Anthropogenic Activities Impact on Zooplankton Community in a Tropical Coastal Lagoon (Ebrié, Côte d'Ivoire)

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Abstract

Anthropogenic activities impact on zooplankton community was investigated in a tropical coastal lagoon (Ebrié lagoon, Côte d'Ivoire). The zooplankton samples were collected during the rainy season (June and July) and the maximum of the Comoé river outflow (October) of three successive years (2006, 2007 and 2008) at six stations selected in the central-eastern and estuarine area of the Ebrié lagoon, mainly influenced by marine and freshwater inputs. The zooplankton community was composed of 47 taxa including 15 Copepoda, 13 Rotifera, 7 Cladocera and 12 other zooplanktonic organisms. Community structure was characterized by Copepoda dominance (88% and 61%, respectively of total abundance and biomass), followed by Rotifera in abundance term (7%) and by other zooplankton organisms in biomass term (35%). The main zooplankton specie was *Acartia clausi* (37% and 51%, respectively of total abundance and biomass). This specie showed highest abundance (5-20 ind.l^{-1}) and biomass (4-15 µgC.l^{-1}), mainly observed in lagoon area near Abidjan, influenced by pollution and marine water, and lowest values (< 1 ind.l^{-1} and < 1 µgC.l^{-1}) in stations distant of Abidjan, under Comoé river inputs influence and less polluted.

Keywords: Zooplankton, abundance, Biomass, Pollution impact, Tropical lagoon**,** Côte d'Ivoire

1. Introduction

Coastal ecosystems are characterized by their relatively shallow waters, partially or entirely separated from the sea by sand. They are among the most fluctuating and productive ecosystems in the world. They ecosystems are extensively exposed to anthropogenic contamination since it receives inputs from terrestrial, riverine, marine and atmospheric sources. Besides, they also constituted ecosystems most affected by anthropogenic activities such as fish, crab, and shrimp catching and farming [1] and which are subject to diverse impacts as landfills, dredging and construction, and changes in depth, etc. [2]. Also, the urban development around coastal areas and consequent increase in the levels of anthropogenic pollutants from the catchment area cause serious water quality deterioration problems worldwide [3].

In many regions of the world, the major problem that affects urban coastal lagoons is eutrophication, a process by which a body of water acquires a high concentration of nutrients from its surrounding areas [4]. Eutrophication due to the increase of anthropogenic nutrients loading, mainly nitrogen and phosphorus, from watersheds has been a central environmental issue along many marine coastal areas over a decade [5]. Some of these activities can cause irreversible deterioration of these coastal lagoon ecosystems inducing biodiversity decrease.

Zooplankton plays a major role in the functioning and productivity of aquatic ecosystems through its impact on nutrient dynamics and its key position in food webs. Most mesozooplanktonic organisms exert a strong grazing impact on the phytoplankton and on the microzooplankton ([6]; [7]). They are also a food source for organisms of the upper trophic levels such as planktivorous fish and carnivorous invertebrates [8]. So, zooplankton makes excellent indicators of environmental conditions and aquatic health within ponds because they are sensitive to changes in water quality. Indeed, they respond quickly to some factors as low dissolved oxygen levels, high nutrient levels, toxic contaminants, poor food quality or abundance, and predation [9], [10].

The coastal lagoons of Côte d’Ivoire include Aby, Ebrié, and Grand-Lahou lagoons. Among these lagoons ecosystems, Ebrié lagoon is extensively exposed to anthropogenic contamination since it receives domestic and industrial sewages, and solids wastes. Several studies on zooplankton have been performed in the Ebrié Lagoon, of which most recent are 11], [12], [13], [14]. The zooplankton organisms were discerned as a very sensitive tool for monitoring environmental variations in coastal lagoons. Due to ability of zooplankton to immediately react to changes in the water column, [15] was proposed a pattern for its community spatio-temporal variations in Ebrié lagoon urban area. This study concludes that zooplankton communities spatio-temporal variations depending on the combined effects of salinity and trophic conditions. They showed that eutrophication due to pollution in the urban area led to changes in the lagoonal zooplankton community with increasing importance of smaller organisms (*Oithona brevicornis*, *Brachionus plicatilis*, etc..). Thirty years after, the present study aims is to evaluate anthropogenic activity impact on zooplankton diversity, distribution and abundance in the Ebrié lagoons on the one hand and the relationships between zooplankton assemblages and environmental variables on the other hand.

2. Materials and methods

2.1 Study area

The Ebrié Lagoon is a brackish lagoon situated in the south of Côte d'Ivoire (5°N, 5°W), along the Gulf of Guinea shoreline [16]. This ecosystem lagoon is an elongated shallow basin, with an area of 536 km^2, a length of 130 km, and a mean depth of 4.8 m) which communicates with the Atlantic Ocean through the Vridi Canal near of Abidjan (Figure 1). It receives freshwater inputs from the Comoé, Bété, Djibi and Mé Rivers, located in the eastern extremity, and from the Agnéby River, in the central part of the lagoon. These inputs are very high during the rainy season (June-July) and during the maximum river outflow (October-November). Three main ecological areas were differentiated is this ecosystem: the western area which is oligohaline (salinity permanently < 6), the central-eastern area, estuarine, alternatively influenced by marine and freshwater inputs, with salinities showing large spatial and temporal variations (0 < salinity < 30) [13], and the north-eastern area permanently influenced by freshwater inputs (salinity permanently near to zero).

2.2 Data collection

During this study in Ebrié lagoon, data were collected in six sites select in the central-eastern area, estuarine, influenced by marine and freshwater inputs (EB1-EB6) (Figure 1). Four stations of this study were situated in zone impacted by human activities (near from Abidjan and receive domestic and industrial sewages) and located in the estuarine part of the Ebrié lagoon (near of the Vridi channel) (Cocody bay: EB3; Banco bay: EB4; Boulay island: EB5 and Biétry bay: EB6). The two other sites were no (or relatively less) impacted by human activities (far from Abidjan), so less polluted and located far from the Vridi channel

(Comoé river: EB1 and Comoé river estuary: EB2). Data (zooplankton and abiotic parameters) were collected during the rainy season (June and July) and the maximum of the Comoé river outflow (October) of three successive years (2006, 2007 and 2008).

The physical and chemical parameters (water temperature, dissolved oxygen concentration, electrical conductivity, turbidity and pH) were measured in surface and near the bottom, with a portable multi-parameter probe (HANNA HI 9829). Water samples were collected with a Niskin-bottle and preserved at 4°C for subsequent analyses of nutrients (phosphate, nitrite, nitrate and ammonia) with a Spectrophotometer (model Shimadzu, UV visible), according to protocols described by [17]. Suspended solids (seston) were determined on preweighed Whatman GF/F filters (47 mm diameter). After filtration, filters were dried (105°C, >1 h) and reweighed. The same filters were then burnt (500°C, >2 h) and reweighed to estimate the suspended mineral matter. Biochemical oxygen demand was measured using methods according to [18] for water analysis.

The zooplankton sampling was made using a cylindro-conical net (64 µm in mesh opening size, 30 cm in mouth diameter and 1 m in length) by filtration. All sampling was performed during the day (6:30-10:30) by vertical hauls from the bottom to the surface to integrate possible vertical variations in zooplankton abundance and minimize effects of diel vertical migrations [11], [12, [19]. Samples were immediately preserved in a mixture of lagoon water and borax-neutralized formalin at a final concentration of 5%. Zooplanktonic organisms were identified according several documents: [20] for marine Copepods and [21] freshwater copepods identification; [22] for Rotifers, [23] and [24] for Cladoceran.

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 individual per taxa.

2.3 Zooplankton density estimation and analytical procedure

Zooplankton densities, expressed as numbers per liter (ind.l^{-1}), were calculated by dividing the number of organisms estimated in each sample by the volume of water filtered in the field (that is, cylinder defined by the net opening area: 0,071 m^2) and the water depth which varied between 3-6 m according the stations. Environmental influences on zooplankton composition and distribution were assessed with a ReDundancy Analysis (RDA). For this analysis, only taxa whose abundance was ≥ 0.1% of the total numbers were taken into account. Species richness and ecological diversity indices (Shannon and Equitability) were used to determine structure and ecological dynamics of zooplankton community. Besides, one-way analyses of variance (ANOVAs, with a general linear model) were performed to test the effects of site on the zooplankton density, species richness and ecological diversity indices. All data have been $\log_{10}(x + 1)$ transformed prior to analysis to increase normality. All steps of this method were computed using Statistica 7.1 software.

3. Results

3.1 Environmental parameters

Mean, minimum and maximum values of environmental parameters measured in Ebrié lagoon during this study are consigned in the table 1. Generally, environmental parameters measured during this study were characterized by highest average values obtained in the estuarine and polluted area, near Abidjan and the Vridi channel (EB3 to EB6) and lowest values in area far from Abidjan and the Vridi channel: Comoé river (EB1) and its estuary (EB2), excepted for dissolved oxygen. For this variable, average values in area far from Abidjan and the Vridi channel were higher (4.17-6.54 mg/L) than average values in area near Abidjan and Vridi channel (2.93-4.86 mg/L). In these areas near Abidjan and Vridi channel, anoxias (0 mg/l) were observed near the bottom in Cocody, Banco and Biétry bays. Salinity in the sites EB1 and EB2 were zero in the water column while it were < 1 ‰ in surface water and varied between 12 and 31 ‰ in the bottom of sites near Abidjan and Vridi channel (EB3 to EB6).

Conductivity showed the same variation pattern as salinity, with low values in stations EB1 and EB2, and in the bottom of sites near the vridi channel (< 2 mS/cm) and high in the other sites (8-45 mS/cm). The same tendency is also observed with suspended solids and biochemical oxygen demand. For nutrient, nitrite shows the same variation pattern as salinity and conductivity. Highest nitrate average values were obtained in Banco bay (10.25-11.35 µM/L, mean: 7.83 µM/L) while lowest values were unregistered in stations EB1 and EB2, and in Biétry bay (0.90-5.80 µM/L, means: 3.23-3.73 µM/L). Highest ammonium values were observed in Cocody, Banco and Biétry bays (3.33 to 59.90 µM/L), with peak in Biétry bay (12.20-59.90 µM/L, mean: 33.28 µM/L).

3.2 Zooplankton composition

A total of forty-seven zooplankton taxa were enumerated in all the sampling stations during this study. Their spatial distribution is shown in Table 2. These 47 zooplanktonic taxa were belonging to Rotifers (12 Taxa, 25.53% of total diversity), Cladocerans (7 taxa, 14.89% of total diversity), Copepods (15 taxa, 31.92% of total diversity), and other zooplankton organisms (13 taxa, 27.66% of total diversity). Rotifers taxa were belonging 9 genuses. *Brachionus* was the greatest diversity (with 4 species), followed by *Filinia* (2 species).

The others genuses (*Platyas*, *Keratella*, *Lecane*, *Hexarthra*, *Trichocerca*, *Asplanchna* and *Epiphanes*) have a single taxon each. Cladocerans group includes 7 taxa belonging to 7 genera. Copepods include 12 genuses plus undetermined copepods nauplii and harpacticoids. Other groups including mainly various insect, gastropods, Polychaete and fish larvaes, plus decapods zoe, fish egg and *Banalus* spp. Nauplii. Other group also includes coastal marine or estuarine organisms such as chaetognaths, Euphausiacea, mysids and ostracods.

According to their origin, they could be grouped into three main zooplankton assemblages: freshwater (25 taxa, 53.19% of total diversity), brackish (9 taxa, 19.15% of total diversity), and marine (12 taxa, 25.53% of total diversity) (Table 2).

Our study show that in Ebrié lagoon, zooplankton taxonomic richness varied according to sampling stations and year (Figure 2). Zooplankton richness obtained in 2007 was highest (8-22 taxa) than richness unregistered in 2006 and 2008 (8 -14 taxa). According to sampling site, in 2007, the highest diversity was recorded in Boulay island (EB5) (22 taxa), versus 8 taxa in Biétri bay (EB6). In 2006 and 2008, the highest diversity was obtained in Cocody bay (EB3) (13-14 taxa). Shannon diversity index values were low and varied between 0.73 and 1.6 bit/ind. The highest values of Shannon diversity index were recorded in far away from Abidjan and the Vridi channel (impacted by urban pollution) (EB1 to EB2) (1.38 - 1.6 bit/ind.). Opposite, lowest Shannon values were obtained in stations in area near Abidjan and the Vridi channel (more polluted) (EB3 to EB6) (0.73-1.03 bit/ind.). Similar spatial pattern was observed for equitability index, with lowest values in sites EB3 to EB6 (polluted area) (0.33-0.63) and highest values in stations less polluted (EB1 and EB2) (0.70-0.81).

3.3 Zooplankton community structure, Abundance and Biomass

Zooplankton abundance and biomass varied, respectively from < 0.39 to 105.30 ind.l^{-1} and 2.68 to 39.67 µgC.l^{-1}depending on the station and the years (Figure 2). During the study, lowest zooplankton abundance (< 10 ind.l^{-1}) and biomass (< 10 µgC.l^{-1}) were generally obtained in the sampling sites EB1 and EB2. In contrast, highest abundances were observed in stations EB5 (Boulay island) (41-105 ind.l^{-1}) in 2006 and 2007, and in stations EB4 (Banco bay) and EB5 (11-13 ind.l^{-1}) in 2008. Highest zooplankton biomass were observed in stations EB3 (Cocody bay) and EB4 (13-17 µgC.l^{-1}) in 2006, in stations EB5 and EB6 (Biétry bay) (36-40 µgC.l^{-1}) in 2007 and in EB4 and EB5 (12-13 µgC.l^{-1}) in 2008.

On average, zooplankton community was dominated by copepods groups in terms of abundance (15.58 ind.l^{-1}; 88.2% of total zooplankton abundance) and biomass (8.00 µgC.l^{-1}, 60.81% of total zooplankton biomass). However, in station EB1 and EB2, zooplankton community was dominated by rotifers (43.96-53.70%), followed by copepods (23.85-33.06%). Of course, rotifers were unregistered with most important density in the Banco bay (EB4) (4.85 ind.l^{-1}) with *Brachionus plicatilis* as species. It was the most abundant rotifer species (63.95%), followed by *Trichocerca* sp. (12.62%), *Brachionus falcatus* (9.62%), *B. calyciflorus* (5.57%). So, our study shows that in Ebrié lagoon, rotifers were mainly dominated by *Brachionus* (76.14%). Copepods group was mainly dominated by *Acartia clausi* (7 ind.l^{-1}, 45.10% of total abundance; 6.65 µgC.l^{-1}, 83.13% of total biomass) and undetermined copepod nauplii (7.30 ind.l^{-1}, 46.92%) who are certainly those of *Acartia clausi*. *Acartia clausi* lowest density and biomass was obtained in stations EB1 and EB2 ($<$ 0.02 ind.l^{-1}, $<$ 0.01 µgC.l^{-1}) while highest abundance and biomass were observed in Biétry bay (EB6) (20.10 ind.l^{-1} and 15.49 µgC.l^{-1}) and in Boulay island (EB5) (12.32 ind.l^{-1} and 12.36 µgC.l^{-1}). Undetermined copepod nauplii show the same tendency, with lowest abundance and biomass in stations EB1 and EB2 ($<$ 2 ind.l^{-1} and $\leq$ 0.2 µgC.l^{-1}) and maximum values in Biétry bay (17.72 ind.l^{-1} and 2.30 µgC.l^{-1}).

3.4 Correlation zooplankton-environmental parameters analyses

Zooplankton taxa-environmental parameters relationships are shown in figure 4. Cumulative percentage variance of species-environmental relation expressed by the first two axes was equal to 75%, the first axis representing ≈ 55.3%. Analysis performed on zooplankton and environmental data distinguish principal 2 two zones (Figure 4).

The first group, was positively correlated with the axis I and comprised stations located far from to important human activities area and the Vridi channel (Comoé river: EB1 and Comoé river-Ebrié lagoon confluent: EB2). The second group of stations was negatively correlated to the axis I and comprised stations located in human activities area (near Abidjan) and near the Vridi channel and (Cocody bay: EB3, Banco bay: EB4, Boulay island: EB5, and Biétry bay: EB6). The first group of stations was characterized by salinity equal zero in water column, positively correlated to dissolved oxygen and mainly characterized by the presence of freshwater zooplankton taxa (as *Brachionus calyciflorus*, *B. falcatus*, *trichocerca* spp., *Filinia* spp., *Lecane* sp., *Bosmina longirostris*, *Ceriodaphnia cornuta* and undetermined harpacthicoids).

The second group of stations was positively correlated to nutrient (nitrite: NO_2^-, nitrate: NO_3^-, ammonium NH_4^+, and phosphate: P-PO_4), pH, suspended solids, chemical and biological oxygen demand. Zooplankton taxa associated to this part of the Ebrié lagoon were marine (*Paracalanus* sp., *Temora stylifera*), brackish (*Acartia clausi*, *Brachionus plicatilis*, Cirripedia larvae, Gastropods larvae) and freshwater communities (*Thermocyclops* sp., *Moina micrura* and Chironomidae larvae).

4. Discussion

A total of Forty-seven zooplankton taxa were identified in all the sampling stations during this study. These taxa are divided into four groups Copepoda, Rotifera, Cladocera and other zooplankton. Total zooplankton richness (47 taxa) recorded in Ebrié lagoon during this study is relatively low compared to zooplankton richness obtained in this lagoon by [25] (66 taxa). It is also relatively low compared to other lagoon of Côte d'Ivoire: Grand-Lahou (65 taxa ; [26]), Aby-Tendo-Ehy (53 taxa ; [27]). The difference in richness in this study (47 taxa) and previous studies cited below (53 to 66 taxa) could be explained by factors as study or sampling duration (one season during three years versus annual cycle for other studies), sampling sites prospected (one part of Ebrié lagoon versus sampling performed in all lagoon area for other studies), etc.. Zooplankton taxonomic richness varied according stations (10 to 28 taxa), with highest richness in sampling site Comoé river (less polluted) (EB1, 28 taxa) and lowest richness in Biétry bay (more polluted) (EB6, 10 taxa). Similar situation, with low richness in polluted area and high richness in area no or less polluted, was also reported by several authors as [15], [28] and [29]. In these polluted areas as Biétry bay, low zooplankton diversity may be due to the organic wastes like blood and animal faeces (from slaughterhouse Port-Bouët) and domestic and industrial sewages increased nitrate levels which in turn increased the biochemical oxygen demand values of the sites. These factors can have an effect on certain zooplankton species filtration mechanism (food acquisition limitation) and recruitment [30].

This study revealed quantitative dominance of copepods (88.2% and 61%, respectively of total zooplankton abundance and biomass) and confirms their numerical dominance in lagoons of Côte d'Ivoire: Aby (92% of total abundance; [31]), Ebrié (51-99%; [31], [15], Grand-Lahou (81%; [26]). However, these results were in contradiction with those of [27] in Aby-Tendo-Ehy lagoon system where numerical dominance of rotifers was mentioned (83% of zooplankton total abundance).

Difference in zooplankton composition between Aby-Tendo-Ehy lagoon system (rotifers qualitative dominance) and the others lagoons of Côte d'Ivoire (copepods dominance) may be explained mainly by salinity and pollution action in these ecosystems. Indeed, in Grand-Lahou and Ebrié lagoons, salinity varied largely between 0 and 30, predisposing in these ecosystems to development of different zooplankton communities (freshwater, brackish and marine) [15], [16], [26] while in Aby-Tendo-Ehy lagoon system, salinity is low (< 2) and favours freshwater zooplankton community with rotifer dominance [27]. In the present study, the main zooplankton taxa obtained is *Acartia clausi* (37% and 51%, respectively of total zooplankton abundance and biomass). This result confirms those reported by [16] in Ebrié lagoon where *A. clausi* represents 32 to 88% of total abundance. In contrast, *Oithona bravicornis* was the main taxa in Grand-Lahou lagoon (28% of total abundance vs. 5% for *A. clausi*; [26]), while *Lecane leontina* was the main taxa in Aby-Tendo-Ehy lagoon system [27]. Numerical dominance of *A. clausi* in Ebrié lagoon [15], [16] and in this study could be explained by combined impact of pollution and salinity on zooplankton community in the sampling zone. Indeed, in this study, *A. clausi* is obtained mainly in lagoon zone (Cocody, Banco, Biétry bay and Boulay island) impacted by domestic and industrial sewages, and solids wastes and located in the estuarine part of the Ebrié lagoon (near of the Vridi channel). In these areas near Abidjan and Vridi channel (Cocody, Banco and Biétry bays), sea water incursion during the tide increases salinity, generally in bottom water during the rainy season and the Comoé river outflow. Moreover in this zone, anoxia (0 mg/l) consecutive to eutrophication was observed near the bottom (vs. 3.19-4.17 mg/L), with high values of suspended solids (Mean: 33.38 to 48.81 mg/L vs. 17.16 and 20.88 mg/L in zone no or less impacted by pollution: EB1 and EB2), biochemical oxygen demand (Mean: 122 to 702 mg/L vs. 32 to 200 in other zones) and ammonium (Mean: 20 to 33 µM/L vs. < 5 µM/L in other zones). *Acartia* species are considered as organisms supported the low oxygen concentrations (< 2 $mg.l^{-1}$) as demonstrated for the co-generic species *A. tonsa* by [32]. This result is also in agreement with those reported in other lagoon and marine ecosystems where *Acartia* species dominance (*A. clausi* and *A. tonsa*) was associated inshore polluted waters and with the environmental quality deterioration due to the anthropogenic activity [33], [34], [35], [36].

Development of *Acartia* in zones greatly polluted and organic debris loaded may be explained by its large tolerance of environmental factors variation, its omnivorous and its capacity to adapt to food variety [37], with particles sizes varying between 6 and 21 µm [12]. The suitability of other zooplankton organisms as indicator of water quality, with dominance of several geneses and/or species in polluted aquatic ecosystems, has been demonstrated several previous studies: *Brachionus* and *keratella* [8], [38]; *Eurytemora affinis* [39], [40]; *Thermocyclops decipiens* [41].

The numerical predominance of *Oithona brevicornis* in the Grand-Lahou lagoon could be explained by the stronger marine influence in this ecosystem and it's less polluted status [26]. Freshwater zooplankton numerical predominance (*Lecane leontina*) in Aby-Tendo-Ehy lagoon system could be explained by the high freshwater inflow from Bia and Tanoe rivers on the one hand, and the weak marine influence in this ecosystem on the other hand, who confer to this coastal lagoon a freshwater character (< 2 ppt) [27].

Structuring action of salinity on zooplankton community composition and distribution in lagoon ecosystem is also mentioned by several authors as [4], [17], [26] and [42]. According to [43], the action of the salinity drives the taxonomic composition of zooplankton by either supporting or excluding species (directly, or indirectly by modifying inter specific competition). So, marine and brackish zooplankton organisms (as *Paracalanus* sp., *Temora stylifera*, *Acartia clausi*, *Oithona brevicornis*, *Brachionus plicatilis*, Gastropod and Cirripedia larvae, etc.) were always recorded mainly in the zones near the vridi channel, which is a communication channel between Atlantic Ocean and Ebrié lagoon. On the contrary, freshwaters organisms (as *Brachionus falcatus*, *B. calyciflorus*, *Filinia* sp., *Lecane* sp., *Ceridaphnia cornuta*, *Bosmina longirostris*, etc.) were observed in the lagoon sectors (sampling site EB1 and EB2) with maximal continental influence through Comoé river.

As well as these parameters, several factors can affect zooplankton abundance, distribution and structure in coastal lagoons, notably: predation by other invertebrates and fish [44], [45], [46], nutritive particles size [47], competition for food 48, food quality and the quantity [49], etc.

5. Conclusion

The present study evaluates anthropogenic activity impact on zooplankton diversity, distribution and structure in the Ebrié lagoons and proposes a pattern of abundance and biomass spatial variation in relation with environmental parameters. This study reveals that, zooplankton community composition and their spatial variations are mainly controlled by salinity variations closely linked to marine water influence and Comoé river freshwater inputs on the one hand, and by pollution on the other hand. Pollution due to high input of solids maters, industrial and domestic sewastes in Ebrié lagoon impact on zooplankton abundance and structure and contribute to *Acrtia clausi* predominance in area near Abidjan (45.10% of total copepod abundance and 83.13% of total copepod biomass). This study confirms as well as the zooplankton constitutes a sensitive tool for monitoring environmental changes in coastal lagoons.

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Tables and figures

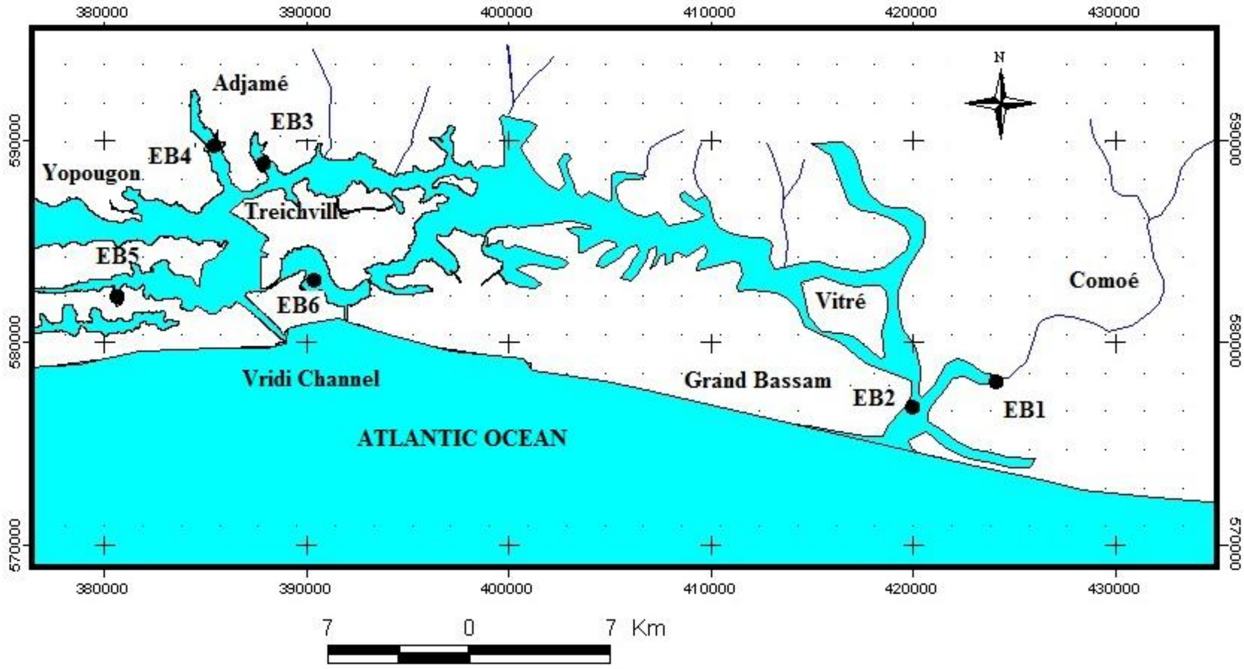


Table 1: Summary of the Physico-chemical parameters measured in Ebrié lagoon during three studies: June, July and October 2006, 2007 and 2008 (Temp.: Temperature, Cond.: Conductivity, NO_2^-: Nitrite, NO_3^-: Nitrate, NH_4^+: Ammonium, PO_4^3: Phosphates, SS: Suspended Solids, COD: Chemical Oxygen Demand, BOD_5: Biological Oxygen Demand)

		Temp. (¦C)	pH	Salinity (‰)	Cond. (mS/cm)	Oxygen (mg/L)	NO_2^- (µM/L)	NO_3^- (µM/L)	NH_4^+ (µM/L)	PO_4^{3-} (µM/L)	SS (mg/L)	DCO (mg/L)	BOD_5 (mg/L)
Bietry bay	Max.	35,10	8,53	27,60	45,70	8,16	6,40	5,80	59,90	10,30	71,80	1147,00	197,00
	Min.	28,50	6,93	0,60	1,67	0,00	1,02	0,90	12,20	1,22	13,24	373,30	100,80
	Moy.	31,49	7,85	8,53	14,37	3,93	3,53	3,23	33,28	5,84	38,66	702,04	146,29
Boulay island	Max.	35,30	7,85	27,60	40,80	6,95	6,91	6,80	9,80	3,02	53,66	500,00	89,00
	Min.	28,30	7,58	0,70	1,60	2,93	0,84	3,65	1,70	1,20	9,72	89,00	44,13
	Moy.	31,80	7,72	8,99	14,71	4,86	2,04	4,88	4,50	1,83	33,38	309,63	65,73
Banco bay	Max.	39,50	8,88	30,80	40,60	9,27	11,10	11,35	35,50	4,85	2611,00	633,00	178,20
	Min.	27,80	7,33	0,00	0,13	0,00	1,76	10,25	3,33	1,40	15,00	200,00	61,00
	Moy.	33,36	7,33	8,11	12,07	2,93	4,20	7,83	19,83	2,60	43,47	365,45	116,50
Cocody Baiy	Max.	38,70	7,49	12,50	31,70	5,87	6,91	6,10	42,60	5,70	80,40	467,00	145,60
	Min.	27,80	6,97	0,00	0,11	0,00	1,76	4,60	10,50	1,40	17,04	200,00	75,00
	Moy.	32,93	7,22	4,29	8,65	3,66	3,75	4,73	23,75	2,79	48,81	365,58	122,23
Comoé estuary	Max.	29,80	7,06	0,00	0,18	5,73	1,62	4,05	8,33	2,33	23,10	200,00	26,40
	Min.	29,20	6,71	0,00	0,04	3,19	0,62	3,25	2,22	1,66	13,40	80,00	8,80
	Moy.	29,50	6,89	0,00	0,09	4,83	1,28	3,65	4,72	1,99	17,16	145,00	19,70
Comoé river	Max.	29,70	7,11	0,05	0,62	11,70	1,57	4,05	5,94	2,40	33,90	240,00	42,50
	Min.	29,10	6,83	0,00	0,04	4,17	0,72	3,40	2,80	1,76	12,50	190,00	18,00
	Moy.	29,40	6,93	0,01	0,21	6,54	1,23	3,73	4,67	2,15	20,88	207,50	32,60

Table 2: Distribution of zooplankton taxa collected in the Ebrié lagoon during June, July and October 2006, 2007 and 2008 ; + : taxa presence, the symbols of the taxa for the multivariate analyses (RDA). (*freshwater origin, ** brackish origin and *** marine origin).

		Symbols	EB1	EB2	EB3	EB4	EB5	EB6
Rotifers	*Brachionus falcatus**	Bfal	+	+	+			
	*B. calyciflorus**	Bcal	+	+	+			
	*B. plicatilis***	Bpli			+	+		+
	*B. caudatus**	Bcau		+	+			
	*Platyias quadricornis**	Pqua	+	+				
	Keratella sp.*	Kera	+		+			
	Lecane sp. *	Leca	+					
	Filinia longiseta. *	Flon	+					
	Filinia opoliensis *	Fopo	+					
	Hexarthra sp. *	Hexa	+	+				
	Trichocerca sp. *	Tric	+	+				+
	Asplanchna sp. *	Aspl	+	+				
	Epiphanes sp. *	Epip	+					
Cladocerans	*Bosmina longiristris**	Blon	+	+	+		+	
	Bosminopsis sp. *	Bosm	+	+				
	*Moina micrura**	Mmic	+	+	+	+		+
	Chydorus sp. *	Chyd	+	+				
	*Diaphanosoma excisum**	Dexc	+	+	+	+		+
	*Moinodaphnia maclayi**	Mmac			+	+		
	*Ceriodaphnia cornuta**	Ccor	+			+		
Copepods	Nauplii undetermined	Ncop	+	+	+	+	+	+
	*Acartia clausi***	Acla	+	+	+	+	+	+
	*Pseudodiaptomus hessei***	Phes			+	+	+	
	Eucalanus sp. ***	Euca					+	
	*Centropages furcarus****	Cfur					+	
	Paracalanus sp. ***	Para			+	+	+	
	*Temora stylifera****	Tsty					+	
	*Oithona brevicornis***	Obre					+	

	*O plumifera****	Oplu					+	
	Oncea spp. ***	Once					+	
	Corycaeus spp. ***	Cory					+	
	Mesocyclops sp. *	Meso	+	+	+			
	Thermocyclops sp. *	Ther		+	+	+	+	+
	Harpacticoids	Harp		+		+	+	
	undetermined							
	*Euterpinia acutifrons****	Eacu					+	
	Chaetognathe***	Chae					+	
	Euphausiacea***	Euph	+	+	+		+	
Other	Mysidacea***	Mysi					+	
Zooplankton	Ostracoda*	Ostr	+		+			
	Chironomidae larvae*	Chirolarv	+	+	+	+		
	Chaoborus larvae *	Chaolarv	+	+	+			
	Other insect larvae *	Ineslarv	+	+				
	Gastropods larvae**	Gaslarv	+		+		+	+
	Polychaete larvae**	Pollarv					+	
	Decapoda Zoe***	Dzoe	+	+	+		+	
	Banalus spp. nauplii**	Cirlar			+		+	+
	Fish larves**	Fishl	+	+	+		+	+
	Fish Egg**	FishEg					+	
	47		28	23	23	12	23	10

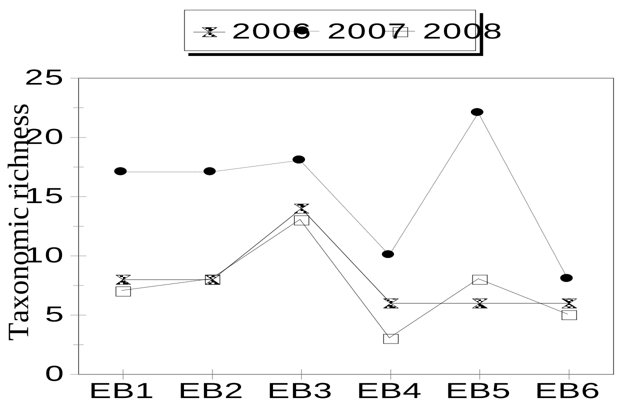
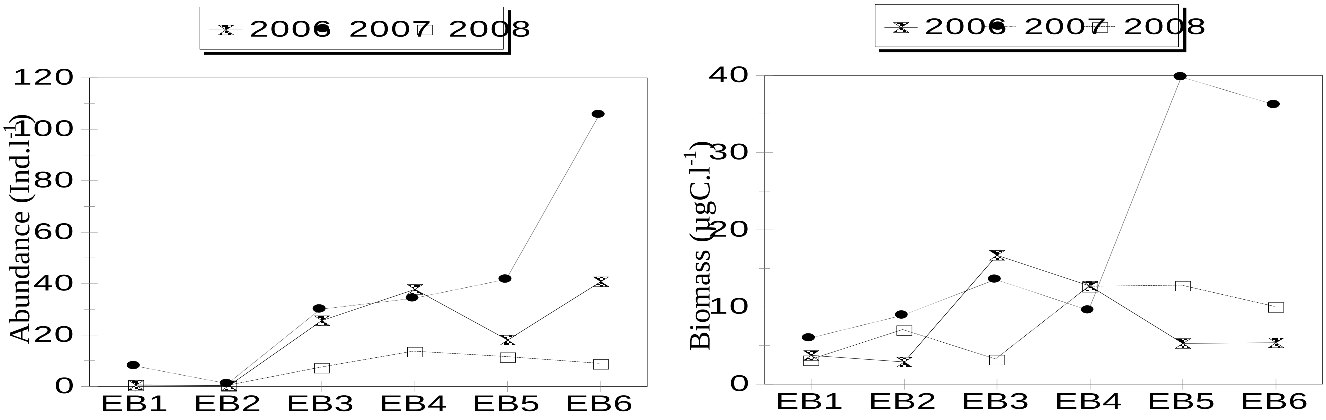
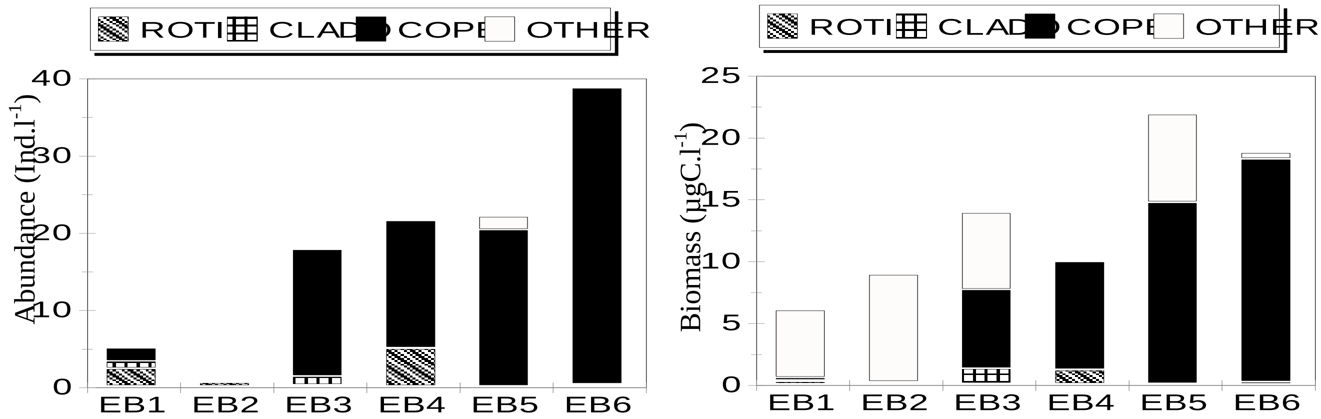


Figure 2: Spatial variation of taxonomic richness of zooplankton sampling in Ebrié lagoon during June, July and October (rainy seasons) 2006, 2007 and 2008.



Rotifera, Clado: Cladoceran, Cope: Copepoda, Others: others zooplankton)



zooplankton group obtained during three studies in Ebrié lagoon: June, July and October 2006, 2007 and 2008 (Roti: Rotifera, Clado: Cladoceran, Cope: Copepoda, Others: others zooplankton)

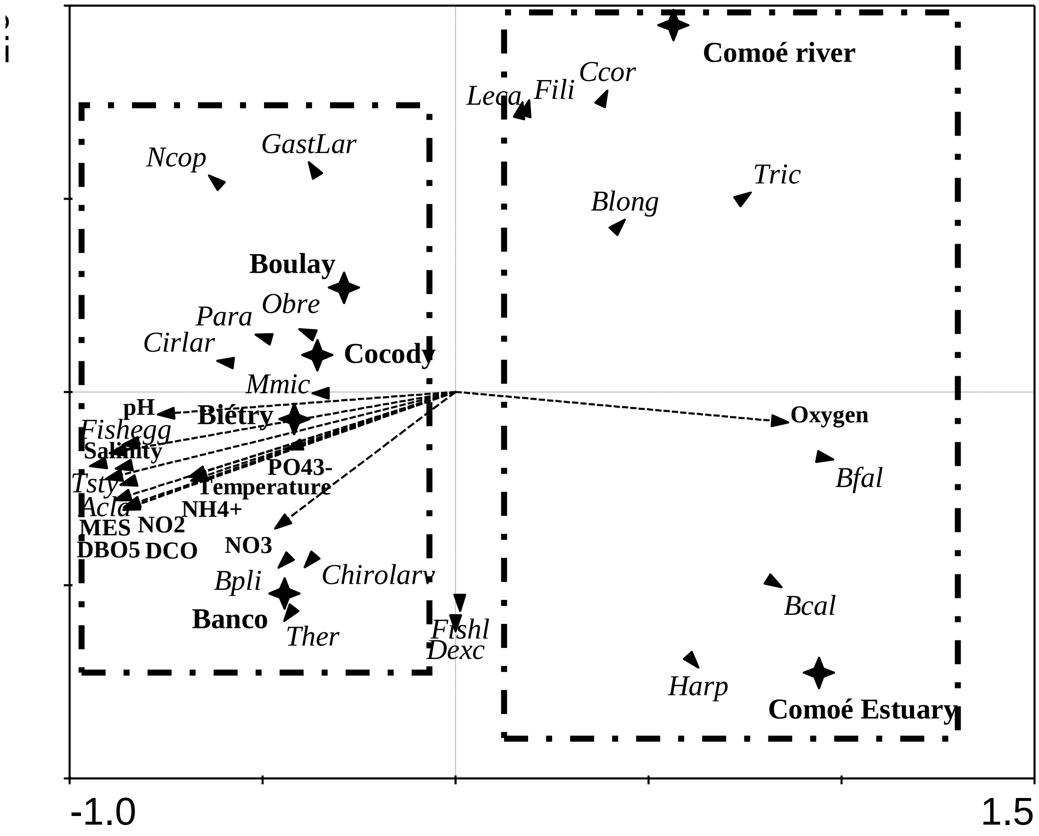


Figure 4: RDA on data from environmental parameters and zooplankton taxa collected in the Ebrié lagoon during three studies: June, July and October 2006, 2007 and 2008 (Symbols: see table 1).