(RESEARCH ARTICLE)

Ecological Status of a Coastal Stream in the sea Port Area of Kribi, Cameroon: Diversity of Benthic Macroinvertebrates and Relationship to Some Physico-Chemical Parameters of the aquatic ecosystem

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Abstract

A study aimed to assess the ecological status of the water of the Mboro coastal stream, located in the sea port area of Kribi, South Region of Cameroon, through the diversity of benthic macroinvertebrates and some physico-chemical parameters of the water were carried out. Samples were done seasonally using a multi-habitat approach. Physico-chemical analyses revealed a relatively high oxygen saturation level (79.88 ± 4.91%), an average temperature of (27.70°C ± 1.66°C), and a slightly basic average pH of (7.20 ± 0.77 UC). The relatively low values of the Organic Pollution Index (IPO) indicate that the water of the Mboro stream are polluted. The biological results show a taxonomic richness of 78 taxa including 9391 individuals. Divided into 2 phyla (Molluscs and Arthropods), 4 classes, 20 orders, and 52 families. The class Gastropods was predominant with 35% relative abundance, dominated by the family of Neritidae (Nerita senegalensis), followed by the class Bivalves with a relative abundance of 33%, supplanted by the family of Mytilidae (Mytilus edulis, Xenostrobus pulex) and Mutelidae (Mutela rostrata). These organisms are pollutant-tolerant and can survive in degraded environments. Their significant presence downstream reflects the advanced deterioration of the water quality in that section of the stream. Thus, the development upstream of pollutant-sensitive groups such as the Baetidae (Ephemeroptera), Veliidae and Gerridae (Heteroptera), and Aeshnidae (Odonata) indicates a habitat of good ecological quality. The Hilsenhoff Biotic Index also revealed a notable deterioration of water quality downstream of this industrial complex.

Keywords: Ecological status; Benthic macroinvertebrates; Physico-chemical parameters; Coastal stream; Mboro; Kribi sea port area

1. Introduction

A coastal environment is defined as a dual terrestrial and marine fringe, one corresponding to the nearby watershed, the other to the area influenced with telluric inputs [1]. Coastal watercourses, located at the interface between terrestrial and marine ecosystems, play a crucial role in the water cycle, maintaining water quality, and supporting great biological diversity [2]. In Cameroon, watercources are subject to increasingly growing and diverse disturbances on a daily basis due to natural factors and the rapid anthropization of natural environments [3,4]. The impact of such human activities as rapid urbanization, intensive agriculture, industrial pollution, and climate change threatens the health of watercourses, leading to the degradation of water quality, the modification of aquatic populations [5], and consequently, the reduction of biodiversity [6]. Hence, the need for a permanent assessment of their health status using reliable and adequate indicators, such as biological indicators [7,8].

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The autonomous port of Kribi, linked to natural resources, promotes both economic development and environmental preservation, although it requires sustainable management to avoid pollution and ecosystem degradation. In this context, assessing the ecological status of a coastal watercourse in a port area becomes a priority to ensure its sustainable management and to prevent irreversible degradation. Thus, to assess the quality of these waters, the measurement of physico-chemical variables coupled with the diversity of bioindicators such as benthic macroinvertebrates constitutes the complete and most informative method [9,10].

Benthic macroinvertebrates are, by definition, organisms visible to the naked eye, lacking a skeleton, and spending at least part of their life cycle in water. They are recognized as good indicators of the health of aquatic ecosystems [11] due to their sedentary nature, high diversity, varied life cycles, and variable tolerance to pollution and habitat degradation [12,13].

In Cameroon, these organisms have already been the subject of several studies [14,15,16,17]. Unfortunately, few data are available on the ecological status of watercourses in the coastal area of Kribi. This study was therefore conducted to fill this gap. It aims to determine the biodiversity of benthic macroinvertebrates in the Mboro coastal river in Kribi and to analyze their relationship with certain environmental factors.

2. Material and methods

2.1. Geographical framework of study

The coastal city of Kribi, located on the Gulf of Guinea in the South Region of Cameroon, is the capital of the Ocean department. It is located between 2°56'14" N latitude and 9°54'27" E longitude, with an average altitude of 18 m. Kribi is a strategic port city and an important economic center, with key economic activities including fishing, tourism, the timber industry, energy, and the deep-water port. The climate is equatorial with four unevenly distributed seasons: a long dry season (November - March), a short rainy season (April - June), a short dry season (July), and a long rainy season (August - October), with an average monthly rainfall of 239.3 mm [18]. However, field studies have shown that the long dry season actually runs from mid-December to early March, the short rainy season from late March to May, the short dry season from June to July, and the long rainy season from August to November.

2.2. Description of the Study Site and Sampling Stations

Mboro is a watercourse located within the area designated for the Kribi deep sea port construction project, called Zone 1. Its source is located in the public utility declaration zone, at the foot of the Mamelles Mountains, only its lower course before the estuary lying outside Zone 1. Sampling was conducted by season (beginning and end of each season) from March 2023 to March 2024 over 12 campaigns. Four sampling stations named Mboro 1 (Mb1), Mboro 2 (Mb2), Mboro 3 (Mb3), and Mboro 4 (Mb4) and they were chosen based on the representativeness of different river sections (crenon, rhithron, potamon), site accessibility, the presence of microhabitats, and proximity to pollution sources (Figure 1). The substrate is composed of mud, sand, and granite (Table 1). As in all of Southern Cameroon, the soils fall into three categories: ferralitic soils found at the top of interfluves and at the base of slopes, hydromorphic soils in the marshy valleys, and soils in the lowlands. The geographical coordinates of these stations are contained in Table 1.

Table 1 Some characteristics of the Mboro river sampling stations

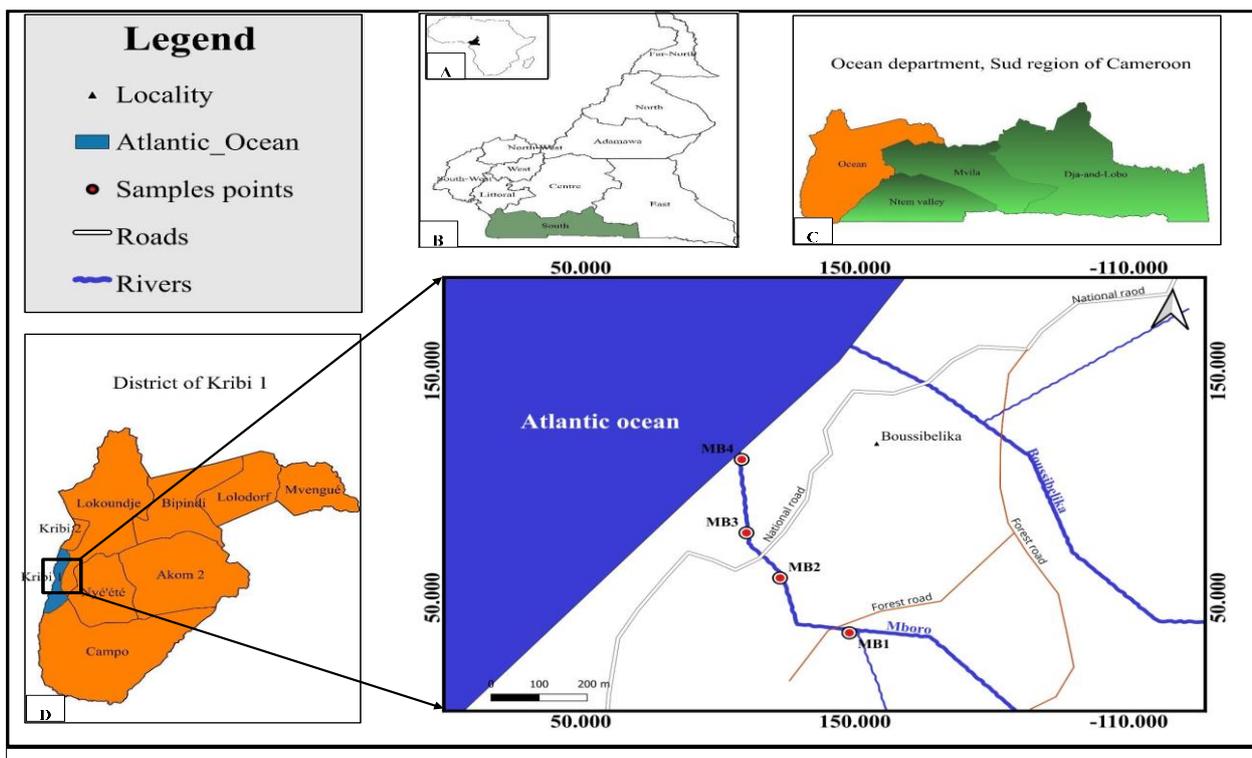| Code	Longitude	Latitude	Humain action
MB1	E 9°52'21.74412''	N 2°43'48.378''	No action identified
MB2	E 9°52'22.18476''	N 2°43'48.52344''	Fishing, swimming, washing dishes and laundry
MB3	E 9°52'18.73272''	N 2°43'50.69388''	fishing, swimming, washing dishes and laundry
MB4	E 9°52'17.59548''	N 2°43'51.93516''	Swimming, presence of pirogues

Figure 1 Hydrographic map of the Mboro river showing the sampling stations. Open Street Map (OSM)

2.3. Measurement of physico-chemical parameters

Physicochemical parameters were measured both in the field and in the laboratory following the recommendations of [19]. Temperature, pH, dissolved oxygen content, electrical conductivity, and salinity were measured in situ using a thermometer and a multiparameter of the HANNA HI 98130 brand respectively. In the laboratory, orthophosphates, the forms of nitrogen, were measured with a WAHTECH spectrophotometer, the alkalinity by volumetry from water samples taken in the field using the 1000 mL polyethylene vials, double-capped. The organic load of the waters was assessed by measuring the Organic Pollution Index (OPI) Table 2 and 3.

Table 2 Limits of the OPI classes [20]

Parameters / Classes	NH_4^+ (mg/L)	NO_2^- (µg/L)	PO_4^{3-} (µg/L)
5	< 0,1	≤ 5	≤ 15
4	0.1 - 0,9	6 – 10	16 – 75
2	2.5 – 6	51 – 150	251 -900
1	> 6	> 150	> 900

Table 3 Interpretation of the class average [20]

Class average	level of organic pollution
5.0 – 4.6	Nul
4.5 – 4.0	Low
3.9 – 3.0	Moderate
2.9 – 2.0	Strong
1.9 – 1.0	Very Strong

2.4. Measurement of biological variables

Regarding biology, benthic macroinvertebrates were sampled using the multihabitat approach [21]. Using a square-shaped cutter of 30 cm on each side equipped with a conical net of 500 μm mesh opening and 50 cm deep, about twenty dips were made over an area of 3m^2. The organisms caught in the net were collected using a pair of fine forceps and fixed with 10% formalin in polyethylene bottles. In the laboratory, the organisms were thoroughly rinsed with tap water to remove formalin and preserve in pill boxes containing 70 °C alcohol. They were then identified under a binocular magnifying glass using appropriate keys and books. Organic water pollution was assessed using the Hilsenhoff index (FBI) Table 4. The data analysis was done using Excel 2016, Spss 20.0 and XLSTAT version 2018.

Table 4 Interprétation grid for Hilsenhoff Biotic Index (FBI) (1988)

Hilsenhoff scale	Water quality class
0.00 to 3.75	Excellent : no organic pollution
3.76 to 4.25	Very good: slight organic pollution possible
4.26 to 5.00	Good: Likely to be organic pollution
5.01 to 5.75	Average: fairly substantial organic pollution
5.76 to 6.50	Somewhat poor: substantial organic pollution
6.51 to 7.25	Poor: substantial organic pollution
7.26 to 10.00	Poor: substantial organic pollution grave

3. Results

3.1. Physicochemical parameters

3.1.1. Temperature

The water temperature varies from 25.6 °C to 30.8 °C with an average value of 27.70 ± 1.66 °C (Figure 2). The Kruskal-Wallis test showed significant differences over time ($p < 0.05$).
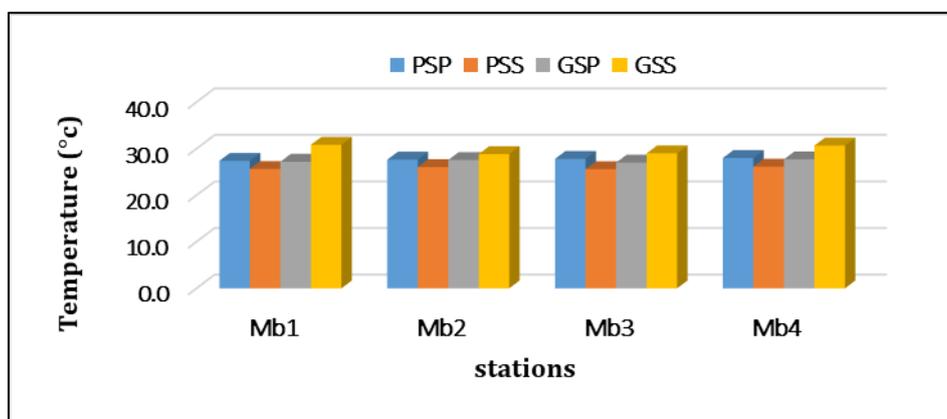

Figure 2 Spatio-temporal variation in the water temperature of the Mboro watercourse during the study period

3.1.2. pH

The pH values of the waters vary from 6.50 CU (Mb2, LDS) to 8.25 CU (Mb4, LRS) for an average of 7.35 ± 0.44 CU. The Kruskal-Wallis test revealed no significant spatiotemporal differences ($p > 0.05$) (Figure 3).
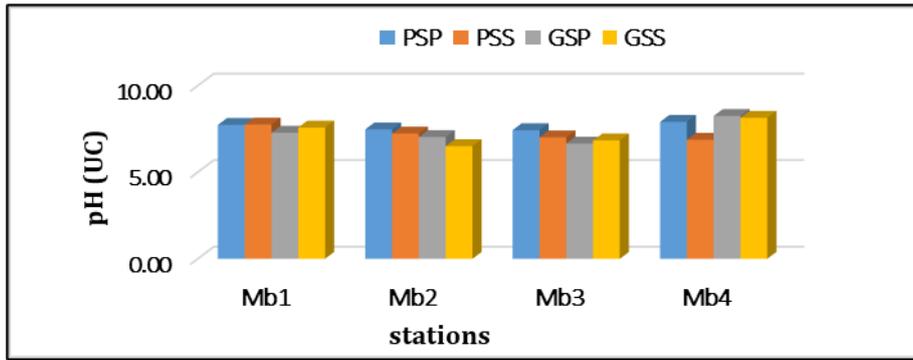
Figure 3 Spatio-temporal variation of the pH of the Mboro watercourse during the study period

3.1.3. Dissolved Oxygen

The maximum dissolved oxygen saturation rate of the water (Figure 4) is obtained at station Mb4 (92.40%) in SDS and the minimum rate at station Mb1 (66%) in SRS. Significant differences were observed between stations (p <0.05).
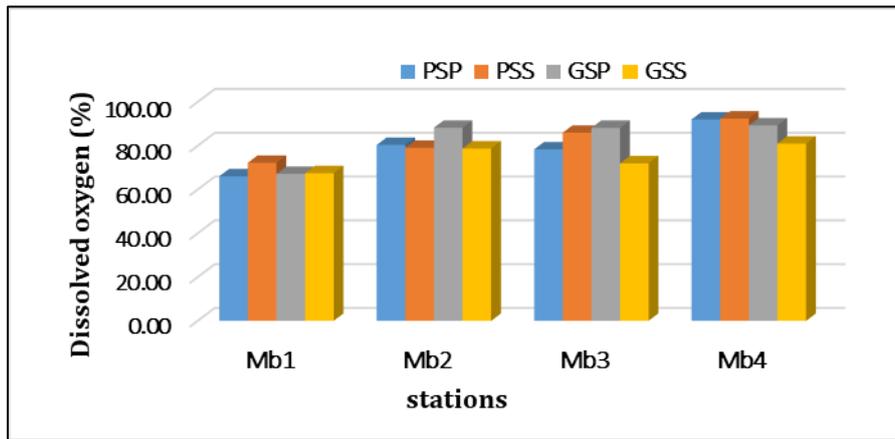

Figure 4 Spatio-temporal variation in dissolved oxygen concentrations in waters of the Mboro stream during the study

3.1.4. Electrical Conductivity

The electrical conductivity of the water has a minimum value of 35.70 µS/cm at the Mb2 station LDS and a maximum value of 34600 µS/cm at the Mb4 station in Lds (Figure 5). Spatially, the Kruskal-Wallis test revealed significant differences between station (p<0.05).
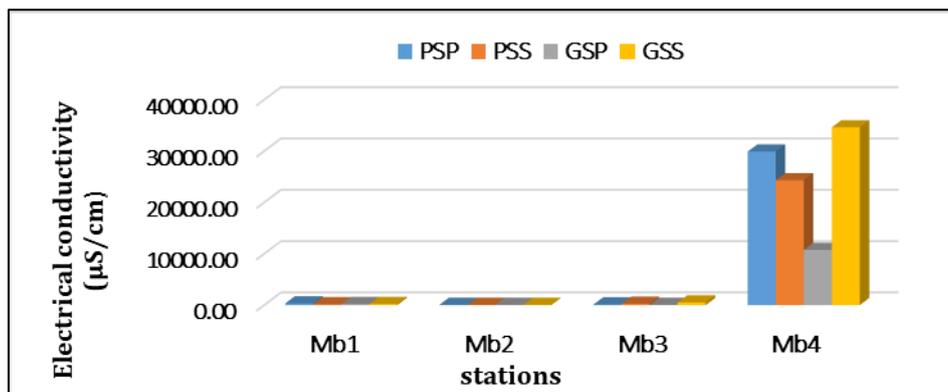

Figure 5 Spatio-temporal variation in the electrical conductivity of the waters of the Mboro stream during the study period

3.1.5. Salinity

Water salinity values range from 0 ppt (Mb1, Mb2, Mb3) to 2.27 ppt (Mb 4) (Figure 6). The Kruskal Wallis test showed significant differences from one season to another ($p < 0.05$).
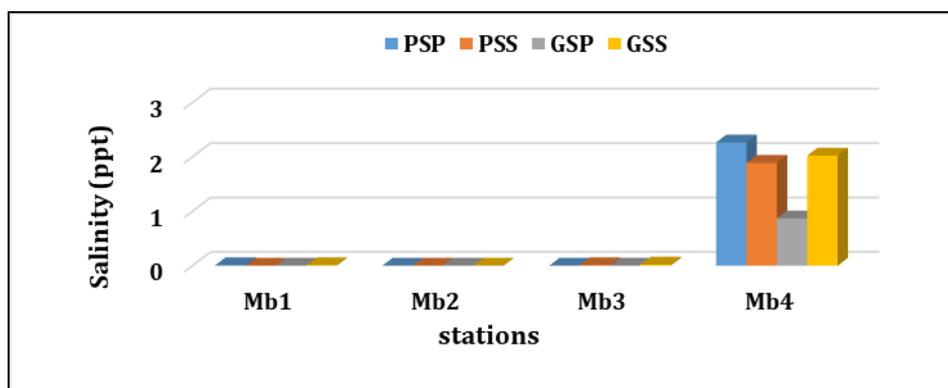

Figure 6 Spatio-temporal variation of the salinity of the Mboro stream waters during the study period

3.1.6. Alkalinity

The alkalinity values of the waters vary from 11 mg/L in SDS (Mb2 and Mb3 stations) to 91.33 mg/L in LDS (Mb4 station). The Kruskal-Wallis test revealed significant differences between seasons ($p < 0.05$) (Figure 7).

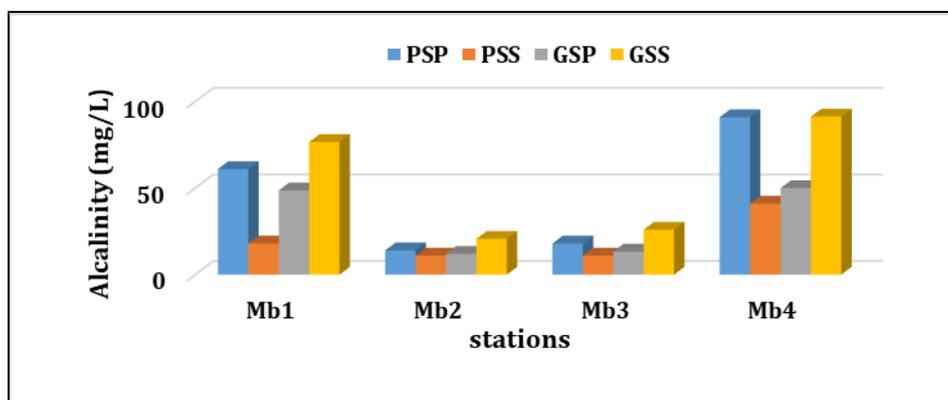**Figure 7** Spatio-temporal variation in the alkalinity of the Mboro stream waters during the study period

3.2. Organic Pollution Index (OPI)

The calculation of the organic pollution index (IPO) shows values that vary between 2 indicating high pollution (all stations in the long rainy season) and 3.69 indicating moderate pollution (stations Mb1 and Mb4 in the short dry season) (Figure 8).
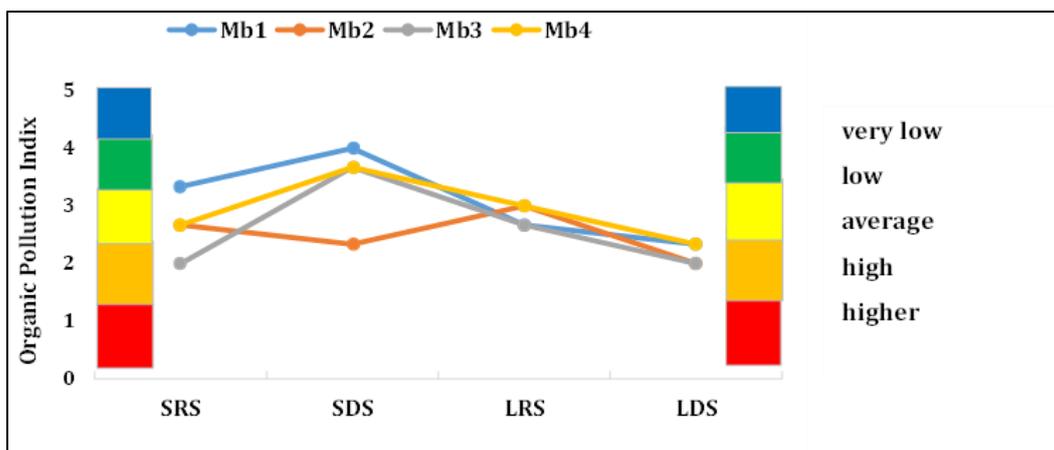
Figure 8 Spatio-seasonal variation of the Organic Pollution Index (OPI) during the study period

3.3. Biological parameters

3.3.1. Taxonomic richness and abundance of benthic macroinvertebrates

The benthic macroinvertebrate population belongs to 02 phyla (Molluscs and Arthropods), 04 classes (Insects, Malacostracae, Gastropods and bivalves), 20 orders, 52 families and 78 genera/species for a total of 9391 individuals (Table 5).

Table 5 Benthic macroinvertebrates sampled at the various stations of the Mboro stream during the study period

Phyla	Classes	Orders	Families	Genera	Species	Mb 1	Mb 2	Mb 3	Mb 4	Total
Arthropods	Insects	Heteroptera	Veliidae	Velia sp	Velia sp	99	101	146	0	346
				Microvelia sp	Microvelia sp	39	7	25	0	71
			Mesoveliidae	Mesovelia sp	Mesovelia sp	14	0	0	0	14
			Gerridae	Hynesionella omer-cooperi	Hynesionella omer-cooperi	32	11	0	0	43
				Gerris sp	Gerris sp	228	84	76	0	388
				Cylindrostethus quadrivittatus	Cylindrostethus quadrivittatus	2	0	0	0	2
			Naucoridae	Laccocoris sp	Laccocoris sp	6	0	0	0	6
				Naucoris	Naucoris	3	3	0	0	6
			Belostomidae	Belostoma	Belostoma cordofana	3	0	0	0	3
				Sphaerodema	Sphaerodema	27	0	0	0	27
			Nepinae	Laccotrephes	Laccotrephes alter	0	2	0	0	2
			Hydrometridae	Hydrometra sp	Hydrometra sp	1	0	0	0	1
			Nepidae	Nepa	Nepa seurati berg	10	0	0	0	10

				Ranatra	Ranatra linearis	6	7	0	0	13
			Notonectidae	Notonecta sp	Notonecta sp	3	0	0	0	3
				Anisops	Anisops	4	2	0	0	6
				Pleasp	Plea sp	1	0	0	0	1
		Ephemeroptera	Baetidae	Baetis	Baetis	34	0	0	0	34
		Coleoptera	Haliplidae	Haliplus natalensis	Haliplus natalensis	5	0	0	0	5
			Hydrophilidae	Hydrochara	Hydrochara	3	0	0	0	3
				hydrophilus	hydrophilus	8	0	0	0	8
			Dytiscidae	Hydaticus flavolineatus Boheman	Hydaticus flavolineatus Boheman	16	0	0	0	16
				Laccophilus	Laccophilus	3	0	0	0	3
		Odonata	Aeshnidae	Anaciaeschna	Anaciaeschna	30	0	0	0	30
				Aeshna	Aeshna	72	0	0	0	72
				Boyeria irene	Boyeria irene	32	0	0	0	32
			Gomphidae	Gomphus	Gomphus	10	0	0	0	10
			Libellulidae	Libellula	Libellula	40	0	0	0	40
				Orthetrum	Orthetrum	25	0	0	0	25
				Sympetrum	Sympetrum	60	0	0	0	60
			Coenagrionidae	Coenagrio proparte	Coenagrio proparte	12	0	0	0	12
			Calopterygidae	Calopteryx	Calopteryx	1	0	0	0	1
			Hydrophilidae	Enochrus	Enochrus	1	0	0	0	1
			Corduliidae	Cordulia	Cordulia	1	0	0	0	1
		Diptera	Dasyheleinae	Dasyhelea sp	Dasyhelea sp.	17	0	0	0	17
			Chironomidae	Chironomus	Chironomus	40	10	0	0	50
				Chironomini	Chironomini	68	35	0	0	103
				Tanytarsini	Tanytarsini	0	10	0	0	10
		Orthoptera	Gryllotalpidae	Neocurtilla	Neocurtilla	0	3	0	0	3
	Malacostraceae	Decapoda	Palaemonidae	Macrobrachium	Macrobrachium vollenovenii	20	190	437	0	647
					Macrobrachium macrobrachion	0	31	10	0	41
					Macrobrachium niloticus	0	0	2	0	2
			Atyidae	Atya	Atya africana	0	0	32	0	32

				Caridina	*Caridina africana*	0	0	0	0	0
			Sesarmidae	*Perisesarma sp*	*Perisesarma sp*	0	0	309	323	632
			Potamidae	*Potamonaute*	*Potamonaute ecorssei*	0	16	26	30	72
			Paguridae	*Pagurus*	*Pagurus*	0	0	0	18	18
Molluscs	Gastropods	Neogastropoda	*Volutiddae*	*Cymbium*	*Cymbium glans*	0	0	2	0	2
			Muricidae	*Stramonita*	*Stramonita*	0	0	1	0	1
				Murex	*Murex sp*	0	0	0	1	1
		Caenogastropoda	*Paludomidae*	*Cleopatra*	*Cleopatra sp*	0	0	0	306	306
			Thiaridae	*Melanoïdes*	*Melanoïdes tuberculata*	0	0	0	10	10
			Hemisinidae	*Pachymelania*	*Pachymelania aurita*	0	0	0	2	2
					Pachymelania fusca	0	0	0	1	1
			Melanopsidae	*Melanopsis*	*Melanopsis praemorsa*	0	0	0	32	32
		Sorbeoconcha	*Pachycilidae*	*Potadoma*	*Potadoma sp*	0	0	0	3	3
					Potadoma bicarinata	0	0	0	2	2
		Cycloneritida	*Neritidae*	*Nerita*	*Nerita senegalensis*	0	0	0	1228	1228
				Neritina	*Neritina afra*	0	0	0	607	607
					Neritina nattalensis	0	0	1	0	1
					Neritina tiassalensis	0	0	0	4	4
					Nerit a iris	0	0	0	133	133
				Theodoxus	*Theodoxus fluviatilis*	0	0	0	2	2
		Littorinimorpha	*Cypraeidae*	*Cypraea*	*Cypraea*	0	0	3	0	3
			Littorinidae	*Echinolittorina*	*Echinolittorina reticulata*	0	0	0	834	834
				Littoraria	*Littoraria angulifera*	0	0	0	2	2
			Strombidae	*Lobatus*	*Lobatus gigas*	0	0	2	0	2
			Hydrobiidae	*Tomichia*	*Tomichia producta*	0	2	0	0	2
			Potamididae	*Pirenella*	*Pirenella conica*	0	0	0	64	64
		Systellommatophora	*Onchidiidae*	*Onchidella*	*Onchidella*	0	0	0	18	18

		Archaeogastropoda	*Patellidae*	*Patella*	Patella	0	0	0	61	61
		Prosobranchia	*Pomatiopsidae*	*Tomichia*	*Tomichia zwellendamensis*	0	0	0	1	1
		Basommatophora	*Ellobiidae*	*Auriculastra*	*Auriculastra sp*	0	0	0	2	2
	Bivalves	Mytiloïda	*Mytilidae*	*Mytilus*	*Mytilus edulis*	0	0	0	918	918
				Xenostrobus	*Xenostrobus pulex*	0	0	0	1238	1238
			Mutelidae	*Mutela*	*Mutela rostrata*	0	0	0	944	944
		Venerida	*Veneridae*	*Pitar*	*Pitar sp*	0	0	0	1	1
				Irus	*Irussp*	0	0	0	1	1
				Dosinia	*Dosiniasp*	0	0	0	1	1
				Venus	*Venusp*	0	0	1	0	1
					Venus verrucosa	0	0	1	0	1
			Mactridae	*Lutraria*	*Lutrariasp*	0	0	1	0	1
		Unionida	*Margaritiferidae*	*Pseudunia*	*Pseudunia sp*	0	0	1	0	1
			Unionidae	*Hyriopsis*	*Hyriopsis cumingii*	0	0	12	0	12
				Cristaria	*Cristaria plicata*	0	0	20	0	20
		Cardiida	*Cardiidae*	*Cardium*	Cardium	0	0	6	0	6
2	4	20	52	78		976	514	1114	6787	9391

The class of Gastropods is the most abundant with 35% of relative abundance divided into 13 orders, 24 families and 33 genera, followed by the Bivalves with a relative abundance of 33% divided into 04 orders, 07 families and 12 genera. Then come the classes of Insects with 16% relative abundance, divided into 06 orders, 23 families and 39 genera, and Malacostraceae with 15% relative abundance divided into 01 order, 05 families and 06 genera (Figure 9).
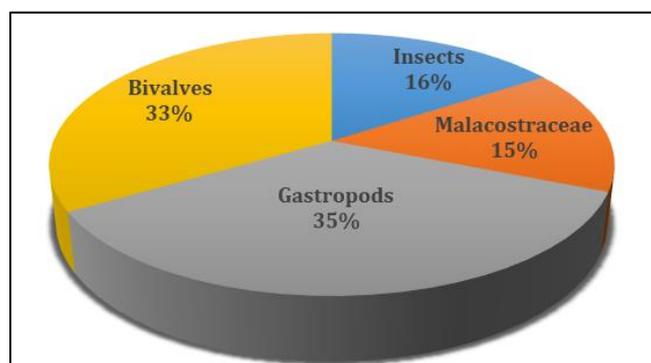

Figure 9 Relative abundance of benthic macroinvertebrate classes in the Mboro stream during the study period

Spatio-temporal variation in the absolute abundance of benthic macroinvertebrates Spatially, station Mb4 has the highest absolute abundance (6787 individuals) and station Mb2, the lowest (514 individuals) (Figure 10).
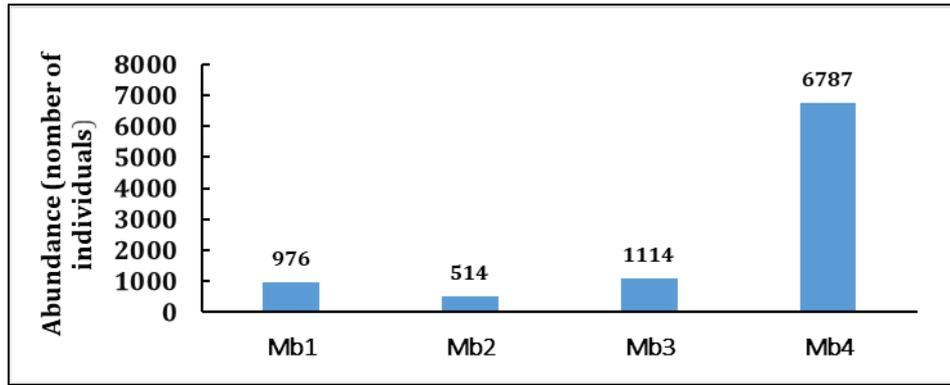
Figure 10 Spatial dynamics of absolute abundance of benthic macroinvertebrates in the Mboro stream throughout the study period

The long dry season has the highest absolute abundance with 3625 individuals, followed by the long rainy season with an absolute abundance of 2826 individuals, then the short rainy season with 1727 individuals and the short dry season with 1203 individuals of absolute abundance (Figure 11).
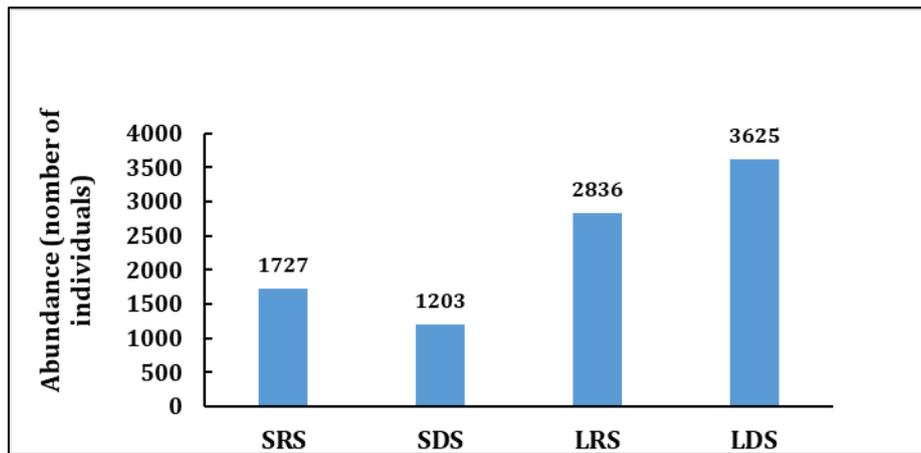

Figure 11 Seasonal dynamics of the absolute abundance of benthic macroinvertebrate in the Mboro stream throughout the study period

3.4. Spatio-temporal variation in the Shannon and Weaver diversity index, the Piélou Equitability (J) index and the Simpson index

Spatially, the values of the Shannon and Weaver index vary from 2.22 bits/ind (Mb2 and Mb3 stations) to 3.25 bits/ind (Mb1 stations) with an average value of 2.5 ± 0.50 bits/ind. The Pielou Equitability Index (J) varied from 0.4 bits/ind (Mb2 and Mb3 stations) to 0.6 bits/ind (Mb1 stations), these values oscillated around an average value of 0.44 ± 0.9 bits/ind. Regarding Simpson's dominance values, these values fluctuate from 0.72 bits/ind (Mb2 and Mb3 stations) to 0.86 bits/ind (Mb1 stations) with an average value of 0.8 ± 0.06 bits/ind (Figure 12).
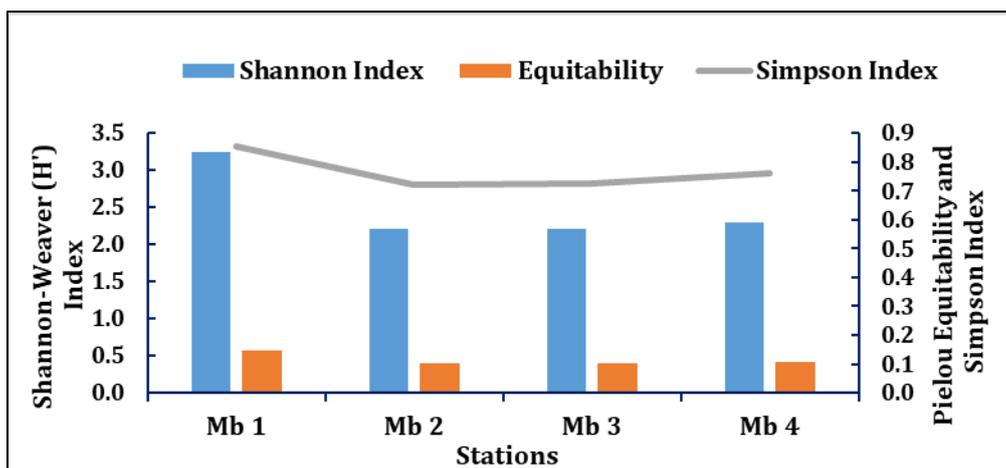
Figure 12 Spatial variation of Shannon and Weaver diversity index, Pielou J equitability and Simpson index during the study period

Seasonally, Shannon and Weaver index values range from 3.07 bits/ind (LDS) to 3.29 bits/ind (LRS) with an average value of 3.15 ± 0.09 bits/ind. The Piélou Equitability Index (J) ranged from 0.55 bits/ind (LDS) to 0.6 bits/ind (LRS); These values hover around an average value of 0.56 ± 0.02 bits/ind. For Simpson's dominance values, these values fluctuate from 0.84 bits/ind (SDS) to 0.87 bits/ind (LRS), for an average value of 0.85 ± 0.01 bits/ind (Figure 13).
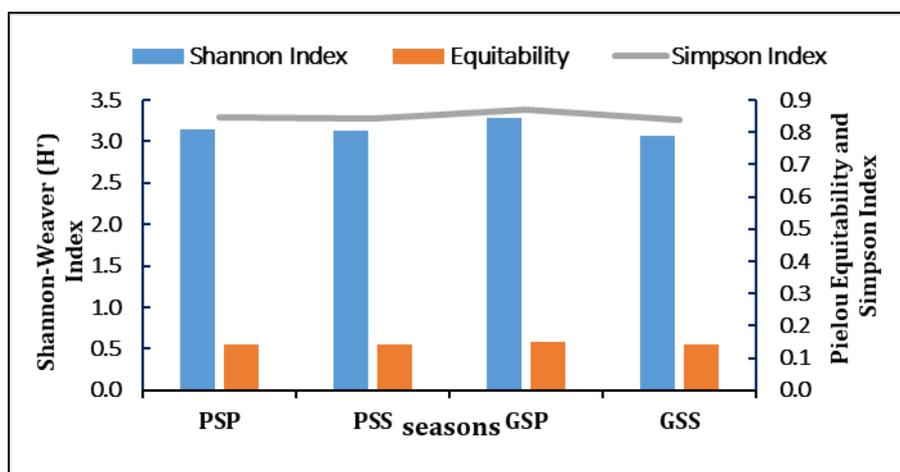

Figure 13 Seasonal variation of Shannon and Weaver diversity index, Piélou J equitability and Simpson index during the study period

3.5. Hilsenhoff's biotic index [22]

The Hilsenhoff Biotic Index (FBI) value increase remarkably from upstream to downstream, i.e., the Mb1 (3.11), Mb2 (4.51), Mb3 (6,17), Mb4 (7) stations, respectively. This reflects the excellent ecological quality upstream and the poor ecological quality downstream (Table 6).

Table 6 Evolution of the [22] (FBI) in the Mboro stream during the study period

Stations	Values	Ecological integrity Interpretation
Mb1	3.11	Excellent without organic pollution
Mb2	4.51	Good organic pollution likely
Mb3	6.17	Rather poor substantial organic pollution
Mb4	7	Very substantial poor organic pollution

4. Discussion

The results of the physico-chemical analyses reveal that the water temperature varies very little between the stations, with an average value of 27.70 °C ± 1.66 °C, higher than the average ambient temperature of the area (26°C) [23]. This rise in temperature is due to the proximity of the river to the sea coupled with solar radiation. In this regard, [19] stipulate that the temperature of seawater is due to the climate that influences the surface layer. These results are similar to those obtained by [24] in a few coastal rivers in the Southern Cameroon region.

The waters of the Mboro stream reveal an average pH of more than 7 CU (7.20 ± 0.77 CU), reflecting the tendency towards the basicity of water. This basicity is thought to be related to the input of alkaline ions into the watercourse during high tides. [25] points out that the pH of marine waters and marine environments is between 7.5 and 8.4 CU. This value is lower than that of [26] in brackish water (7.71 CU).

The dissolved oxygen saturation values remain above 65% during the study period at all stations and in all seasons. This relatively high oxygenation is due to the photosynthetic activity of the watercourse and the presence of riffles and meanders. Some authors have noticed that the waters of forest rivers are richer in oxygen dissolved during the day thanks to the photosynthetic process [4,27] Similar results are obtained in a few forest streams in the same agro-ecological zone such as the Nyong [28] and the Abouda [29]. In addition, the high dissolved oxygen contents in the Mb3 and Mb4 stations are attributable to the movements of the waves induced by the sea.

The high values of electrical conductivity and salinity observed at the Mb4 station are due to saline and ionic inputs from the sea, the accumulation of which with dissolved salts and ions from the watercourse can generate values higher than those of the sea. According to [30], the conductivity of seawater is about 32,000 µS.cm-l, lower than that obtained at the Mb4 station and higher than that of [31] in mangroves. The high alkalinity values at station Mb 4 are due to the addition of alkaline carbonates from the seawater. These results are higher than those of [24] in the casino stream of the same ecological zone.

The analysis of the values of the Organic Pollution Index shows that the Mboro watercourse is subject to increasing organic pollution from upstream to downstream which would be linked to the various port and infrastructural activities carried out near the watercourse. Indeed, Mboro is a watercourse included in the area assigned to the construction project of the deep-water port of Kribi called Zone 1, which has several other infrastructures within it. These results are similar to those of [32] in the Missole in the littoral zone.

The biological results show an overall taxonomic richness of 78 taxa with 9391 individuals divided into 02 phyla (Molluscs and Arthropods), 04 classes, 20 orders and 52 families. These results are relatively higher than those obtained by [7] in the Mfoundi basin (29 families) but lower than those of [33] in Esoa. The class of Gastropods is predominant with 35% of relative abundance dominated by the family Neritidae (*Nerita senegalensis*), followed by Bivalves with 33% of relative abundance supplanted by the families Mytilidae (*Mytilus edulise*, *Xenostrobus pulex*) and Mutelidae (*Mutela rostrata*). Spatially, the Mb4 station records the highest relative abundance (72.27%) fostered by a high immigration of marine organisms and, the Mb2 station the lowest relative abundance (5.49%) due to the low diversity of microhabitats. [34] point out in this regard that taxonomic richness is positively correlated with the number of microhabitats. In addition, the long dry season is the richest in organisms with 38.60% relative abundance. These results are similar to those of [35] on the Nyamessamba river and [36] in New Caledonia. The predominance downstream at the Mb4 station of *Mytilus edulis*, *Xenostrobus pulex*, *Mutela rostrata* and *Nerita senegalensis* whose polluo-tolerance is proven, attests to the pronounced degradation of the waters of the Mboro river in this station. In addition, the remarkable presence of polluting-sensitive groups such as the Ephemeroptera Baetidae, the Heteroptera Veliidae and Gerridae as well as the Odonates Aeshnidae upstream at station Mb1 reflects the minimally polluted or unpolluted nature of this station.

The values of the Shannon and Weaver diversity index, the Pielou equitability and the Simpson index are higher at stations Mb1 and Mb4 respectively, probably due to the diversity of microhabitats at station Mb1 creating environmental conditions favorable to the establishment and maintenance of a balanced and integrated biological community, capable of adapting to environmental variations [37] and [38]. For station Mb4, the high values of these indices could be explained by the effect of recruitment or immigration of organisms from the sea. Even if the taxonomic richness remains a little lower, it is still compensated by considerable relative abundances. Similar results are obtained by [33] in the Esoa stream in the Littoral.

The values of the Hilsenhoff Biotic Index (FBI) show that the waters of the Mboro stream are subject to substantial organic pollution downstream. This is linked to the increasing port and anthropogenic activities observed around the

Mboro river. However, the Mb1 station is not subject to any organic pollution, and would therefore be of excellent ecological integrity. Similar results were obtained by [17] in Ndog-Bissolo

5. Conclusion

Mboro is a coastal waterway, located in the port area of Kribi. It is drained by a forested area upstream and empties into the Atlantic Ocean downstream. Physico-chemical analyses show good oxygenation of the water, a basic pH and a fairly high temperature. The low values of the pollution index (IPO) reveal that these waters are disturbed. The upstream presence (Mb1) of sensitive polluting groups such as the Ephemeroptera Baetidae, the Heteroptera veliidae and Gerridae, and the Odonates Aeshnidae indicates an environment of good ecological integrity. On the other hand, the remarkable dominance downstream of polluting-tolerant organisms such as Neritidae, Mytilidae and Mutelidae testifies to the advanced deterioration of the waters of this portion of the river (Mb3 and Mb4). This distribution of benthic macroinvertebrates along the watercourse reveals the gradual state of water degradation from upstream to downstream, this phenomenon being more increased in the downstream. The Hilsenhoff Biotic Index (FBI) confirms this progressive water quality of this river from upstream to downstream.

The preservation of this ecosystem requires the strengthening of the management of waste emitted by port activities. Continuous monitoring and appropriate conservation measures would be necessary to ensure the sustainability of this watercourse

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

Contributions

Bisse Ndiva, Thérèse Inès, Nwaha Mathias, Ndourwe Far Bo livar, Ladibe Pélagie, and the PAK team collected data in the field. Bisse Ndiva, Thérèse Inès, Ndourwe Far, Bolivar, Betsi Wilfreid, Christiane Noël, Tchouta Ulrich, Lactio, Larry Nathaniel did the data analysis, produced the figures, and wrote the article by Bisse Ndiva, Thérèse Inès. Professor Foto Menbohan Samuel and Professor Ajeagah Gideon Aghaindum have corrected the article

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Authors short biography

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