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Research Article
Carbonate Chemistry and Structure of Macro-invertebrate Communities in Relation to Organic Pollution in the Coastal Atlantic Ocean at Kribi (Cameroon)

[1,2]Bilounga Ulrich Joel Felicien, [1]Onana Fils Mamert, [1]Nyamsi Tchatcho Nectaire Lié, [3]Koji Ernest, [4]Tchakonte Siméon, [4]Tamsa Antoine Arfao, [1]Mfoula Nkolo Frederic, [2]Ntyam Ondo Sylvie Carole and [5]Zebaze Togouet Serge Hubert

[1]Department of Aquatic Ecosystems Management, Institute of Fisheries and Aquatic Sciences, University of Douala, P.O. Box 2701, Douala, Cameroon
[2]Specialized Research Centre for Marine Ecosystems, P.O. BOX 219, Kribi, Cameroon
[3]Microbiology and Biotechnology Laboratory, Saint Jerome Polytechnic Institute, Saint Jerome Catholic University, P.O. Box 5949, Douala, Cameroon
[4]Department of Animal Biology and Physiology, Faculty of Sciences, University of Douala, P.O. Box 24 157, Douala, Cameroon
[5]Department of Animal Biology and Physiology, Faculty of Science, University of Yaoundé I, P.O. Box 812, Yaoundé, Cameroon

Abstract
Background and Objective: In tropical Africa, the chemistry of carbonates in coastal waters has been little studied, which does not predict ocean acidification and its impact on the viability of coastal ecosystems. In this study, the variability of the carbonate system and the structure of macro-invertebrate communities in relation to organic pollution in the coastal Atlantic Ocean at Kribi in Cameroon are described for the 1st time. **Materials and Methods:** Macro-invertebrates were sampled monthly over a 3 months period (May to July, 2018) using the quadrant method, in three stations. Measurements of the physicochemical variables (nutrients, pH, salinity, temperature, total alkalinity and dissolved oxygen) were done simultaneously. Carbonate system parameters were calculated using the CO_2 cal software V4.0.9. **Results:** The organic pollution index (OPI) has shown that the coastal waters of Kribi are subject to heavy organic pollution. The values of the parameters of the carbonate system indicate that the coastal ocean at Kribi is not subject to acidification. Also, the saturation rates of aragonite and calcite are greater than 1. The pH is alkaline, >8.02. The Shannon and Weaver (1.87-2.87) and Piélou (0.59-0.69) indices indicate poorly diversified stands of macro-invertebrates, numerically dominated at each site by two or three species and characterizing disturbed intertidal ecosystems. **Conclusion:** This study made it possible to show through the positive and significant correlation between pH and OPI, that organic pollution of coastal waters is a precursor to the acidification phenomenon, the consequences of which are disastrous for biodiversity.

Key words: Coastal Atlantic ocean, carbonate chemistry, organic pollution, macro-invertebrates community structure, Kribi

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Corresponding Author: Onana Fils Mamert, Department of Aquatic Ecosystems Management, Institute of Fisheries and Aquatic Sciences, University of Douala, P.O. Box 2701, Douala, Cameroon

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Since the industrial revolution, atmospheric concentrations of carbon dioxide (CO_2) have increased exponentially[1]. About a quarter of this atmospheric CO_2 is absorbed annually by the oceans, causing changes in marine water chemistry and pH, a phenomenon known as ocean acidification[2]. The United Nations has recognized this phenomenon as requiring immediate action[3], as it has the effect of inducing major changes in marine ecosystems, particularly in ocean biocenosis. Indeed, according to numerous studies, the survival, calcification, growth, development and abundance of a wide range of marine species would be reduced in response to ocean acidification[4].

To assess the potential impact of an ocean acidification scenario on coastal ocean organisms and ecosystems, it is useful to understand the variability of the parameters defining it, including the variability of the carbonate system[1]. However, in coastal areas, interactions between hydrological and biogeochemical processes result in complex variations in carbonate chemistry. Thus, on various time scales, several processes can influence the chemistry of the carbonate system, including primary production, stream inputs, terrigenous particles and pollution[5,6]. Also, the impact of ocean acidification on coastal organisms is much more difficult to predict than for offshore species because, in coastal habitats, carbonate chemistry is highly variable, the conditions to which organisms are exposed are more difficult to measure and the sensitivity of organisms can vary under the interaction of different abiotic stress factors. However, among the communities that inhabit coastal ecosystems, benthic invertebrates are the best indicators of ecological conditions[7,8]. These benthic macro-fauna, in addition to playing a decisive role in the material and energy flows of coastal ecosystems[9,10], integrates disturbances and response by fluctuations in its structural parameters, such as the number of species and abundance[11]. In addition, this macro-fauna includes organisms with long life cycles which allow them to integrate the effects of both accidental and chronic disturbances[12].

In Cameroon, the coastal city of Kribi has undergone significant socio-spatial changes over the past decade, with inevitable repercussions on the environment in general and on coastal aquatic ecosystems in particular. Indeed, the establishment of a deep-water Port in this tourist city is at the origin of an anarchic urbanization and the beginning of industrialization, which leads to a quantitative and qualitative increase in the emission of pollutants, most of which are untreated and transported to the ocean by the rivers draining this city[13]. Till date, several studies have been carried out to assess the impact of anthropogenic pollution on the quality of coastal waters and on the biocenosis of coastal aquatic ecosystems[14-16]. However, in Cameroon, no studies have been carried out on the carbonate chemistry o f coastal waters and the potential impact of its variability on the structure of aquatic communities. The objective of this study was to describe for the first time the chemistry of carbonate system in the coastal waters of Kribi, Cameroon (Central Africa) and to determine the structure of macro-invertebrate communities in relation to organic pollution and carbonate chemistry.

MATERIALS AND METHODS

Study area: This study was conducted in the coastal area of Kribi in Southern Cameroon from May to July, 2018. The climate is equatorial Guinean type, characterized by high and constant temperatures with an annual average[17] of 26.8°C. Precipitation is divided into 4 seasons: 2 rainy seasons (September-November and April-June) and 2 dry seasons (December-March and July-August)[17].

Sampling sites: Three sampling sites were selected for this study: Kribi urbain, Eboundja and Bipaga (Fig. 1). The Kribi urbain site (2°56'21.71"N, 9°54'11.78"E) located at the mouth of the Kienké River which covers the urban area of Kribi and the agro-industries for rubber (HEVECAM) and oil palm production (SOCAPALM). Kienke thus drains urban and industrial pollutants produced on the continent to the ocean. The Eboundja site (2°48'5.88"N, 9°53'37.16"E) located approximately 10 km from the Kribi deep-water Port, near a forest area crossed by a river. The Bipaga site (3°7'0.6"N, 9°57'41.75"E) located approximately 5 km from the Kribi natural gas liquefaction plant. This site is bordered by a coastal forest with several small rivers carrying litter to the ocean. The substrates of the Kribi urbain and Eboundja sites are sandy and strewn with rocks, meanwhile Bipaga is essentially sandy.

Physicochemical analysis: Measurements of the physicochemical parameters of seawater were carried out monthly at each site during May, June and July, 2018, following the recommendations of Rodier *et al.*[18]. Temperature (T), salinity (Sal), dissolved oxygen (DO) and pH were measured *in situ* at low and high tides using a multiparameter HORIBA U-50. For physicochemical laboratory analyses, water samples for total alkalinity (TA) measurements were collected from the surface at low and high tides using 500 mL double-sealed polyethylene bottles, fixed with 0.2 mL mercuric chloride and stored in a refrigerated environment[19]

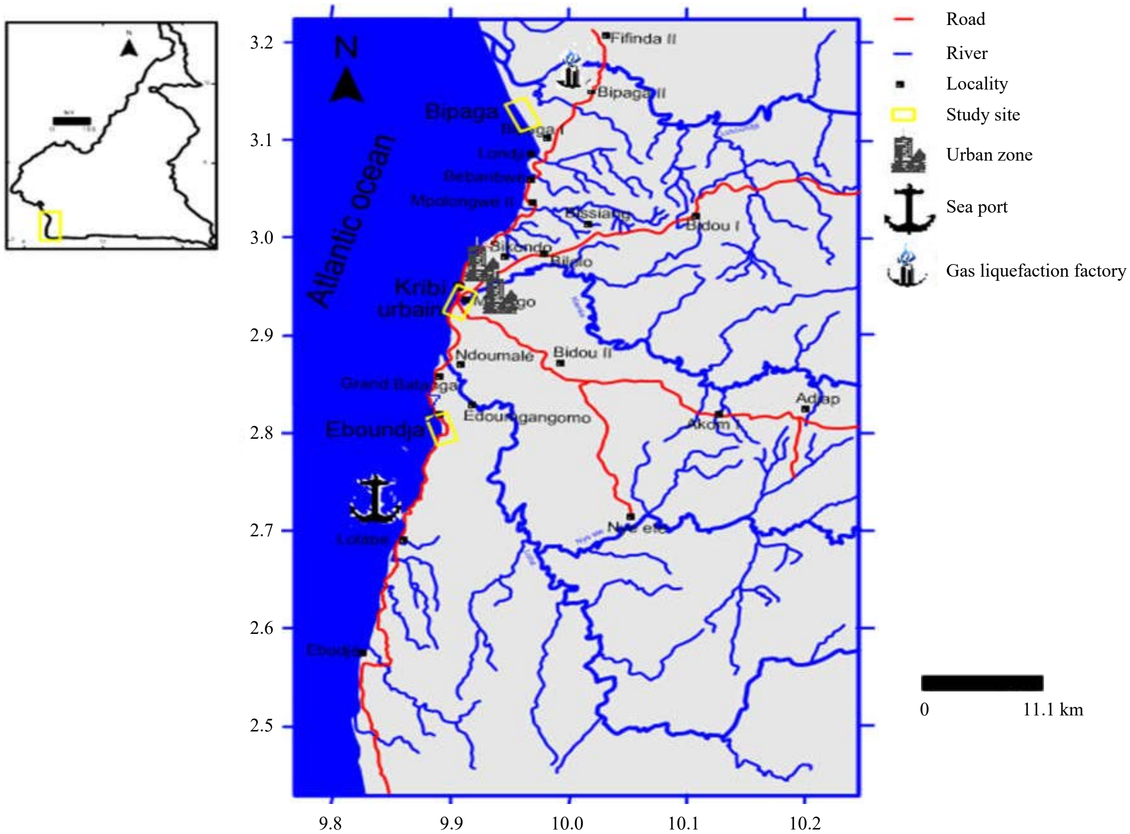

Fig. 1: Map of the study area showing sampling stations

at 4°C. Water samples for the measurement of the nutrients nitrites (NO_2^-), ammonium (NH_4^+) and orthophosphate (PO_4^{3-}) were collected only once per tidal period at the surface in 500 mL double-sealed polyethylene bottles and stored in a refrigerated environment at 4°C. Carbonate system parameters, including total carbon dioxide (TCO_2), carbonate ions (CO_3^{2-}), bicarbonate ions (HCO_3^-), aragonite saturation rate (ΩAr) and calcite saturation rate (ΩCa) were calculated from total alkalinity, pH, temperature and salinity values using the CO_2 cal software V4.0.9[20]. The CO_2 constants used in this calculation are those developed by Millero *et al.*[21] and Dickson[22] for coastal areas. The organic pollution index (OPI) was calculated according to the methodology described by Leclercq and Maquet[23], taking into consideration the concentrations of three variables: NH_4^+, NO_2^- and PO_4^{3-}.

Sampling and identification of macro-invertebrates: Macro-invertebrate sampling was conducted in the intertidal zone of each sampling site using the quadrant method described by Cucherat and Demuynck[24]. A transect of about 450 m was materialized at low tide using a string, parallel to and about 2 m from the ocean water withdrawal line. Subsequently, 10 quadrants of 1 m^2 each, spaced 50 m apart, were placed on either side of the transect line. Thus, a total area of 10 m^2 was used to sample macro- invertebrates at each site. All macro-invertebrates found on the surface and within the first 10 cm of the substrate of each quadrant were collected by hand or with tongs. Similarly, organisms attached to rocks were torn off. The macro-invertebrates collected in this way were stored in a mixture of 40% formaldehyde and seawater in glass jars, then washed with tap water in the laboratory and stored in 70° ethanol. Macro-invertebrates were identified under a stereomicroscope of the brand WILD M5. Identification was successfully accomplished to species level of each specimen using Bandel and Kowalke[25], Lindner[26] and Olivier[27].

Macro-invertebrates metrics and indices: Two benthic macro-invertebrate's metrics were calculated to analyze the community structure: The diversity index of Shannon and Weaver (H') and the Pielou's evenness index (J), calculated from the taxonomic richness (S) and abundance (A) of macro-invertebrates. These indices informed on the distribution of individuals within the taxa so as to compare the

Table 1: Pollution classification from H' values, in sandy/muddy habitats

Ecological states	H' values	Pollution classifications
Bad	$0<H'\leq 1.5$	Azoic, very polluted
Mediocre	$1.5<H'\leq 3$	Strongly polluted
Average	$3<H'\leq 4$	Moderately polluted
Good	$4<H'\leq 5$	Transition zones
Very good	$H'>5$	Reference sites

diversity of the communities amongst the sampling stations[28]. The assumption is that undisturbed environments are characterized by high diversity or richness and an even distribution of individuals among the Taxa[29]. In addition, the values of H' were compared with the threshold values of sandy/muddy habitats as described by Simboura and Zenetos[30] (Table 1) to determine the ecological status of each sampling station.

Rank-frequency diagrams (RFD): The RFD were used to monitor the demographic structure of the macro-fauna in order to visualize the spatial evolution of the invertebrate population[31]. They have the advantage of providing a synthetic, accurate and more detailed representation of the distribution of individuals within a stand[32]. In addition, they can detect the ecological successions of a community (stages 1, 2 and 3) from a stress stage with proliferation of opportunistic species to a healthier community[32].

Statistical analysis: The pearson correlation between carbonate system variables and organic pollution made it possible to assess the influence of organic pollution on carbonate chemistry. The simultaneous comparison of variances by the ANOVA test after verification of normal conditions by the Shapiro-Wilk test made it possible to compare the values of the physicochemical parameters obtained at low tide and at high tide. The relationships between abiotic variables and macro-invertebrates were determined using the Spearman correlation test. All statistics were compiled using the XLSTAT 2007 and MATLAB R2013a software.

RESULTS

Nutrients, dissolved oxygen and organic pollution: Table 2 presents the average values of the parameters describing organic pollution in the coastal waters of Kribi. Nitrite concentrations ranged from 0.063-0.882 mg L^{-1}. Ammonium varied between 0.026 and 23.346 mg L^{-1}. Orthophosphate concentrations ranged from 0.13-10 mg L^{-1}. Dissolved oxygen in Kribi's coastal waters ranged from 13.4-55.7 mg L^{-1}. In addition, the OPI showed that the waters of Kribi urbain are subjected to very high organic pollution (OPI = 1.86±0.61) while the coastal waters of the Eboundja and Bipaga sites showed high organic pollution with respective OPI values of 2.2±0.28 and 2.08±0.43.

Salinity, pH and temperature: Salinity in the coastal waters of Kribi varied between 18.42 and 28.06 ppt (Fig. 2a). The Eboundja site had the highest salinities (23.32±3.3 ppt) while the Kribi urbain site had the lowest salinities (20.73±0.16 ppt) (Fig. 2a). The pH of the coastal waters of Kribi fluctuated between 8.01 and 9.98 (Fig. 2b). Kribi urbain with an average pH of 8.69±0.48 had the lowest pH values while the Bipaga site (9.13±0.22) had the highest values. The highest salinities and pH values were obtained at low tide and the lowest salinities and pH values were recorded at high tide. The temperature fluctuated between 28.06 and 31.2°C (Fig. 2c). The hottest waters were recorded in Bipaga (30.74±0.85°C) and the least hot in Eboundja (29.74±0.95°C). At low tide the average temperature was 29.71±0.64°C and at high tide it was 30.57±0.9°C.

Carbonate chemistry: The TA of the coastal waters of Kribi ranged from 1198.8-5994.01 µmol kg^{-1} (Fig. 3a). The TCO_2 varied between 315.55 and 6005.16 µmol kg^{-1} (Fig. 3b). Carbonate ion concentrations ranged from 130.96-2064.64 µmol kg^{-1} (Fig. 3c). Bicarbonate ion concentrations ranged from 89.39-4286.14 µmol kg^{-1} (Fig. 3d). Values of calcite and aragonite saturation rates in Kribi coastal waters remained above the saturation threshold ($\Omega>1$) (Fig. 3e, f). The mean values of TA, carbonate, calcite and aragonite were the highest at the Bipaga site, while the lowest values of these parameters were observed at Eboundja. The highest values for TCO_2 and bicarbonate ions were obtained in Eboundja. Overall, the highest values of the carbonate system parameters were recorded at low tide while its lowest values were obtained at high tide. However, except for the bicarbonate values that differ significantly between high and low tide ($p<0.05$), all other parameters describing carbonate chemistry do not vary significantly from one tide to another ($p>0.05$).

Relationship between carbonate chemistry and organic pollution parameters: Pearson correlation between carbonate system variables and variables describing organic pollution at the 5% significance level showed a positive and significant correlation between total alkalinity and bicarbonate ($r = 0.70$, $p = 0.03$). Similarly, positive and significant correlations were recorded between total alkalinity and ammoniacal nitrogen ($r = 0.79$, $p = 0.01$), between pH and

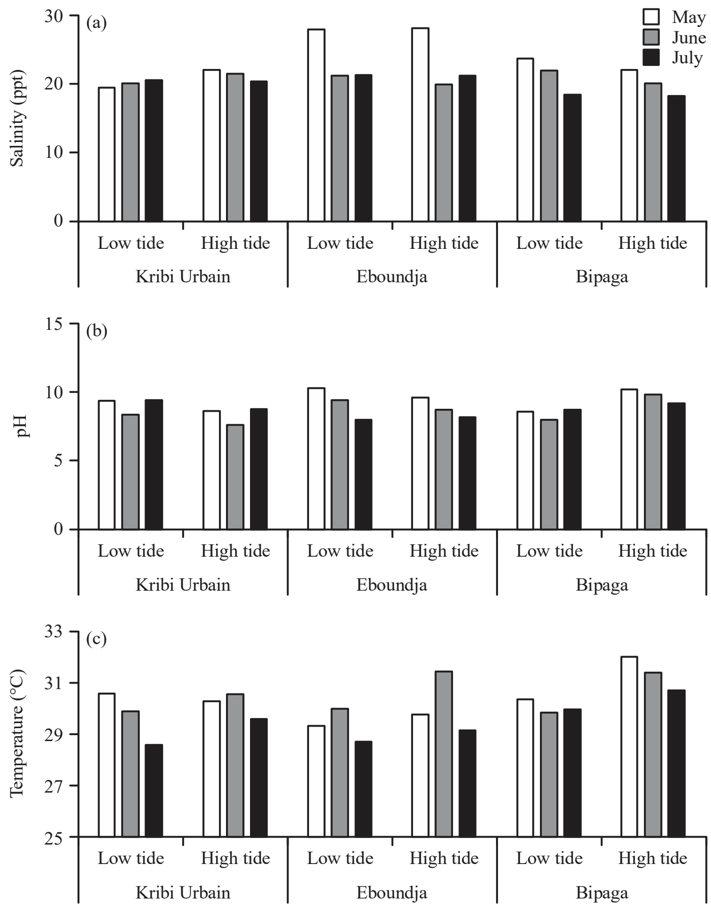

Fig. 2(a-c): Variation of (a) Salinity, (b) Temperature and (c) pH in the Kribi coastal sea water

Table 2: Average values of the parameters describing organic pollution in the coastal waters of Kribi during the study period

Sampling sites	DO (mg L^{-1})	NO_2^- (mg L^{-1})	NH_4^+ (mg L^{-1})	PO_4^{3-} (mg L^{-1})	OPI
Kribi Urbain	23.22±8.25	0.23±0.12	14.00±10.07	4.67±4.06	1.86±0.61
Eboundja	29.96±14.4	0.47±0.3	11.32±8.36	0.84±0.54	2.20±0.28
Bipaga	35.68±14.9	0.37±0.28	5.96±5.3	0.70±0.37	2.08±0.43

OPI ($r = 0.76$, $p = 0.015$), between carbonate and calcite saturation ($r = 1.0$, $p = 0.0001$) and between ammoniacal nitrogen and total carbon dioxide ($r = 0.83$, $p = 0.006$). On the other hand, negative and significant correlations were found between the OPI and total alkalinity ($r = -0.79$, $p = 0.01$), between pH and TCO_2 ($r = -0.84$, $p = 0.005$) and between TCO_2 and OPI ($r = -0.90$, $p = 0.001$).

Macro-invertebrates communities' structure: During this study, 22 macro-invertebrate species were identified (Table 3). 81.82% of the identified species belonged to the Mollusca Phylum, 9.10% to the Arthropoda phylum, 4.54% to the Cnidaria phylum and 4.54% to the Echinodermata phylum. In the Kribi urbain site, 14 species have been identified (13 Mollusca and 1 Arthropoda). In Eboundja, 18 species have also been identified (15 Mollusca, 1 Arthropoda, 1 Echinodermata and 1 Cnidaria). In the Bipaga site, the population consists of 9 species (7 Mollusca and 2 Arthropoda).

With regard to macro-invertebrate abundances, a total of 5990 individuals were collected, including 4087 Mollusca (68.23%), 1741 Arthropoda (29.06%), 149 Cnidaria (2.49%) and 13 Echinodermata (0.22%). In the Kribi urbain site, 2265 individuals were recorded, involving 2 058 Mollusca and 207 Arthropoda. This stand is dominated by 3 species: *Plicopurpura* sp. (25.39%), *Nerita scabricosta* (25.08%) and *Lithophaga* sp. (20.93%) (Table 3). In Eboundja, 2051 individuals were counted. Mollusca are the most represented branch with 84.01% relative abundance. The species *Nerita scabricosta* (36.03%), largely dominates the population of this

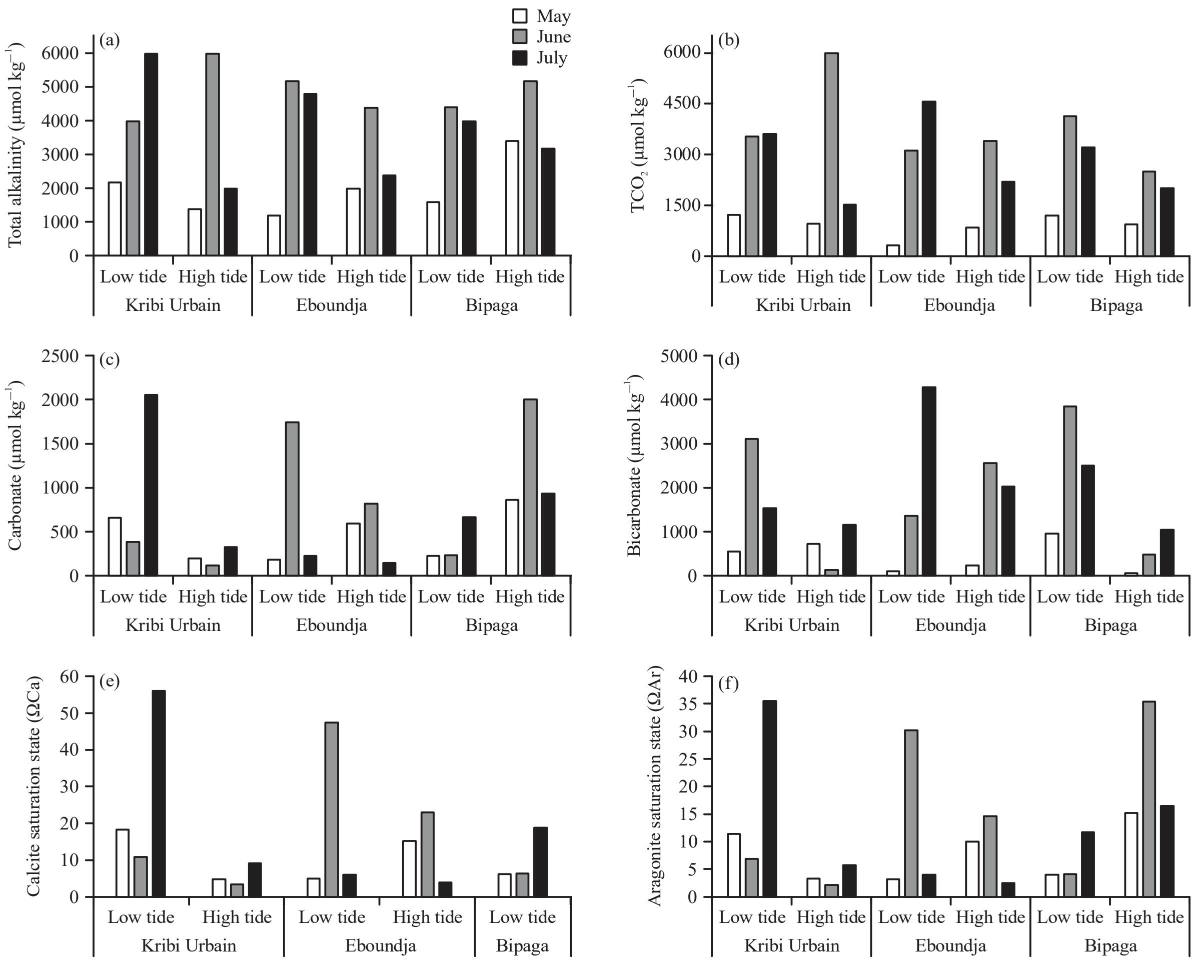

Fig. 3(a-f): Carbonate chemistry variables of the coastal waters of Kribi, (a) TA, (b) TCO_2, (c) CO_3^{2}, (d) HCO_3^-, (e) ΩCa and (f) ΩAr

station. *Lithophaga* sp. (19.06%) is the second most abundant species. Five other species were also noted for their abundance: *Nerita* sp. (9.95%), *Grapsus* sp. (8.09%), *Actinia* sp. (7.26%), *Plicopurpura* sp. (6.19%) and *Thais* sp. (5.27%). In the Bipaga site, 1674 individuals were collected. *Ocypode* sp. (47.67%) and *Grapsus* sp. (34.05%) were the most abundant species (Table 3).

The index of Shannon and Weaver (H') is 2.64 bits/ind, 2.81 bits/ind and 1.87 bits/ind obtained, respectively in the Kribi urbain, Eboundja and Bipaga stations (Table 3). The H' index values between 1.5 and 3 indicate that the three study sites considered in this study are in poor ecological conditions characteristic of high pollution. The values of the equitability J of Pielou are 0.69, 0.67 and 0.59 obtained respectively in the Kribi urbain, Eboundja and Bipaga sites (Table 3). Thus, a better distribution of species is observed within the Kribi urbain site. The RFD of the Bipaga site (Fig. 4) shows a stage 1 (early succession) appearance, characteristic of a pioneer community, with exclusive dominance of two species: *Ocypode* sp. (47.67%) and *Grapsus* sp. (34.05%). The RFD of the Kribi urbain and Eboundja sites have a completely convex curve showing a stand at stage 2 (Fig. 4). At these stations, there is a better distribution of individuals within the different species, resulting in higher H' and J indices.

Relationship between environmental variables and macro-invertebrates: Spearman correlation between biotic and abiotic variables showed significant and negative correlations between TA and *Plicopurpura* sp. ($r = -0.71$, $p = 0.037$), *Nerita scabricosta* ($r = -0.73$, $p = 0.025$), *Lithophaga* sp. ($r = -0.71$, $p = 0.037$), *Pitar* sp. ($r = -0.76$, $p = 0.021$), *Iphigenia* sp. ($r = -0.78$, $p = 0.014$) (Table 4). Similarly, bicarbonate showed negative and significant correlations with *Grapsus* sp., *Cardium costatum*, *Pitar* sp. ($r = -0.78$, $p = 0.017$) and *Iphigenia* sp. ($r = -0.82$, $p = 0.008$). On the other hand, the OPI showed positive and significant correlations with *Grapsus* sp., *Cardium costatum*, *Pitar* sp. ($r = 0.79$, $p = 0.014$) and *Iphigenia* sp. ($r = 0.82$, $p = 0.011$) (Table 4).

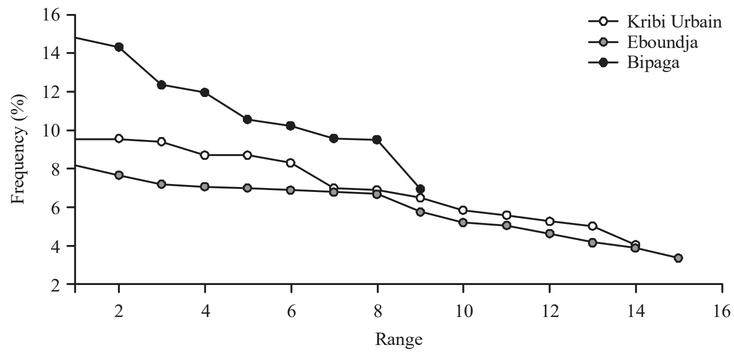

Fig. 4: RFD of macro-invertebrate stands at the 3 study sites

Table 3: Taxonomic composition and values of the metrics of macro-invertebrates in the Kribi intertidal zone

		Kribi urbain		Eboundja		Bipaga	
Phyla/families	Species	Number	Percentage	Number	Percentage	Number	Percentage
Mollusca							
Muricidae	*Plicopurpura* sp.	575.00	25.39	127.00	6.19	0.00	0.00
	Thais sp.	134.00	5.92	108.00	5.27	0.00	0.00
Neritidae	*Nerita scabricosta*	568.00	25.08	739.00	36.03	0.00	0.00
	Nerita sp.	0.00	0.00	204.00	9.95	0.00	0.00
Siphonaridae	*Siphonaria pectinata*	211.00	9.32	99.00	4.83	0.00	0.00
Naticidae	*Natica* sp.	30.00	1.32	0.00	0.00	0.00	0.00
Fasciolaridae	*Latirolagena* sp.	27.00	1.19	28.00	1.36	0.00	0.00
Terebridae	*Terebra* sp.	6.00	0.26	1.00	0.05	2.00	0.12
Nassariidae	*Nassarius* sp.	0.00	0.00	2.00	0.10	0.00	0.00
Cypreidae	*Cypreara tigris*	0.00	0.00	6.00	0.29	0.00	0.00
Mytilidae	*Lithophaga* sp.	474.00	20.93	391.00	19.06	0.00	0.00
Cardidae	*Cardium costatum*	17.00	0.75	3.00	0.15	25.00	1.49
	Donax sp.	3.00	0.13	0.00	0.00	126.00	7.53
Donacidae	*Donax vittatus*	0.00	0.00	1.00	0.05	14.00	0.83
	Iphigenia sp.	1.00	0.04	10.00	0.49	15.00	0.90
Veneridae	*Pitar* sp.	8.00	0.35	2.00	0.10	92.00	5.50
Mactridae	*Spisula* sp.	0.00	0.00	2.00	0.10	0.00	0.00
Sepiidae	*Sepia bertheloti*	4.00	0.18	0.00	0.00	32.00	1.91
Arthropoda							
Grapsidae	*Grapsus* sp.	207.00	9.14	166.00	8.09	570.00	34.05
Ocypodidae	*Ocypode* sp.	0.00	0.00	0.00	0.00	798.00	47.67
Cnidaria							
Actinidae	*Actinia* sp.	0.00	0.00	149.00	7.26	0.00	0.00
Echinodermata							
Stomopneustidae	*Stomopneustes*	0.00	0.00	13.00	0.63	0.00	0.00
Metrics							
Specific richness		14.00		18.00		9.00	
Abundance		2265.00	100.00	2051.00	100.00	1674.00	100.00
Shannon and weaver index (H′)		2.64		2.81		1.87	
Pielou's evenness index (J)		0.69		0.67		0.59	

Table 4: Spearman's correlation coefficient between the physico-chemical variables and macro-invertebrate species

	Macro-invertebrate species									
Physicochemical variables	*Plicopurpura* sp.	*Nerita scabricosta*	*Lithophaga* sp.	*Grapsus* sp.	*Siphonaria pectinata*	*Thais* sp.	*Latirolagena* sp.	*Cardium costatum*	*Pitar* sp.	*Iphigenia* sp.
TA	-0.71*	-0.73*	-0.71*	-0.76*	-0.71*	-0.71*	-0.73*	-0.76*	-0.76*	-0.78*
TCO_2	NS	NS	NS	-0.78*	NS	NS	NS	-0.78*	-0.78*	-0.82**
HCO_3^-	NS	NS	NS	-0.78*	NS	NS	NS	-0.78*	-0.78*	-0.82**
NO_2^-	NS	NS	NS	-0.78*	NS	NS	NS	0.78*	-0.78*	0.82*
NH_4^+	-0.72*	-0.72*	-0.72*	-0.77*	-0.72*	-0.72*	-0.72*	-0.77*	-0.77*	-0.77*
OPI	NS	NS	NS	0.79*	NS	NS	NS	0.79*	0.79*	0.82*

Significant correlation (*p<0.05, **p<0.01), NS: Non-significant correlation

DISCUSSION

The coastal waters of Kribi have shown a trend in organic pollution from strong (Eboundja, Bipaga) to very strong (Kribi urbain). Indeed, the combined action of untreated domestic effluent from the town of Kribi and agro-industrial effluents, originating from SOCAPALM and HEVECAM and drained by the Kienké River towards the coastal ocean, is at the origin of the very high organic matter loads in the water of the Kribi urbain site. As for the Eboundja and Bipaga sites, the high organic matter loads of the water at these sites would be linked to the presence of coastal forest around these sites. This forest produces a significant amount of litter drained to the ocean by small rivers that crosses these sites and whose degradation is at the origin of the high organic pollution observed[33]. This high organic pollution is accompanied by a depletion of dissolved oxygen in coastal waters. Indeed, the aerobic degradation by bacteria of the large quantities of organic matter consumes large quantities of dissolved oxygen in the water, which greatly reduces its concentration[34].

The carbonate system in the coastal waters of Kribi showed great variability depending on the sampling sites. The pH varied between 8.01 and 9.98, corresponding to alkaline waters. These pH values obtained during the study are above the global average and therefore do not appear to follow the acidification trends observed in the global ocean as a function of the increasing absorption of atmospheric CO_2 by the ocean. Indeed, Gonzalez-Davila *et al.*[35] have shown the need for longer-term observations to determine a possible lowering of ocean pH. However, the Kribi urbain site with the highest organic pollution (lowest OPI) recorded the lowest pH values. Aerobic degradation of organic matter by microorganisms leads to the production of CO_2, which is responsible for lowering oceanic pH[36,37] as confirmed by the positive and significant correlation between pH and OPI.

Analysis of the macro-invertebrates structure revealed that the Kribi urbain and Eboundja sites have the greatest diversities. Two factors would explain this great diversity: The presence of a herbarium canopy and the presence of a rocky substrate. Indeed, the meadows and rocks offer living conditions favorable to the proliferation of various organisms because they are used as a support, food source or refuge area[38,39]. The predominance of Mollusca in these sites would be linked to the super saturation of the waters of the Eboundja and Kribi urbain sites with aragonite and calcite, which are polymorphs of calcium carbonate[40] used by Mollusca during the bio-mineralization process to manufacture their shell. In addition, the Kribi urbain and Eboundja sites showed similar assemblages with 3 predominant species (*Plicopurpura* sp., *Nerita scabricosta* and *Lithophaga* sp. in Kribi urbain; *Nerita scabricosta*, *Lithophaga* sp. and *Nerita* sp., In Eboundja). These species, grouped within the families Muricidae, Neritidae and Mytilidae, are characteristic of tropical intertidal fauna[25,41]. Indeed, the agglutination of these Gastropoda in rock crevices allows the conservation of water and moisture during dry periods at low tide, making them resilient and able to thrive in disturbed ecosystems[42]. However, at the Kribi urbain and Eboundja sites, 4 other species (*Thais* sp., *Siphonaria pectinata*, *Grapsus* sp. and *Actinia* sp.) also distinguished themselves during the study by their abundance and are at the origin of the relatively higher J and H' indices at these study sites. At the Bipaga site, t h e preponderance of only two species (*Ocypode* sp. and *Grapsus* sp.) constituting 81.72% of the stand, is at the origin of the low diversity indices H' and J obtained at this site. Indeed, according to Levêque and Balian[43], the H' and J diversity indices decreases when a small number of taxa in a stand have very high relative abundances. The proliferation of Arthropods *Ocypode* sp. and *Grapsus* sp. is thought to be related to the sandy nature of the substrate in which they dig burrows that provide shelter from heat, dehydration and predators[44]. Bipaga site being a quay for the local fishermen, these two species can easily find their food (carrion from fishing waste).

The Frontier RFD illustrate that the stands of the 3 study sites show spatial fluctuations around stages 1 and 2. Zaabi-Sendi[32] showed that such Frontier RFD profiles, characterized by the preponderance of small number of species are indicators of disturbed environments.

This study is the first step in monitoring of coastal acidification in Central Africa and their impact on marine organisms and ecosystems. Nevertheless, long term data collection is necessary for accurate and precise evaluation of this phenomenon.

CONCLUSION

This first study of the coastal ocean carbonate system at Kribi in Southern Cameroon showed that the pH of coastal waters are alkaline and above the global average do not appear to follow the acidification trends observed in the global ocean. However, a slight decrease in pH values has been positively correlated with the presence of high organic matter loads in coastal waters, the degradation of which increases CO_2 concentrations. Invertebrates harvested in the Kribi intertidal zone reveal, through H' and J indices and RFDs, relatively undiversified populations characterized by the proliferation of a limited number of species, indicating a disturbed environment; this confirms their use as bio indicators of Cameroon's intertidal ecosystems.

SIGNIFICANCE STATEMENT

This study lays the foundation for understanding the variability of the carbonate system in a context of multiple stresses in the coastal ocean of Cameroon. It brings new knowledge to the elements other than atmospheric carbon dioxide likely to favor the acidification of the coastal ocean in Cameroon. In addition, it also provides information on the diversity of macro invertebrates and their use as tools for monitoring disturbances in tropical coastal ecosystems.

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