

Zooplankton Dynamics of the Kienke Estuary (Kribi, South Region of Cameroon): Importance of Physico-Chemical Parameters

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Abstract

All Cameroonian estuarine systems, like the Kienke estuarine system (urban area of the port city of Kribi), are considered, as everywhere in the world, as unstable and vulnerable coastal ecosystems insofar as they are influenced by anthropogenic activities (port facilities, industrial facilities), without forgetting climate change. The present work was initiated in order to assess the influence of the seasonal evolution of physico-chemical parameters on the dynamics of zooplankton in the estuarine system of the Kienke. A study to assess the influence of seasonal evolution of some physico-chemical parameters on Zooplankton population dynamics was conducted from June 2016 to August 2017 in the Kienke estuarine system (Kribi, South Cameroon Region). Samples were collected in five (05) sampling points at the lower stream, at the confluence and then at 100 meters from the bank at sea following a monthly frequency. The Kienke estuary was characterized by spatio-temporal variations of physico-chemical parameters. These parameters are high temperature, relatively high electrical conductivity and salinity, and a relatively basic hydrogen potential (pH). Nutrients (ammonia nitrogen, nitrates and orthophosphates) were relatively low in the Kienke estuary. The organic pollution index (OPI) indicated moderate to high water pollution. At the surface and at depth, during the long dry season (December to February), Zooplankton densities were very low in the Kienke estuarine system. But rather high during the main rainy season (August to October). The results show that 105 species of Zooplankton belonging to 46 families grouped into four orders were identified. At the surface, 52 species of Zooplankton belonging to 23

families and 4 orders were identified, while at depth, 53 species of Zooplankton belonging to 23 families were also identified. The most abundant group was the Copepods represented by the following species: *Tropocyclops confinis* Kiefer, 1930; *Mesocyclops* sp. Sars, 1914; *Macrocyclus* sp. Claus, 1893; *Thermocyclops* sp. Kiefer, 1929; *Parvocalanus elegans* Adronov, 1972 and *Clausocalanus* sp. Giesbrecht, 1888. Overall, there was a predominance of microcrustaceans (Cladocera and Copepoda) over rotifers. The results obtained in this work will be of capital importance for the elaboration of sustainable management policies for the estuary of the city of Kribi.

Keywords

Dynamics, Kienke Estuary, Kribi, Physico-Chemical, Zooplankton

1. Introduction

Estuaries are privileged areas for human activities. Indeed, these transition zones between continental and marine waters are favorable places for the development of economic activity [1]. Estuaries are also sites of great biological interest in which physical, chemical and biological interactions generate ecosystems among the most active of all natural environments. The interest of estuarine ecosystems for marine species is linked to the presence of high populations of Zooplankton, essential links in the trophic chain between primary and secondary production, which make estuaries ideal nursery areas for the development of larvae and juveniles of crustaceans and fish (estuarine ecophase). Estuaries are also sites of great biological interest in which physical, chemical and biological interactions generate some of the most active ecosystems of all natural environments. They constitute a gateway for the transport of organic matter of continental and oceanic origin, either from upstream to downstream, or from downstream to upstream depending on the conditions, the rhythm of the tides and the seasonal fluctuations of the flows [2]. The interest of estuarine ecosystems for marine species is linked to the presence of high populations of Zooplankton, essential links in the trophic chain between primary and secondary production, which make estuaries ideal nursery areas for the development of larvae and juveniles of crustaceans and fish (estuarine ecophase) [3]. Thus, the different species of the estuarine pelagic ecosystem have developed strategies to migrate or maintain themselves in these environments favorable to their growth and/or reproduction [4]. One of the key phenomena generated by the interaction of stream dynamics and tidal dynamics, especially in high tidal seas, is the formation of a zone of maximum turbidity [5]. Previous studies have reported the practice of industrial fishing in these areas since 1912 [6]. Crosnier [7]; Raitt and Niven [8] observed the daily behavior of shrimp on experimental trawlers to guide fishermen. Le Guen [9] and Crosnier [10] studied the daily activity rate of the shrimp *Penaeus duorarum* Burkenroad, 1939 on board a Cameroonian trawler "MALIMBA".

Philip Hisard [11] has also studied the influence of the variation of hydrological parameters on the enrichment of the waters of the euphotic layer. Similarly, for several decades, scientific campaigns have made it possible to determine the oceanographic parameters of the Cameroonian continental shelf, such as the “Guinea Trawling Survey (GTS)” campaigns from 1963 to 1964; the first of the Oceanographic Vessels (N/O) Fiolent in 1976; the first of the oceanographic Vessels (N/O), Fridtjof Nansen in 1981, Longhurst [12]; Robertson [13] and Stromme [14]. The work on board the Oceanographic Vessels (N/O) Nizery 1991, 1992, & 1993 aimed at developing sedimentological maps of the Cameroonian shelf. Otherwise, the coastal zone of Cameroon is historically the maritime gateway of several Central African countries, little is known about the dynamics of Zooplankton. This study aimed to investigate the structure and dynamics of Zooplankton in the lower Kribi estuary in the southern region (Cameroon).

2. Material and Methods

2.1. Study Site Parameters

The study was carried out from March 2015 to August 2017, in two phases: the first phase (March-April 2015) consisted of surveys, which allowed the selection of the different sampling points. Based on multiple factors, of which the most determining were the human activity around the stream, the type of water (fresh, brackish and salt) and fishing activity, as well as, the interest of the populations and the distance from the sea. Five sampling points designated as K1, K2, K3, K4 and K5 were selected. The location of these study points was done using a GARMIN etrex 30 global positioning system (GPS). These five (05) sampling points were delineated over a distance of approximately 18 Km. The second phase, from June 2016 to August 2017 consisted of measuring hydrological variables and taking samples for physicochemical and biological analyses.

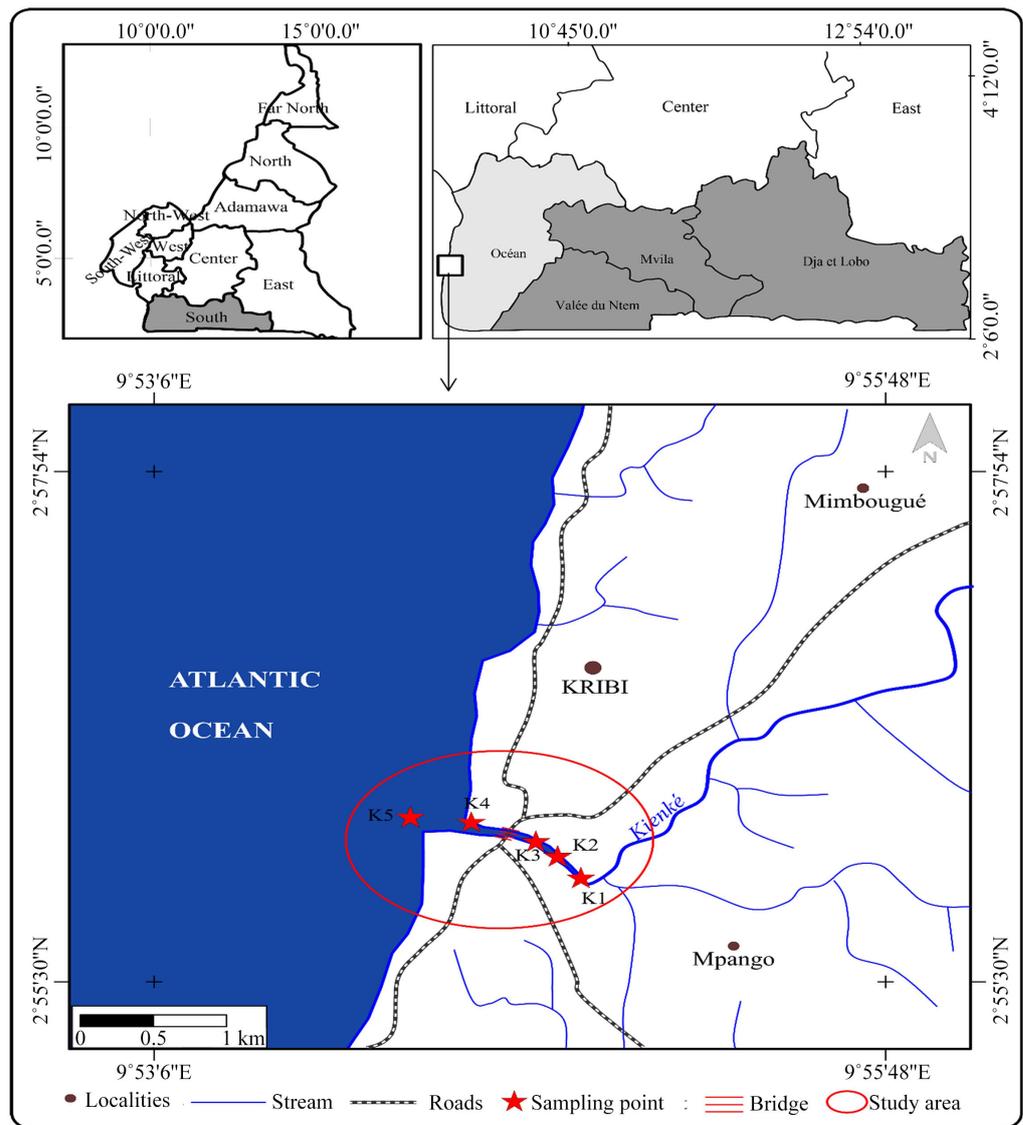
2.2. Presentation of the Sampling Points of the Kienke Estuary

The sample points codes, geographic coordinates, altitudes and main activities of these sample points are represented in **Table 1**. Overall, it appears that this estuary is located between 9°53'6" and 9°55'48" East longitude and 2°55'30" and 2°57'54" North latitude with an average altitude of around 10 m above sea level and an economic activity that revolves around artisanal fishing (**Figure 1**).

Tous les systèmes estuariens Camerounais à l'instar, du système estuarien de la Kienke (zone urbaine de la ville portuaire de Kribi) sont tous considérés partout dans le monde, comme étant des écosystèmes côtiers instables et vulnérables dans la mesure où ils sont influencés par des activités anthropiques (installations portuaires, installations industrielles) sans toutefois oublier le changement climatique. C'est dans ce contexte que le présent travail a été initié afin de comprendre l'influence de l'évolution saisonnière des paramètres physico-chimiques sur la dynamique du zooplancton dans ce système estuarien de la Kienke.

Table 1. Geographical coordinates of the sampling points studies.

Sampling points (codes)	Altitude (meters)	Distance separating the sampling points from the sea (m) (K5)	Geographical coordinates	Main activities
K1	24.36	1366	009°54'421"E 02°56'30"N	Disembarkation/embarkation of ships/open defecation
K2	23.99	1092.48	009°54'389"E 02°56'309"N	Disembarkation/embarkation of boats
K3	22.43	911.59	009°54'313"E 02°56'405 " N	Swimming/fishing
K4	9.66	434.39	009°54'185"E 02°56'578"N	Sand mining/peaches
K5	0	0	009°54'094"E 02°56'539"N	Marine environment



(a)



Figure 1. Geographical situation of the sampling points (a) in Kienke stream INC [15]: partial view of sampling points K1 (b), K2 (c), K3 (d), K4 (e) and K5 (f).

All Cameroonian estuarine systems, like the Kienke estuarine system (urban area of the port city of Kribi), are considered, as everywhere in the world, to be unstable and vulnerable coastal ecosystems insofar as they are influenced by anthropic activities (port installations, industrial installations), without forgetting air conditioning. It is in this context that the present work was initiated in order to understand the influence of the seasonal evolution of physico-chemical parameters on the dynamics of zooplankton in the estuarine system of the Kienke.

T Dans la Kienke de surface, les copépodes dominent la communauté zooplanctonique avec 81.89% des individus récoltés. Ils sont suivis par les Cladocères qui représentent 17.04% des individus puis les rotifères et les Ostracodes qui constituent respectivement 66.27%, 70.45%, 71.87%, 76.76%, 81.89%, des abondances aux points d'échantillonnage K1, K2, K3, K4, K5. En surface, la variation des densités de Zooplancton au cours du temps, les plus fortes densités ont été notées en août 2017 puis en juillet 2017 avec respectivement 0.098 ind/L puis 0.050 ind/L. Tandis que les plus faibles densités, ont été observées en octobre 2016 puis en février 2017 avec respectivement 0.050 ind/L et 0.057 ind/L (**Figure 8(a)**). Par ailleurs, les variations saisonnières des abondances du Zooplancton n'étaient pas significatives ($p < 0.100$; $I = 0.05$) en effet, les densités de 0.0625 ind/L, 0.0725 ind/L et 0.0825 ind/L ont été enregistrées respectivement aux points d'échantillonnage.

2.3. Data Collection and Analysis

2.3.1. Sampling Water for Physico-Chemical Analysis

Shifty on the Kienke stream was carried out using a 15 horsepower outboard motor boat (YAMAHA Enduro). Samples destined for physico-chemical analysis were collected at three sampling points at the level of lower of the Kienke watercourse, then at the level of the confluence and finally in open water (sea) 100 m from the river bank. For each station 250 and 1000 ml of water samples were collected in double-capped polyethylene containers and transported to the Laboratory of Hydrobiology and Environment in a cooler containing carboglaces for laboratory analysis APHA [16] and Rodier *et al.* [17]. These samples were collected at the surface.

2.3.2. Zooplankton Sampling

Biological samples were collected from the surface precisely at the level of the lower course (lentic area), using a 10 L bucket after having stirred the herbarium and filtered through a 64 μm sieve of 10cm in diameter. At the estuary, the filtration was carried out in a longitudinal radial and vertical manner using 200 μm plankton net. The process was repeated ten times to achieve a volume of 100 ml, for the surface samples; the water sample was taken from the quiet areas of each sampling points. While for the depth samples, the samples were collected using the six (6) liter Van Dorn Bottle and then poured into water. The collected filtrate of each sample was introduced into a 0.25 L test tube, of which 0.1 L (not fixed) was used for observations on living organisms and 0.15 L fixed with 0.01 L of formalin (5%) was used for identification and counting [18].

2.4. Measurement of Physico-Chemical Parameters

The physico-chemical parameters (**Table 2**) were analyzed by the techniques recommended by the parameters considered were temperature, Hydrogen potential (pH), Electric Conductivity, Dissolved Oxygen (O_2), Suspended Solids (SS), Color, Turbidity, Nitrates, Ammoniacal Nitrogen, Orthophosphates and Dissolved Carbon Dioxide (CO_2).

Table 2. Physico-chemical parameters measured in the laboratory with spectrophotometer.

Parameters	Method	Reagents used	λ (nm)	Units
Suspended Solid (SS)		//	810	mg/L
Color		//	455	Pt/Co
Turbidity		//	450	FTU
Nitrate (NO_3^-)	Spectrophotometry	-Nitriver V	500	mg/L of NO_3^-
Nitrite (NO_2^-)		-Nitriver V	507	mg/L of NO_2^-
Phosphate (PO_4^{3-})		-Phosver III	880	mg/L of PO_4^{3-}
Ammoniacal Nitrogen (NH_4^+)		-Rochelle salt and Nessler	425	mg/L of NH_4^+
Carbon Dioxide	Volumetry	-Sodium Hydroxide N/20 -Phenoltaleine -Hydrochloric acid N/10	//	mg/L
Biological Oxygen Demand (BOD5)	BOD meter	-Potassium Hydroxide pellet	//	mg/L

The temperature, Hydrogen potential (pH), Electric Conductivity and Dissolved Oxygen (O_2) were measured in situ using a mercury column thermometer graduated to 1/10 th of a degree Celsius, digital pHmeter model brand SCHOTT GERATE CG 818, a portable Total Dissolved Solids (TDS)/ Conductivity meter from HANNA series HT 8733, and an oxymeter from HANNA, model HI 9146; the units are expressed in °C, UC, $\mu\text{S}/\text{cm}$ and in Dissolved Oxygen percentage (O_2) saturation respectively. The measurement of the Dissolved Carbon Dioxide (CO_2) content was carried out in two stages. On the field, the Dissolved Carbon Dioxide (CO_2) was fixed by introducing into a 200 ml volumetric flask, 20 ml of Sodium Hydroxide (NaOH) N/20 plus 2 to 3 drops of phenolphthalein, this mixture was made up with the sample of raw water up to the gauge mark. The resulting mixture of pink color was stored in a 250 ml double-capped polyethylene flask and then returned to the laboratory. In the laboratory, 50 ml of this sample was titrated with N/10 Hydrochloric acid (HCl) until complete discoloration. The dissolved carbon dioxide (CO_2) content of the water expressed in mg/L was then determined by the formula: $[\text{CO}_2] \text{ (mg/L)} = (\text{control burette used volume} - \text{sample burette use volume}) \times 17.6$ (1). Shows the physico-chemical parameters measured in the laboratory, the method of analysis, and the reagents used, the wavelengths (λ) of reading with the DR/2010 spectrophotometer.

2.5. Organic Pollution Index (OPI)

The Organic Pollution Index (OPI) was calculated. This index was calculated from the quality classes obtained for the concentrations of the three variables; Ammoniacal Nitrogen (NH_4^+), Nitrites (NO_2^-) and Orthophosphates (PO_4^{3-}).

2.6. Evaluation of the Zooplankton Diversity of the Sampled Waters

A qualitative and quantitative study was carried out on the Zooplankton.

2.6.1. Qualitative Analysis

In the laboratory, the samples were homogenized by shaking. Using a pipette, 10 ml of the sample was taken and poured into a 90 mm diameter grid Petri dish. Using a binocular magnifying glass of the brand WILD M5 at 25 x and 50 x magnifications, the identification of Zooplankton species was carried out using specific keys and works of Amoros [19]; Zebaze Togouet [20] and Fernando [21]. The identification of Rotifers was referred to the keys and identification works of Koste [22]; Durand [23]; Pourriot and Francez [24]; Dussart and Defaye [25]. The organisms, which could not be identified with a binocular magnifying glass, were mounted between slide and coverslip for observation under the IVYMEN brand microscope in order to identify them down to the scale of the species. Regarding Cladocerans, their identification is based on the observation of morphological characters, such as the shape of the body, the shape of the cephalic capsule in ventral or dorsal view, and the detailed examination of the appendages of the post-abdomen. This identification was done with a WILD M5 binocular magnifying glass after dissection, using the keys and identification works of Dumont [26]; Al-Yamani and Pruso [27]; Sharma and Sharma [28]. As for the Copepods, they are identified on the basis of the shape of the body, the length of the antennules and antennae, the lateral ornamentation of the segments of the abdomen, the position of the ovigerous sacs, the number of eggs in the ovigerous sacs and the shape of the rostrum. This identification was done with a WILD M5 binocular magnifying glass after dissection, using the keys and identification works of Leszek and Rybak [29] Al-Yamani and Kolesnikova [30]; Beleem and Kamboj [31]; Juan and Tores [32]; Jaume and Lopez [33].

2.6.2. Quantitative Analysis

Counting of individuals was done on the fixed sample. In fact, 10 ml of homogenized sample was taken with a calibrated pipette and introduced into a grid Petri dish 30 mm in diameter in which the counts were carried out on five samples of 10 ml each time. The density was calculated as follows: $D = (nv)/V(2)$ where D is the density (expressed in individuals per liter), n is the number of individuals found in the volume of water analyzed under the microscope, v is the volume of water analyzed (ml) and V is the volume of filtered water (ml). The results obtained were used to calculate various indices making it possible to characterize the composition and evolution of Zooplankton.

2.7. Specific Richness

The specific richness of an ecosystem is the number of species found regardless of the number of individuals each taxon represents. This can only be assessed through a sample and for this reason it may differ from actual richness. The specific richness may well be a distinctive criterion of the ecosystems or of the sample points studied within a given ecosystem. This measure has the advantage of allowing an initial assessment of the richness of the environment from a qualitative point of view. This richness depends on the volume of water withdrawn. This is why it is important to keep a similar sampling method when surveying

multiple sites. Among the indices established for estimating diversity, the Shannon and Weaver index (H') remains the most widely used. He is endowed with an indisputable superiority over others such as that of Margalef in Daget [34]. The Shannon and Weaver Index represent a richness of information about the stand structure of a given sample and how individuals are distributed among different species. A low richness index indicates that the community is young with high multiplication power with dominance of one or a few species, while a high index characterizes mature populations with a complex specific composition with relatively high stand stability of Iltis [35].

2.8. Index of Diversity

The diversity index chosen is that of Shannon and Weaver [36] because it accounts for the diversity of the species that make up the stands in an environment. It establishes the link between the number of species and the number of individuals in the same ecosystem or in the same Community [37]. The Shannon and Weaver index was calculated accompanied by the Pielou equitability (J) (1966) which measures the distribution of species in the stand compared to an equal theoretical distribution for all species. The Sørensen similarity coefficient (1948) is used to compare the different stations from a biological point of view Moisan and Pelletier [38].

2.9. Statistical Analysis

The Analysis of Variance (ANOVA) and Student Fischer tests made it possible to compare biological indicators (specific wealth, abundance, diversity indices and Zooplankton biomasses) in time and space [39]. It makes it possible to assess the level of dependence between the different variables in the same ecosystem. Thus, Spearman's correlations were sought between the physico-chemical variables and the biological variables [40]. All of these tests will be performed using Statistical Package for Social Sciences (SPSS 20.0) software. In this study, Principal Component Analysis (PCA) was used to establish the abiotic typology of sampling points based on all of the environmental parameters measured at each sampling points throughout the study. The objective of this descriptive factorial statistics method is to present in graphic form the maximum amount of information contained in a large data table [41]. The principal components are obtained by the diagonalization of a matrix which, depending on the nature of the initial variables, is either the correlation matrix or the covariance matrix [42]. The correlation matrix was used. There are two types of representation; the scatterplot of the variables which is a correlation circle; and the scatterplot of the sites. The initial percentage explained by each principal component is shown in the form of a histogram. XLSTAT version 11.0 software was used for this analysis.

The abiotic typology of the different sampling points was made by Discriminant Factor Analysis (DFA) in order to highlight the parameters discriminating. The Discriminant Factor Analysis (DFA) approach consists in producing a series

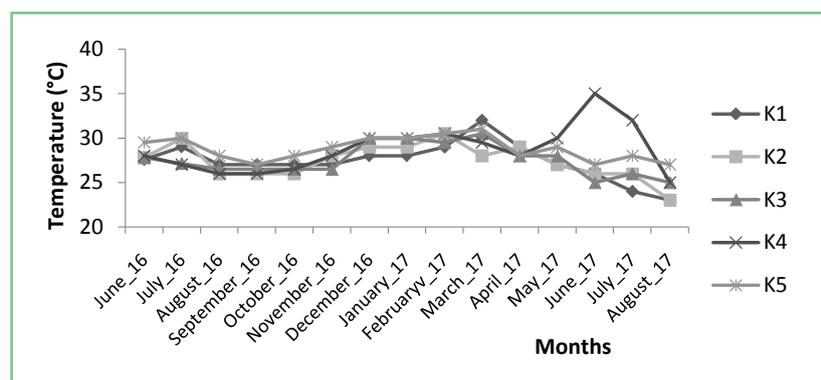
of discriminating variables, uncorrelated 2 to 2, so that the observations 49 belonging to the same group are as close as possible when they are projected on the demographic axes, and those of different groups are distant from each other of Bados [43]; Desbois [44]; Villanueva [45]. The Monte Carlo permutation test ($n = 1000$ random permutations) was performed in order to assess the reliability of the Discriminant Factor Analysis (DFA) [46]. The Discriminant Factor Analysis (DFA) was done using XLSTAT software version 11.0.

3. Results and Discussion

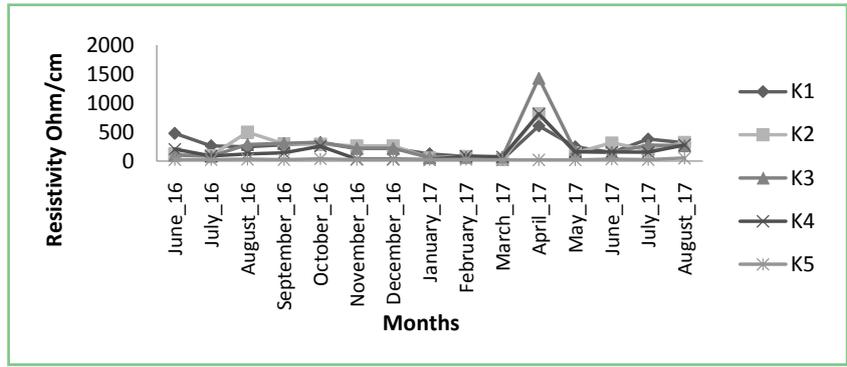
3.1. Results

3.1.1. Physico-Chemical Variables

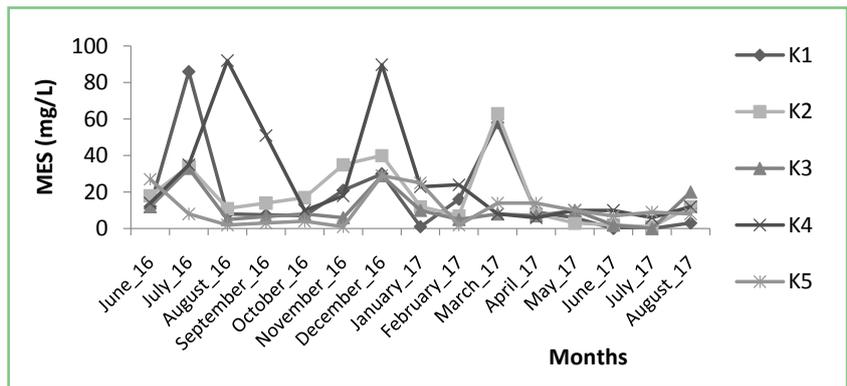
The surface water temperature of the Kienke estuary varies between 23°C and 35°C with thermal amplitude of 12°C and an average of 27.9°C. These values were obtained at sampling points K2 and K4 respectively in June and August 2017. The temperature showed no significant difference between these sampling points ($P < 0.01$; $\alpha = 0.05$). The lowest temperatures were observed between November 2016 and August 2017, corresponding to the short rainy season, while the highest temperatures were notably recorded during the long and short dry seasons (January-June) (Figure 2(a)). The resistivity of the water ranged from 21 to 1431 Ω/Cm at sampling points K5 and K1 in March and April 2017 (Figure 2(b)). Suspend Solid varied from 0.001 mg/L to 92 mg/L. The lowest value was recorded in July 2017 at sampling point K3 while the highest value was observed in August 2016 at sampling point K4 (Figure 2(c)). Turbidity contents in the Kienke estuary at the surface varied between 0 and 74 FTU. The highest value 74 FTU was obtained in November 2016 at sampling point K2. The lowest 0 was recorded at the K5 FTU sampling point in October 2016 (Figure 2(d)). The color of the water fluctuated between 0 and 256 Pt-Co. The highest grade was recorded at sampling point K2 in July 2016 and the smallest 0Pt-Co was recorded at sampling point K5 in February 2017 (Figure 2(e)). In the Kienke estuary, the values of the Hydrogen potential fluctuated between 5.08 and 10.78 UC. The highest value 10.8 UC was recorded at sample point K5 in August 2017 while the lowest 5.08 UC was observed at sample point K2 in May 2017 (Figure 2(f)).



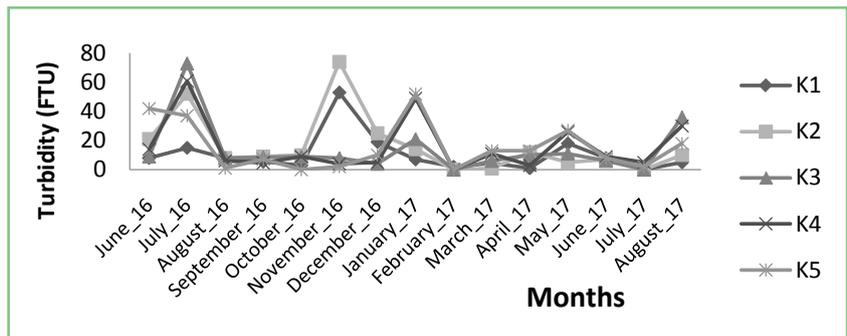
(a)



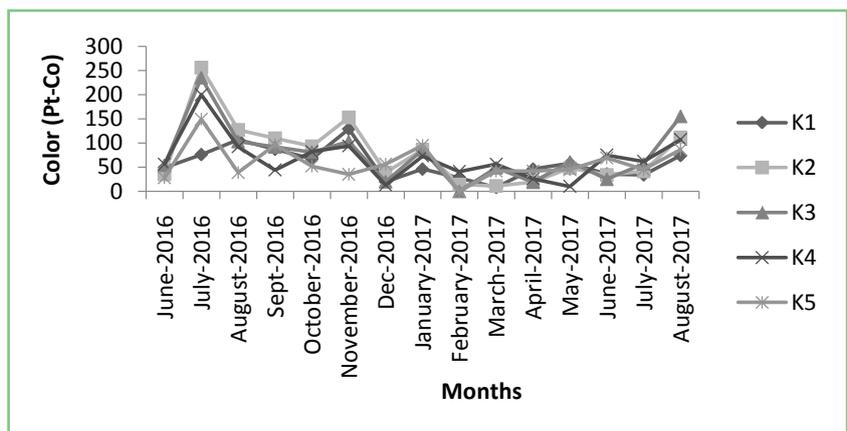
(b)



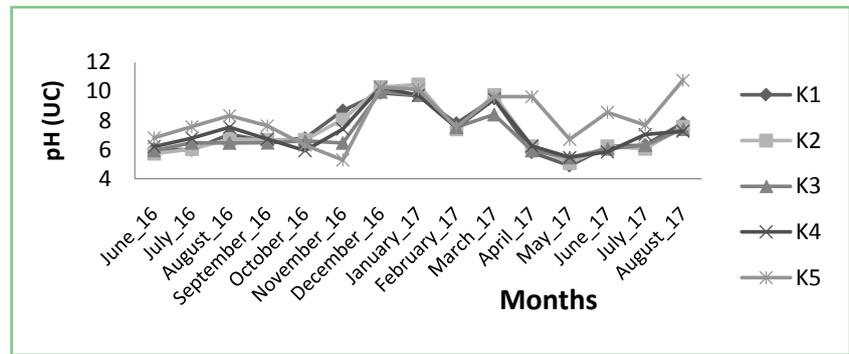
(c)



(d)



(e)



(f)

Figure 2. Spatio-temporal variations of the Temperature (a), Resistivity (b), Suspended Solid (c), Turbidity (d), Color (e) and Hydrogen Potential (f) in the Kienke stream.

The Electrical Conductivity contents varied between 1310 and 169,600 $\mu\text{S}/\text{cm}$. The highest value 169,600 $\mu\text{S}/\text{cm}$ was obtained in March 2017 at sampling point K5 and the lowest 1310 $\mu\text{S}/\text{cm}$ was recorded at sampling point K3 in September 2016 (**Figure 3(a)**). Ammoniacal Nitrogen values were varied from 0.008 to 6.96 mg/L. The highest content 6.96 mg/L was recorded at sampling point K5 in July 2016 and the smallest 0.008 mg/L was recorded at sampling point K3 in July 2017 (**Figure 3(b)**).

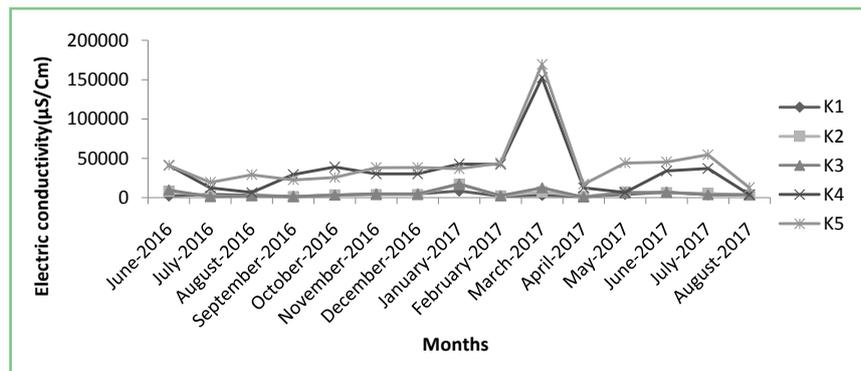
The nitrite ion contents were varied between 0.01 and 4.1 mg/L. The highest value 4.1 mg/L was obtained in August 2017 at sampling point K3 and the lowest 0.001 mg/L was recorded at sampling point K5 in June 2016 (**Figure 4(a)**). Values for orthophosphate ions have varied from 0.001 to 0.085 mg/L. The highest content was recorded at sampling point K5 in December 2016 and the smallest 0.001 mg/L was recorded at K4 and K5 sampling points in May and April 2017 (**Figure 4(b)**). Dissolved Oxygen values fluctuated between 60(%) and 90(%) saturation. The highest (90%) saturation was recorded at sampling point K3 in December 2016 while the smallest (60%) saturation was recorded at sampling point K4 in August 2016 (**Figure 4(c)**). The dissolved carbon dioxide levels in the Kienke estuary varied between 1.76 and 60 mg/L. The highest value 60 mg/L was obtained in March 2017 at sampling point K1 and the lowest 1.76 mg/L was recorded at sampling points K4 and K5 in October, November, December, July and August 2016 then February, August and March 2017 (**Figure 4(d)**). In the Kienke estuary, biological oxygen demand values fluctuated between 0 and 85 mg/L. The highest level was recorded at sampling point K3 in July 2016 and the smallest 0 mg/L was recorded at sampling point K5 in August and February 2017 (**Figure 4(e)**).

3.1.2. Organic Pollution Index (OPI)

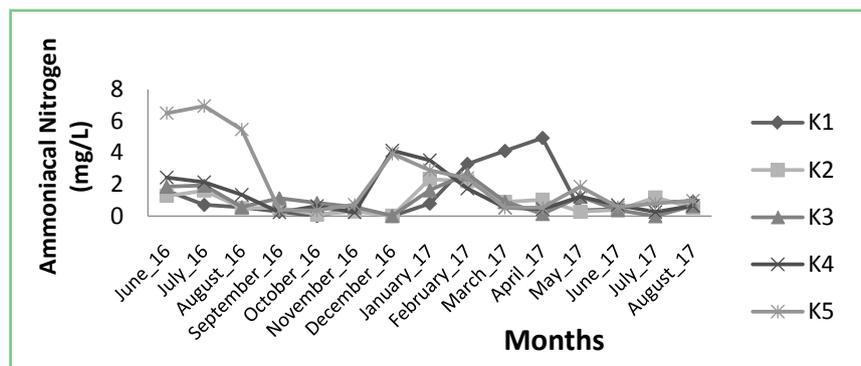
The Organic Pollution Index is 1.75 in the Kienke estuary in March, where organic pollution is very high (**Table 3**). But in the months of May, June, July, August and September the Organic Pollution Index is 2.5. The Organic Pollution Index varied between 3 and 3.25 respectively in November, February and January in the Kienke estuary where organic pollution is moderate. Organic pollution

Table 3. Average value of the POI calculated for the Kienke watercourse in the study. Legend: LRS: Long Rainy Season; LDS: Long Dry Season; SRS: Short Rainy Season; SDS: Short Dry Season; OPI: Organic Pollution Index.

Months	Seasons	POI/Seasons	POI/months	Color	Organic pollution level
December			2		
January	LDS	2.75	3.25	Yellow and brown	Pollution is moderate to high
February			3.25		
March			1.75		
April	SRS	2.25	2	Brown and red	Pollution is high to very high
May			2.75		
June			2.5		
July	SDS	2.25	2.5	Brown	High pollution
August			2.5		
September	LRS	2.75	2.5	Yellow and brown	Pollution is moderate to high
October			2.25		
November			3		

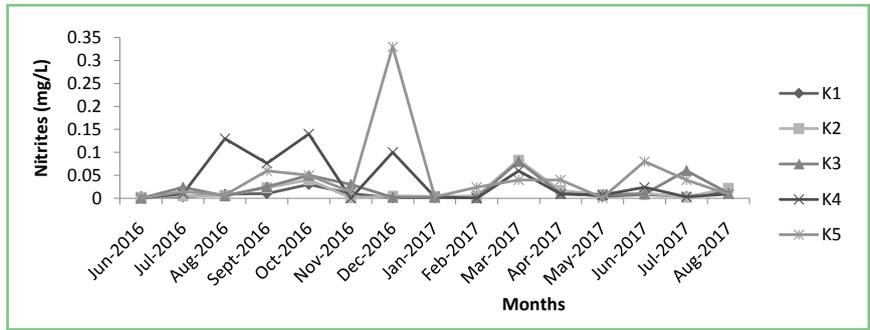


(a)

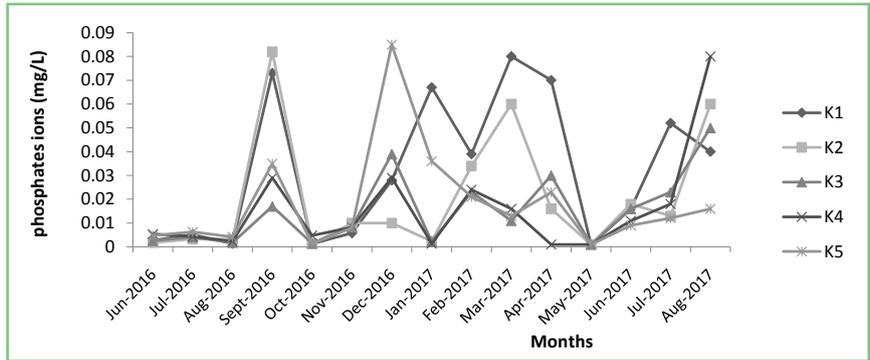


(b)

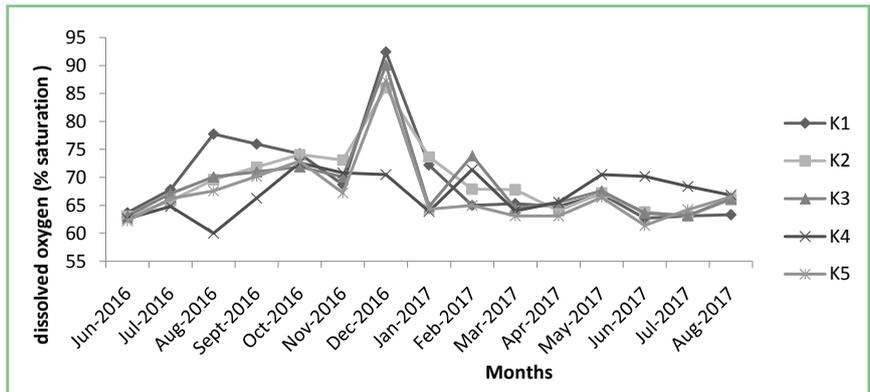
Figure 3. Spatio-temporal variations of the Electrical Conductivity (a) and Ammoniacal Nitrogen (b) in the Kienke stream.



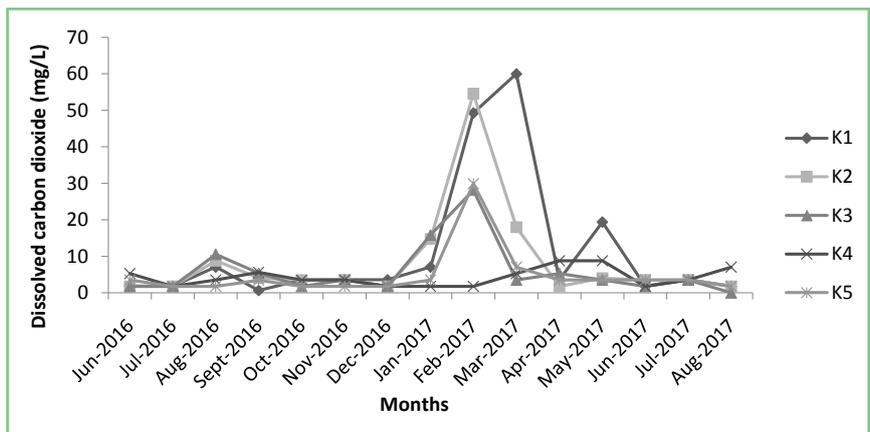
(a)



(b)



(c)



(d)

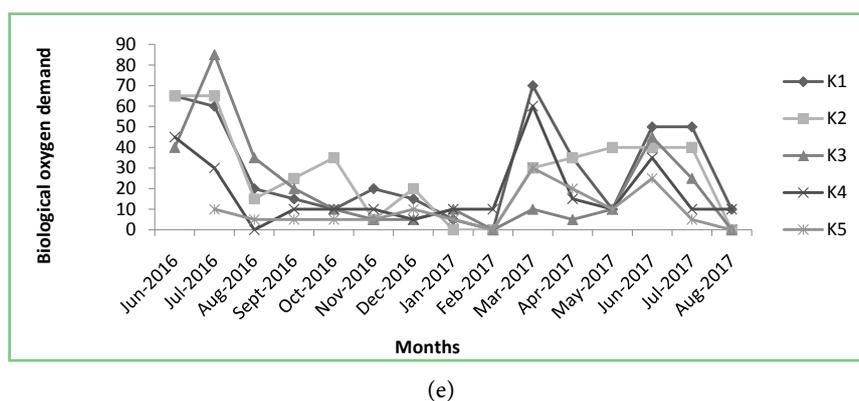
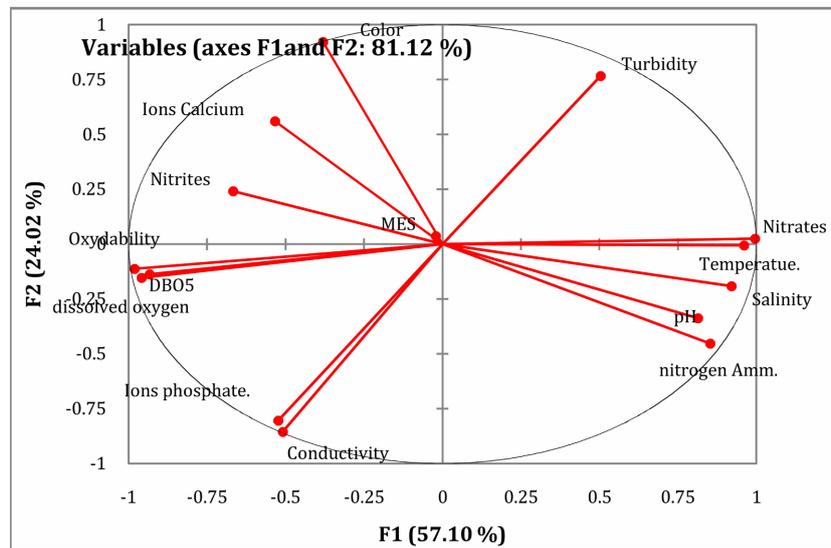


Figure 4. Spatio-temporal variations of the nitrite (a), phosphate ions (b), dissolved oxygen (c), carbon oxygen (d) and DBO5 (e) in the Kienke stream.

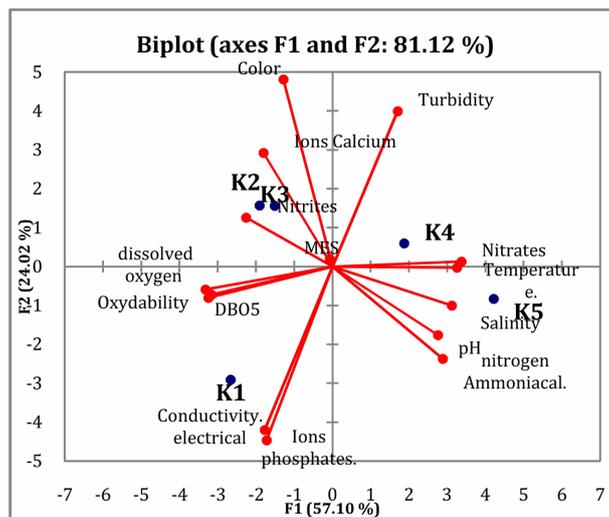
is high in April, December and October in the Kienke estuary because the pollution index varied between 2 and 2.25. The student test indicated that there is a highly significant difference in the Kienke estuary in terms of Organic Pollution Index (OPI) because ($p < 0.001$; $\alpha = 0.05$). The Organic Pollution Index (OPI) values measured from one season to the next in the Kienke estuary generally indicated that organic pollution is strong and even very strong during the four seasons studied during our study (Table 3). The average Organic Pollution Index (OPI) calculated from one season to another in the Kienke estuary has indicated that the waters are loaded with organic matter during the long rainy season (2.75) followed by the long dry season (2.75), the short dry season (2.25) and the short rainy season (2.25).

3.1.3. Principal Component Analysis of Physico-Chemical Variables

A Principal Component Analysis (PCA) carried out using the values of the 13 physico-chemical variables measured at the 5 study sampling stations shows that the first two axes F1 and F2 explain 81.12% of the information. The F1 axis of the Principal Component Analysis (PCA) explains 57.10% of the total variance. It is positively and strongly correlated with nitrate ions, electrical conductivity, dissolved oxygen, Biological Oxygen Demand, which is opposed to turbidity, nitrate ions, ammoniacal nitrogen, phosphate ions, (Figure 5(a)). This axis characterizes water, turbid, colored, rich in organic matter and dissolved oxygen because the more the organic matter is important, the more the characteristics of these variables are important. We can therefore think that this axis indicates the quality of the water, that is to say the degree of organic pollution. The F2 axis (24.02% inertia) indicates temperature and hydrogen potential. These axes combine at the same time, but with a dominance, the physical characteristics of the waters. This is the axis of mineralization and physical pollution. These two axes made it possible to divide the study sampling points into 2 groups (Figure 5(b)): Group 1 is made up of sampling points K1, K2, K3 which are characterized by water with relatively high color concentrations, at high temperatures low loads of organic matter. Group 2 comprises the K4 and K5 stations which present colored water, and with high loads of suspended solids.



(a)



(b)

Figure 5. PCA of the physico-chemical parameters of the various study sampling points of the Kienke estuary: (a) projection of physico-chemical variables on the plane of the first two factorial axes of the PCA; (b) projection of the sampling points study described by their physico-chemical characteristics, in terms of the first two factorial axes of PCA.

3.1.4. Taxonomic Composition of Zooplankton

A total of 105 Zooplankton species belonging to 24 families grouped into four orders were identified throughout the study. These 105 species belong to the four Zooplankton groups which are: Rotifers, Copepods, Cladocera and Ostracods. The species of Copepods recorded in the waters of the Kienke estuary have been divided into 13 families: Cyclopidae, Clytemnestidae, Parvocalanidae, Arctiidae, Euterpinidae, Pontellidae, Centropagidae, Corycaeidae, Ectinosamatiidae, Miracianiidae, Sapphaciridae, (Figure 6). The most represented family is the Cyclopidae with 6 species, of which the most represented during the study period were *Mesocyclops* sp. Sars, 1914 and *Clausocalanus* sp. Giesbrecht, 1888.

Species such as *Tropocyclops confinis* Kiefer, 1930; *Macrocyclops* sp. Claus, 1893 and *Parvocalanus elegans* Adronov, 1972 were poorly represented.

The Cladocerans identified during the study belonged to 5 families which are: Chydoridae, Moinidae, Sididae, Daphnidae, Oncaeidae. The most represented family was that of the Chydoridae with 6 species of which the most represented were *Alona* sp. Baird, 1843; *Chydorus sphaericus* Muller, 1776; *Chydorus piger* Sars, 1862. Species such as *Acroperus elongatus* Sars, 1862; *Chydorus ovalis* Kurz, 1875; *Chydorus* sp. Elford, 1816 were poorly represented (Table 4).

The species of Rotifers collected during this study belonged to 05 families namely: Philodinidae, Brachionidae, Lecanidae, Trichocercidae, Testudinellidae. The most represented family was that of the Philodinidae with low represented species. Species such as *Rotaria* sp. Scopoli, 1777; *Rotaria rotaria* Pallas, 1766 and *Rotaria neptunia* Ehrenberg, 1830 were poorly represented. The Ostracods identified during this study belonged to the only family the taxon (Figure 6).

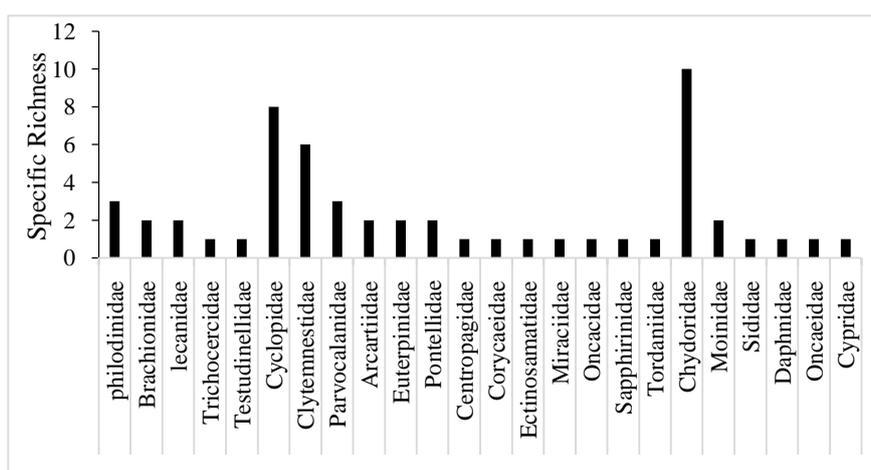


Figure 6. Specific richness of the different Zooplanktonic families inventoried in the waters of the Kienke estuary during the study (Ost: Ostracods).

Table 4. Diversity and abundance of community Zooplankton observed in the estuary of the Kienke during the period study.

Order	Families	Taxons	Density/month/station					N (In./L)
			K1S	K2S	K3S	K4S	K5S	
			T (ind/L)	T (ind/L)	T (ind/L)	T (ind/L)	T (ind/L)	
Brachionidae		<i>Dicranophorus caudatus</i>	1	1	1	0	0	3
		<i>Keratella tropica</i>	0	0	3	1	0	4
	Lecanidae	<i>lecanella bulla</i>	2	0	1	1	0	4
<i>Lecane</i> sp.		2	2	0	1	1	6	
Rotifers	Philodinidae	<i>Rotaria rotatoria</i>	3	0	2	0	0	5
		<i>Rotaria neptunia</i>	4	2	3	3	0	12
Testudinellidae		<i>Rotaria neptunia</i>	1	0	0	0	0	1
		<i>Testudinella patina</i>	1	0	0	0	0	1
Trichocercidae		<i>Trichocerca elongata</i>	2	1	0	1	0	4

Continued

	Specific richness	9	//	//	//	//	//	//
	Total abundance (ind/L)	//	16	6	10	7	1	40
Cladocerans		<i>Acroperus elongatus</i>	1	0	0	1	0	2
		<i>Acroperus</i> sp.	1	3	0	0	2	6
		<i>Alona</i> sp.	0	1	1	2	2	6
		<i>Chydorus ovalis</i>	1	1	2	1	1	6
	Chydoridae	<i>Chydorus piger</i>	0	2	0	0	2	4
		<i>Chydorus sphaericus</i>	2	1	1	5	2	11
		<i>Chydorus</i> sp.	3	2	1	1	1	8
		<i>Pleuroxus chappuisi</i>	1	0	1	1	0	3
		<i>Pleuroxus striatus</i>	3	0	3	0	1	7
	Daphnidae	<i>Ceriodaphnia</i> sp.	1	4	2	0	0	7
	Moinidae	<i>Moina macropa</i>	1	0	0	1	0	2
	<i>Moina micrura</i>	0	0	1	0	1	2	
Sididae	<i>Diaphanosoma</i> sp.	0	1	0	0	2	3	
	Specific richness	13	//	//	//	//	//	//
	Total abundance (ind/L)	//	14	15	12	12	14	67
Copepods	Arcatiidae	<i>Arcatia</i> sp.	4	4	0	4	3	15
		<i>Sagitta regularis</i>	0	0	0	2	2	4
	Centropagidae	<i>Microsetella</i> sp.	7	6	5	4	6	28
		<i>Clausocalanus</i> sp.	5	1	5	4	4	19
		<i>Macrocylops</i> sp.	0	1	0	0	2	3
		<i>Mesocyclops</i> sp.	2	4	0	1	4	11
	Cyclopidae	<i>Parvocalanus elegans</i>	4	3	4	6	4	21
		<i>Thermocyclops</i> sp.	2	3	1	2	5	13
		<i>Tropocyclops confinis</i>	2	3	2	3	3	13
		Nauplii Larvae	7	4	11	11	11	44
		Copepodite	7	6	7	8	9	37
		<i>Acetes japonicus</i>	5	0	3	3	1	12
		<i>Corycaeus dahli</i>	0	4	6	5	3	18
	Clytemnestidae	<i>Oithona</i> sp.	0	3	5	4	3	15
		<i>Parthenope</i> sp.	5	0	0	2	4	11
		<i>Sergestes</i> sp.	0	5	5	3	2	15
	Corycaeidae	<i>Ebalia</i> sp.	3	0	1	3	7	14
	Ectinosamatidae	<i>Acartia amboinensis</i>	3	2	1	2	2	10
	Euterpinidae	<i>Calanopia minor</i>	9	6	3	3	4	25
		<i>Lucifer hanseni</i>	8	2	7	7	7	31
Miraciidae	<i>Clytemnestra</i> sp.	0	1	1	1	2	5	
Oncaeidae	<i>Macrosetella gracilis</i>	6	0	2	1	5	14	

Continued

		<i>Acrocalanus longicornis</i>	3	2	4	1	3	13
	Parvocalanidae	<i>Lapidocerca acuta</i>	1	0	2	1	3	7
		<i>Oncaea</i> sp.	0	3	1	5	4	13
	Pontellidae	<i>Centropage</i> sp.	1	0	1	1	3	6
		<i>Temora</i> sp.	0	1	2	0	0	3
	Sapphirinidae	<i>Euterpina acutifrons</i>	0	1	1	2	3	7
	Tordaniidae	<i>Sapphirina</i> sp.	0	0	0	1	2	3
	Specific richness	27	//	//	//	//	//	//
	Total abundance (ind/L)	//	66	62	69	76	95	368
Ostracods	Cypridae	Nd	3	5	5	4	6	23
	Specific richness	1	//	//	//	//	//	//
	Total (Ind./L)							498
			Density/month/station					
Orders	Families	Taxons	K1P	K2P	K3P	K4P	K5P	N(In./L)
			T (ind/L)	T (ind/L)	T (ind/L)	T (ind/L)	T (ind/L)	
	Brachionidae	<i>Dicranophorus caudatus</i>	0	0	1	0	0	1
		<i>Keratella tropica</i>	1	0	2	2	0	5
	Lecanidae	<i>lecanella bulla</i>	1	0	0	0	0	1
		<i>Lecane</i> sp.	1	1	0	0	0	2
Rotifers		<i>Rotaria neptunia</i>	1	0	0	0	0	1
	Philodinidae	<i>Rotaria rotatoria</i>	2	2	1	0	0	5
		<i>Rotaria</i> sp.	1	0	1	0	0	2
	Testudinellidae	<i>Testudinella patina</i>	0	0	0	0	0	0
	Trichocercidae	<i>Trichocerca elongata</i>	1	0	0	0	0	1
	Specific richness	9	//	//	//	//	//	//
	Total abundance (Ind./L)	//	8	3	5	2	0	18
		<i>Acroperus elongatus</i>	0	0	1	2	0	3
		<i>Acroperus</i> sp.	1	5	2	0	2	10
		<i>Alona monacantha</i>	2	3	3	0	2	10
		<i>Alona</i> sp.	4	1	1	0	1	7
Cladocerans	Chydoridae	<i>Chydorus ovalis</i>	3	3	1	1	1	9
		<i>Chydorus piger</i>	1	2	2	1	4	10
		<i>Chydorus</i> sp.	1	2	2	2	1	8
		<i>Chydorus sphaericus</i>	0	1	1	1	3	6
		<i>Pleuroxus chappuisi</i>	3	0	1	2	3	9
		<i>Pleuroxus striatus</i>	0	0	1	1	0	2
	Daphnidae	<i>Ceriodaphnia</i> sp.	1	1	1	1	2	6
	Moinidae	<i>Moina macropa</i>	3	0	1	2	2	8
		<i>Moina micrura</i>	0	0	1	0	1	2
	Sididae	<i>Diaphanosoma</i> sp.	0	1	1	1	2	1

Continued

Specific richness		14	//	//	//	//	//	//
Total abundance (Ind./L)		//	19	19	19	14	24	95
	Acartiidae	<i>Acartia</i> sp.	2	5	2	5	6	20
	Centropagidae	<i>Microsetella</i> sp.	6	5	6	8	8	33
		<i>Acetes japonicus</i>	5	0	3	3	1	12
	Clytemnestidae	<i>Corycaeus dahli</i>	0	4	6	5	3	18
		<i>Oithona</i> sp.	0	3	5	4	3	15
		<i>Parthenope</i> sp.	5	0	0	2	4	11
	Corycaeidae	<i>Sergestes</i> sp.	0	5	5	3	2	15
		<i>Ebalia</i> sp.	3	0	1	3	7	14
	Cyclopidae	<i>Clausocalanus</i> sp.	3	5	2	3	3	16
		<i>Macrocylops</i> sp.	4	0	0	0	5	9
		<i>Mesocylops</i> sp.	1	1	2	4	4	12
		<i>Parvocalanus elegans</i>	4	3	4	6	4	21
		<i>Thermocylops</i> sp.	2	3	1	2	5	13
Copepods		<i>Tropocyclops confinis</i>	2	3	2	3	3	13
		Nauplii Larvae	2	11	9	11	11	44
		Copepodite	6	7	12	10	11	46
	Ectinosamatidae	<i>Acartia amboinensis</i>	3	2	1	2	2	10
	Euterpinae	<i>Calanopia minor</i>	9	6	3	3	4	25
		<i>Lucifer hansenii</i>	8	2	7	7	7	31
	Pontellidae	<i>Centropage</i> sp.	7	0	1	3	4	15
		<i>Temora</i> sp.	3	0	2	4	0	9
	Miraciidae	<i>Clytemnestra</i> sp.	3	5	7	3	6	24
	Oncaeidae	<i>Macrosetella gracilis</i>	2	0	4	4	6	16
		<i>Acrocalanus longicornis</i>	0	2	2	1	5	10
	Paracalanidae	<i>Lapidocerca acuta</i>	0	1	3	4	5	13
		<i>Oncaea</i> sp.	6	5	3	2	5	21
	Pontellidae	<i>Centropage</i> sp.	7	0	1	3	4	15
		<i>Temora</i> sp.	3	0	2	4	0	9
	Sapphirinidae	<i>Euterpina acutifrons</i>	0	5	4	7	2	18
	Sagittidae	<i>Sagitta regularis</i>	0	0	0	2	6	8
	Tordaniidae	<i>Sapphirina</i> sp.	1	0	0	3	2	6
Specific richness		29	//	//	//	//	//	//
Total abundance (Ind./L)		//	87	83	97	117	134	518
Ostracods	Cypridae	Nd	6	5	7	3	5	26
Total (Ind./L)					657			

Legend: N = total density; S = surface; P = depth; T = total; Nd = not determined.

3.1.5. Quantitative Aspect

Quantitatively, Copepods were highly dominant in the Kienke estuary studied and constituted 76.75% of total abundance. They are followed by Cladocerans, which respectively represent 14.09% of the total abundance of Zooplankton in the waters of the Kienke estuary. Rotifers and Ostracods were the least represented with 4.94% and 4.24% of total abundance (Figure 7).

3.1.6. Relative Abundance of Zooplankton Communities in the Waters of the Kienke

In the surface Kienke, Copepods dominate the Zooplankton community with 81.89% of individuals harvested. This was followed by the Cladocerans which accounted for 17.04% of the individuals then the rotifers and the Ostracods which constitute respectively 66.27%, 70.45%, 71.87%, 76.76%, 81.89%, of the abundances at sampling points K1, K2, K3, K4, K5. On the surface, the variation in Zooplankton densities over time, the highest densities were noted in August 2017 then in July 2017 with respectively 0.098 ind/L then 0.050 ind/L. While the lowest densities, were observed in October 2016 then in February 2017 with respectively 0.050 ind/L and 0.057 ind/L (Figure 8(a)). Furthermore, the seasonal variations in Zooplankton abundances were not significant ($p < 0.100$; $I = 0.05$) in fact, the densities of 0.0625 ind/L, 0.0725 ind/L and 0.0825 ind/L were recorded respectively at sampling points KS2, KS1 and KS5 during the dry season. During the rainy season, on the other hand, these densities increased with 0.07ind/L, 0.0775 ind/L and 0.0775 ind/L respectively in sampling points KS3, KS4 and KS5 (Figure 8(b)).

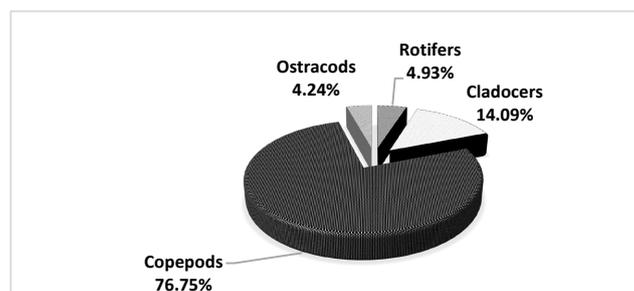
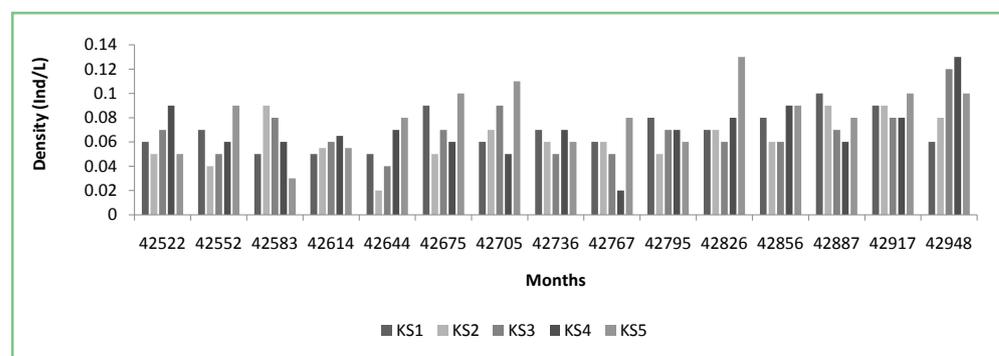
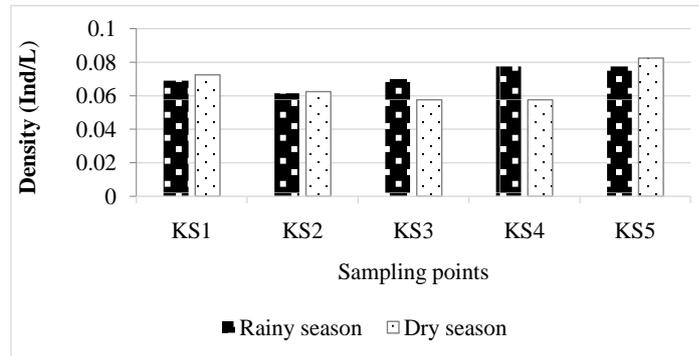


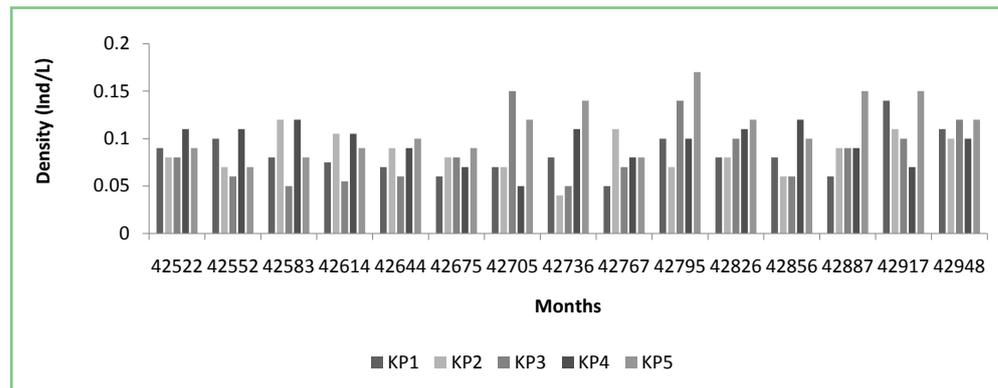
Figure 7. Relative abundance of Zooplankton in the waters of the Kienke estuary.



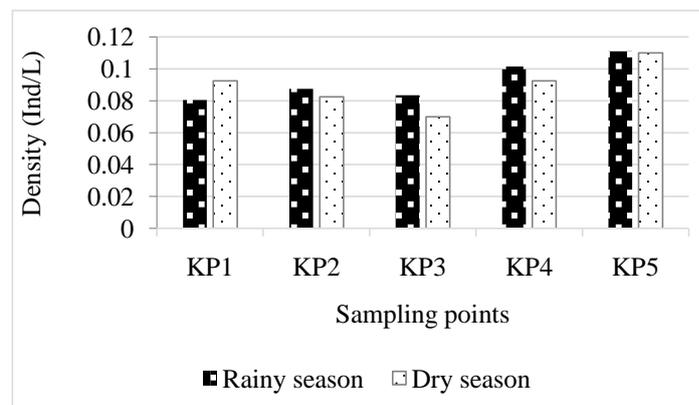
(a)



(b)



(c)



(d)

Figure 8. Densities of zooplankton in the Kienke at the surface (a) and depth (c) during the dry and the rainy season (b and d). (K1 = kienke surface KP: Kienke depth).

In the depth Kienke, the dominance of Copepods over Cladocerans, Rotifers and Ostracods is very pronounced as in the depth of Kienke. Indeed, these represent 86.76% of the individuals collected in the Kienke. The Cladocerans and the Rotifers then the Ostracods present respective relative abundances of 18.85% and 6.50%, 5.46%. At each sampling points, Copepods also take dominated over Rotifers and Cladocerans and Ostracods. They constitute 73, 17%, 73.77% and 75.78%, 86.76% then 82.20% of the individuals enumerated respectively in the sampling points (Figure 8(c)). In depth, the variation in Zooplank-

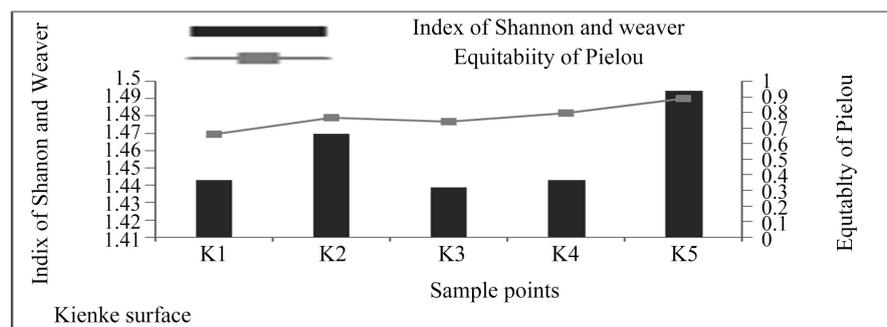
ton densities over time, the highest densities were noted in March, July and August 2017 with respectively 0.116 ind/L, 0.114 ind/L then 0.11 ind/L. And the densities, the lowest in November 2016 then in February 2017 with respectively 0.076 ind/L and 0.078 ind/L. In addition, the seasonal variations in Zooplankton abundances are not significant ($p < 0.100$; $\alpha = 0.05$) in fact, the densities of 0.0111 ind /L, 0.01015 ind/L were noted respectively at the level of sampling points KP5, KP4 and KP5 during the dry season. During the rainy season, on the other hand, these densities increase 0.0925 ind/L, 0.0925 ind/L and 0.11 ind/L respectively in sampling points KP1, KP4 and KP5 (**Figure 8(d)**).

3.1.7. Spatial Variations of the Shannon-Weaver Diversity Index (H') and Pielou Equitability (J)

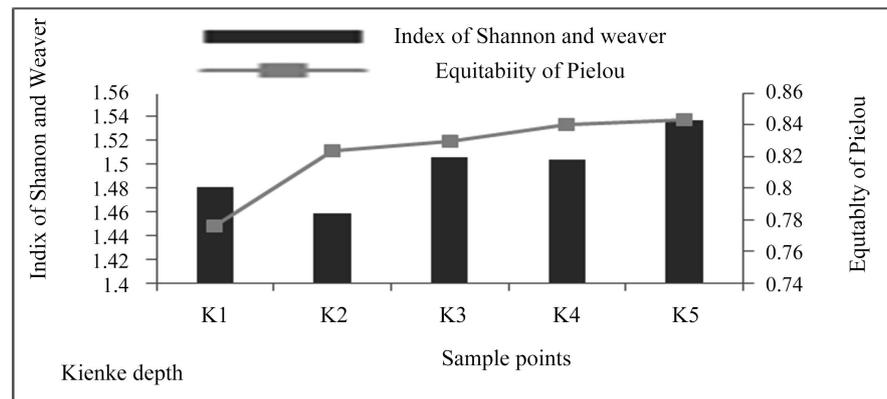
In the Kienke estuary, the Shannon-Weaver diversity index (H') and the Pielou equitability (E) were higher in the K2 and K5 sampling points and lower in the other sampling points (K1, K3 and K4). In the Kienke estuary on the surface, the highest values of Shannon-Weaver diversity index ($H' = 1.49$ bits/ind.) and equitability ($J = 0.88$) are noted at the sampling point K5. Sampling point K2 is placed in second position with $H' = 1.46$ bits/ind. and $J = 0.76$. The K3 sampling point is the least diversified ($H' = 1.43$ bits/ind. and $E = 0.74$). At the other sampling points, the Shannon-Weaver index is 1.44 bits/ind. (K4) at 1.44 bits/ind. (K1) while the equitability oscillates between 0.79 (K4) and 0.65 (K1) (**Figure 9(a)**). In depth, sampling point K5 ($H' = 1.53$ bits/ind. and $J = 0.84$) and K3 ($H' = 1.50$ bits/ind. and $J = 0.82$) are the most diverse. Sampling point K2 remains the least diversified with $H' = 1.45$ bits/ind. and $J = 0.82$. In other sampling points, the diversity index is between 1.50 bits/ind. in (K4) and 1.48 bits/ind. in (K1) while the equitability of Pielou varies from 0.84 in (K4) to 0.77 (K1) (**Figure 9(b)**).

3.1.8. Sørensen Similarity Index

The rates of taxonomic resemblance between the Zooplanktonic populations collected in the different sampling points. Likewise, the taxa listed at the surface of the Kienke estuary at sampling points K2 and K3 have a similarity rate of 85%; sampling points K3 and K4 have a similarity rate of 91%. The taxa listed at the surface of the Kienke estuary at sampling points K3 and K5 have a similarity rate of 88%; sampling points K4 and K5 have a similarity rate of 86%.



(a)



(b)

Figure 9. Spatial variations of the Shannon and Weaver diversity index and Pielou Equitability in Kienke stream at the surface (a) and the depth (b).

The taxa collected at sampling points K3, K4 and K5 show high rates of similarity, with values between 91% (K3 and K4) and 94% (K4 and K5). In addition, the Zooplankton inventoried in the other sampling points is dissimilar to those obtained in the other sampling points located in estuarine zones because the similarity rates obtained are overall less than 42%.

3.1.9. Physico-Chemical Variables at the Abundance of Zooplankton Organisms

Spearman's rank correlations between the abundance of Zooplankton organisms and the values of physico-chemical variables revealed some significant and positive correlation. The main ones are represented in **Table 5**. It emerges from this table that the organisms of the indicator families of environments rich in organic matter (Sididae, Oncaeilidae, Tordaniidae, Cyclopidae) are positively and significantly correlated with the variables. Orthophosphates, ammoniacal nitrogen, Suspended Solids and electrical conductivity also showed positive and very significant correlations with organisms from these three families (Pontellidae, Lecanidae, Oncaeidae). We also note positive and significant correlations between the high values of turbidity, nitrates and organisms of the families (Testudinellidae, Moinidae, Euterpinidae, Sididae, Ectinosamatidae, Tordaniidae, Sapphinnidae, Brachionidae, Corycaeidae, Cyclopidae). The values of Color, Hydrogen potential (pH), Dissolved Oxygen (O_2), on the other hand, show negative and significant correlations with Philodinidae, Euterpinidae, Sapphirinidae, Oncaeidae, Testudinellidae, Lecanidae, Clytemmestidae, Parvocalanidae and Corycaeidae.

Principal Component Analysis (PCA) of Zooplankton communities in the estuaries studied. Principal component analysis was performed using the numbers of constant Zooplankton species. The objective of these analyses was to evaluate the amount of Zooplankton per sampling points and analyzed the temporal distribution of the Zooplankton community throughout study. A first Principal Component Analysis (PCA) carried out from the abundances of constant Zooplankton species collected at different study sampling points made it

Table 5. Spearman correlation between the abundance of different zooplankton families and some physicochemical variables.

	Temperature	Suspended Solids	Turbidity	Color	Potential Hydrogen	Electrical conductivity	Amm. nitrogen	Nitrate	Nitrites	Ions phosphates	Dissolved Oxygen	Oxydability	Ions calcium	Salinity
Philodinidae	-0.349**			0.283*					0.326**		0.256*			-0.278*
Lecanidae						0.314**					0.280*			
Brachionidae												0.259**		
Testudinellidae			0.261*						0.384**					
Daphnidae					-0.237*									
Moinidae			0.260*											
Sididae							0.332**	0.427**		0.309**				
Parvocalanidae														0.238*
Pontellidae		0.276*												
Oncaeidae					0.308*	0.371**				0.287*				
Centropagidae		-0.347**	-0.246*	-0.276*										
Clytemnestidae													-0.238*	
Tordniidae								0.406**		0.380**				
Corycaeidae												0.338**		0.246*
Sapphirinidae								0.244*			0.254*			
Euterpinidae			0.416**	0.419**					0.240*					
Cyclopidae										0.316**		0.280*		0.266*

NB: empty space indicate an absence of correlation; ** the correlation is significant at the level 0.01 (bilateral); *the correlation significant at the level 0.05 (bilateral).

possible to visualize the main features of the spatial distribution of these species. The first two axes (F1, F2) of the Principal Component Analysis (PCA) accumulate 58.83% of the explained information and distinguish the sampling points into three groups characterized by different Zooplankton assemblages. One single group bringing together the sampling stations KP1, KP2, KP3, KP4, KP5, KS1, KS2, KS3, KS4, KS5.

3.1.10. Biotic Typology of Stations

A group of sampling points with distinct edaphic, hydromorphometric and physico-chemical characteristics is identified from the Hierarchical Classification Analysis (HCA) (Figure 10). This group is made up of ten other sampling points (KP3, KP1, KP2, KP5, KP4, KS4, KS2, KS3, KS1 and KS5) and shows that the waters of the Kienke estuary have the same biotic typology at surface and at depth.

3.2. Discussion

3.2.1. Physico-Chemical

During this study, the physico-chemical quality of surface water generally varied significantly in the Kienke estuary from one study sampling points and from one sampling period to another. In the water of the Kienke estuary on the surface, temperatures are between 23°C and 35°C respectively in sampling points K2 and

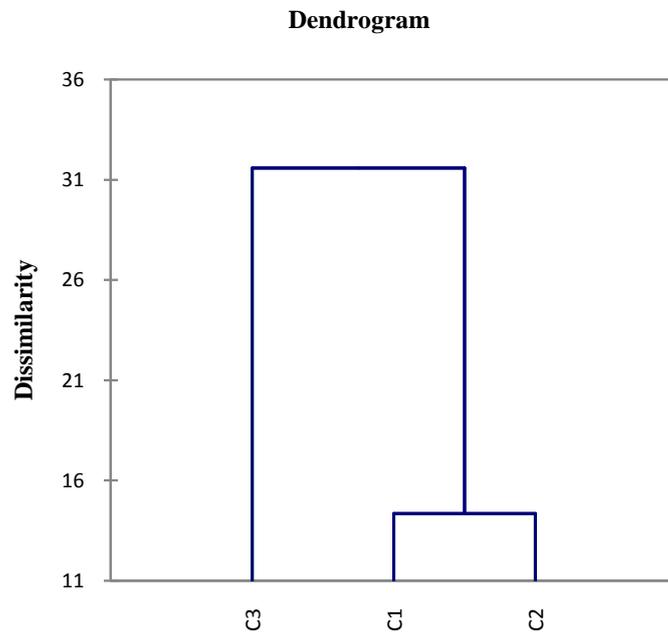


Figure 10. Hierarchical classification of sampling stations from the biological values.

K4 in the month of June and August with a thermal difference of 12°C and an average of 27.9°C. This variation could be explained by the fact that the water temperature may be related to the ambient temperature [47]. These temperature values are close to ones obtained by [48] at the level of the estuary of the Comoe river 27.20°C and 32.45°C (South-East of the Ivory Coast). However, the temperature of the estuarine water of Kribi showed a seasonal evolution a more or less sinusoidal aspect.

Seasonal variations in observed surface temperatures remain linked to local conditions. The same observations were made by [49] on the Loukkos estuary in Morocco. The low values of turbidity (0 - 74 NTU) recorded in the water of the Kienke estuary at the surface during the study period could be explained by the low load of the water in organic matter and the low intake of allogenic materials in the water body. According to Camacho [50] and AE [51], Suspended Solids levels below 75 mg/L generally do not adversely affect the development of most aquatic communities. On the other hand, in the K1 (86 mg/L) sample point in July 2016, K4 (89.7 mg/L, 92 mg/L) respectively in December and August 2016 located in the water of the Kienke estuary, having relatively high values would be an index of anthropogenic pollution, this increase in Suspended Solids (SS) could also be due to settling phenomena which results in the progressive deposition of solid loads during transport [52]. The high solids content could also be explained by intense erosion of the watershed, following brutal rains, such as the Moulouya Oued in eastern Morocco [53].

The Hydrogen potential (pH) values recorded during the study period (5.08 - 10.78 UC) in the Kienke estuary show overall that the waters of these two estuaries are slightly basic. This basicity would be due to the exogenous contribu-

tions of domestic and urban effluents discharged either directly or indirectly by rivers such as: Kienke and Bagadoué. However, these values remain within the Hydrogen potential (pH) range of natural waters favorable to aquatic life (5 - 9 UC) [54]. Like salinity, the Hydrogen potential (pH) of estuary water depends on continental and oceanic inputs. The high values (60% - 90%) of the percentage of saturation of the water in dissolved oxygen(%) in the waters of the Kienke estuary in the K3 and K4 sampling points and respectively in August and December 2016 could be explained by the fact that upstream of the estuary has an abundant vegetation but also an important current. This same observation was made by [55] on the upper reaches of Oued Za in Morocco. While the low oxygenation of the water at the other stations may be linked to the confinement of the estuary and the presence of organic matter transported into the estuary by the runoff waters.

Likewise, the indicator parameters of Organic pollution such as nitrites and orthophosphates remained low, in the water of the Kienke estuary (0.01 - 4.1 mg/L, 0 - 0.33 mg/L, 0.001 - 0.085 mg/L and 0 - 5.8 mg /L, 0 - 0.08 mg/L, 0.001 - 0.24 mg/L respectively). These low values would be due to the rains which would have induced the dilution of these ions in a larger volume of water on one and to the low use of nitrogenous and phosphorus fertilizers and the low presence of anthropogenic activities in the study area. The high nitrite levels in the water of the Kienke estuary on the surface at sampling points K3 (4.1 mg/L) could be explained by the fact that the inputs of mineral or organic fertilizers in agriculture constitute a door entry of certain nutrients into the soil, agricultural practices (tillage, lack of anti-erosion, etc.) also facilitate their mobilization by runoff water.

The Organic Pollution Index (OPI) calculated from the averages of the quality classes of Ammoniacal Nitrogen, Nitrites and Orthophosphates is included in an interval which, according to [56], corresponds to a moderate and very high level of organic pollution. The data from the Organic Pollution Index (OPI) confirm the results obtained with the previous parameters and allow the conclusion that the water of the Kienke is not of good ecological quality.

The Principal Component Analysis (PCA) carried out made it possible to differentiate two large groups within the different study stations. Group 1 is represented by sample points K1, K2, K3 which are characterized by relatively high color concentrations, at high temperatures and low loads of organic matter attributed to domestic wastewater inputs. Group 2 comprises the K4 and K5 sample points which present colored water with high loads of Suspended Solids.

3.2.2. Kienke Zooplankton Communities

The present study made it possible to collect in the waters of the Kienke estuary on the surface 52 Zooplanktonic organisms including 29 species of Copepods, 13 species of Cladocera, 9 species of Rotifers and 01 species of Ostracod. Of the four Zooplankton groups collected, there is a predominance of Copepods. This would be explained by the fact that some species of this group have the possibility of

surviving in the state of resting stages, thus allowing them to be transported from one environment to another, and thus to have a larger range. These results corroborate with those found by Vives [57] on the coasts of Castellon and Gaudy [58] on the Gulf of Marseille, who identified 41 different species with a majority of Copepods.

The analysis of the specific richness within the different families (13) of Copepods, collected in the Kienke estuary on the surface during our study, shows the existence of four families, the richest of which are Cyclopidae followed by Clytemnestidae then the Parvocalanidae and finally the Euterpinidae. Such a classification would be characteristic of Zooplanktonic populations in estuarine water.

In terms of abundance, the Zooplanktonic population of the surface waters of the Kienke estuary was largely dominated by microcrustaceans (87.42%). In this group, Copepods represent about (74.02%) of this abundance. *Parvocalanus elegans* Andronov, 1972 they were more present at the KS4 sampling point located a few meters from the Atlantic Ocean and receiving marine waters. According to Mollo and Noury [59], Copepods represent up to (80%) of Zooplankton and are the most numerous marine animals. It also emerges that among 29 taxa of Copepods identified, the most represented species are *Tropocyclops Confinis* Kiefer, 1930; *Mesocyclops* sp. Sars, 1914; *Macrocylops* sp. Claus, 1893; *Thermocyclops* sp. Kiefer, 1929 and *Clausocalanus* sp. Giesbrecht, 1888. The latter being copepods with affinity with neritic waters [60]. This could be explained by the fact that the latter would have migrated from the waters of the Atlantic Ocean via the strong tides to these sampling points.

During the study period, in the waters of the Kienke estuary in depth 53 species of Zooplankton including 43 belonging to the group of microcrustaceans (Copepods and Cladocerans), 09 species to that of rotifers and 01 species of Ostracod were identified. In this group, the Copepods represent approximately (78.72%) of this abundance followed by the Cladocerans which represent (14.58%) then the Ostracods with (3.87%) and finally the Rotifers with (2.83%). Copepods were more present at sampling point KP5 in March, June and July 2017 then at sampling point KP3 in December 2016. Of the four Zooplankton groups collected, there is a predominance of Copepods. This would be explained by the fact that some species of this group have the possibility of surviving in the state of resting stages, thus allowing them to be transported from one environment to another, and thus to have a larger range of Khalki and Moncef [61]. Moreover, the positive and significant correlations obtained between the dominant species were: *Tropocyclops confinis* Kiefer, 1930; *Mesocyclops* sp. Sars, 1914; *Macrocylops* sp. Claus, 1893; *Thermocyclops* sp. Kiefer, 1930; *Parvocalanus elegans* Andronov, 1972 and *Clausocalanus* sp. Giesbrecht, 1888. With certain physico-chemical parameters such as phosphate ions, Oxidability and Salinity confirm these hypotheses. In general, during the study period in the waters of the Kienke estuary, 105 taxa belonging to 46 families were identified in the waters of the Kienke estuary, which reflects a relatively high biodiversity. In addition, these

species are taxonomically representatives of four Zooplanktonic groups: Copepods, Cladocera, Rotifers and Ostracod. During the entire study period (June 2016-August 2017), Copepods constitute the major microzooplankton in the waters of the Kienke estuary because they represent (76.75%) of the total Zooplankton. This dominance of Copepods has already been reported in several studies carried out in Tunisia in the Bay of Tunis Daly-Yahia and Daly-Yahia [62]; Annabi-Trabelsi and Ben Maiz [63]. Pearson's chi-square (χ^2) = 4.714, p-value = 0.695 > 0.05 thus, in the Kienke specific richness does not depend on depth. There is no significant difference between the surface and the bottom at the 5% level.

3.2.3. Spatial Dynamics of Zooplankton Communities

The values of the Shannon and Weaver diversity index obtained during the study indicate spatially that the sampling point K3 on the surface and the sampling point K2 at depth have the lowest diversities, namely: the sampling point K3 on the surface has for Shannon and Weaver (H) diversity index = 1.43 bits/ind while the depth K2 sampling point has Shannon and Weaver (H) diversity index = 1.45 bits/ind. This value could be explained by the high-water flow speeds, the intense sand extraction activities carried out in these stations and by the rise in water following the precipitation in the months (April and May) with the immediate consequence of the submersion of riparian macrophytic. In fact, according to [64], riparian macrophytic lying around in water are likely to promote greater diversity, as they constitute not only a trophic niche, but above all habitats and refuges for various species.

Concerning the Shannon-Weaver and Pielou indices, the high values recorded at the K2 and K5 sampling points in the water of the Kienke estuary at the surface, K3 and K5 at depth would reflect a good structure of the population and would be linked to a weak degradation, characterized by a high development of several different individuals [65]. These results corroborate with those observed by [66] on the EL Jadida rating. Furthermore, the Sørensen similarity coefficient of the Zooplankton community in the Kienke estuary at the surface was greater than 50% between K2-K3 (E = 85%); K3-K4 (SI = 91%); K3-K5 (E = 88%); K4-K5 (E = 55.17%), while the Sørensen similarity index of the Zooplankton community in the Kienke estuary at depth was greater than 50% between K3 and K4 (E = 91%); K4 and K5 (E = 94%) corroborate with the results obtained for the analysis of the hierarchical classification between stations, this would mean that the different Zooplankton species would be influenced by the same environmental factors at these sample point.

4. Conclusion

At the end of this study, the general objective of which was to assess the diversity and structure of Zooplankton communities in relation to the physico-chemical quality of the water of the Kienke estuary, it emerges that the water of the Kienke estuary is relatively basic; with more or less high temperature and high Electrical

Conductivity and Salinity. Overall, this water has low and high values of organic pollution indicator parameters (Ammoniacal Nitrogen, Orthophosphates, Nitrates and Nitrites), thus reflecting the oligotrophic character of these environments. In addition, Zooplankton analysis shows the dominance of Copepods over Cladocerans and Rotifer. In the future, we plan to extend the study in other areas and to reinforce database that will serve as a reference for scientific community and also consider fish and crustaceans because they feed on Zooplankton and have a great capacity to accumulate pollutants. They are also good indicators of pollution.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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