemical parameters and zooplankton diversity and abundance. A significance level of $p < 0.05$ was considered. Analyses were carried out using the software package Statistica version 7.1.

## Results and discussion

*Environmental parameters*

Spatial variations of environmental parameters in sectors IV and V of Ebrié lagoon during the rainy season (RS) and dry season (DS) were showed in Fig. 2. In all sampling sites, highest temperatures were always obtained during the dry season.

**Table 1.**Distribution and occurrence of different taxa collected in Ebrié lagoon from August 2015 to July 2016 (+ = presence of the taxon at the sampling stations, *new taxa identified in Ebrié lagoon).

| Group | Order | Family | Taxon | Occurrence (%) | Mop | Lay | Ndj | Ahu | Kok |
|---|---|---|---|---|---|---|---|---|---|
| Rotifers | Ploima | Brachionidae | *Anureopsis fissa* | 20 | + | | | | + |
| | | | *Brachionus angularis* | 80 | + | + | | + | + |
| | | | *Brachionus calyciflorus* | 60 | + | + | | | |
| | | | *Brachionus caudatus* | 50 | + | + | + | | |
| | | | *Brachionus dichotomus* | 10 | | + | | | |
| | | | *Brachionus falcatus* | 70 | + | + | + | + | |
| | | | *Brachionus plicatilis* | 60 | + | + | + | + | + |
| | | | *Brachionus quadridentatus* | 10 | | + | | | |
| | | | *Kellicottia* sp. | 10 | | | | + | |
| | | | *Keratella cochlearis* | 10 | | + | | | |
| | | | *Keratella lenzi* | 30 | + | + | | | |
| | | | *Keratella procurva* | 10 | + | | | | |
| | | | *Keratella quadrata* | 20 | + | + | | | |
| | | | *Keratella tropica* | 70 | + | + | + | + | |
| | | | *Plationu spatulus* | 10 | | + | | | |
| | | | *Platyias quadricornis* | 20 | | + | | | |
| | | Lecanidae | *Lecaneluna* | 10 | | + | | | |
| | | | *Lecane* sp. | 50 | + | + | | + | |
| | | Asplanchnidae | *Asplanchna* sp. | 10 | + | | | | |
| | | Lepadellidae | *Colullera* spp. | 30 | + | + | | + | |
| | | Mytilinidae | *Mytilina* sp. | 10 | | + | | | |
| | | Synchaetidae | *Synchaeta* sp. | 10 | | + | | | + |
| | | Trichocercidae | *Trichocerca* sp. | 50 | + | | + | + | |
| | | Epiphanidae | *Epiphanes* sp. | 10 | + | + | | | |
| | Flosculariaceae | Filiniidae | *Filiniaca masecla** | 10 | | + | | | |
| | | | *Filinia longiseta* | 40 | + | + | | | |
| | | | *Filinia opoliensis* | 70 | + | + | + | + | + |
| | | | *Filinia terminalis* | 10 | | + | | | |
| | | Hexarthridae | *Hexarthraintermedia* | 10 | + | | | | |
| | | Testudinellida | *Testudinella* sp. | 10 | | + | | | |
| | Bdelloidea | Philodinidae | *Rotaria* sp. | 10 | + | | | | |

**Continued table 1.**

| Group | Order | Family | Taxon | Occurrence (%) | Mop | Lay | Ndj | Ahu | Kok |
|---|---|---|---|---|---|---|---|---|---|
| Copepod | Calanoïda | Undetermined | Nauplii | 100 | + | + | + | + | + |
| | | Acartiidae | *Acartia clausi* | 100 | + | + | + | + | + |
| | | Paracalanidae | *Paracalanusparvus* | 30 | | | + | | |
| | | Pseudodiaptomidae | *Pseudodiaptomus hessei* | 60 | + | + | + | + | + |
| | Cyclopoïda | Cyclopidae | *Eucyclops* sp. | 40 | + | + | | + | + |
| | | | *Mesocyclops* sp. | 40 | + | + | | + | |
| | | | *Thermocyclops neglectus* | 50 | + | + | + | + | |
| | | Oithonidae | *Oithona brevicornis* | 50 | | | + | + | + |
| | | Ergasilidae | *Ergasilus* sp. | 40 | | | + | + | + |
| | Harpacticoïda | Tachidiidae | *Euterpina acutifrons* | 10 | | | + | | |
| | | Undetermined | Harpacticoïda | 90 | + | + | + | + | + |
| Cladoceran | Anomopoda | Chydoridae | *Alona*sp. | 10 | | | | + | |
| | | | *Camptocercus* sp. | 10 | | + | | | |
| | | Daphniidae | *Ceriodaphnia* sp. | 10 | + | | | | + |
| Others planktons | Ephemeroptera | Baetidae | *Baetis*sp. | 10 | + | | | | |
| | Dipterans | Chironomidae | *Chironomus* sp. | 60 | + | + | + | | + |
| | Amphipods | Undetermined | Amphipods | 20 | | | + | | |
| | Euphausiacea | | Euphausiacea | 20 | | | + | | |
| | Bivalves | | Lamellibranches | 60 | | | + | + | + |
| | Fish | | Fish larvae | 20 | | | + | | + |
| | Cirriped | | Cirripedia Larvae | 50 | + | | + | | |
| | Gastropods | | Gastropods larvae | 60 | + | + | + | + | + |
| | Polychaetes | | Polychaetes larvae | 50 | | | + | | |
| | Mysidacea | | Mysidacea | 20 | | | + | | |
| | Ostracod | | Ostracod | 30 | + | + | + | | |
| | plecopteran | | Plecopteran | 30 | + | | | | |
| | Decapod | | Decapod zoea | 40 | + | | + | | |
| Rhizopod | Arcellinida | Centropyxidae | *Centropyxis* sp.* | 30 | + | + | + | | |
| Total | | 23 | 59 | | 35 | 36 | 27 | 21 | 17 |

The high value (29.6°C) obtained in Layo. pH was basic at Ahua, Koko and N'Djèm stations during the both seasons and the highest basicity was obtained in Ahua (7.6) during a dry season, but pH was acid at Layo and Mopoyèm during a both seasons. Dissolved oxygen saturation was lowest at Mopoyèm station (4.9 mg/l) and was highest at Koko (9 mg/l) during the dry season.

The total dissolved solids rate (TDS) lowest (115.4mg/l) and highest (3025.4 mg/l) values were obtained in N'Djèm during the rainy season and dry season respectively. Highest values of salinity were obtained in station near the Vridi Canal with a peak of 6.08‰ in N'Djèm during dry season and lowest values with 1.03‰ in Layo during rainy season. Variation of conductivity is the similar with fluctuation of salinity. Water transparency fluctuated slightly between 43.4cm (Layo) during the rainy season and 131.2cm (Ahua) during the dry season. The depth of sectors IV and V of Ebrié lagoon was ranged between 0.72m (Koko) and 2.46m (N'Djèm) during dry season.

The mean phosphate values were ranged between 0.03 mg/l (Koko) and 0.098 mg/l (Layo) in rainy period. Also, the mean nitrate concentration of sectors IV and V were varied between 0.35 mg/l (Ahua) and 1.83 mg/l (N'Djèm) in rainy season. Nitrite concentration increased from Mopoyèm (0.06 mg/l) during the rainy season to Ahua (0.72 mg/l) during rainy season. Ammonium concentration varied between 0.06 mg/l (Ahua) during the dry season and 0.2 mg/l (Koko) during the rainy season. No significant difference ($p > 0.05$) was observed between seasons for Nitrate, Nitrite, temperature, dissolved oxygen, salinity, conductivity, transparency, depth and pH rates. But difference significant was observed between seasons for ammonium and total dissolved solid rates.

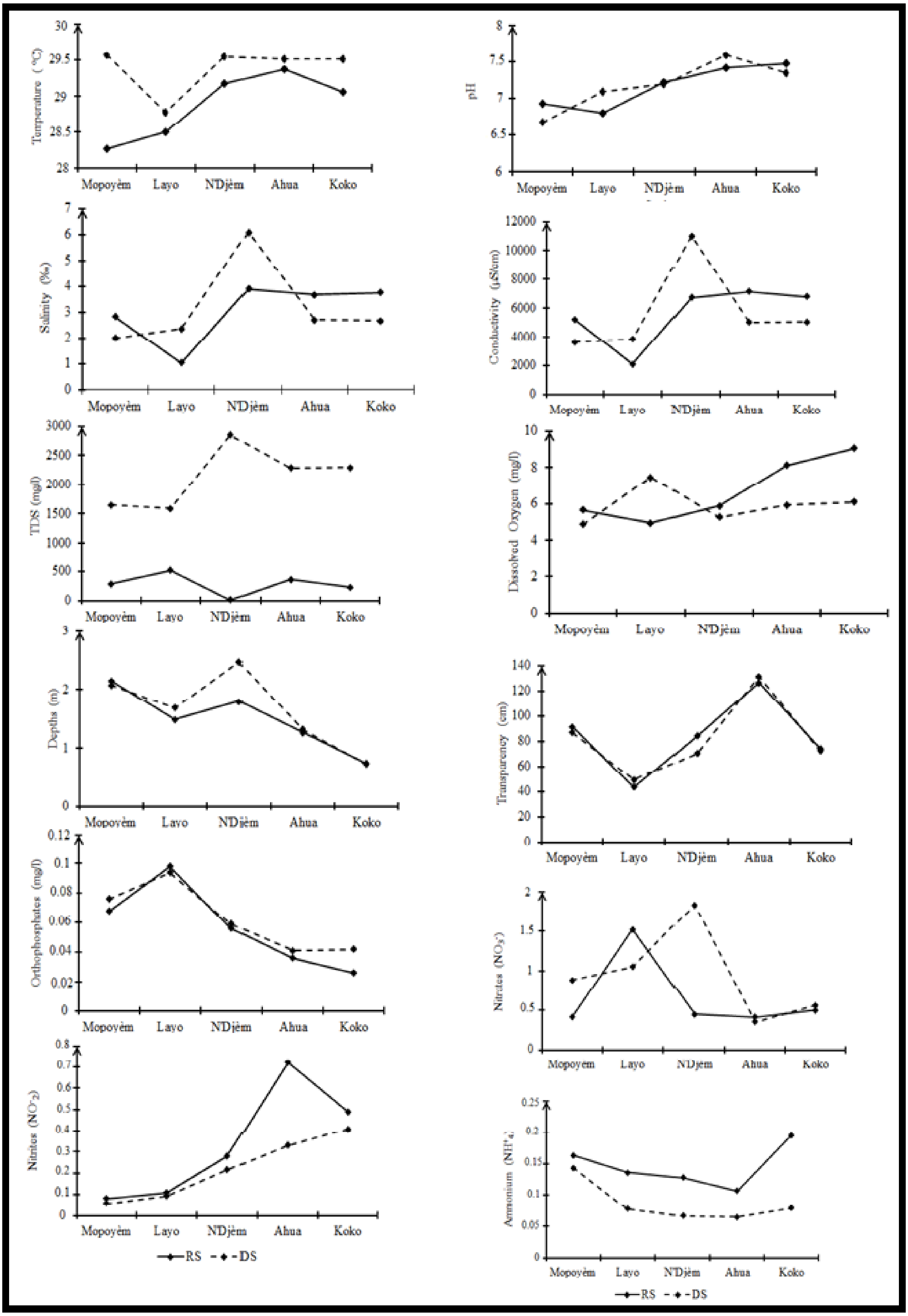


**Fig. 2.**Spatio-temporal of environmental variables during the dry and rainy seasons in the sectors IV and V of Ebrié lagoon (RS: rainy season, DS: dry season).

The seasonal variations observed in sectors IV and V are the result of the seasonal succession and the influence of the Agne by River and / or the Atlantic Ocean via the Vridi Canal. In fact, the inflow of fresh water by the Agne by river, in addition to increasing the water level, leads to a decrease in salinity and consequently in conductivity. On the other hand, the intrusion of the seawater increases the salinity then the pH of the water of the lagoon (in the dry season).

Moreover, the spatial variations of the physicochemical parameters observed can be explained by the diversity and intensity of the anthropic activities undergone by the ecosystem. However, the relative position of the sampling stations relative to the ecosystems adjacent to sectors IV and V could explain some spatial variations. Stations closest to the sea are saltier than others that are less close (Adandedjan *et al.,* 2017).

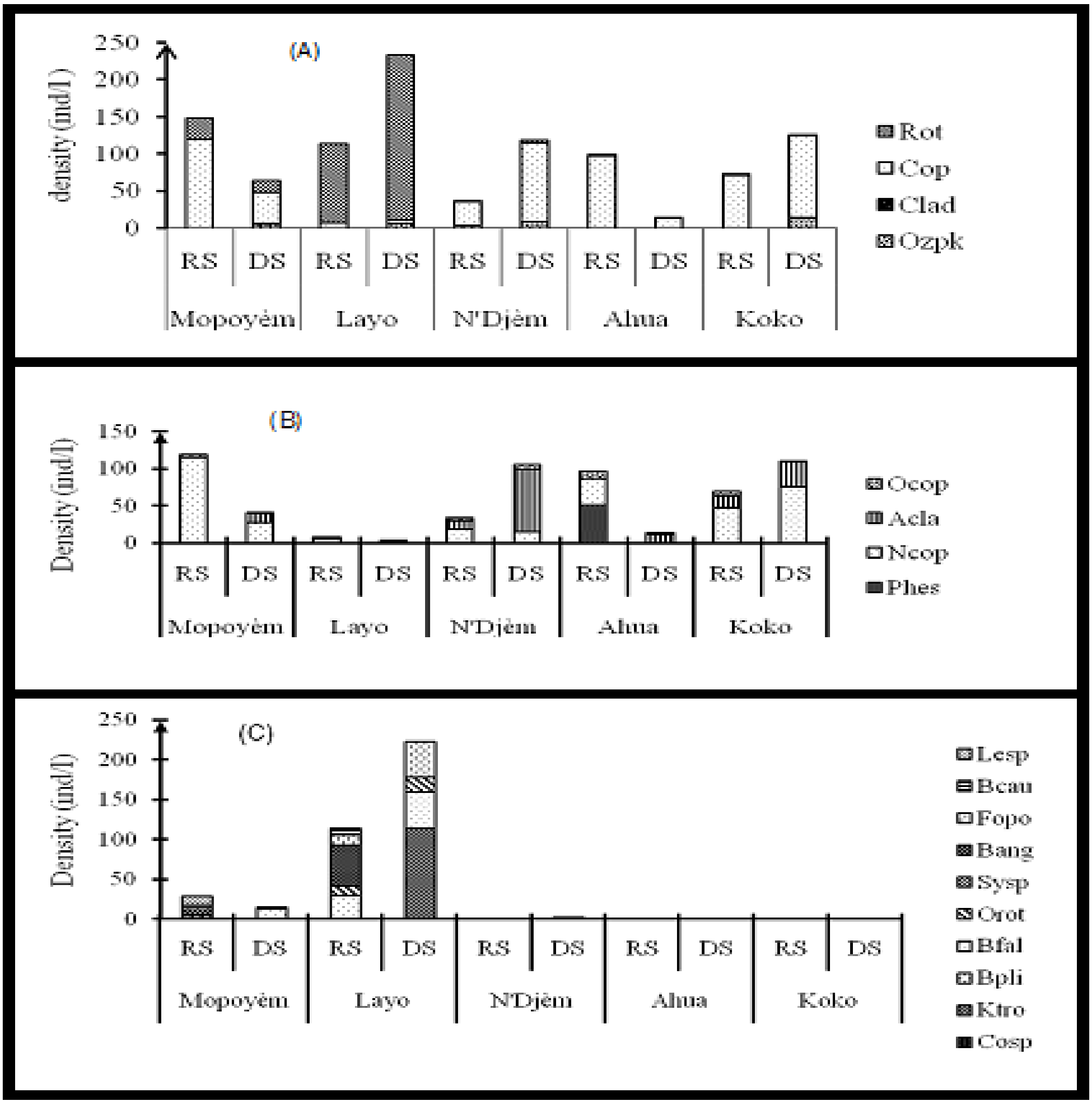


**Fig. 3.** Spatiotemporal variation of the relative density of the main zooplankton groups (A) Copepoda (B) and Rotifera (C) taxa in the Ebrié lagoon: Ozpk :others organisms of zooplankton Ocop :Others Copepoda, Acla : *Acartia clausi*, Ncop : Nauplii of Copepoda, Phes : *Pseudodiaptomus hessei*, Orot : Others Rotifera, Lesp : Lecane sp., Bcau : *Brachionus caudatus*, Fopo : *Filinia opoliensis*, Bang : *Brachionus angularis*, Sysp : *Synchaeta* sp, Bpli : *Brachionus plicatilis*, Ktro : *Keratella tropica*, Cosp : *Colullera* spp, Bfal : *Brachionus falcatus*.

A total of 59 taxa of zooplankton belonging to Rotifer (31 taxa, 52.5% of total diversity), Copepod (11 taxon, 18.6%), Cladocera (3 taxon, 5.08%), Rhizopoda (1 taxon, 2%) and other zooplankton (13 taxon, 22%) were identified in sectors IV and V of Ebrié lagoon (Table 1).

Zooplankton sampled during this study includes 25 families and 39 genera. Rotifer dominates qualitatively the zooplankton community in the sectors IV and V of Ebrié lagoon (52.5% of total diversity) with 12 families and 17 genera. Brachionidae was the family the most diversity with 16 species followed by Filinidae (4 species), and Lecanidae (2 species).

The others families are represented by one species each. *Brachionus* was the most important genus, with 7 species, followed by the genus *Keratella* (5 species) and *Filinia* (4 species).

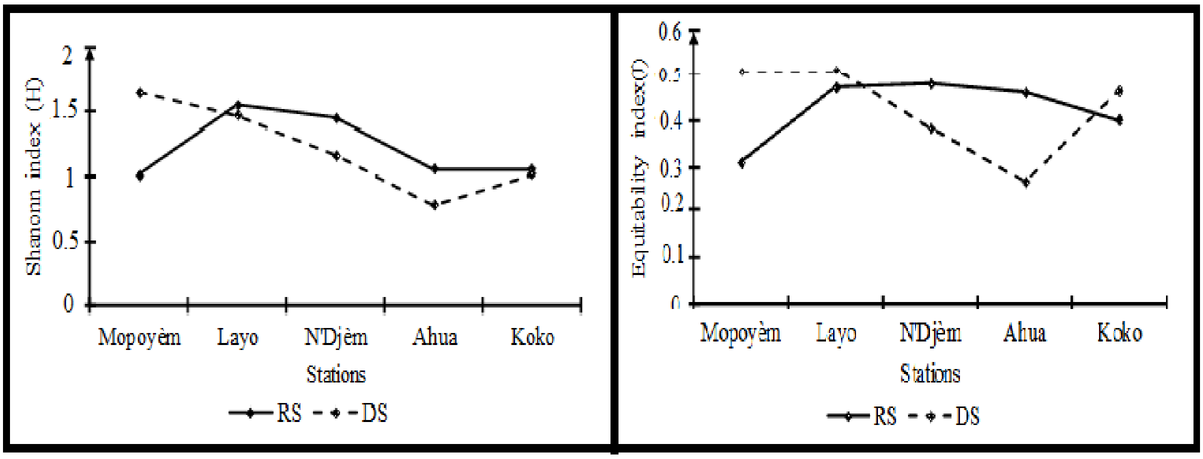


**Fig. 4.**Spatiotemporal variation of Shannon and Equitability index in the sectors IV and V of Ebrié Lagoon.

Copepod were represented by 11 taxa (19 %) belonging to 7 families and 9 genera plus unidentified Copepod nauplii and harpacticoid taxa. Cyclopidae was the most diversified family of Copepod group (3 taxa and 3 genera), the six others families were monospecific. Cladocera (5%) and Rhizopoda (2 %) were represented respectively by two families (Chydoridae and Daphnidae) and one family (Arcellinida).

Zooplankton community richness varied according to seasons and sampling site. The highest taxonomic richness was observed in Mopoyèm and Layo (26 to 27 taxa) during rainy season while lowest diversities were recorded in Ahua and Koko (9 to 18 taxa) during dry season. Seasonal variation of zooplankton richness was not marked by significantly difference between dry season (9-26 taxa) and rainy season (10-27 taxa) values. However, the most diversity were recorded during the rainy period.

Zooplankton richness obtained in the present study (59 taxa) similar to those of Aka *et al.* (2016b) in Aghien lagoon (59 taxa). However, it is relatively higher than those mentioned by Arfi *et al.* (1987**)** (42 taxa) in Ebrié lagoon (sectors II, III and IV), by Aka *et al.* (2016a**)** (47 taxa) (sectors I and III of Ebrié lagoon). Zooplankton community richness collected in the present study was relatively lower than those reported by Etilé *et al.* (2009) (65 taxa) in Grand-Lahou lagoon, but it was relatively higher than zooplankton richness collected by Monney *et al.* (2015) (53 taxa) in Aby-Tendo-Ehy lagoons system. Zooplankton diversity in the present study is also higher than taxon richness obtained by Abdul *et al.* (2016) in tropical coastal estuarine ecosystem impounding Bight of Benin, Nigeria in South-west of Nigeria) and by Adandedjan *et al.* (2017) (31 taxa) in the Lake of Nokoué (South of Benin). The high number of species in those sectors of Ebrié lagoon may be explained by stability of environmental parameters and trophic conditions associated to the shallowness of the lagoon and combined low influence of freshwater and marine water (Guiral, 1992; Monney *et al.,* 2015). The difference in richness in this study and previous studies cited below, could be explained by factors as study or sampling duration (annual cycle for this study), sampling sites prospected (one part of Ebrié lagoon versus sampling performed in all lagoon area for other studies).In fact, according to Guiral (1992), the waters of sectors IV and V are characterized by low salinities and by a great physico-chemical stability.Salinity can thus be considered as the main factor of zooplankton diversity according to Etilé *et al.* (2009), Monney *et al.* (2015).

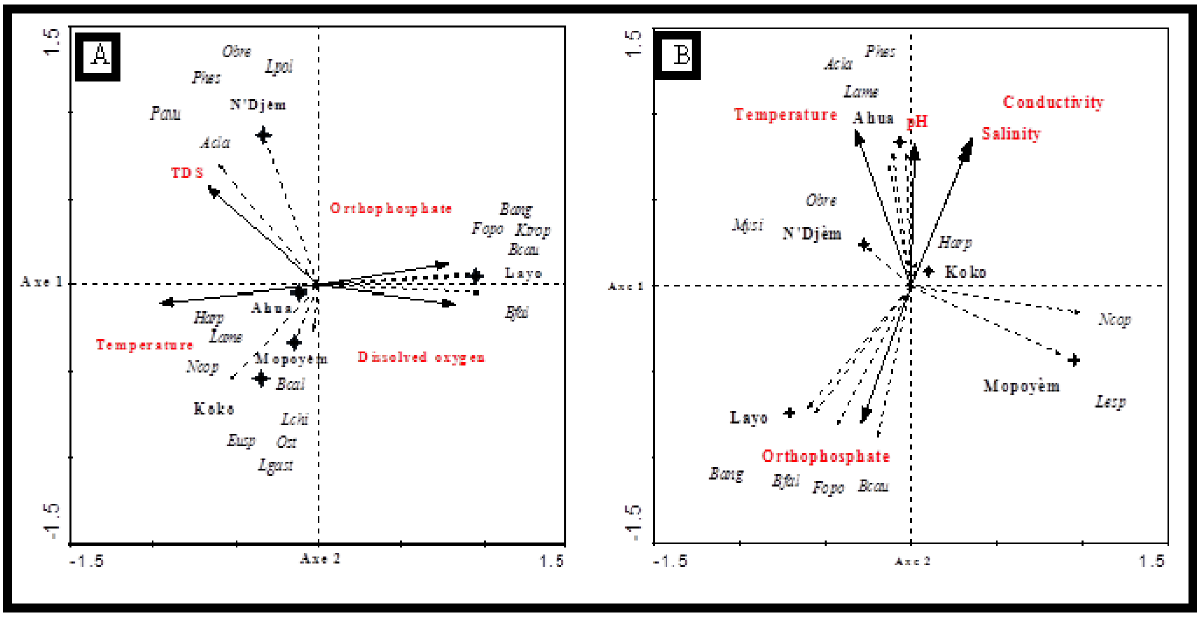


**Fig. 5.**Redundancy analysis ordination diagram applied to environmental variables and zooplankton abundance during the dry season (A) and rainy season (B) in the Ebrié lagoon. Ktro : *Keratellatropica*, Bcau: *Brachionus caudatus*, Fopo: *Filinia opoliensis*, Bang: *Brachionus angularis*, Bfal: *Brachionus falcatus*, Phes: *Pseudodiaptomus hessei*, Ncop: copepods Nauplii, Acla: *Acartiaclausi*, Lesp: *Lecane* sp, Bcal: *Brachionus calyciflorus*, Ost: Ostracoda, Lgast: Gastropods larvae, Lam : Lamellibranches larvaa, Obre :*Oithona brevicorni*, Lpol : Polycheata Larvae , Harp : Harpaticoïds, Eusp : *Eucyclops* sp., Lchi : Chironomidae Larvae, Pavu : *Paracalanusparvu*, Mysi : Mysidacea, TDS: Total Dissolved Solid.

These authors pointed out that even relatively small increase in salinity have important consequences for zooplankton communities in coastal systems. Monney et al. (2015) consider that the low salinity could have encouraged the development of a freshwater zooplankton such Rotifer group. However, according to Onyema *et al.* (2008), more stable conditions including water flow characteristics, light penetration, reduced rainfall and increased salinity conditions experienced could have encouraged the development of a richer zooplankton.

The present study revealed that Rotifer (31 taxa, 52.5 % of total diversity) was the most diversified groups of zooplankton community. These results agreed with those reported by Monney *et al.* (2015) in Aby-Tendo-Ehy lagoons system, Aka *et al.* (2016a and b)in Ebrié lagoon, Abdul *et al.* (2016) in a tropical coastal estuarine ecosystem impounding Bight of Benin, Nigeria in South-west of Nigeria and by Adandedjan *et al.* (2017) in the Lake of Nokoué. In contrast, in Grand-Lahou lagoon (Etilé *et al.,* 2009) and in Ebrié lagoons (Pagano and Saint-Jean, 1994), Copepod presented highest diversity (30 to 40 %).

This Qualitative dominance of rotifers is characteristic of tropical lakes (Mwebaza-Ndawula *et al.,* 2005). According to Ayoagui and Bonecker (2004), families of Brachionidae and Lecanidae are generally represented by the largest number of species belonging to the genera *Brachionus, Lecane* and *Keratella*. Abdul *et al.* (2016) reported the prevalence of *Brachionus, Lecane* and *Keratella* as indicators of eutrophic condition in aquatic system. High species richness of rotifers in sectors IV and V shows a favourable environmental condition, mainly at Mopoyèm and Layo where salinity was low (< 3) all time due to freshwater inflow in these sampling stations from Agne by, and Layo rivers and low incursion of sea water (Guiral, 1992).This richness spatial variation may be explained by salinity fluctuation ay Mopoyèm and Layo sites were characterized by low salinities (< 3) while the other sites were marked by relative higher salinities (≈ 3 to 6). Rotifers constituted the main zooplankton group in Layo. This highest diversity of rotifers obtained at the Layo may be linked to the fact that this station is under the Agne by River influence.

This rotifers dominance is due to proliferation of *Brachionus caudatus, B. angularis, B. falcatus* and *Filinia opoliensis* all seasons, associated to phosphates concentrations and dissolved oxygen rate. This situation would be justified by the fact that during the dry season, the waters are relatively calm and have many facies favourable to the proliferation of Rotifers, which is not the case in times of flood when strong currents and flows are unfavourable to the installation of planktonic organisms (Onana *et al.,* 2014).

*Community structure and abundance variation*

Zooplankton community, with mean abundance of 103 individuals per liter (ind/l), was characterized by Copepod dominance (58.7 % of the total zooplankton abundance), followed byRotifer (37 %) and others zooplanktons (4.5 %). Cladocerans and Rhizopda were relatively rare in Ebrié lagoon (sectors IV and V) (mean: < 1% each). Copepods comprised 57 % of nauplii and 43 % of Copepodid and adult stages. *Acartia clausi* constitutes on average 71 % of Copepodid and adult stages abundance, followed by *Pseudodiaptomus hessei* (22.5 %). *Keratella tropica* (30.67%), *Brachionusfalcatus* (24.11 %), *Brachionus angularis* (16.84 %), *Filinia opoliensis* (16.52 %) constituted the bulk of the Rotifer total abundance. Cladocerans were dominated by *Ceriodaphnia* cornuta (58%) and *Alona* sp. (29 %). Other zooplanktonic forms were dominated by Gastropods larvae (57%), Bivalves larvae (15%) and Ostracoda (11%).

The zooplankton composition and abundance showed a strong temporal and spatial variation (Fig. 3). At Layo, N'Djèm and Koko, highest zooplankton abundance was obtained during the dry season, 118.32 to 234.11 ind/l versus 37.22 to 113.9 ind/l during the rainy season. In contrast, at Mopoyem and Ahua, highest abundances were obtained during the rainy season, with 99.1 to 148.42 ind/l versus 14.67 to 63.76 Ind/l during the dry season (Fig. 3A). Copepods were abundant at station Mopoyèm and Ahua (97.13 to 119.05 ind/l) during the rainy season versus (13.84 to 41.73 ind/l) during the dry season. In contrast, at N'Djèm and Koko, the highest abundance was observed during the dry season with 106.08 to 110.5 ind/l versus 33.51 to 69.47 ind/l during the rainy season. Copepod abundance spatio-temporal fluctuation was mainly due to undetermined copepods nauplii stages, *Acartia clausi* and *Pseudodiaptomus hessei* (Fig. 3B). Undeterminedcopepod nauplii constituted the dominant taxa for Mopoyèm and Koko during the both seasons (47.6 % to 97.11 %), followed by *Acartiaclausi* at Koko during dry season (30.72 %). *Acartiaclausi* was the main taxa in N'Djèm during the dry season (97.3 %), followed Nauplii Copepod (14.6 %) while *Pseudodiaptomus hessei* constituted the main Copepod taxa at Ahua during the rainy season (52.95 %), followed Nauplii Copepod (36.73 %). Beside; *Acartia clausi* was the main taxa during the dry season (87.35 %) and followed Nauplii Copepod (9.58 %) (Fig. 3B).

The highest Rotifer abundances were observed at Layo and Mopoyem (43.9 to 337.72 ind/l)(Fig. 3C). At Layo, rotifers abundance during the dry season (223.43 ind/l) was more important than those of the rainy season (114.28 ind/l) while it presents inverse situation at Mopoyem; with 28.83.ind/l during the rainy season versus 15.08.ind/l during the dry season. At Layo, *Keratella tropica*(51.02 %) showed highest abundance during dry season. During the rainy season, *Brachionus angularis* was most the abundant taxa (48.5 %). These two species were followed by *Brachionus falcatus* during the bothseasons (24 %). In all others stations, the total abundance of Rotifer was very weak during the both seasons (Fig. 3C).

Quantitative analyse of zooplankton data reveals that zooplankton community structure was characterized by Copepod dominance. The quantitative dominance of Copepod is also reported in Grand-Lahou lagoon (82-87 %) (Etilé *et al.,* 2009), Ebrié lagoon (51-99 %) (Arfi *et al.,* 1987; Pagano and Saint-Jean, 1994; Aka *et al.,* 2016a) and in the Senegal River Estuary (53-66 %) (Champalbert *et al.,* 2007). However, this result contrasts with those of Monney *et al.* (2015)in Aby-Tendo-Ehy lagoon system, Aka *et al.* (2016b) in Ebrié lagoon (Aghien) where numerical dominance of Rotifer was mentioned (respectively 83% and 50.66 % of zooplankton total abundance). Difference observed could be explained by salinity structuring action on zooplankton composition and distribution in estuary and coastal lagoon (Etilé *et al.,* 2009; Monney *et al.,* 2015). Our study confirms the dominance of *Acartiaclausi* in Ebrié lagoon (Pagano and Saint-Jean, 1994; Aka *et al.,* 2016a).

In contrary, in Grand-Lahou lagoon, Etilé*et al.,* 2009 reported that the abundance of main Copepod was *Oithonia brevicornis*. Copepod comprises the most abundant taxa of the marine, lagoon and estuarine zooplankton in tropical and subtropical regions. According to Champalbert *et al.* (2007), the high density seems more related to the euryhaline and opportunistic character of *A. clausi.* It has in fact been reported in various temperate and tropical estuaries at salinities ranging from 0 to 38.

Our result showed that copepod nauplii stages were most abundant that copepodite and adult stages. The nauplii stage predominance found in this study is also reported in different tropical freshwater habitats (Sampaio *et al.,* 1999). According to Neves *et al.* (2003) highest densities of copepod immature stages are generally attributed to their continuous reproduction in tropical regions. This situation of immature stage dominance can also be explained by intense predation on adult stages by invertebrates and vertebrates (Dumont *et al.,* 1994). Numerous studies have shown that copepod nauplii, and other small copepods are important prey of fish larvae and other planktivorous organisms (Turner, 2004).

Nauplii stages predominance obtained in this study may be due to planktivorous fish species (*Ethmalosa fimbriata*, *Sarotherodon melanotheron* and *Oreochromis niloticus*) presence and predation in sectors IV and V of the Ebrié lagoon as reported by Boni*et al.* (2016).

*Diversity evaluation*

During the dry season Shannon diversity index values varied between 0.7 bit/ind (Ahua) and 1.7 bit/ind (Mopoyèm) while during the rainy season it was ranged between 1.01 bit/ind (Mopoyèm) and 1.6 bit/ind (Layo). During the dry season equitability index were varied between 0.27 (Ahua) and 0.51 (Layo). But during the rainy season, it varied between 0.31 (Mopoyèm) and 0.48 (N'Djèm). No significant difference was observed in the diversity index (Shannon diversity and equitability index) between seasons for each lagoon (Fig. 4). Fluctuations in the Shannon and Wiener index and the Piélou equitability index during the study period reveal a great instability in the structure of the zooplankton community. This explains the variability of the environmental conditions that prevailed during the study along the water body. This instability of the environment is also justified by the preponderance of accidental and / or rare species.

*Zooplankton and environmental variables*

The main pattern shown by the RDA is a longitudinal in gradient species composition. Forward selection and Monte Carlo permutation allowed to 4 environmental variables accounting for 60 % of the variance during a dry period and 5 environmental variables accounting for 55 % variance explained during rainy period by 12 variables (Fig. 5).

In the Redundancy Analysis of the dry season performed, axis 1 (eigenvalue = 0.67) and axis 2 (eigenvalue = 0.38) expressed 86.6 % of the cumulative variance in the species data. The analysis distinguished also three zones (Fig. 5A). The first zone was Layo. This zone was positively correlated to the dissolved oxygen and orthophosphate. The main taxa associated to this station were *Brachionus falcatus, B. angularis, B. caudatus, Keratella tropica* and *Filinia opoliensis*. The second zone (Ahua Mopoyèm and Koko) was positively correlated to temperature and negatively correlated to the dissolved oxygen and orthophosphate. The main taxa associated to the second zone were *Brachionus calyciflorus*, Ostracod taxa, *Eucyclops* sp., Chironomidae larva, Lamellibranchia and gastropod larvae.The third zone (N'Djèm) was correlated to TDS. The main taxa associated to this third zone were, *Acartia clausi, Paracalanusparvu*, Polychaeta larvae, *Pseudodiaptomus hessei* and *Oithona*

Besides, in the Redundancy Analysis of the rainy season performed, axis 1 (eigenvalue = 0.68) and axis 2 (eigenvalue = 0.092) expressed 88.5 % of the cumulative variance in the species data. The analysis distinguished, two groups of samples and taxa can be distinguished (Fig. 5B). The first group was defined by Layo and Mopoyèm. This zone was correlated to the orthophosphate. The main taxa associated to the first zone were *Brachionus falcatus, B. angularis, B. caudatus, Filinia opoliensis*, and *Lecane* sp. The second group (N'Djèm, Ahua and Koko) was correlated to conductivity, salinity, pH and temperature. The main taxa associated to the second zone were *Pseudodiaptomus hessei*, *Acartia clausi*, *Oithona brevicornis*, Lamellibranchia, Harpacticoids and Mysidacae were associated.

The ordination of the zooplankton species by the redundancy analysis distinguished three zones. The redundancy analysis showed that the species variation patterns were significantly related to the environmental heterogeneity patterns observed in lagoon. However, environmental variables strongly affect the distribution of zooplankton species (Dauvin *et al.,* 1998). The positive correlation between the freshwater zooplankton taxa (*Brachionus falcatus, Brachinous angularis, Keratella tropica, Brachionus caudatus, Filinia opoliensis*) and phosphate and dissolved oxygen reported in the present study is similar to the findings of Aka *et al.* (2016a) in Ebrié lagoon. Conductivity, salinity, TDS, pH and water temperature affect the distribution of *Pseudodiaptomus hessei*, Nauplii, *Acartia clausi*, *Oithona brevicornis*, Lamellibranchia, Harpacticoids, Mysidacae. This result agrees with studies of Aka *et al.* (2016a) which showed that salinity, temperature and pH characteristics affect the distribution of zooplankton.

**Conclusion**

A total of 59 taxa of zooplankton taxa were recorded in the Ebrié Lagoon in this study.

*Centropyxis* sp and *Filiniaca masecla* were the first time identified in the Ebrié lagoon and all of Côte d'Ivoire lagoons. Our study also proposes a pattern of short-term temporal variations of the zooplankton community and abundance in relation with environmental variables.

This study revealed that in sector IV and V, the zooplankton taxa were dominated by Rotifer diversity. The presence of some zooplankton in the lagoon indicated that there was a high level of anthropogenic activities in and around the water body. This therefore calls for urgent checks on the activities around the lagoon to enhancing sustainable ecosystem health and productivity.

**Acknowledgements**
The authors are grateful to Hydrobiology Laboratory of Félix Houphouet-Boigny University for making available the material for supporting this study. We express our appreciation to anonymous reviewers for their valuable comments and editing of the manuscript.

## References

**Abdul WO, Adekoya EO, Ademolu KO, Omoniyi IT, Odulate DO, Akindokun TE, Olajide AE.** 2016. The effects of environmental parameters on zooplankton assemblages in tropical coastal estuary, South-west, Nigeria. The Egyptian Journal of Aquatic Research **42(3),** 281-287. https://doi.org/10.1016/j.ejar.2016.05.005

**Adandedjan D, Makponse E, Hinvi LC, Laleye P.** 2017. Données préliminaires sur la diversité du zooplancton du lac Nokoué (Sud-Bénin).Journal of Applied Biosciences **115(1),** 11476-11489. http://dx.doi.org/10.4314/jab.v115i1.7

**Aka NM, Etilé RN, Blahoua KG.** 2016a. Anthropogenic Activities Impact on Zooplankton Community in a Tropical Coastal Lagoon (Ebrié, Côte d'Ivoire) International Journal of Contemporary Applied Sciences **(3)9,** 1365-2308.

**Aka NM, Etilé RN, Konan FK, Bony YK.** 2016b.Zooplankton Composition and Distribution in Relationship with Environmental Parameters in a Tropical Coastal Lagoon (Ebriélagoon: Aghien, Côte d'Ivoire). International Research Journal of Biological Sciences **5(12),** 1-12.

**Aminot A, Chaussepied M.** 1983**.** Manuel des analyses chimiques en milieu marin. CNEXO, Editions Jouve, Paris, p 395.

**Anoh KP.** 2010**.** Stratégies comparées de l'exploitation des plans d'eaulagunaire de Côte d'Ivoire. Document d'outre-mer 347-363.

**Aoyagui AS, Bonecker CC.** 2004. Rotifers in different environments of the Upper Paraná River floodplain (Brazil): richness, abundance and the relationship with connectivity. Hydrobiology **522(1-3),** 281-290. https://doi.org/10.1023/B:HYDR.000

**Arfi R, Pagano M, Saint-Jean L.** 1987. Communautés zooplanctoniques dans unelagune tropicale (la laguneEbrié, Côte d'Ivoire) : variations spatio-temporelles. Revue d'hydrobiologie tropicale, **20(1),** 21-35.

**Boni L, Aboua BRD, Atsé BC, Kouamélan EP.**2016.Seasonal Influence of Environment Variables on the Fish Assemblages Pattern to the West of the Ebrié Lagoon, European Journal of Scientific Research **140 (1),** 5-16.

**Cassie RM.** 1968. Sample design in zooplankton sampling. UNESCO, Monographs Oceanographic methodology **2,** 105-121.

**Castel J, Caumette P, Herbert R.** 1996. Eutrophication gradients in coastal lagoons as exemplified by the Bassind' Arcachon and the Etang du Prevost, Hydrobiologia **329,** 1-20. https://doi.org/10.1007/BF0003454

**Champalbert G, Pagano M, Sene P, Corbin D.** 2007. Relationships between meso- and macro-zooplankton communities and hydrology in the Senegal River Estuary.Estuarine, Coastal and Shelf Science **74,** 381-394. https://doi.org/10.1016/j.ecss.2007.04.023

**Coulibaly AS, Monde S, Wognin AV, Aka K.** 2010. Dynamique des éléments tracesmé talliques dans les sédiments des baiesd' Abidjan (baie du

Banco et rade Portuaire). European Journal of Scientific Research **46,** 204-215.

**Dauvin JC, Thiebaut E, Wang Z.** 1998. Short-term changes in the mesozooplankton community in the Seine ROFI (Region of Freshwater Influence) (eastern English Channel).Journal of Plankton Research **20(6),** 1145-1167.
https://doi.org/10.1093/plankt/20.6.1145

**De Ridder M.** 1981.Rotifères, Volume XI, fascicule 4, Cercle hydrobiologique de Bruxelles, Bruxelles, 191p

**Dumont HJ, Rocha O, Tundisi JG.** 1994. The impact of predation in structuring zooplankton communities with emphasis on some lakes in Brazil, In Proceedings of the International Water Seminar. México Mazatlán 11-43.

**Durand JR, Skubich J.** 1982. Les lagunesivoiriennes.Aquaculture **27(3),** 211-250.
https://doi.org/10.1016/0044-8486(82)90059-X

**Durand JR, Guiral D.** 1994. Hydroclimate thydrochimie. In Durand JR, Dufour P, Guiral D, Zabi SGF eds, Environne mentetres sources aquatiques de Côte d'Ivoire. Tome II. Les Milieux lagunaires. Orstom, Paris 129-136.

**Etilé NR, Kouassi AM, Aka MN, Pagano M, N'douba V, Kouassi NJ.** 2009. Spatiotemporal variations of the zooplankton abundance and composition in West African tropical coastal lagoon (Grand-Lahou, Côte d'Ivoire). Hydrobiologia **624,** 171-189.
https://doi.org/10.1007/s10750-008-9691-7

**Guiral D.** 1992.L'instabilité physique, facteurd' organisation et de structuration d'un écosystème tropical saumâtre peu profond : la lagune Ebrié. Vie milieu **42,** 73-92.

**Keister JE, Bonnet D, Chiba S, Johnson CL, Mackas DL, Escribano R.** 2012. Zooplankton population connections, community dynamics, and climate variability. International Council for Exploration Sea Journal of Marine Science **69,** 347–350.
https://doi.org/10.1093/icesjms/fss034

**Kouamélan EP, Teugels GG, N'Douba V, Gooré Bi G, Koné T.** 2003. Fish diversity and its relationships with environmental variable in a West African basin.Hydrobiologia **505(1-3),** 139-146.
https://doi.org/10.1023/B:HYDR.0000007302.74296.84

**Kouassi AM, Kaba N, Métongo BS.** 1995.Land-based sources of pollution and environmental quality of the Ebrié lagoon waters. Marine Pollution Bulletin **30(5),** 295-300.
https://doi.org/10.1016/0025326X(94)00245-5

**Kouassi E, Pagano M, Saint-Jean L, Arfi, R, Bouvy M.** 2001. Vertical migrations and feeding rhythms of *Acartia clausi* and *Pseudodiaptomus hessei*(Copepod: Calanoida) in a tropical lagoon (Ebrié, Côte d'Ivoire). Estuarine, Coastal and Shelf Science **52,** 715-728.
https://doi.org/10.1006/ecss.2001.0769

**Kouassi E, Pagano M, Saint-Jean L, Sorbe C.** 2006. Diel vertical migrations and feeding behavior of the mysid *Rhopalophthalmus africana* (Crustacea: Mysidacea) in a tropical lagoon (Ebrié, Côte d'Ivoire). Estuarine, Coastal and Shelf Science **67(3),** 355-368.
https://doi.org/10.1016/j.ecss.2005.10.019

**Kress N, Coto SL, Brenes CL, Brenner S, Arroyo G.** 2002. Horizontal transport and seasonal distribution of nutrients, dissolved oxygen and chlorophyll-a in the Gulf of Nicoya, Costa Rica: a tropical estuary. Continental Shelf Research **22(1),** 51-66.
https://doi.org/10.1016/S0278-4343(01)00064-4

**Lévêque C, Paugy D.** 1999. Les poissons des eaux continentales africaines :diversité, écologie et utilisation par l'homme. Editions de l'IRD, Paris, p 521.

**Monney AI, Etilé NR, Ouattara NI, Kone T.** 2015.Seasonal distribution of zooplankton in the Aby-Tendo-Ehy lagoons system (Côte d'Ivoire, West Africa). International Journal of Biological and Chemical Sciences **9(5),** 362-2376. http://dx.doi.org/10.4314/ijbcs.v9i5.9

**Murphy J, Riley JP.** 1962. A modified single solution method for the determination of phosphate in natural waters. Analyticachimicaacta**27,** 31-36.https://doi.org/10.1016/S0003-2670(00)88444-5

**Mwebaza-Ndawula L, Sekiranda SBK, Kiggundu V.** 2005. Variability of zooplankton community along a section of the Upper Victoria Nile, Uganda. African Journal of Ecology **43(3),** 251-257. https://doi.org/10.1111/j.1365-2028.2005.00583.x

**Naz F, Qureshi NA, Saher NU.** 2015. Spatial and temporal assemblage *of Potamides cingulatus* (Gmelin) found in the mangrove creek area of Karachi, Pakistan. Mausam **66(1),** 87-92.

**Neves IF, Rocha O, Roche KF, Pinto AA.** 2003. Zooplankton community structure of two marginal lakes of the river Cuiabá (Mato Grosso, Brazil) with analysis of Rotifer and Cladocera diversity, Brazilian Journal of Biology **63(2),** 29-343. http://dx.doi.org/10.1590/S151969842003000200018

**Onana FM, Togouet SZ, Tchatcho NN, Teham HD, Ngassam P.** 2014. Distribution spatio-temporelle du zooplancton en relation avec les facteurs abiotiques dans un hydrosystèmeurbain : le ruisseau Kondi (Douala, Cameroun). Journal of Applied Biosciences **82(1),** 7326-7338. http://dx.doi.org/10.4314/jab.v82i1.6

**Onyema IC, Ojo AA.** 2008. The zooplankton and phytoplankton biomass in a tropical creek, in relation to water quality indices. Life Science Journal **5(4),** 75-82.

**Pagano M, Saint-Jean L.** 1994. Le zooplancton. *In* Durand J.R., Dufour, P., Guiral, D.&Zabi, G.S. (Eds.). Environnemente tres sources aquatiques de Côte d'Ivoire, Tome II- milieux lagunaires. Editions ORSTOM, p. 155-188.

**Pagano M, Kouassi E, Saint-Jean L, Arfi R, Bouvy M.** 2003. Feeding of *Acartia clausi* and *Pseudodiaptomus hessei* (Copepod: Calanoida) on natural particles in a tropical lagoon (Ebrié, Côte d'Ivoire). Estuarine, Coastal and Shelf Science **56(3-4),** 433-445. https://doi.org/10.1016/S0272-7714(02)00193-2

**Pagano M, Kouassi E, Arfi R, Bouvy M, Saint Jean L.** 2004. In situ spawning rate of the calanoid copepod *Acartiaclausi* in a tropical lagoon (Ebrié, Côte d'Ivoire): diel variations and effects of environmental factors. Zoological Studies **43(2),** 244-254.

**Pourriot R.** 1980.Rotifères.In : Flore et Faune Aquatiques de l'Afrique Sahélo-Soudanienne. Tome 1, Durand, J.R. and C. Lévêque (Eds.).ORSTOM, Paris 333-356p.

**Rey J, Saint-Jean L.** 1968.Les cladocères (crustacésbranchiopodes) du Tchad (Première note).Cahiers ORSTOM.SérieHydrobiologie **2(3-4),** 79-118.

**Rey J, Saint-Jean L.** 1969.Les Cladocères (Crustacés Branchiopodes) du lac Tchad (Deuxième note), Cahiers. ORSTOM, série.Hydrobiologie **3(3-4),** 21-42.

**Sampaio EV, López CM.** 1999. Zooplankton community composition and some limnological aspects of an oxbow lake of the Paraopeba River, São

Francisco River Basin, Minas Gerais, Brazil, Brazilian Archives of Biology and Technology **43,** 285-293. http://dx.doi.org/10.1590/S151689132000000030000 7

**Turner JT.** 2004. The importance of small planktonic copepods and their roles in pelagic marine food webs. Zoological Studies **43(2),** 255-266.