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Spatiotemporal distribution of zooplankton in relation to some abiotic variables in the waters of the Kribian Atlantic coast (South Cameroon)

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Abstract

A research to study the zooplanktonic population in relation to some abiotic variables of the Kribian coast waters was conducted from July to December 2020 following a monthly sampling in six (6) selected sites. The physicochemical parameters were determining out using standard methods. Concerning the zooplankton, the water was collected at the surface, in the trophogenic and tropholytic layers, then filtered through a 64 µm plankton sieve and the retentate was fixed with 96% alcohol. Identification and counting were done in the laboratory using a Wild M5 binocular loupe, appropriate keys and works. The physicochemical results showed a very good oxygenation of the waters (91.85 ± 3.87%), basic pH (8.43 ± 0.54 U.C), a low salinity and conductivity of respectively 13.04 ± 3.92 g/L and 23.07±4.23 µS/cm characteristic of the haline domains and a temperature of 28.66 ± 1.35°C. With regard to nutrients, the values recorded showed a progressive enrichment of the water in nitrate (2.2±1.81mg/L) and a low concentration in orthophosphate (0.25±0.41mg/L). the zooplankton community haboured, 54 taxa belonging to 3 major groups (Copepoda, Cladocera, Ciliate) and other Zooplankton, 24 families and 29 genera were recorded. The Copepod group dominated the taxonomic richness with 34 taxa (62.96% of total richness), followed by Tintinidae with 4 taxa (7.4%), Cladocera with 1 marine taxa (1.9%) and 15 taxa for other zooplankton (27.8%). Quantitatively, Copepods were once again the most abundant group in the population, with an average of 78.3% of the total zooplankton abundance. The dominant copepod taxa in terms of abundance were those of the families of: Paracalanidae (mean abundance: 116 ind/L) and Oithonidae (mean abundance: 99ind/L).

Keywords: Zooplanktonic; Physicochemical; Kribian; Coast

1. Introduction

Cameroon, with about 402 km of coastline, attracts tourists and favors urbanization and therefore anarchic occupation of the coast. Thus, the coastal strip of Kribi is at the center of great stakes because it is the focal point of economic development of Cameroon with the realization of large structuring projects (gas power plan, deep water port, fisheries, agro-industries, Kribi-Edea highway...). This could make it particularly vulnerable to anthropogenic pressures [1] and also to climate change with the consequences, among others, of temperature rise and decline in biodiversity [2] et [3]. It could therefore result in a modification of the physicochemical properties of water and especially an alteration of the structure of communities controlling the dynamics of ecosystems [4]. Faced with this worrying situation, the United Nations (UN) proclaimed 2010 as the International Year of Biodiversity to alert public opinion to the state and consequences of its decline worldwide. Thus, for the assessment of the health of aquatic ecosystems, in addition to physicochemical variables measurements, biological variables are also cited as indicators of environmental quality.

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Among these biological organisms, zooplankton is frequently cited as an indicator of pollution [5]. It is particularly sensitive to environmental variations and responds rapidly to changes in environmental conditions [6]. In a global context of increasing anthropogenic pressures on coastal ecosystems, leading to their pollution, it would be important to have in the case of Cameroon quality indicators that can serve as references. At the level of the Atlantic coast of Kribi, few research works have been carried out that have taken into account zooplankton in particular. To date, the only known work on zooplankton in the study area is that [7] on the zooplankton Dynamics of the Kienke Estuary (Kribi, South Region of Cameroon). To fill this gap, this work aims to assess the abiotic variables of the waters that influence the diversity and the dynamics of the zooplankton in order to contribute to the implementation of a reference database which would be used by the scientific community and the managers of these ecosystems.

2. Material and methods

2.1. Material

2.1.1. Study site

The study was conducted in the coastal town of Kribi which is located on the Gulf of Guinea, in the South Cameroon Region, Department Ocean and at the mouth of the Kienke River. The Kribian coast borders the vast South Cameroonian plateau and is made up mainly of sedimentary rocks found in the coastal plain [8]. The present study concerns the part of the Kribian coast that goes from Ngoyé to the deep water port of Kribi (Figure 1). Kribi present a southern coastal equatorial climate, but much more humid and characterized by the existence of four seasons, 02 dry seasons (December to March for the long season and July to August for the short season) and 02 rainy seasons (September to November for the long season and April to June for the short season) [9] . The average daily maximum temperatures range between 25°C and 33°C while the average daily minimum temperatures range between 15°C and 22°C [10]. Rainfall reaches monthly values of 504 mm in September in Kribi while monthly temperature peak of 28.2°C is noted in February and March [11] The hydrographic network of Kribi is dominated by the Atlantic Ocean with a low tidal range and small waves. The presence of the Lobé and Kiénké rivers is remarkable as well as the Ngoyè, Abondé, Wamie, Nzami, and Bidou rivers, which receive household waste and that some agro-industrial companies (Socapalm, Hevecam and Chocolaterie) [11].

2.1.2. Sampling points.

The sampling points were located in the stretch of the Atlantic coast from Ngoye to the northern limit of the deep water port of Kribi where 06 sampling points were selected (Figure 1). The geographical coordinates, characteristics and codes of these sampling points are recorded in Table 1 below.

Table 1 Geographical coordinates and characteristics of each point.

Stations	Codes	GPS coordinates	Characteristics	Distance to the bank
''Ngoyé''	P1	N :02º57’50.6'' E :009º54’36.9''	Most visited beach of Kribi and artisanal fishing site.	500 m
Mouth of ''Kiénké''	P2	N :02º56’35.7'' E :009º54’08.3''	Fish market and boat	500 m
Spawning area	P3	N :02º55'05.4'' E :009º53'50.6''	Artisanal net fishing site	400 m
''Lobé mouth''	P4	N :02º53'14.8'' E :009º53'40.7''	Boating area and tourist site	500 m
Grand Batanga Beach	P5	N :02º49'34.2'' E :009º53'10.0''	Very clean and less visited beach. Presence of an offshore visible from the coast	500 m
''Port''	P6	N :02º47'46.8'' E :009º52'52.7''	Northern limit of the deep water port of Kribi	300 m

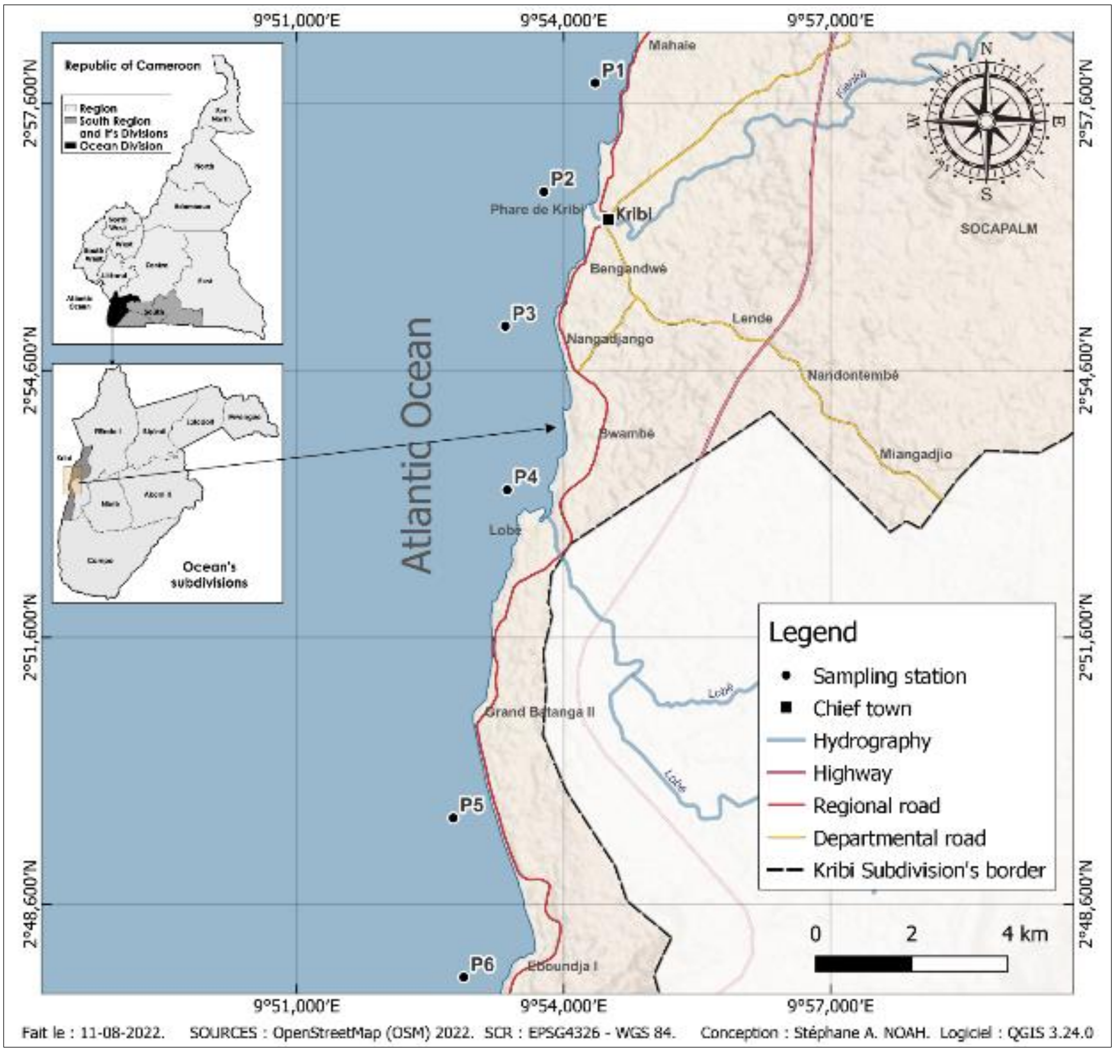


Figure 1 Geographic location of sampling points

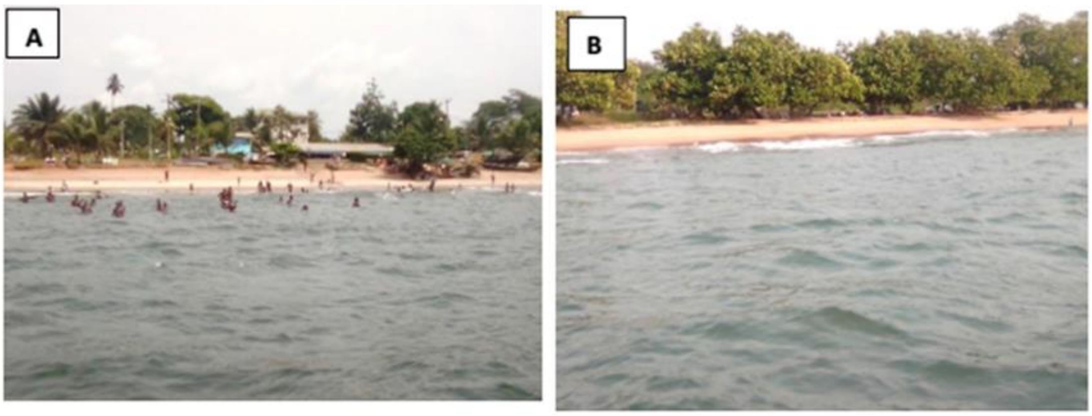


Figure 2 Partial views of the surveyed sections (A) Anthropized area and (B) Unanthropized area

2.2. Sampling methods

The differents samples (for physicochemistry and biology) were taken from July to December 2020 which a monthly frequency aboard a 20 horsepower Yamaha motorized Dugout.

2.2.1. Water sampling and measurement of abiotic factors.

After determining the euphotic layer using a Secchi disk, water was sampling from 03 slices of the water layer, notably at the surface, in the trophogenic layer and in the tropholytic layer. A composite sample was made in a 20 L bucket previously rinsed with there waters. Sampling in the trophogenic and tropholytic layer was done with a 6 L Van Dorn bottle. In situ and in the composite, parameters such as temperature, pH, conductivity, salinity, TDS, were measured with a Waterproof TESTER multiparameter and dissolved oxygen with a HACH HQ30d Oximeter. In addition, for the water samples intended for laboratory analysis, 1 liter of the composite was taken in a 1000 cc polyethylene bottle and then stored in a refrigerated chamber until to laboratory. In the laboratory, parameters such as Suspended Solids, color, nitrate, nitrite, and orthophosphate were measured with a HACH DR 3900 spectrophotometer following standard analytical protocols and recommendations of [12]. Alkalinity on the other hand was measured by titration.

2.2.2. Sampling and analysis of Zooplankton.

The sampling of Zooplankton was done out in the same water layer as the samples used for the measurement of abiotic factors. Thus, a volume of 100 L of water was filtered through a Zooplankton sieve of 64 µm mesh open. The collected retentate, about 200 mL, was introduced into two 100 mL bottles. The first bottle was used to preserve one half of the sample which was fixed *in-situ* with 96% alcohol and the second bottle was used to preserve the sample without alcohol in order to observe the organisms that can be deform under the action of alcohol. In the laboratory, the identification and counting of individuals were done on the fixed sample. Indeed, 10 mL of this previously homogenized sample was taken with an automatic calibrated pipette and introduced into a 30 mm diameter Petri dish, squared in 3 mm sides. The Petri dish prepared in this way prevents any repetition of counting [13]. All zooplanktonic organisms in this volume were counted at 500 X magnification under a WILD M5 binocular stereomicroscope. Thus, for a fixed sample of 100 mL, counts were made each time on each of ten 10 mL intakes until the sample was exhausted. The Zooplanktonic organisms were identified according to the keys of [14]; [15]; [16]; [17] et [18].

2.2.3. Data Analysis

The biological data analysis is based on the calculation of biological indices. These indices allow the evaluation of the biological quality of aquatic environments by the expression of of a simple and unique value. The taxonomic richness (S) is the number of distinct taxa present in a sample. It reflects the diversity of a sample [19] and appears to be a good indicator of the health of the community. The Shannon and Weaver diversity index (H') [20] was used to assess the numerical importance of the taxa in a stand. This index has the formula: $H' = -[(ni/N) \log_2 (ni/N)]$. where H' represents the specific diversity, (in bits/individual), *ni* the number of species i, *N* the total number of individuals. It reflects the diversity of species that make up the community in the environment. Pielou's equitability index (J) [21] was used to measure the equitability (or equi-partition) of species in the stand. A low equitability represents a dominance of a few species [22]. It is obtained by the formula: $J = H'/\log_2 S$. with H' the Shannon-Weaver index, log2 the logarithm to base 2 and S the species richness. The index J varies from 0 (dominance of a single species) to 1 (even distribution of individuals in the community). The frequency of occurrence of a species is the ratio, expressed as a percentage, of the number of samples where this species is present over the total number of samples taken. It has the formula: $F = (Si / St) \times 100$, with Si: number of samples where taxon i was caught and St: total number of samples. The classification of taxa on the basis of their percentage of occurrence was done according to [23].

2.2.4. Statistical tests

The SPSS 20.0 software allowed to perform the non-parametric H tests of Kruskal Wallis and the Mann Whitney test. These tests were performed to show the influence of abiotic variables on the abundance of study organisms between sampling stations. Spearman correlations were used to show the relationships between abiotic variables and the different taxa surveyed. However, before performing these tests, normality of the data was sought using the Kolmogorov-Smirnov test.

3. Results

3.1. Physico-chemical characteristics

The abiotic variables of the waters of the Kribi coast did not show significant differences ($P > 0.05$) between the sampling points during our study, except for nitrate, nitrite, ammonia nitrogen and salinity. As for the months, these variables mostly presented significant differences ($P < 0.05$) between months except for nitrate, nitrite and ammonia nitrogen. The temperature during this study ranged from 27 to 31.1°C. On the one hand, the maximum value was recorded at P1, P5 and P6 in December and at P5 in November. On the other hand, the minimum value was obtained in July and September at P2 and at P4 in September (Figure 3A). Concerning TSS (Total Suspended Solids), it varied between 0 and 13 mg/L during the study period. The zero value was recorded in all stations in September and in stations (P1, P2, P3 and P5) in December and in stations (P2, P4 and P5) in November. The higher value (13 mg/L), it was obtained in October at stations P3 and P6 (Figure 3B).

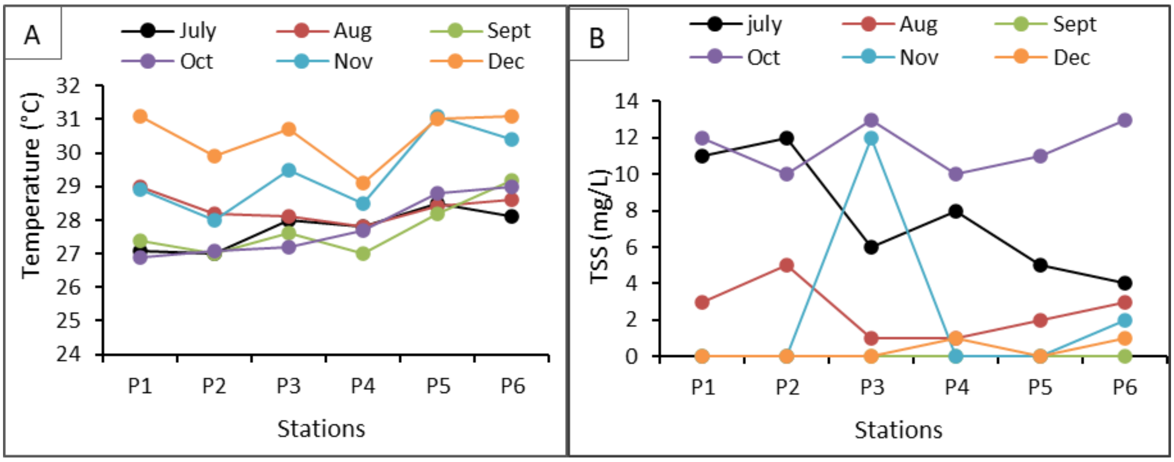


Figure 3 Spatio-temporal variation of temperature (A) and TSS (B) during the study

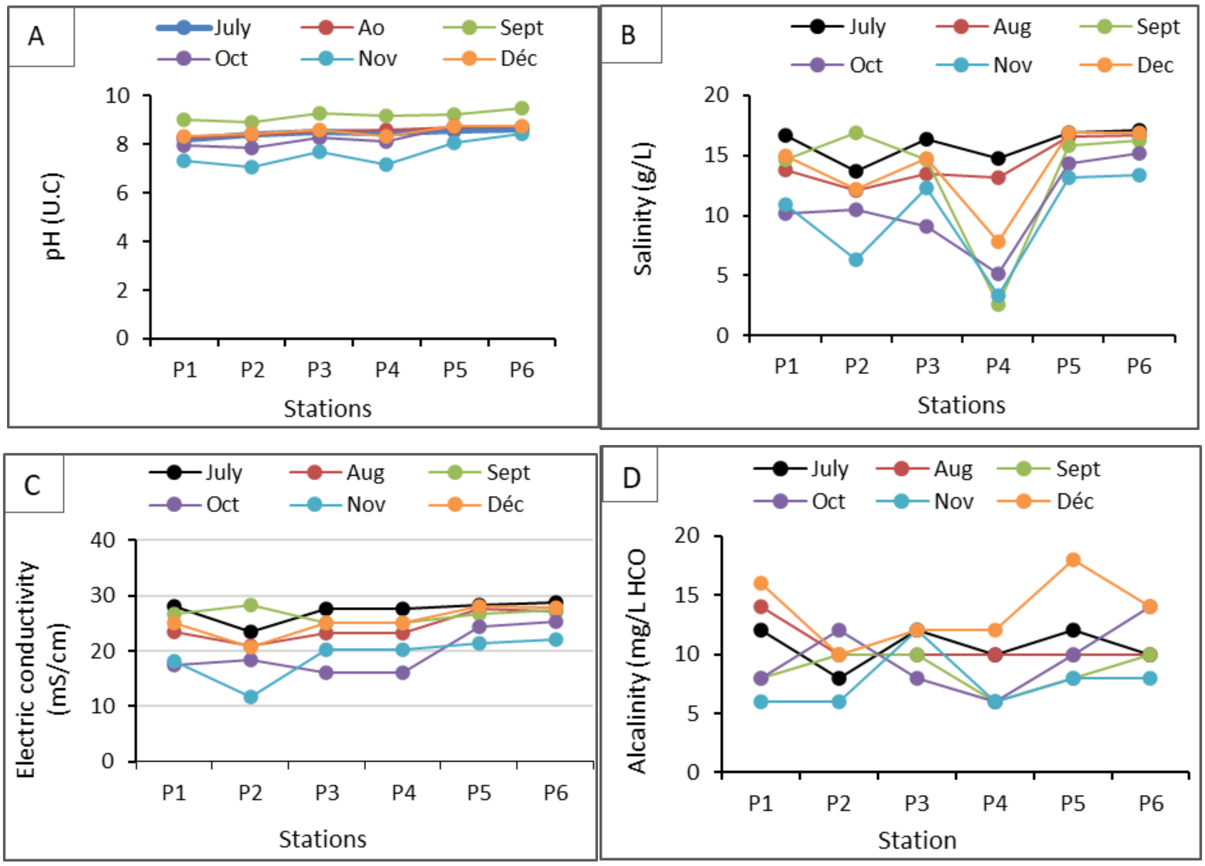


Figure 4 Spatio-temporal variation of pH (A), salinity (B), electrical conductivity (C) and alkalinity (D) during the study

The pH, salinity, conductivity, and alkalinity varied throughout the study from point to point. The pH, varied between 7.05 and 9.03 UC (Figure 4A). The minimum pH value was recorded at station P2 in November while the maximum value was observed in September at station P3. Salinity fluctuated between 3.3g/L at P5 in November and 17.15 g/L in July at P6, a range of 13.85 g/L (Figure 4B). Electrical conductivity ranged from 11.66 µS/cm in November at P2 to 28.8 mS/cm in July at P6 (Figure 4C). Alkalinity for its part presented values varying from 6 to 16 mg/L HCO_3^-. The minimum value was obtained at stations P1, P2 and P4 in November while the maximum value was observed in December at station P5 (Figure 4D).

Dissolved oxygen presented values that varied between 84.13% obtained at station P1 in December and 97.4% recorded at the same station in November with an average of 91.85 ± 3.87 % (Figure 5A). Transparency oscillated around an average value of 2.42 ± 0.70 m (Figure 5B).

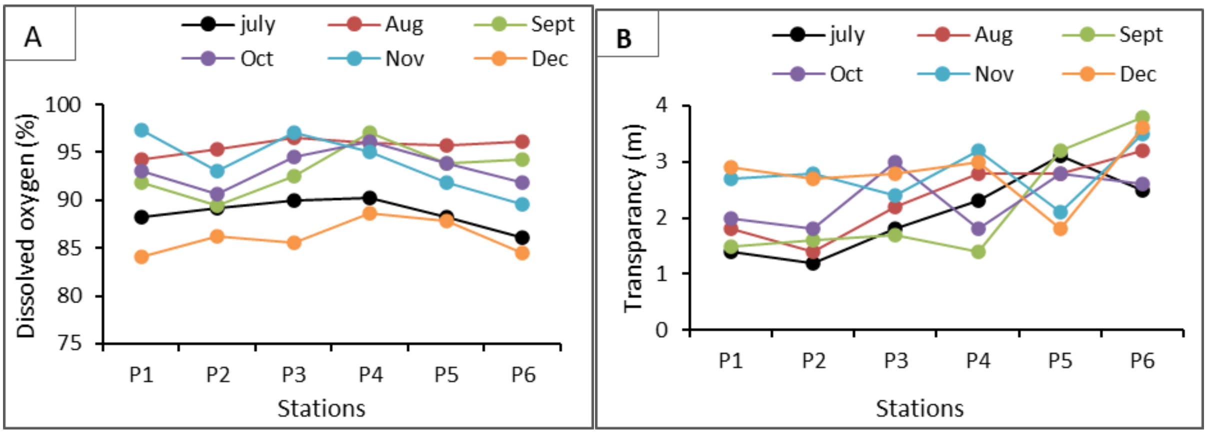


Figure 5 Spatio-temporal variation of dissolved oxygen (A) and transparency (B) during study

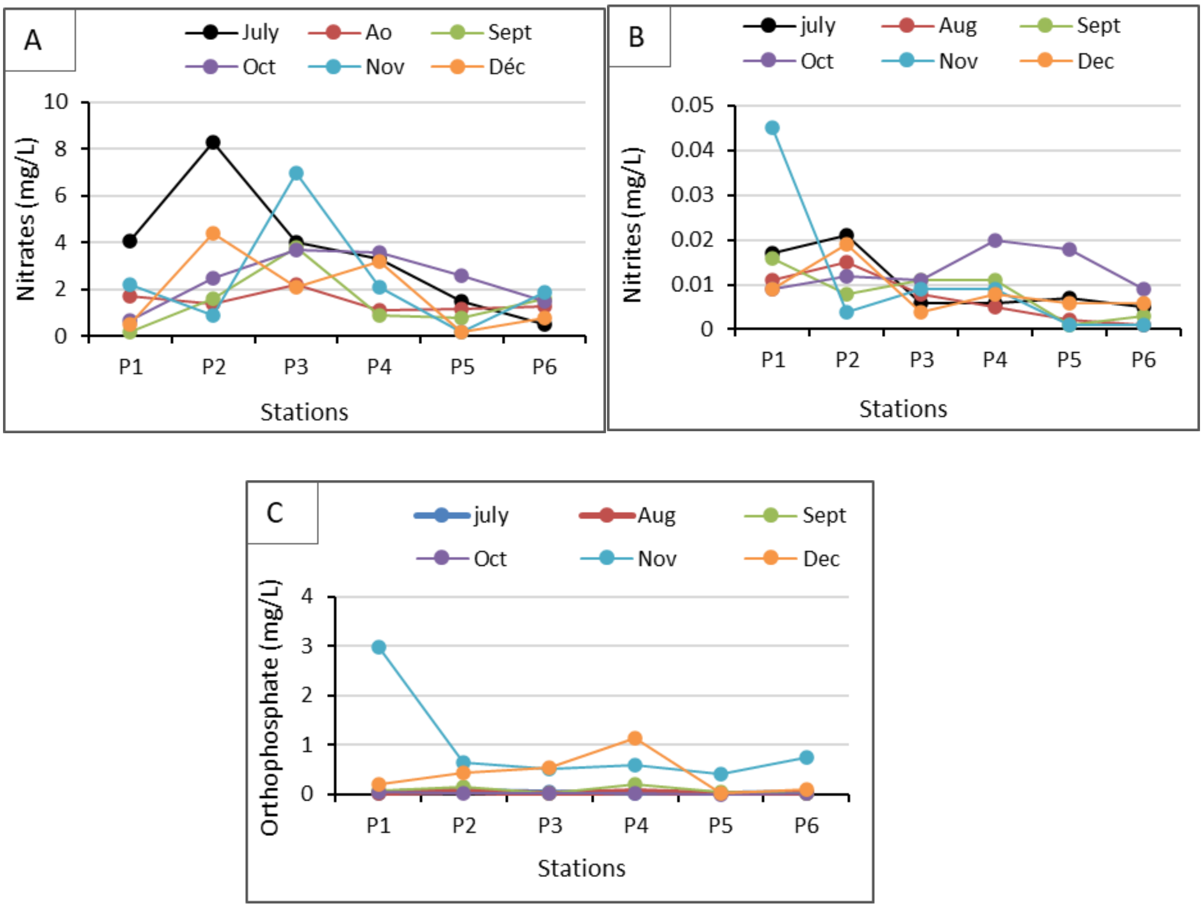


Figure 6 Spatio-temporal variation of Nitrate (A), Nitrite (B) and Orthophosphate (C) during the study

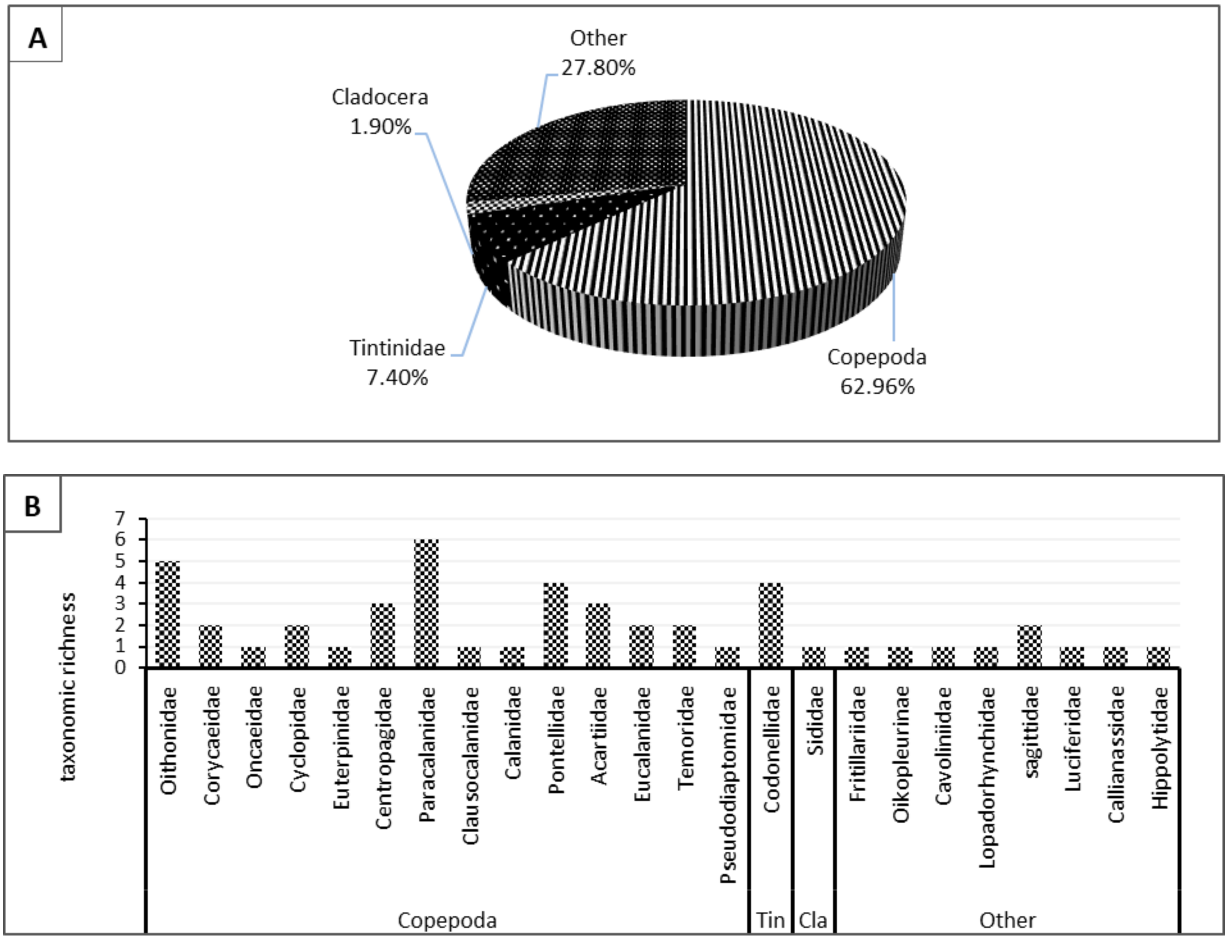
For the forms of nitrogen and orthophosphates, nitrates fluctuated around a mean value of 2.2 ± 1.8 mg/L (Figure 6A). For nitrites, they fluctuated around a mean value of 0.009±0.008 mg/L (Figure 6B). With regard to orthophosphate, they presented values that varied between 0 mg/L obtained at station P5 in October and 2.99mg/L recorded at station P1 in November (Figure 6D).

3.2. Biological variables

3.2.1. Qualitative analysis of the zooplankton community.

Taxonomic richness and relative abundance

This study revealed, 54 zooplanktonic taxa belonging to 3 major groups (Copepods, Cladocerans, Tintinidae) and other Zooplankton, 24 families and 29 genera were inventoried (Table 2). This population is composed of 34 taxa of copepods, i.e. 62.96% of the total taxonomic richness, 4 Tintinidae (7.4%), 1 marine cladoceran (1.9%), and 15 taxa of other zooplankton (27.8%), including larvae of neritic and benthic organisms (figure 7A). The copepods were divided into 14 families (figure 7B) and 19 genera. The family Paracalinidae is the most diverse (6 species), followed by the Oithonidae with 5 species, then the Pontellidae with 4 species, the Centropagidae and Acattiidae with 3 species each and the rest of the copepods with 2 to 1 species. The cladocerans were composed of only 1 species belonging to the genus Penilia and the family Sididae (Figure 7B). As for the Tintinidae, they presented 1 family (Codonellidae) (figure 7B) with 1 genus and 4 species. In the group Other Zooplankton, the determination could not be done up to the specific level and we stopped at higher determination levels. However, it includes 8 families (figure 7B), notably those of the Luciferidae (*Lucifer hanseni*), Oikopleurinae (*Oikopleura dioica*), Sagittidae (*Sagitta neglecta*) and Cavoliniidae (*Creseis cherchae*), among others. This group also includes Ostracods, Decapods, Brochiopods, crab zoea, polychaete larvae, etc.



(Tin = Tintinidae; Cla = Cladocera)

Figure 7 Relative abundance (A) and taxonomic richness (B) of zooplankton during the study

Frequency of occurrence

Table 2 Frequency of occurrence of zooplankton groups surveyed in the waters of the Kribian coast of the Kribian coast during the study period

Groups	Family	Taxa	P1	P2	P3	P4	P5	P6	FOG (%)
Copepods Cyclopid	Oithonidae	*Oithona brevicornis*	83.33	66.67	66.67	83.33	50	83.33	72.22
		Oithona atlantica	83.33	50	50	33.33	16.67	0	38.88
		Oithona nana	50	33.33	33.333	50	0	0	27.77
		Oithona sp.	66.67	66.67	33.33	33.33	50	33.33	47.22
		Oithona attenuata	0	33.33	0	0	0	0	5.56
	Corycaeidae	*Corycaeus dahli*	100	83.33	83.33	66.67	50	83.33	77.78
		Corycaeus andre	0	0	0	0	16.67	0	2.78
	Oncaeidae	*Oncaea clevei*	33.33	0	0	0	0	0	5.56
	Cyclopidae	*Mesocyclops* sp.	33.33	16.67	0	16.67	0	0	11.11
		Thermocyclop sp.	0	33.33	0	16.67	0	0	8.33
Harpaticoid copepods	Euterpinidae	*Euterpina acutifrons*	66.67	83.33	50	100	50	83.33	72.22
Copepods Calanid	Centropagidae	*Centropage* sp.	50	83.33	50	33.33	66.67	50	58.33
		Centropage furcatus	66.67	16.67	16.67	33.33	33.33	50	36.11
		Centropage tenuiremis	0	16.67	33.33	33.33	16.67	16.67	25
	Paracalanidae	*Paracalanus* sp.	66.67	83.33	66.67	50	50	83.33	66.67
		Paracalanus. indicus	50	33.33	16.67	50	16.67	33.33	33.33
		Parvocalanus sp.	33.33	33.33	33.33	33.33	16.67	50	33.33
		Acrocalanus Longicornis	66.67	50	33.33	50	33.33	50	47.22
		Acrocalanus sp.	66.67	50	16.67	33.33	16.67	50	38.89
		Bestiolina arabica	0	0	16.67	0	0	0	2.78
	Clausocalanidae	*Clausocalanus minor*	66.67	50	33.33	66.67	33.33	33.33	47.22
	Calanidae	*Cantocalanus. Pauper*	16.667	0	0	0	0	0	2.78
	Pontellidae	*Labidocera Kroyeri*	0	0	0	16.67	16.67	16.67	8.33
		Labidocera sp.	33.33	66.67	33.33	16.67	0	50	36.11
		Labidocera minuta	50	0	33.33	33.33	0	33.33	25
		Calanopia sp.	33.33	16.67	0	16.67	0	0	11.11
	Acartidae	*Acartia Clausi*	33.33	33.33	33.33	50	0	16.67	27.78
		Acartia margalef	33.33	50	83.33	66.67	0	33.33	44.44
		Acartia sp.	50	50	33.33	16.67	0	16.67	27.78
	Eucalanidae	*Subeucalanus subcrassus*	50	16.67	16.67	16.67	33.33	50	30.56
		Subeucalanus. fleminger	0	0	0	0	0	16.67	2.78
	Temoridae	*Temora discotada*	16.67	33.33	33.33	33.33	16.67	16.67	25

		Temora turbinata	50	33.33	33.33	0	0	16.67	22.22
	Pseudodiaptomidae	*Pseudodiaptomus* sp.	50	16.67	0	16.67	16.67	0	16.67
Tintinidae	Codonellidae	*Tintinnopsis. parva*	0	0	16.67	16.67	0	16.67	8.33
		Tintinnopsis gracilis	0	0	0	33.33	0	0	5.56
		Tintinnopsis radix	50	50	0	33.33	33.33	33.33	33.33
		Tintinnopsis ampla	0	0	16.67	0	0	0	2.78
Cladocerans	Sididae	*Penilia aviris*	33.33	0	0	33.33	0	16.67	13.89
	Fritillariidae	*Appendicularia sicula*	16.67	33.33	33.33	33.33	16.67	33.33	25
Other Zooplankton	Oikopleurinae	*Oikopleura dioica*	50	50	66.67	50	66.67	66.67	58.33
	Non déterminé	*Ophioplutei*	50	0	0	0	0	33.33	8.33
	Non déterminé	Polychaete larva	0	33.33	33.33	33.33	16.67	33.33	25
	Cavoliniidae	*Creseis chierchiae*	16.67	0	16.67	16.67	33.33	0	13.89
	Lopadorhynchidae	*Lopadorhynchus henseni*	33.33	0	0	0	0	0	5.56
	Non déterminé	*Lepro.bul*	0	16.67	0	0	0	0	2.78
	sagittidae	*Sagitta néglecta*	50	83.33	33.33	33.33	83.33	50	55.56
		Sagitta enflata	50	16.67	16.67	66.67	16.67	16.67	30.56
	Non déterminé	Brachiopod larva	0	16.67	0	33.33	0	0	8.33
	Non déterminé	*Cyphonaute*	16.67	0	16.67	0	0	33.33	11.11
	Luciferidae	*Lucifer hanseni*	50	33.33	66.67	66.67	33.33	66.67	52.78
	Non déterminé	Ostracode	50	0	0	0	33.33	16.67	19.44
	Callianassidae	*Callianassa* spp.	33.33	16.67	0	16.67	0	33.33	13.89
	Hippolytidae	*Latreute* sp.	0	0	0	0	16.667	0	2.78

The frequency of occurrence of the taxa of the different groups collected in the 6 sampling points shows that only one taxon *Corycaeus dahli (*77.7%) was regular (1.86% of the total taxonomic richness), 7 taxa (*Oithona brevicornis* (72.2%); *Euterpina acutifron* (72.2%); *Centropage* sp. (58.3%); *Paracalanus* sp. (66.6%); *Sagitta neglecta* (55.5%); *Oikopleura dioica* (58.3%) and *Lucifère hanseni* (52.7%)) were constant, i.e. 12.97% of the total taxonomic richness, 21 taxa were accessory (38.9% of the taxonomic richness) and 25 were accidental, i.e. 46.3% of the taxonomic richness (Table 2) From one point to another, the following taxa were remarkable for their frequency: *Corycaeus dahli* and *Euterpina acutifrons* were omnipresent at P1 and P4 respectively. *Corycaeus dahli* was regular at P2, P3, P6 and constant at P4 and P5 while *Euterpina acutifrons* was regular at P2 and P6, constant at P1 and incidental at P3 and P5 (Table 2).

3.2.2. Quantitative analysis.

Zooplankton abundance

Spatially (Figure 8A), Copepods were the most abundant (78.46% of the zooplanktonic population) and varied from one station to another, with a predominance of the families Paracalanidae (100 ind/L) and Oithonidae (122 ind/L) at station P1 (541 ind/L). It is followed by stations P2 (389 ind/L), P3 (385 ind/), P4 (250 ind/L) and P6 (217 ind/L). Station P5 shown the lowest abundance of Copepods at 149 ind/L. As for the other Zooplankton group (19.42% of the population), they were present in all stations at relatively low abundances. Nevertheless, some high values were recorded at stations P1 (153 ind/L) and P3 (116 ind/L). These high 14 values were marked by the predominance of Oikopleurinae (92 ind/L) for P1 and Sagittidae (65 ind/L) for P3. These stations were followed by P4 (67 ind/L), P2 (48 ind/L), P5 and P6 (47 ind/L each). Tintinidae were present at very low abundances at all stations. The highest value (16 ind/L) for this group was obtained at station P2. Cladocerans were absent at stations P2, P3 and P5.

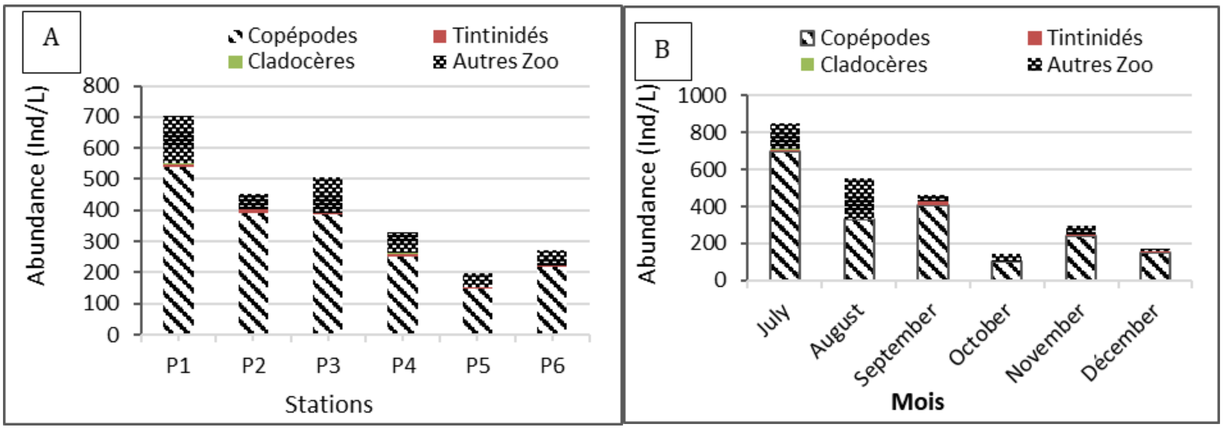


Figure 8 Spatial (A) and temporal (B) variations in abundance of zooplankton groups during the study

On the one hand, they were only obtained at stations P1, P4 and P6 with an abundance of 3 ind/L in each of them. As with the spatial plan, the temporal plan (Figure 8B) was marked by the high abundance of copepods (78.14% of the total abundance) in all months. The highest abundance was marked by the predominance of the family Euterpinidae (301 ind/L) in July (695 ind/L) followed by the family Oithonidae (97 ind/L) in September (407 ind/L) and the family Paracalanidae (109 ind/L) in August (331 ind/L). On the other hand, relatively low abundances were noted with a predominance of the family Oithonidae (97 ind/L ; 19 ind/L) in November (250 ind/L) and December (152 ind/L) respectively, followed by October (104 ind/L). For Tintinidae (1.74% of total abundance), abundances were very low but September and July stood out with abundances of 19 ind/L and 11 ind/L respectively. The months of December, November, October and August showed abundances of 6 ind/L, 5 ind/L and 1 ind/L respectively. For the other zooplankton group, August was the most abundant month (217 ind/L) with a predominance of the Oikopleurinae family (114 ind/L), followed by July (142 ind/L), also dominated by the same family (89 ind/L). The months of November, October, September and December showed abundances of 44 ind/L, 36 ind/L, 33 ind/L and 16 ind/L respectively. Cladocerans absent in October and December showed low abundances in July and November (3 ind/L), September (2 ind/L) and August (1 ind/L).

3.3. Diversity index

Spatially, the Shannon and Weaver diversity index (H') varied between 1.8 bits/ind at P3 and 2.4 bits/ind at P1 (Figure 9A). The Piélou equitability (J) fluctuated between 0.70 at P3 and 0.93 at P1 with an average of 0.85±0.08 (Figure 9A). Temporally, the Shannon and Weaver diversity index (H') fluctuated between 1.8 bits/ind in September and 2.5 bits/ind in December with an average of 2.3±0.21 bits/ind (Figure 9B). The Piélou equitability (J) varied from 0.73 in September to 0.96 in December with an average of 0.89 ± 0.08 (Figure 9B). The Kruskal Wallis test showed no significant difference ($p > 0.05$) in terms of space and time.

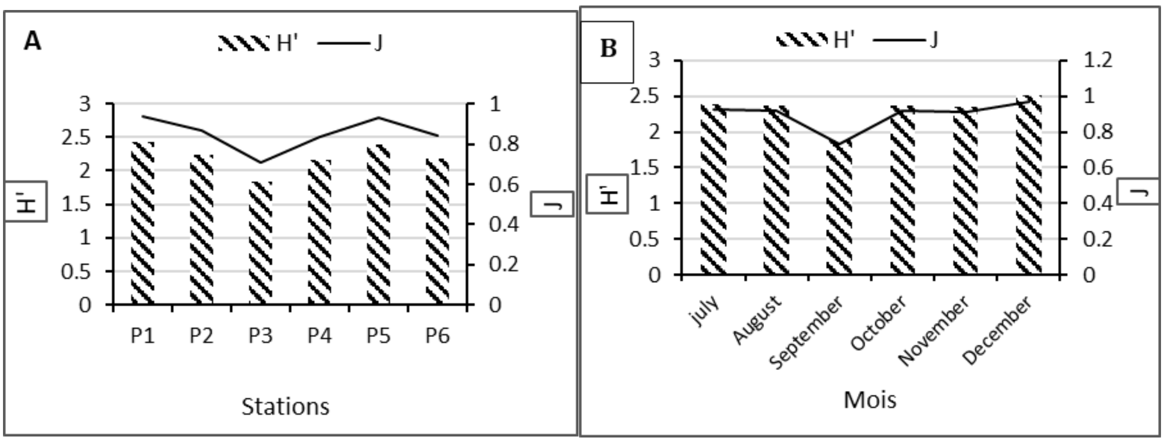


Figure 9 Spatial (A) and temporal (B) variations in the Shannon and Weaver (H') and Piélou equitability indices (J) over the study period

3.4. Abiotic factors associated with zooplankton taxa*.*

Table 3 Correlations between abiotic factors and recorded taxa

	phosphate	nitrite	nitrate	conductivity	TSS	salinity	pH	temperature
Oithona atlantica	0.439**	0.045	-0.093	-0.207	-0.355*	-0.272	-0.215	-0.172
Euterpina acutifrons	-0.102	-0.123	0.077	0.579**	0.096	0.429**	0.209	-0.271
Centropage sp	0.346*	-0.005	-0.016	0.224	-0.398*	0.172	0.164	-0.068
Clausocalanus minor	0.751**	-0.039	-0.13	-0.057	-0.536**	-0.082	-0.209	0.425**
Oithona nana	0.272	0.341*	0.254	-0.189	0.060	-0.315	-0.360*	-0.241
Oikopleura dioica	-0.317	0.038	0.289	0.216	0.461**	0.205	0.091	-0.135
Tintinnopsis parva	0.431**	-0.277	0.124	-0.021	-0.125	-0.128	-0.058	0.335*
Labidocera sp	0.01	0.034	0.04	0.305	-0.012	0.202	0.17	-0.446**
Acartia margaleff	0.146	0.173	0.459**	-0.128	0.357*	-0.245	-0.295	-0.128
Calanopia sp	0.131	0.243	-0.109	0.311	-0.195	0.124	0.272	-0.463**

Abbreviations: TSS: Total Suspended Solids; pH: Hydrogen potential; **. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level

The analysis of correlations was made it possible to highlight the links between the abiotic factors and the different taxa recorded. Table 3 below shows the abiotic factors that have a significant positive or significant negative influence on the taxa identified. In the case of orthophosphate, it was positively and significantly correlated with *Oithona atlantica*, *Centropage* sp*,* *Clausocalanus minor*, and *Tintinnopsis parva*. On the other hand, TSS was negatively and significantly correlated with *Oithona atlantica*, *Centropage* sp. and *Clausocalanus minor* and positively and significantly correlated with *Oikopleura dioica* and *Acartia margalef*. As for temperature, it presented positive and significant correlations with *Clausocalanus minor*, and *Tintinnopsis, parva* on the one hand, and negative and significant with *Labidocera* sp. and *Calanopia* sp. on the other. Salinity and electrical conductivity were positively and significantly correlated with *Euterpina acutifrons*. Nitrite and Nitrate were positively and significantly correlated with *Oithona nana* and *Acartia margalef* respectively (Table 3).

3.5. Influences of abiotic variables on the distribution of zooplankton populations.

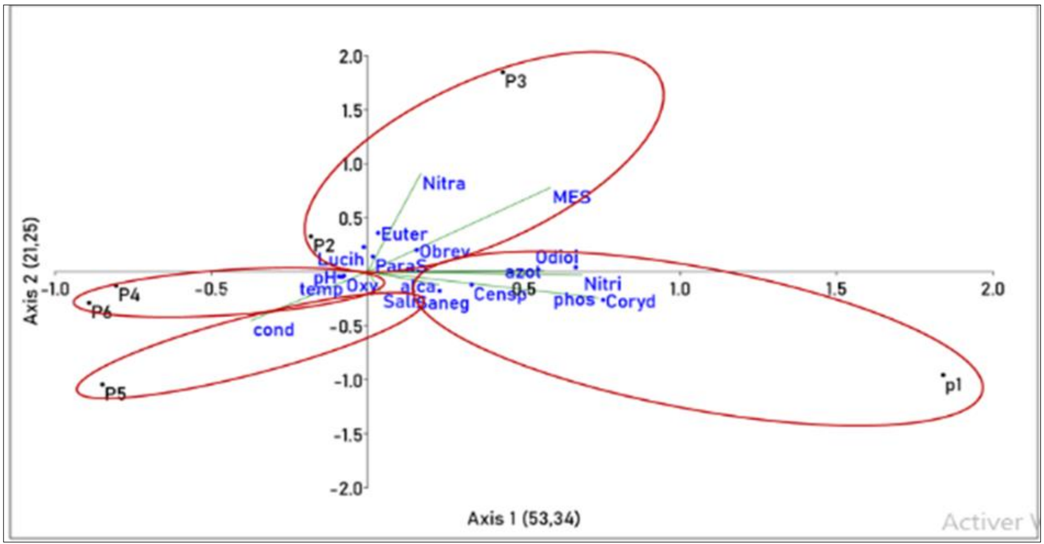


Figure 10 Canonical Correspondence Analysis (CCA) showing relationships between abiotic variables, sampling points and taxa at six stations (Abiotic variables: Temp = Temperature, TSS = Suspended solids, Nitri = Nitrite, Nitra = Nitrate, Cond = Electrical conductivity, phos = Phosphate, Oxy = Dissolved oxygen, Azo = Ammoniacal nitrogen, Sali = Salinity, pH = Hydrogen potential, Alca = Alkalinity; Biological variables: Euter = *Euterpina acutifrons*, Coryd = *Corycaeus dahli*, Obre = *Oithona brevicornis*, Lucih =*Lucifer hanseni*, Censp = *Centropage sp*, Saneg = *Sagitta neglecta* and Paras = *Paracalanus sp.*

The results of the Canonical Correspondence Analysis (CCA) showed that the correlations between the abiotic factors and the taxa studied were divided into two axes, axis 1 (53.34%) and axis 2 (21.25%), which account for 74.59% of the total variance (Figure 10). The factorial axis 1 separates the stations P2 and P3 from P1, P4, P5 and P6. The first group, positively correlated to axis 1, containing the taxa, *Centropage* sp., *Corycaeus dahli*, *Sagitta neglecta* and *Oikopleura dioica*, is characterised by orthophosphate, nitrite and alkalinity. The second group, negatively correlated with axis 1, did not present any taxa but is characterised by pH, temperature and dissolved oxygen. Group 3, positively correlated to axis 2, containing the taxa *Euterpina acutifrons*, *Oithona brevicornis*, *Lucifer hanseni* and *Paracalanus* sp. is characterized by TSS and nitrates. Group 4 is negatively correlated with axis 2, contains no taxa but is characterized by salinity and electrical conductivity. Thus, the average values of nitrites, nitrates, TSS, alkalinity and orthophosphate obtained positively influence the presence of some zooplanktonic organisms.

4. Discussion

The abiotic factors (temperature, TSS, salinity, nitrates, nitrites and phosphates) varied along the studied stretch of coast during the whole study period. The mean temperature value (28.58 ± 1.29°C) recorded during this study shows an increase in temperature in the Kribi coast over the years compared to those obtained [24] in 2004 and 2005, i.e. 27.2°C and 27.4°C respectively. This difference in temperature values would be linked to the frequency of measurements, the duration of the various works or the effects of climate change on temperature. This difference is justified by the fact that the measurements were carried out in a punctual manner from one station to another and at different times of the day, sometimes when the sun was at its zenith along the estuary [25]. TSS is generally low from one station to another and ranges from 0 to 13 mg/l with an average of 4.08 ± 4.82 mg/l. However, these observed values remain lower overall than those obtained upstream of the coastal river (the Kienké) at Kribi by [7]. These low TSS contents are linked to the phenomenon of clogging and sedimentation in the marine environment. As for salinity, the very low values observed at stations P2 and P4 compared to the other stations would indicate an increased influence of the fresh water of the ''Kienké'' and ''Lobé'' rivers. On the other hand, according to [26], the increase in salinity in some places may be due to a weak influence of freshwater (e.g. in the Kribi region compared to the Limbé region near the Wouri estuary). For nitrate, nitrite and orthophosphate, the values recorded during this study were higher (nitrate and nitrite) and lower (orthophosphate) than those recorded by [24] during a 7-month study with a monthly measurement frequency (<0.003; 0; 0.5 mg/L) for Nitrite, Nitrate and Orthophosphate respectively. The high values of orthophosphates (2.99 mg/L) and nitrites (0.045 mg/L) in November at station P1 are the result of the activities carried out (swimming, artisanal fishing, etc.) on this beach and the contributions of the ''Kienké'' River, which receives all types of waste and detergents from the fish market located at the landing stage, which is discharged upstream from this station. The significant concentrations of orthophosphates (0.25 ± 0.54 mg/L) and nitrates (2.2 ± 1.8mg/L) during this study remain too high compared to international (0.04 mg/l and 0.05 mg/l respectively) and national standards as recommended by the Ministry of Mines and Energy of Cameroon for fisheries resources and aquatic life according to [26]. These nutrients would come not only from agricultural activities with the use of fertilisers and other chemicals by large agricultural companies such as HEVECAM and SOCAPALM around Kribi, but also from industrial, domestic, hotel, landing and fish market discharges along the coast. According to the [26], the high concentrations of nitrates and phosphates could have changed the ecological balance of the water in coastal environments, creating favourable conditions for the proliferation of algae, which would be at the origin of the eutrophication of hydrosystems.

During this study, 54 taxa were inventoried in the waters of the Kribi coast. These taxa are divided into 3 main groups (Cladocerans, Copepods, Tintinids) and other zooplankton than those mentioned above, into 29 families and 24 genera. This taxonomic richness is close to that obtained in Casamance (56 taxa) by [27] or in Côte d'Ivoire (52 taxa) by [28]. However, it remains much lower than the species richness recorded by [29] on the Brazilian continental shelf (130 taxa) and the taxonomic richness obtained on the continental shelf of Morocco, on the Atlantic Ocean side (78 species) by [30]. These differences in taxonomic richness could be linked to the types of environment, the physico-chemical properties of the water, the regional climate and the hydrology of the water bodies [31]. This population is dominated qualitatively (taxonomic richness) and quantitatively (abundance) by copepods. They make up 62.96% of the zooplanktonic richness compared with 27.8%, 7.4% and 1.9% respectively for other zooplankton, tintinids and cladocerans. This dominance of copepods is linked to their colonising nature in marine environments. [32] and [33] point out that copepods are the most abundant group of multicellular metazoan zooplankton in the oceans and even on Earth. The dominance of copepods in the zooplanktonic population of the Kribian coast obtained in this study is in line with the results observed in the bibliographic synthesis on the zooplankton of the neritic waters of the Atlantic Ocean on the coasts of Côte d'Ivoire (58%) [28], Brazil (approximately 50%) [29], the Atlantic coasts of Morocco (73%) [30] and Senegal (27 to 93%) [34]. The spatio-temporal distribution of abundance showed an overall abundance of copepods in all stations and during all months with a predominance of the families Paracalanidae, Oithonidae and Euterpinidae. These observations partially corroborate those made on the Brazilian continental shelves in the State of Sergipe and in Ivory Coast where ([29] and [28] respectively observed the predominance of the family Paracalinidae in their work.

According to these authors, the predominance of taxa of the family Paracalanidae in tropical Atlantic waters could be linked to the fact that these taxa are herbivorous and that conditions favouring phytoplankton blooms may be the most important parameters in the distribution pattern of herbivorous copepods, which are by far the most abundant and probably attracted by phytoplankton production induced by several factors including up wellings. The predominance of Oithonidae is, according to [35] linked to their wide tolerance to variations in environmental parameters and their ability to live in environments that present numerous daily and seasonal variations. Moreover, the metabolic and trophic capacities of the taxa of this family, as well as their low respiratory frequency, allow them to develop in abundance in contaminated areas, and in particular in eutrophic systems where zooplankton densities are generally high [36]. The predominance of Eutrpinidae (*Euterpina acutifrons*) in July can be explained by the temperature values obtained in this month, which are close to the optimum temperature for this species. Thus, [37] note that *Euterpina acutifrons* reproduces from April to December with an optimal water temperature of 25°C. Low water temperatures limit its reproduction from 16.5°C.

The spatio-temporal fluctuations of the Shannon and Weaver index (H) and Pielou's equitability reveal an instability in the structuring of the communities studied, thus showing the variability of the environmental conditions that prevailed in the section studied during the study. This instability of the environment is justified by the preponderance of accidental and/or rare species (25/54 taxa). In addition, the low value of the equitability index recorded at station P3 would be due to the high relative abundance of the copepod species *Euterpina acutifrons*, which accounts for nearly 35.06% of the individuals at this station. In this regard, [38] and [39] point out that the Pielou index is low when one or a few taxa have a relatively higher abundance than others. Similarly, the low diversity obtained in the month of September is due to the instability of the environment linked to tidal movements, resulting in the leaching of zooplankton organisms. [40] emphasizes in this respect that the tides create conditions of instability that cause the drift of zooplankton populations. The results of the CCA analyses showed that the variables influencing the distribution of taxa are alkalinity, nitrite, nitrate, TSS and orthophosphate. The first group of axis 1 which presented 4 taxa is characterised by preferring waters rich in orthophosphate, nitrite and alkalinity (station P1). This would mean that the values of these abiotic variables would favour the development of these zooplanktonic organisms. In addition, the 4 other taxa obtained in group 3 of axis 2 preferred water rich in SS and nitrates (stations P2 and P3). These results corroborate [41] statement that zooplankton abundance is high in coastal areas rich in nutrient salts.

5. Conclusion

The results of the study carried out in the Kribian Atlantic coast concerning the spatio-temporal variation of the zooplanktonic population in relation to some abiotic variables show that a total of 54 zooplanktonic taxa divided into 4 groups (3 major ones) with the qualitative (34 taxa, i.e. 62.96% of the total taxonomic richness) and quantitative (78.30% of the total abundance) predominance of Copepods over the other zooplanktonic groups. The most abundant taxa belong to the different families of Oithonidae, Paracalinidae and Euterpinidae. Variations in diversity and abundance over space and time showed that station P1 and the month of December were the most diverse, while the same station and the month of July showed the greatest abundance. However, of the 54 taxa recorded, 1 taxon (*Corycaeus dahli*) was regular and 7 taxa (*Oithona brevicornis*; *Euterpina acutifrons*; *Centropage* sp; *Paracalanus* sp; *Sagitta neglecta*; *Oikopleura dioica* and *Lucifère hanseni*) were constant. With regard to physicochemistry, the average values of temperature, nitrates and orthophosphates of the waters in comparison with previous work showed an increase in temperature over the years on the stretch of coast studied and a progressive enrichment in nutrients with the highest values at stations P1 (temperature, orthophosphates and nitrites) and P2 (nitrate) where anthropic activities are more pronounced. These waters are also moderately salty and haline. Suspended solids, alkalinity, nitrates, nitrites and orthophosphates, which are believed to be the result of various anthropogenic activities along the coast, are the environmental variables that most influence the distribution of taxa. The results of the analyses of the abiotic variables coupled with those of the biological variables could indicate.

Compliance of ethical standard

Acknowledgments

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Disclosure of conflict of interest

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

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