

Study of the Spatio-Temporal Distribution of Zooplankton in the Estuary of the Fatala River, Boffa/Republic of Guinea

Aboubacar Sylla^{1*}, Sory Diakite¹, Ahmed Guissé¹, Mamadou Djouldé Sow¹, Ibrahima Keita¹,
Lamine Konaté¹, Mamady Bérété¹, Ansoumane Keita¹, Bouya Diop^{1,2}

¹Plankton/Hydrobiology Laboratory, Marine and Coastal Research Center (CEREMAC, Formerly the Conakry Rogbanè Scientific Research Center (CERESCOR)), Conakry, Guinea

²Laboratory of Atmospheric and Ocean Sciences, Materials, Energy and Devices (LSAOMED), Training and Research Unit in Science and Technology (UFRSAT), Saint-Louis, Senegal

Email: *aminacybacar4@gmail.com

How to cite this paper: Sylla, A., Diakite, S., Guissé, A., Sow, M.D., Keita, I., Konaté, L., Bérété, M., Keita, A. and Diop, B. (2026) Study of the Spatio-Temporal Distribution of Zooplankton in the Estuary of the Fatala River, Boffa/Republic of Guinea. *Open Journal of Marine Science*, 16, 293-317.
<https://doi.org/10.4236/ojms.2026.164017>

Received: July 13, 2026

Accepted: October 17, 2026

Published: October 20, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

The present study took place during the hydrological season 2022-2023 (dry season, intermediate season and rainy season) in the estuary of the Fatala River. It aims to evaluate the spatio-temporal distribution of zooplankton organisms in the estuary of the Fatala River. The samples were taken at eight (8) fixed stations distributed along the estuary. The samples were collected using a plankton net. The results reveal the presence of 57 species, grouped into 41 genera, 27 families, 17 orders, 11 groups and 68,419.72 individuals. This population is largely dominated by the order of Calanoida (41%) and slightly dominated by the orders of Decapods, Cyclopods, Ctenopods, Spumellaria, Leptothecates, and Halocyprids (1%). Copepods are the most abundant group (52%), followed by Malacostraca (13.71%) and Sagittoides (7.07%). Total zooplankton density varies seasonally: it reaches a maximum in the shoulder season (29,742.96 ind/m³), decreases in the rainy season (26,785.82 ind/m³) and remains minimum in the dry season (11,890.94 ind/m³). Depending on the stations, the highest density (19,233.26 ind/m³) was recorded at station 5, while the lowest density (2329.44 ind/m³) was observed at station 3 (upstream), an area characterized by strong water agitation due to the meeting of two arms of the sea.

Keywords

Estuary, Zooplankton, Spatio-Temporal Distribution, Copepods, Biomass, Density

1. Introduction

Aquatic environments, whether marine (oceans, seas, and estuaries), brackish water, or freshwater (lakes, streams, rivers, and wetlands), play a fundamental role in the maintenance and development of biodiversity. They harbor a great diversity of species, both floral and faunal, and ensure ecological functions essential to the balance of ecosystems. The latter contribute to the nutritional, economic, social, and cultural progress, as well as the recreation, of human populations [1].

Estuaries are transition zones between continental waters and marine waters. They have always been favorable places for the development of economic activity. They contribute **33%** of the economic value of marine systems [2]. They represent a growing scientific interest based on the variety of biotic and abiotic processes; they are also important for the richness of biological diversity on the one hand, and for the importance of socio-economic activities on the other.

The economic value of all these services has been estimated at approximately **30 trillion euros per year** on average at the global scale [3].

Plankton is defined as the set of pelagic organisms, both plant and animal, that float between two waters and are carried by currents and water masses [4]-[12].

Photosynthesis thus makes it possible to recycle carbon into the biomass of primary producers, and then transfer it to consumers throughout the food chain [4] [11] [13]-[15]. Their movement capacities, linked to the presence of vibrating cilia, antennae, or swimming legs, do not allow them to resist currents (<http://at-elierpeche.free.fr/3-Habitants/zooplancton.pdf>) [4] [13] [15]-[18].

Plankton has existed on Earth since the very beginnings of life, nearly **3.8 billion years ago**, in the form of microscopic blue algae called cyanobacteria (<http://educatif.eau-et-rivieres.asso.fr/pdf/plancton-generalites.pdf>).

The importance of estuarine ecosystems for these marine species is also explained by the high abundance of zooplankton.

Zooplankton (**Figure 1**) comprises a group of heterogeneous organisms, including more than **7000** marine species belonging to about fifteen (15) phyla [19].

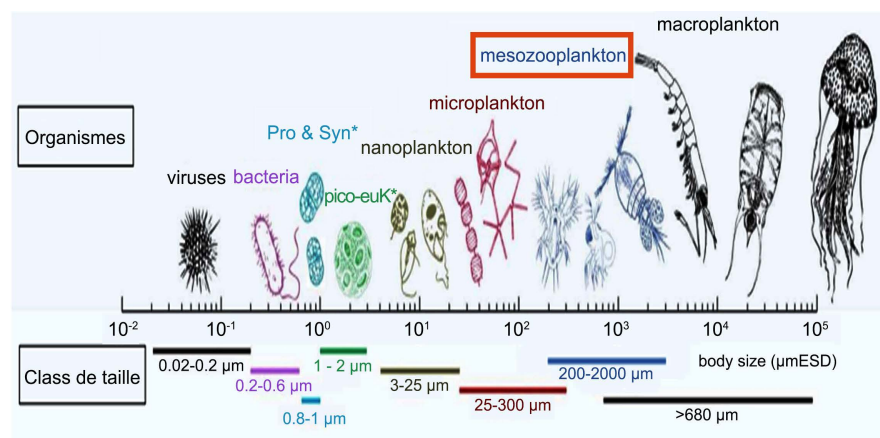


Figure 1. Classification of Zooplankton according to size classes. **Source:** Romagnan (2013).

Zooplankton occupies an important place in marine ecosystems [19]-[21]. A modification in zooplankton communities will therefore have direct and indirect repercussions on the entire trophic network that depends on them [20].

The diversity of the ocean's hydrobiological conditions has been at the origin of the remarkable marine biodiversity [22] [23]. Mangrove forests [24] constitute nursery areas for numerous fish species, shrimps, and plankton, as well as breeding and feeding grounds for certain mammals (dolphins and manatees) and many migratory or resident birds [24]. Marine and coastal ecosystems are the reservoir of resources that support economic and social maritime activities [25] and constitute a valuable source of food [26] [27].

The ocean harbors a community of plankton, composed of microscopic organisms that drift in the ocean according to the currents. It represents more than 95% of the marine biomass and includes a remarkable diversity: viruses, bacteria, microalgae, reproductive cells, fish larvae, and microcrustaceans [4] [11] [28].

Plankton plays a major role in aquatic environments [29].

Zooplankton also constitutes an important source of protein for fish fry [29]-[31].

However, global marine biodiversity is currently under increasing pressure from anthropogenic factors such as pollution, overexploitation of fishery resources, climate warming, and the expansion of economic activities [1] [23] [25] [28].

In Africa, the continuous loss of biodiversity is driven by a set of anthropogenic factors [32] [33]. According to [34] and [35], pollutants, which are contaminants, affect the most productive areas of the marine environment, including estuaries [36].

Microplastics also harm plankton, which is the essential component of the marine habitat [37].

Anthropogenic activities affecting the coastal and marine environment therefore have direct consequences on the living species inhabiting these environments. They modify their abundance, diversity, and distribution, as well as their feeding, development, and reproduction, in addition to the relationships among these species [28] [38]. The climate changes observed at the global scale only exacerbate this problem [13] [33].

The Guinean continental shelf, with an area of approximately **56,000 km²**, together with the adjacent waters, forms a unit characterized by a great diversity of fauna and flora, among which fishery resources are among the most abundant on the West African coast [39] [40].

However, this ecosystem is subjected to multiple severe natural and anthropogenic pressures [41]. The degradation of the coastal zone has intensified with the increase in the Guinean population, which rose from **4.507 million** in **1980** to **12.609 million** in **2015**, and is estimated to reach **27.486 million** by **2050** [41].

Several studies have already attempted to highlight the ecological status of Guinean aquatic ecosystems based on the zooplankton compartment: [40]-[44].

Our study has shown that anthropogenic activities have an impact on the spatio-temporal distribution of zooplankton in the Fatale River estuary. It indicates how the density and biomass of zooplankton vary in the Fatale River estuary over time and space in relation to environmental characteristics.

We assessed the abundance and distribution of zooplankton organisms in the Fatale River estuary over time and space in relation to some abiotic parameters. To achieve this, we:

- Analyzed some physicochemical parameters (temperature, salinity, pH, dissolved oxygen, and turbidity) likely to have a major influence on the distribution of zooplankton in the Fatale River estuary.
- Determined the taxonomic composition and the spatio-temporal distribution of zooplankton.
- Evaluated the specific density of zooplankton.

Estuaries (**Figure 2**) have been the subject of several studies [45]. According to [46]-[48], a sedimentary perspective was added to this definition. The definition proposed by [49] takes biological aspects into account. [50], by modifying the definition of [47], provided a definition that is certainly the most satisfactory from a hydrodynamic point of view. The properties and specific characteristics of estuarine systems have been studied by [2] [45] [51]-[55].

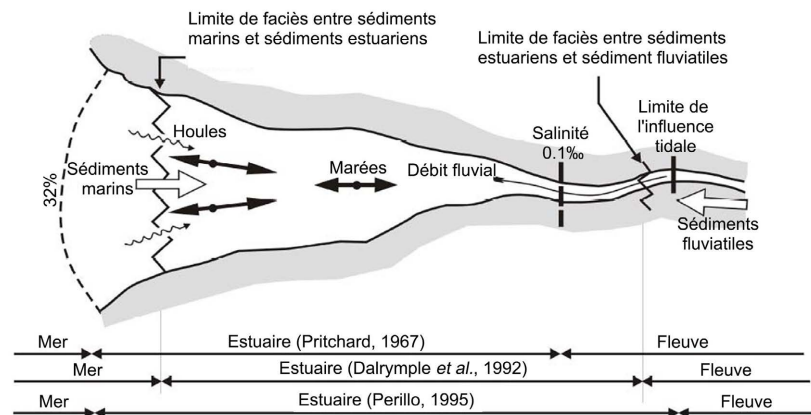


Figure 2. Schematic Representation of an Estuary. **Source:** Deloffre *et al.* (2005).

Marine organisms are divided into two major groups shown in **Figure 3**: the benthos and the pelagos [4] [9]. In **Figure 3**, we have the pelagos, the benthos, the nekton, and the seston.

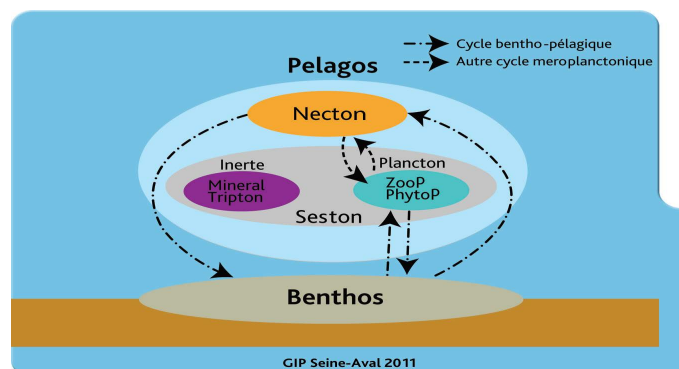


Figure 3. Compartments of the different groups of living organisms in the water mass and the substrate. **Source:** Devreker *et al.* (2012).

The works of [15] [56] [57] have shown the external morphology and the appendages of an adult female copepod. Those of [15] [58]-[61] on the study of the general architecture of a copepod appendage, the characteristics of the life cycle of a copepod, and the general diagram of an euphausiid show the main morphological characteristics that are defined according to the Source: http://www.obs-vlfr.fr/~gaspari/copepodes/cop_doc.htm.

1.1. Presentation of the Study Area

The Prefecture of Boffa

It is located in the west of the country on the Atlantic coast (**Figure 4**), in the natural region of Maritime Guinea. It is one of the ten prefectures that make up the administrative region of Boké. The Guinean coastal zone is characterized by the presence of an extensive continental shelf whose width is between **120 and 200 km** [62]. The slope of this shelf is very low offshore from the mouth of the Fatale River [63] [64].

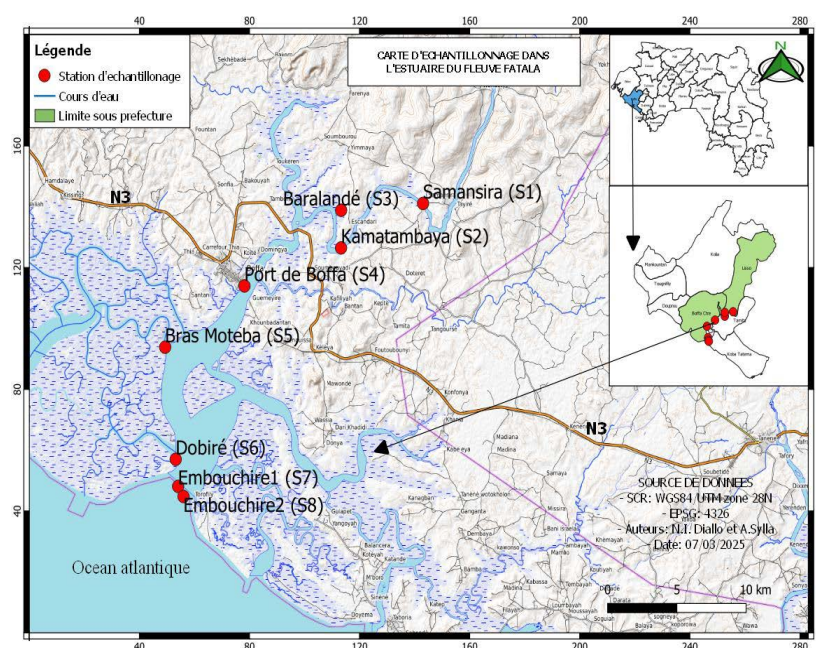


Figure 4. Map of the Prefecture of Boffa. **Source:** Géomatic Laboratory, CERE-UGANC, 2026.

1.2. Material and Methods

1.2.1. Material

⌘ Equipment for measuring abiotic parameters

The equipment used for the measurement of physicochemical parameters consists of: a mercury thermometer graduated in °C, a 70+ WATERPROOF conductivity meter, a 70+ WATERPROOF oxygen meter, a 70+ WATERPROOF pH meter, a Lovibond Model TB210 IR turbidimeter, a Secchi disk, and a GPS of the Germain brand.

⌘ Equipment for the collection and processing of zooplankton samples

For the collection and processing of zooplankton samples, a 15 HP motorized boat and a 55-micron Hensen plankton net were used. We also used 5% formalin, polyethylene bottles, a GPS, and a 40 m long plumb line. A binocular optical microscope, a counting chamber, and pipettes were also used.

1.2.2. Method

Field exploration

To obtain information about the study area and understand its specific characteristics, a reconnaissance mission of the study area was carried out. This visit allowed us to observe field realities, take photographs, and choose the sampling stations for the samples.

The choice of stations was made, on the one hand, by taking into account the distance between two stations and, on the other hand, by considering the movement of the water. Thus, the stations were placed in locations separated from each other by at least more than **2 km** on the one hand, and in locations that were as little disturbed as possible on the other hand.

Sampling

For data collection, sampling of water samples and the analysis of samples were carried out. Sampling was conducted aboard a **15 HP motorized boat** during three (3) missions at eight (8) fixed stations (**Figure 5**). Zooplankton samples were collected using a **55-micron Hensen plankton net** with an opening diameter of **70 cm**. To study the influence of tidal phenomena on the spatio-temporal distribution of zooplankton organisms, total sampling was carried out with a vertical haul from the bottom to the surface (bottom-surface) during the different tidal phases (**high tide, intermediate phase or intermediate tide, and low tide**).

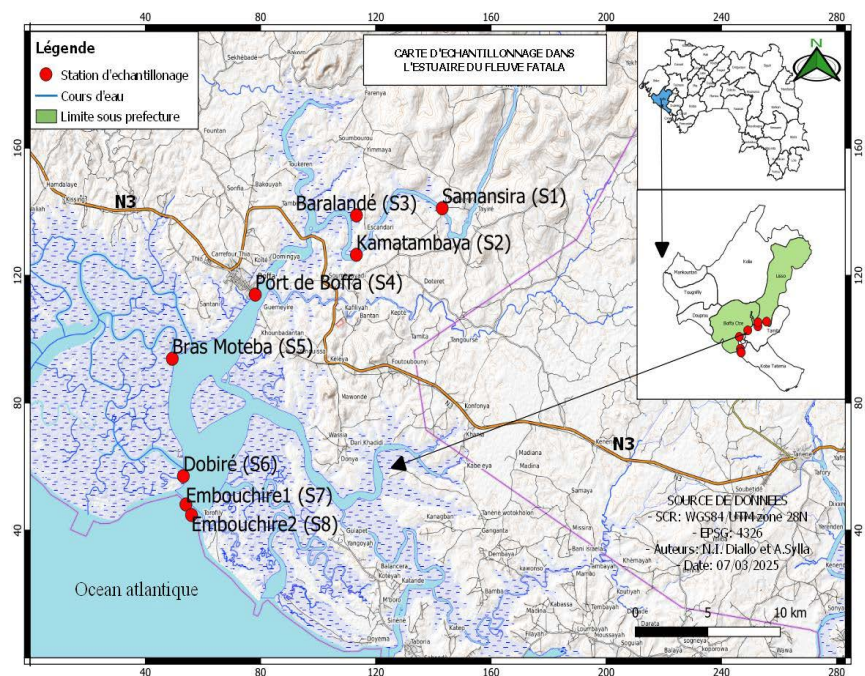


Figure 5. Map of the Sampling Area. **Source:** Géomatic Laboratory, CERE-UGANC, 2026.

During each sampling campaign, one sample was collected at each station and during each tidal phase, giving **3 samples per station**, therefore **24 samples per campaign**. In total, for the three missions, **72 samples** were collected, then concentrated and fixed with **5% formalin** for laboratory analyses.

Alongside the water sample collections, the geographical coordinates of the stations (**Table 1**) were recorded using a **Germain brand GPS**, and depth measurements were carried out using a **40 m long plumb line**.

The geographical coordinates and depths of the sampling stations are recorded in **Table 1**:

Table 1. Geographical coordinates and depths of the stations.

Stations	Location	Latitude	Longitude	Depth (m)
S1	Samansira	10.22195°	−13.91125°	3.5
S2	Kamatambaya	10.20687°	−13.95527°	8
S3	Baralandé	10.20795°	−13.95519°	25
S4	Port de Boffa	10.17358°	−14.02886°	7.5
S5	Bras_Motéba	10.13768°	−14.08109°	4
S6	Dobiré	10.07194°	−14.074118°	4.5
S7	Mouth 1	10.05605°	−14.07255°	9
S8	Mouth 2	10.050065°	−14.06911°	16

Sample Analysis

Biotic Parameter

The identification of zooplankton species, the calculation of density, and mass density were carried out in the laboratory.

Density Calculation

After homogenization of the sample by agitation, three sub-samples of **1 ml** each were collected and observed separately in the counting chamber under an optical microscope. Each individual encountered was identified and counted. The planktonology manuals: [65]-[68] were used for species identification.

The study of certain zooplankton organisms requires a detailed examination of some body parts (cephalic region, post-abdominal region, thoracic appendages, etc.). In the laboratory, a careful dissection of some organisms was carried out, thus separating the parts to be observed in order to better see them under the microscope and/or binocular microscope.

The zooplankton density of each tide is calculated from the arithmetic mean of the number of individuals encountered in the three sub-samples: this mean is multiplied by **100** to give the number of individuals of the tide. The density is expressed as the number of individuals per unit volume of water. Its formula is as follows:

$$D = (n_i \times 100) / V$$

where:

$$V = H \cdot S \text{ with } S = \pi R^2$$

Therefore:

$$V = \pi H (d/2)^2, \text{ knowing that } R = d/2.$$

D is the zooplankton density;

n_i is the number of individuals encountered;

V is the volume of water filtered;

H is the distance traveled by the net ;

S is the surface area of the net opening;

R is the radius of the net opening;

d is the diameter of the net opening.

Biomass Calculation

The tables of [69] were used for the determination of biomass according to the average individual weight of organisms. From these tables, the following formulas are derived:

- **For calanoids**, the weight of the organism is:

$$W = 1/6 \pi L T^2 + 1/4 \pi l t^2$$

- **For Harpacticoids**, it is calculated as follows:

$$W = 1/4 \pi L T + 1/12 \pi l (T^2 + T t + t^2)$$

where:

L and T represent respectively the length and width of the anterior body;

l and t are the length and width of the posterior body.

The body length of zooplankton individuals was measured using a microscope equipped with a graduated eyepiece.

2. Statistical Processing Method

2.1. Principal Component Analysis (PCA)

The R software allowed us to perform Principal Component Analysis (PCA).

2.2. Species Richness

Species richness is the number of species counted in a sampling station. It measures the biodiversity of an entire ecosystem by indicating the number of species present in the environment. This richness can be expressed as total richness, that is to say, the total number of species present in a given station, or as average richness, that is to say, the average number of species present in the samples of a studied community [41].

2.3. Species Diversity (Shannon Index)

The Excel software was used to calculate the Shannon index, which is the most commonly used diversity index. It is also called the Shannon-Wiener index. It is defined by the following formula:

$$H' = -\sum_{i=1}^S P_i \cdot \log_2(P_i)$$

where:

H' corresponds to the Shannon index;

S is the number of species;

P_i is the relative frequency of the i th species: $P_i = n_i/N$, where n_i = the number of individuals counted for a given species present;

N = the total number of individuals counted, all species combined.

The Shannon index makes it possible to express the species diversity of a studied community. Species diversity characterizes the more or less large number of species present in a community. If it is homogeneous (composed of a single and same species), then the index $H' = 0$. The more we have different species, the more its value increases logarithmically.

3. Results, Interpretation and Discussion

3.1. Biotic Parameters

3.1.1. Structure of the Zooplankton Community

The study of the zooplankton community in the Fatale River estuary carried out during this study made it possible to determine 57 species (**Table 2**) distributed into 41 genera, 27 families, 17 orders, and 11 groups.

This community is largely dominated by the Copepod groups represented by 21 species, 13 genera, 7 families, and 2 orders, which are the most numerous. They constitute 52% of the total number of identified species (**Table 2**). Among the 57 species counted, 52 species were identified and 5 species could not be identified because of their state of decomposition: *Paracalanus* sp., *Penilia* sp., *Sagitta* sp., *Tomopteris* sp., *Phyllorhiza* sp.

The Copepod group represents 52%, followed by the Malacostraca (23%) and the Sagittoida (8%). Next come the Thaliacea (3%), followed by the Polychaeta (3%), the Scyphozoa (3%), and the Branchiopoda (3%). There are the Polycystina (1%), the Hydrozoa (1%), the Appendicularia (1%), and the Ostracoda (1%). These percentages are presented in **Figure 6**.

3.1.2. Taxonomic Composition

The main zooplankton species encountered in the Fatale River estuary are found in **Table 2**.

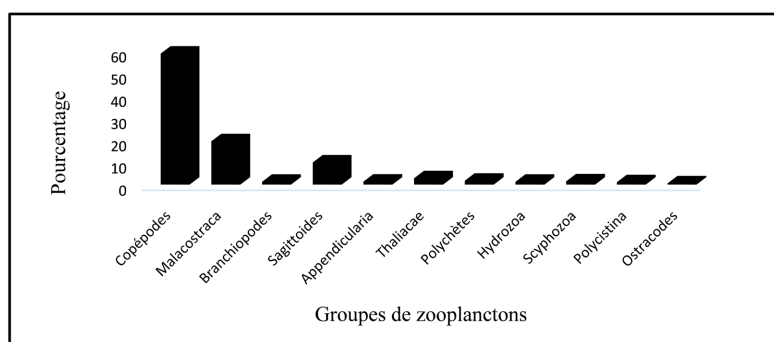


Figure 6. Percentage of the different zooplankton groups.

Table 2. List of the main zooplankton species encountered in the Fatale.

Groupe	Ordre	Famille	Genres	Species	AR	AS
Copépode	Calanoida	Paracalanidés	Paracalanus	<i>Paracalanus scotti</i> (Fruchtl, 1923)	A	SS; SP
				<i>Paracalanus denudatus</i> (Sewell, 1929)	P	SS; SP
				<i>Paracalanus nanus</i> (Sars G.O., 1925)	A	SS; SP
				<i>Paracalanus aculéatus</i> (Sars G.O., 1925)	A	SS; SP
				<i>Paracalanus parvus</i> (Sars G.O., 1925)	P	SS; SP
				<i>Paracalanus</i> sp.	A	SS; SP
				<i>Paracalanus crassirostris</i> (Dahl F., 1894)	P	SS; SP
		Calocalanus	Calocalanus	<i>Calocalanus pavo</i> (Dana, 1852)		
		Pseudocalanus	Pseudocalanus	<i>Pseudocalanus elongatus</i> (Brady, 1865)	A	SS; SP
		Acrocalanus	Acrocalanus	<i>Acrocalanus andersoni</i> (Bowman, 1958)	A	SS; SP
				<i>Acrocalanus longicornis</i> (Giesbrecht, 1888)	P	SP
		Clausocalanidés	Clausocalanus	<i>Clausocalanus furcatus</i> (Brady, 1883)	R	SP
		Calanidés	Nannocalanus	<i>Nannocalanus minor</i> (Claus, 1863)	R	SS; SP
			Calanus	<i>Calanus carinatus</i> (Kroyer, 1849)	R	SS; SP
			Calanoides	<i>Calanoides carinatus</i> (Kroyer, 1849)	R	SS; SP
			Undinula	<i>Undinula vulgaris</i> (Dana, 1849)	A	SP
		Spinocalanidés	Spinocalanus	<i>Spinocalanus abyssalis</i> (Giesbrecht, 1888)	R	SP
		Scolecitrichidés	Scottocalanus	<i>Scottocalanus helenae</i> (Lubbock, 1856)	A	SS; SP
		Aetideidés	Aetideus	<i>Aetideus armatus</i> (Boeck, 1872)	A	SS; SP
	cyclopoida	Oncaeidés	Oncaea	<i>Oncaea media</i> (Giesbrecht, 1891)	R	SP
				<i>Oncaea venusta</i> (Philippi, 1843)	P	SP
Malacostraca	Mysida	Mysidés	Mysis	<i>Mysis relicta</i> (Lovén, 1862)	R	SP
			Boreomysis	<i>Boreomysis microps</i> (O. Sars, 1883)	P	SS; SP
			Siriella	<i>Siriella thompsonii</i> (H. Milne Edwards, 1837)	R	SP
			Mysidella	<i>Mysidella typhlops</i> (GO Sars, 1872)	R	SP
			Praunus	<i>Praunus inermis</i> (Rathke, 1843)	R	SP
			Hemimysis	<i>Hemimysis lamornae</i> (Couch, 1856)	R	SP
			Thysanoessa	<i>Thysanoessa gregaria</i> (GO Sars, 1883)	R	SS; SP
	Euphausiacés	Euphausiidés	Euphausia	<i>Euphausia krohnii</i> (Brandt, 1851)	P	SP
				<i>Euphausia brevis</i> (Hansen, 1905)	P	SS; SP
	Amphipodes	Lestrigonidés	Hyperioidea	<i>Hyperioidea longipes</i> (Chevreux, 1900)	R	SP
		Lycaeidés	Lycaea	<i>Lycaea pulex</i> (Marion, 1874)	A	SS; SP
		Oxycephalidés	Rhabdosoma	<i>Rhabdosoma brevicandatum</i> (Stebbing, 1888)	P	SS; SP
		Phronimidés	Phronima	<i>Phronima sedentaria</i> (Forskål, 1775)	R	SP
		Hyperiidés	Hyperoche	<i>Hyperoche medusarum</i> (Kröyer, 1838)	R	SP
	Décapodes	Luciferidés	Lucifer	<i>Lucifer faxoni</i> (Borradaile, 1915)	A	SS; SP

Continued

Branchiopodes	CTénopodes	Sididés	Penilia	<i>Penilia</i> sp.	A	SS; SP
	Phragmophora	Eukrohniidés	Eukrohnia	<i>Eukrohnia hamata</i> (Möbius, 1875)	P	SS; SP
			Eukrohnia	<i>Eukrohnia fowleri</i> (Rittet-Záhony, 1909)	A	SS; SP
				<i>Sagitta minima</i> (Grassi, 1881)	P	SP
				<i>Sagitta enflata</i> (Grassi, 1881)	P	SP
				<i>Sagitta serratodentata</i> (Krohn, 1853)	P	SS; SP
sagittoides				<i>Sagitta friderici</i> (Ritter-Záhony, 1911)	P	SS; SP
	Aphragmophora	Sagittidés	Sagitta	<i>Sagitta hexaptera</i> (Orbigny, 1836)	P	SS; SP
				<i>Sagitta planctonis</i> (Steinhaus, 1896)	R	SP
				<i>Sagitta macrocephala</i> (Fowler, 1904)	P	SP
				<i>Sagitta</i> sp.	P	SP
Appendiculaires	Copelata	Oikopleuridés	Oikopleura	<i>Oikopleura dioica</i> (Fol, 1872)	A	SP
			Thalia	<i>Thalia democratica</i> (Forsk., 1775)	P	SP
	Thaliacés	Salpides	Salpa	<i>Salpa democratica</i> (Forsk., 1775)	P	SP
				<i>Salpa zonaria</i> (Pallas, 1774)	R	SS; SP
	Doliolides	Doliolidés	Doliolum	<i>Doliolum denticulatum</i> (Gaimard, 1834)	R	SP
		Syllidés	Myrianida	<i>Myrianida fasciata</i> (Milne Edwards, 1845)	P	SP
Polychètes	Phyllodocida	Tomopteridés	Tomopteris	<i>Tomopteris</i> sp.	P	SP
Hydrozoaires	Leptothecata	Phialellidés	Phialella	<i>Phialella quadrata</i> (Forbes, 1848)	R	SP
Scyphozoaires	Rhizostomeae	Mastigiidés	Phyllorhiza	<i>Phyllorhiza</i> sp.	P	SP
Polycystines	Spumellaria	Actinommidés	Acanthosphaera	<i>Acanthosphaera actinota</i> (Haeckel, 1860)	A	SP
Ostracodes	Halocyprida	Halocyprididés	Conchoecia	<i>Conchoecia elegans</i> (G.O. Sars, 1866)	P	SS; SP

Legend: A = Abundant; P = Present; R = Rare; DS = Dry season; RS = Rainy season.

3.1.3. Variation of Zooplankton Community Density

Density is expressed as the number of individuals per volume of filtered water (ind/m³). The study showed that, in the Fatale River estuary, the density of the zooplankton community varies according to the months, the seasons, and the tides (**Table 3**). The total density is 68,419.67 ind/m³.

Table 3. Relative frequency of the different zooplankton groups according to the seasons.

Zooplankton Groups of zooplankton	Dry Season	Intermediate Season	Rainy Season	Total	(%)
Copépodes	6214.37	16501.24	18347.66	41063.26	52%
Malacostraca	2747.73	5645.78	3626.94	12020.45	23%
Sagittoides	942.14	4394.43	1971.44	7308.01	8%
Thaliacés	320.29	803.23	655.33	1778.85	3%
Polychètes	394.58	456.61	709.49	1560.68	3%

Continued

Scyphozoa	403.94	404.61	593.95	1402.50	3%
Branchiopodes	362.12	389.04	131.79	882.95	3%
Polycistina	97.40	85.78	420.64	603.82	1%
Hydrozoa	64.94	479.99	180.54	725.46	1%
Appendicularia	278.46	482.63	115.54	876.63	2%
Ostracodes	64.94	99.64	32.50	197.07	1%
Total	11890.90	29742.96	26785.82	68419.67	100%

The variations in zooplankton density according to the seasons are recorded in **Tables 4-6** and **Figure 7**.

Table 4. Variation in zooplankton density during the dry season.

Zooplankton Fauna	Dry Season		Total	Average Density (ind/m ³)	%
	March	April			
Copépodes	3714.36	2500.01	6214.37	3107.19	51.43
Malacostraca	1708.77	1038.97	2747.74	1373.87	23.23
Sagittoida	520.06	422.08	942.14	471.07	7.75
Thaliacea	222.88	97.41	320.29	160.15	2.53
Polychaeta	297.18	97.41	394.59	197.29	3.07
Scyphozoa	371.47	32.47	403.94	201.97	3.31
Branchiopoda	297.18	64.94	362.12	181.06	2.52
Polycystina	0	97.41	97.41	48.705	2.03
Hydrozoa	0	64.94	64.94	32.47	1.27
Appendicularia	148.59	129.87	278.46	139.23	1.51
Ostracode	0	64.94	64.94	32.47	1.25
Total	7280.49	4610.45	11890.94	5945.475	100.00

Table 4 shows that, during the dry season, the highest value is observed in March (7280.49 ind/m³) and the lowest (4610.45 ind/m³) in April. [41], showed that the highest value of zooplankton density is observed in April in Tabounsou Bay. Copepods (51.43%), still predominant, are followed by Malacostraca, Sagittoida, Scyphozoa, Polychaetes, Thaliaceans, Branchiopods, Polycystina, Appendicularians, Ostracods, and Hydrozoans during the dry season.

During the intermediate season, the highest value (19,233.26 ind/m³) is observed in November and the lowest (10,509.69 ind/m³) in October (**Table 5**). The group with the highest value is the Copepods group, which has a mean density of 8250.62 ind/m³ and represents 54.51% of the zooplankton organisms recorded during this season. They are followed successively by Malacostraca, Sagittoida and Thaliaceans, Appendicularia, Hydrozoa, and Polychaetes.

Table 5. Zooplankton density during the intermediate season.

Zooplankton Fauna	Intermediate Season		Total	Average Density (ind/m ³)	%
	October	November			
Copépodes	5909.94717	10591.29305	16501.2402	8250.6201	54.51
Malacostraca	2266.96119	3378.817414	5645.7786	2822.8893	18.53
Branchiopodes	194.11	194.93	389.04	194.52	1.07
Sagittoida	1015.61306	3378.817414	4394.43047	2197.2152	15.03
Appendicularia	287.69636	194.93	482.62636	241.3132	2.13
Thaliacea	478.340547	324.8862898	803.226837	401.6134	2.69
Polychaeta	131.720097	324.8862898	456.606387	228.3032	1.83
Hydrozoa	90.122759	389.8635478	479.986307	239.9932	2.05
Scyphozoa	79.72342	324.8862898	404.609714	202.3049	1.25
Polycystina	20.7986688	64.97725796	85.7759268	42.8879	0.42
Ostracode	34.66204506	64.97725796	99.639303	49.8197	0.49
Total	10509.6953	19233.2648	29742.9601	14871.4801	100.00

Table 6. Zooplankton density during the rainy season.

Zooplankton Fauna	Rainy Season		Total	Average Density (ind/m ³)	%
	July	August			
Copépodes	10167.53322	8180.12623	18347.6594	9173.8297	67.56
Malacostraca	1617.562103	2009.37351	3626.93561	1813.4678	13.71
Branchiopoda	57.77	74.02	131.79	65.895	0.43
Sagittoida	924.3212016	1047.11781	1971.43902	985.7195	7.07
Appendicularia	57.77	57.77	115.54	57.77	0.25
Thaliacea	404.3905257	250.944044	655.33457	327.6673	1.66
Polychaeta	404.3905257	305099969	709.490495	354.7453	3.09
Hydrozoa	0	180.538525	180.538525	90.2693	2.07
Scyphozoa	346.6204506	247.329894	593.950345	296.9752	1.97
Polycystina	288.8503755	131.789744	420.640119	210.3201	1.72
Ostracode	0	32.49918752	32.4991875	16.2496	0.47
Total	14269.2084	12516.6089	26785.8173	13392.9088	100.00

The analysis of **Tables 4-6** shows that copepods are characterized by their high numbers, with very unequal seasonal mean densities: 3107.19 ind/m³, *i.e.*, 51.43% during the dry season, 8250.62 ind/m³, *i.e.*, 54.51% during the intermediate season, and 9173.83 ind/m³, *i.e.*, 67.56% during the rainy season. These results confirm those of [41] [43] [70]. After the copepods come successively the Malacostraca (13.71%), the Sagittoidea (7.07%), and the Polychaetes (3.09%). Hydrozoa and Ostracods were recorded only in August. They represent 2.07% and 0.47% of

the total density, respectively. Appendicularia, with a mean density of 57.77 ind/m³, represent 0.25%. They represent the lowest mean density during this season. During the rainy season, the month of July recorded the maximum value (14,269.21 ind/m³), and the minimum value (12,516.61 ind/m³) was observed in August. In the Mellakoré estuary, along the Conakry-Benty axis, [43] found, in the area of highest concentration, the maximum density (140,000 ind/m³) in July.

Figure 7 shows that the total density of zooplankton organisms is higher during the intermediate season than during the rainy season and the dry season, with 29,742.96, 26,785.82, and 11,890.94 ind/m³, respectively.

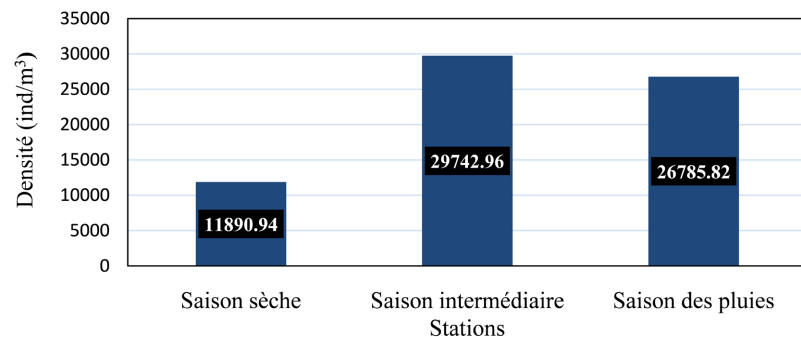


Figure 7. Total zooplankton density according to the seasons.

The increase in zooplankton density during the intermediate season (October–November) in an estuary can be explained by the improvement of ecological conditions after the rainy season. Indeed, heavy rainfall brings many nutrients into the estuary through runoff, but high turbidity and floods can disrupt the development of zooplankton. When rainfall decreases, these nutrients remain available in the water and promote the proliferation of phytoplankton, the main food source of zooplankton. Furthermore, the progressive stabilization of physicochemical parameters (salinity, temperature, turbidity) and the balanced mixing of freshwater and marine waters create favorable conditions for the reproduction and development of zooplankton organisms. These results differ from those of [44], who observed a maximum zooplankton density during the rainy season, followed by the intermediate season and finally the dry season.

The density of zooplankton in the Fatale River estuary by station is presented in **Figure 8**.

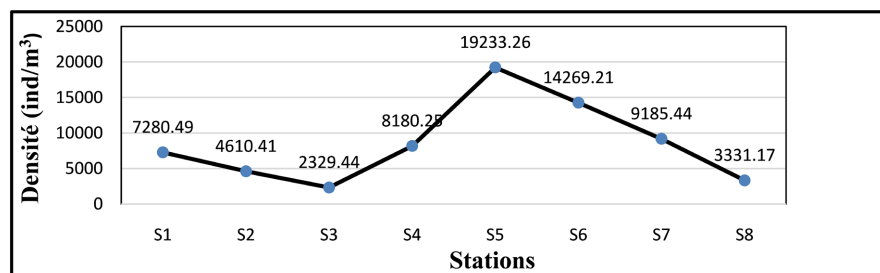


Figure 8. Zooplankton density by station.

Figure 8 shows that zooplankton density differs from one station to another and from upstream to downstream. It is lower upstream (at stations 1, 2, and 3) than downstream.

This situation could be related to the excessive cutting of mangrove wood by woodcutters, as well as agricultural and mining activities that contribute to the degradation of this ecosystem. Mangrove forests, which have a dense and intertwined root system serving as ecological niches for various species, are increasingly degraded upstream. The excessive destruction of mangroves dangerously compromises their role in protecting the coasts against waves and wind-induced erosion. Their role is to preserve biological diversity, provide spawning grounds, and supply nutrients for many species of fish and crustaceans [71].

The lowest zooplankton density (2329.44 ind/m³) was obtained at station 3 (**Figure 8**). This seems to be related to the fact that the pH of the water at this station is pH = 6.3. This slight acidity of the water could be attributed to pollution caused by agricultural activities (which are more intense at station 3), mining activities, and port activities. The highest zooplankton density (19,233.26 ind/m³) was recorded at station 5, located downstream. This high abundance could be explained by the low anthropogenic activity, particularly mining, agricultural, and port activities, in this part of the estuary. Similar results were observed by [71] and [44]. However, the lowest zooplankton density downstream was observed at station 8. This situation could be related to the high water turbidity recorded at this station (31.7 NTU). Indeed, high turbidity reduces light penetration into the water column, which limits the photosynthetic activity of phytoplankton. However, phytoplankton constitutes the main food source for zooplankton; therefore, a decrease in its production can lead to a reduction in zooplankton density.

3.1.4. Biomass of the Zooplankton Community

The mass density, the total mass of zooplankton organisms living in a given place, is expressed in mg/m³. During this study, the biomass of zooplankton organisms varied according to the seasons.

Figure 9 indicates the variation of zooplankton biomass in the Fatale River estuary.

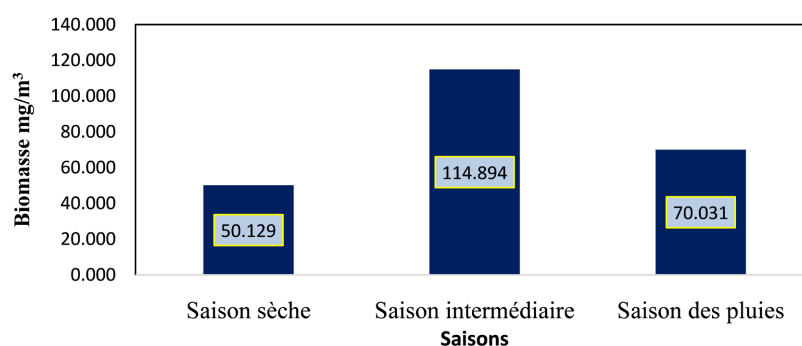


Figure 9. Zooplankton mass density according to the seasons.

Figure 9 shows that the zooplankton biomass in the Fataala River estuary varies according to the seasons. The minimum value (50.129 mg/m³) was recorded during the dry season and the maximum value (114.894 mg/m³) was observed during the intermediate season. This is related to several ecological and physicochemical factors favorable to their development during this period. During the intermediate season:

- Temperatures are moderate, which promotes biological growth (photosynthesis, reproduction);
- Water masses may present moderate stratification; they allow good circulation of nutrients while maintaining favorable areas for zooplankton development.

This intermediate season benefits from sufficient sunshine without being extreme (<https://fr.weatherspark.com>). During the rainy season, heavy rainfall dilutes nutrients and disrupts aquatic communities. During the dry season, evaporation increases salinity, temperature rises, and nutrients are often limited, which can slow down primary production. The intermediate season therefore seems to represent a balance between these two extremes. Many zooplankton species have reproduction cycles synchronized with the intermediate seasons, where conditions appear optimal for the survival of juveniles.

3.1.5. Distribution of Some Main Zooplankton Species

⌘ *Pseudocalanus elongatus*

Pseudocalanus elongatus (Brady, 1865), a copepod of the order Calanoida, was recorded in all stations during all sampling campaigns. Its constant presence seems to indicate its good adaptation to local environmental conditions. Stations 1 and 2 recorded the highest densities, 148.59 ind/m³ and 129.87 ind/m³, respectively.

⌘ *Acrocalanus andersoni*

Acrocalanus andersoni (Browman, 1958) is a copepod species of the order Calanoida, family Paracalanidae. This species is abundant at the mouth of the estuary during all seasons. It presents a high density of 3292.89 ind/m³ at station 6.

⌘ *Aetideus armatus*

Aetideus armatus (Boeck, 1872) is a copepod species of the family Aetideidae. This species is abundant at the mouth of the estuary during all seasons and absent upstream at stations 1, 2, and 3. It presents a high density of 584.79 ind/m³ at station 5.

3.2. Statistical Study

3.2.1. Principal Component Analysis (PCA)

The Principal Component Analysis carried out on the zooplankton data (**Figure 10**) highlights the distribution of species according to the sampling stations.

The F1 axis seems to oppose the stations located on the right side of the factorial plane (stations 1, 2, 4, and 6) to those located on the left side (stations 3, 5, 7, and 8). The stations located on the right are associated with several species such as *Paracalanus parvus*, *Acrocalanus andersoni*, *Oikopleura dioica*, and *Oncaea me-*

dia. This distribution suggests that these stations could present environmental conditions favorable to the development of these species, particularly in terms of salinity, food availability, or hydrological stability.

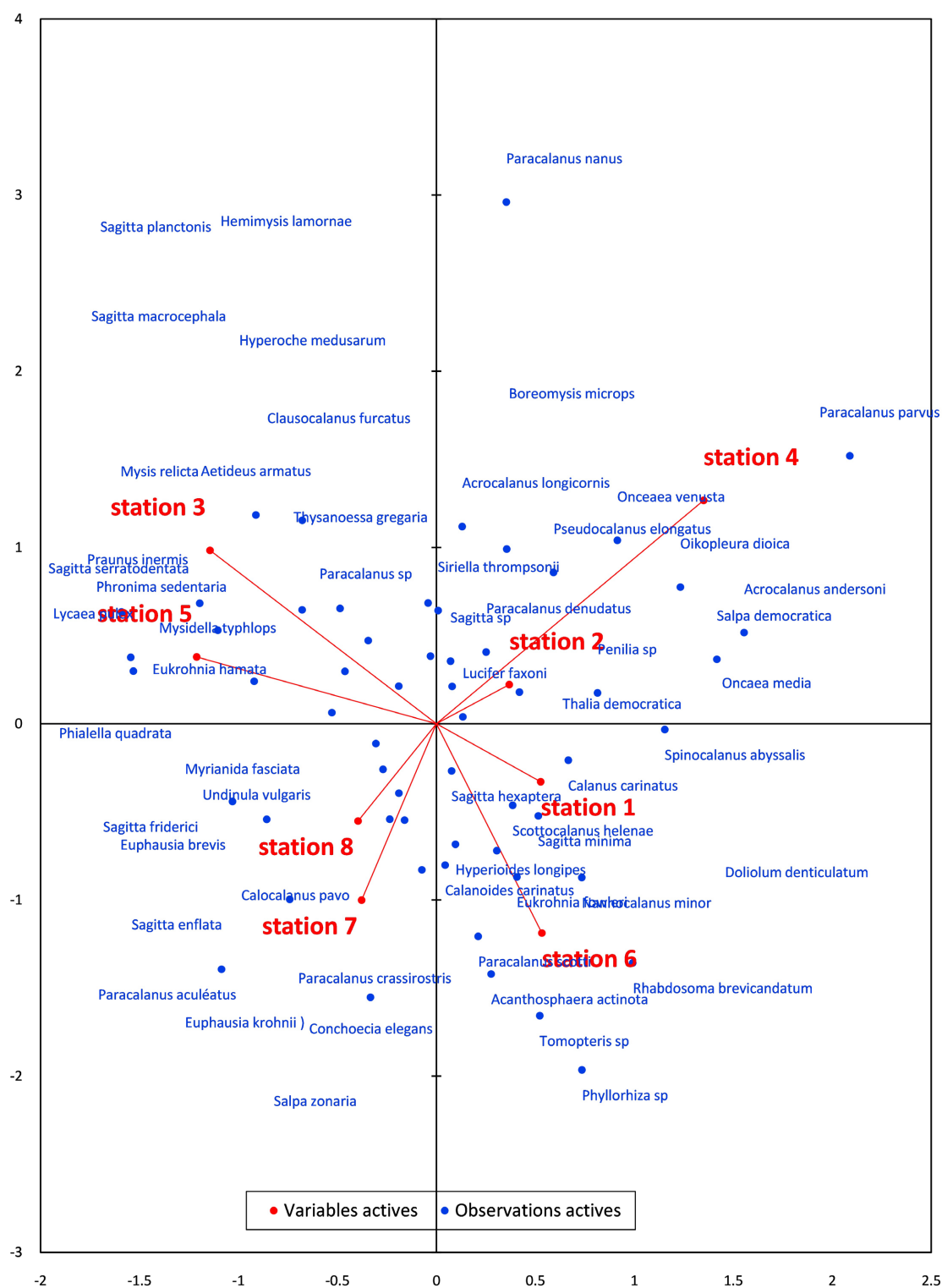


Figure 10. PCA of the variables.

Conversely, the stations located on the left side of the F1 axis (stations 3, 5, 7, and 8) are associated with species such as *Sagitta planktonis*, *Sagitta macrocephala*, *Euphausia brevis*, or *Paracalanus aculeatus*. This distribution could reflect different environmental conditions, possibly related to higher turbidity, continental inputs, or the influence of anthropogenic activities.

The F2 axis, meanwhile, makes it possible to distinguish the stations located in the upper part of the graph (stations 3 and 4) from those located in the lower part (stations 6, 7, and 8). The upper stations are associated with species such as *Paracalanus nanus* or *Boreomysis microps*, whereas those in the lower part are linked to species such as *Paracalanus aculeatus*, *Tomopteris* sp., or *Salpa zonaria*. This organization could reflect an ecological gradient related to certain environmental parameters, such as turbidity, salinity, or trophic availability.

3.2.2. Species Richness

Species richness is the total number of species present in the community. The species richness (S) of zooplankton is represented in **Figure 11**. This figure shows that station 5 is the richest in zooplankton species ($S = 28$). It is followed by station 6 with a species richness ($S = 21$), then by station 7 ($S = 13$). Station 3 ($S = 3$) has the lowest species richness.

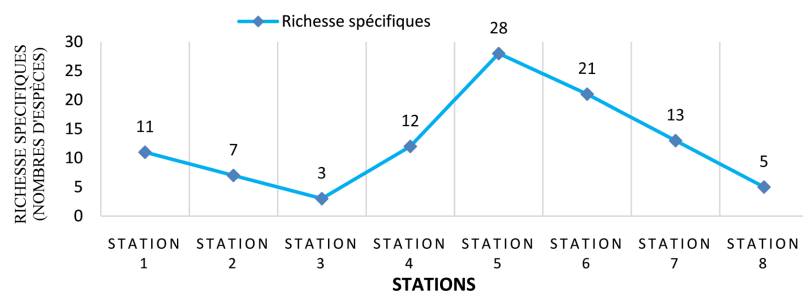


Figure 11. Zooplankton species richness by station.

3.2.3. Shannon Index

The Shannon index of the zooplankton groups is represented in **Figure 12**. The analysis of this figure shows that in the Fatale River estuary, the Copepods ($H' = 0.6$) are the most diversified. They are followed by Malacostraca ($H' = 0.18$), then Sagittoidea ($H' = 0.11$). The Branchiopods, Appendicularians, Hydrozoa, Polycystina, and Ostracods ($H' = 0.01$) are the least diversified.

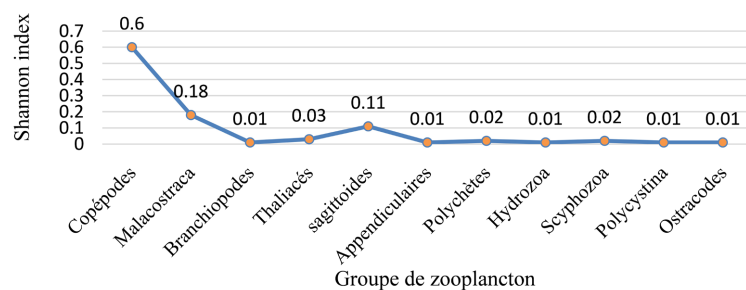


Figure 12. Shannon index of zooplankton groups.

Figure 13 shows the Shannon Index of the main zooplankton species in the study area.

Figure 13 shows that in the Fatale River estuary, the species *Acrocalanus andersoni* with the Shannon index ($H' = 0.29$) is the most diversified in the copepod zooplankton group. It is followed by *Paracalanus nanus* ($H' = 0.23$) and *Lycaea pulex* ($H' = 0.22$). Several species encountered have low specific diversity with $H' = 0.01$. These include, among others: *Doliolum denticulatum*, *Salpa zonaria*, and *Hyperioidea longipes*.

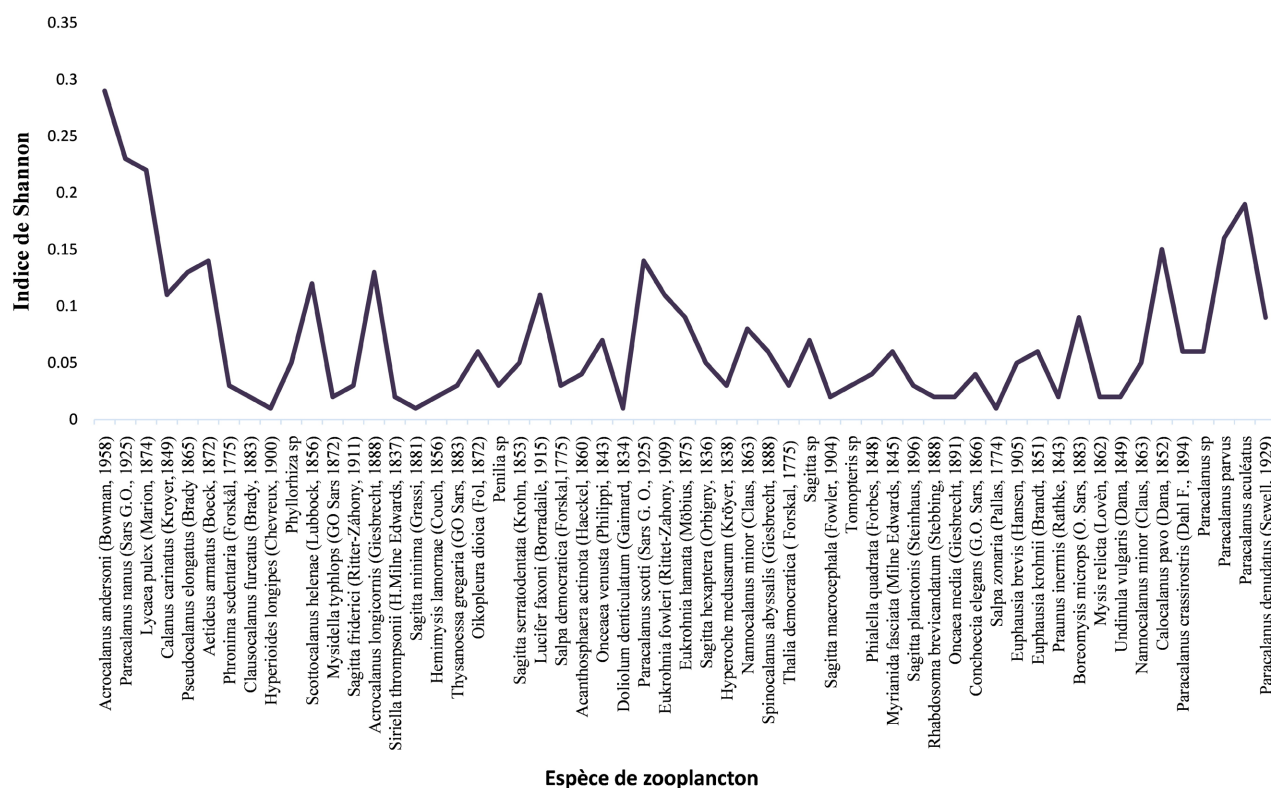


Figure 13. Shannon index of the main zooplankton species in the study area.

4. Conclusions and Perspectives

The results of this study reveal that the pH of 6.3 slightly exceeds the quality standards established by the WHO in certain stations.

The study shows that zooplankton density increases progressively from upstream to downstream and reaches its maximum during the intermediate season, especially in October. This seasonal variation is closely related to environmental and ecological factors (water quality, resource availability, and the stability of physical conditions).

Within the holoplankton group, copepods appear as the most dominant group, representing 52% of the total density, followed by Malacostraca (23%) and Sagittoidea (8%). These three groups also present the greatest diversity. The most constant species observed are *Acrocalanus andersoni*, *Paracalanus nanus*, and *Lycaea*

pulex.

Zooplankton mass density also varies according to the seasons, with a minimum value of 50.129 mg/m³ recorded during the dry season and a maximum value of 114.894 mg/m³ observed during the intermediate season.

In perspective, we will focus on the other links of the aquatic food chain.

Author Contributions

Sylla and Diakit : Conducting sampling and collecting samples. Sylla: Data analysis and processing, interpretation and discussion of the results. Guiss , Sow, Konat  and Diakit : Supervision of laboratory analysis. Sylla, Diakit  and B r t : Contributed to the writing of the scientific article. Keita and Bouya: Overall supervision of the research work.

Conflicts of Interest

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

References

- [1] FAO (2018) The State of the World's Fisheries and Aquaculture. Achieving the Sustainable Development Goals, 227 p.
<https://openknowledge.fao.org/handle/20.500.14283/i9540en>
- [2] Chaalali, A. (2013) Long-Term Evolution of the Gironde Estuarine Ecosystem. Ph.D. Thesis, University of Sciences and Technologies-Bordeaux I, 256 p.
<https://theses.hal.science/tel-01416128v1>
- [3] Serranito, B. (2016) Anthropogenic and Environmental Forcings on the Inter-Annual Dynamics of Coastal Phyto- and Zooplankton Communities in the Northwestern Mediterranean (Toulon, France). Ph.D. Thesis, Universit  de Toulon, 239 p.
<https://theses.hal.science/tel-01563389v1>
- [4] Lakkis, S., Lakkis, V.N. and Zeidane, R. (2013) Zooplankton of Lebanese. Marine Waters (Eastern Mediterranean), 563 p.
- [5] Peres, J.M. and Deuze, L. (1963) Biological Oceanography and Marine Biology. Pelagic Life. Presses Universitaires de France, 117 p.
https://www.persee.fr/doc/revec_0040-3865_1964_num_18_1_4399_t1_0117_0000_2
- [6] Mollo, P. and Noury, A. (2013) The Plankton Manual. 101 p.
https://docs.eclm.fr/pdf_livre/360LeManuelDuPlancton.pdf
- [7] Worden, A.Z., Follows, M.J., Giovannoni, S.J., Wilken, S., Zimmerman, A.E. and Keeling, P.J. (2015) Rethinking the Marine Carbon Cycle: Factoring in the Multifarious Lifestyles of Microbes. *Science*, **347**, Article ID: 1257594.
<https://doi.org/10.1126/science.1257594>
- [8] Barton, A.D., Pershing, A.J., Litchman, E., Record, N.R., Edwards, K.F., Finkel, Z.V., *et al.* (2013) The Biogeography of Marine Plankton Traits. *Ecology Letters*, **16**, 522-534. <https://doi.org/10.1111/ele.12063>
- [9] Benedetti, F. (2016) Impacts du changement climatique sur la diversit  fonctionnelle du zooplancton, le cas des cop podes planctoniques de mer M diterran e. Ph.D. Thesis, L'universit  Pierre-et-Marie-Curie. <https://theses.hal.science/tel-01814326v1>
- [10] Creusot, C. (2010) Seine-Normandie Water Agency. Agricultural Teacher's Logbook,

- 200 p. Classe d'eau: Livre de bord enseignement Agricole.
<https://bdd.pseau.org/outils/biblio/resume.php?d=12298&l=fr>
- [11] Belin, C. and Raffin, B. (1998) Toxic and Harmful Phytoplankton Species on the French Coast from 1984 to 1995, Results of REPHY (Phytoplankton and Phycotoxin Monitoring Network). 151 p. <https://archimer.ifremer.fr/doc/00094/20514>
 - [12] Falkowski, P.G., Barber, R.T. and Smetacek, V. (1998) Biogeochemical Controls and Feedbacks on Ocean Primary Production. *Science*, **281**, 200-206.
<https://doi.org/10.1126/science.281.5374.200>
 - [13] FFEM (2015) Les écosystèmes marins dans la régulation du climat [Marine Ecosystems in Climate Regulation]. French Facility for Global Environment, 80 p.
 - [14] Têtard, H. (2017). Plankton, at the Origin of Life, 4 p.
<https://www.labaleine.occitanie-films.fr/wp-content/uploads/2017/08>
 - [15] Moison, M. (2009) Experimental and Numerical Approach to the Individual Behaviour of *Temora longicornis* (Muller, 1792), a Calanoid Copepod Typical of the Eastern Channel Response to Biotic and Abiotic Forcings. Scientific Research Publishing.
 - [16] Lévesque, S. (2008) Structure spatio-temporelle du zooplancton lacustre: Contribution des courants, de la prédation et des ressources. Master's Thesis, Université du Québec à Montréal.
 - [17] White, M.D. (1998) Horizontal Distribution of Pelagic Zooplankton in Relation to Predation Gradients. *Ecography*, **21**, 44-62.
<https://doi.org/10.1111/j.1600-0587.1998.tb00393.x>
 - [18] Santo, M. (2023) Coastal Zooplankton Biodiversity in the Ecological Importance Zone of the Maritime Estuary of the Saint Lawrence: Use of a Specific and Functional Approach. Master's Thesis, Université du Québec à Rimouski, 101 p.
<https://semaphore.uqar.ca/id/eprint/2837>
 - [19] Romagnan, J.B. (2013) Les communautés planctoniques des bactéries au macroplankton: dynamique temporelle en Mer Ligure et distribution dans l'océan global lors de l'expédition Tara Oceans. -Approche holistique par imagerie-. Doctoral Dissertation, Nice, 184 p. <https://www.researchgate.net/publication/301540981>
 - [20] Strand, E., Klevjer, T., Knutsen, T. and Melle, W. (2020) Ecology of Mesozooplankton across Four North Atlantic Basins. *Deep Sea Research Part II: Topical Studies in Oceanography*, **180**, Article ID: 104844. <https://doi.org/10.1016/j.dsr2.2020.104844>
 - [21] Laprise, F. and Dodson, J. (1994) Environmental Variability as a Factor Controlling Spatial Patterns in Distribution and Species Diversity of Zooplankton in the St. Lawrence Estuary. *Marine Ecology Progress Series*, **107**, 67-81.
<https://doi.org/10.3354/meps107067>
 - [22] Beurier, J.P. (2008) Protection juridique de la biodiversité marine [The Legal Protection of Marine Biodiversity]. 17 p. Zone protégée.
 - [23] Amar, R. (2010) Impact of Anthropization on Biodiversity and the Functioning of Marine Ecosystems: Example of the English Channel-North Sea. 13 p.
https://www.researchgate.net/publication/47514373_Impact_de_lanthropisation_sur_la_biodiversite_et
 - [24] Capo, S., Sottolichio, A., Brenon, I., Castaing, P. and Ferry, L. (2006) Morphology, Hydrography and Sediment Dynamics in a Mangrove Estuary: The Konkoure Estuary, Guinea. *Marine Geology*, **230**, 199-215.
<https://doi.org/10.1016/j.margeo.2006.05.003>
 - [25] IUCN (2007) Marine Biodiversity. Number 13, 16 p.
https://iucn.org/sites/default/files/import/downloads/iucn_no13_english_screen.pdf

- [26] UNEP-WCMC (2016) The State of Biodiversity in Africa: Mid-Term Review of Progress towards Achieving the Aichi Targets. 100 p.
<https://docslib.org/doc/45387/the-state-of-biodiversity-in-africa-a-mid-term-review-of-progress-towards-the-aichi-biodiversi>
- [27] GUINEA/UNEP (2006) National Report on the Marine and Coastal Environment. 65 p. <https://fr.scribd.com/document/332984813>
- [28] Bougeard, X. and Godet, E. (2015) Interactions between the Ocean and Climate. 12 p. <https://www.ocean-climate.org/>
- [29] Adandedjan, D., Makponse, E., Hinvi, L.C. and Laleye, P. (2017) Données préliminaires sur la diversité du zooplancton du lac Nokoué (Sud-Bénin). *Journal of Applied Biosciences*, **115**, 11476-11489. <https://doi.org/10.4314/jab.v115i1.7>
- [30] Tchapgnouo, J.G.N., Njiné, T., Togouet, S.H.Z., Segnou, S.C.D., Tahir, T.S.M., Tchakonté, S., et al. (2012) Diversité spécifique et abondance des communautés de copépodes, cladocères et rotifères des lacs du complexe Ossa (Dizangué, Cameroun). *Physio-Géo*, **6**, 71-93. <https://doi.org/10.4000/physio-geo.2430>
- [31] Lempereur, M. (2015) Variabilité saisonnière et interannuelle de la croissance du chêne vert méditerranéen et vulnérabilité au changement climatique. Ph.D. Thesis, Aix-Marseille University. <https://www.researchgate.net/publication/309704854>
- [32] UNEP/GUINEA (2006) National Report on the Marine and Coastal Environment. 65 p. <https://www.scirp.org/reference/referencespapers?referenceid=3799866>
- [33] UNEP (2020) Marine and Coastal Biodiversity. 2 p. <https://www.unep.org/topics/ocean-seas-and-coasts>
- [34] Goeury, D. (2014) La Pollution Marine. In: Raymond, W., Ed., *Géographie des mers et des océans*, Woessner Raymond, 15 p. <https://www.researchgate.net/publication/280815952>
- [35] Ukwe, C.N., Ibe, C.A. and Sherman, K. (2006) A Sixteen-Country Mobilization for Sustainable Fisheries in the Guinea Current Large Marine Ecosystem. *Ocean & Coastal Management*, **49**, 385-412. <https://doi.org/10.1016/j.ocecoaman.2006.04.006>
- [36] Richardson, K., Haynes, D., Talouli, A. and Donoghue, M. (2016) Marine Pollution Originating from Purse Seine and Longline Fishing Vessel Operations in the Western and Central Pacific Ocean, 2003-2015. *Ambio*, **46**, 190-200. <https://doi.org/10.1007/s13280-016-0811-8>
- [37] Chatterjee, S. and Sharma, S. (2019) Microplastics in Our Oceans and Marine Health. <https://journals.openedition.org/factsreports/5257>
- [38] Ceillier, I. (2015) The Study of Impacts on Biodiversity: Integration of Biodiversity in the Environmental Assessment of Dams on Transboundary Rivers in West Africa. Master's Thesis, Université de Sherbrooke, 93 p. <https://studylibfr.com/doc/8400397>
- [39] Magurran, A.E. and McGill, B.J. (2011) Biological Diversity: Frontiers in Measurement and Assessment. 62 p. https://www.researchgate.net/profile/Robin-Chazdon/publication/284554411_Composition-al_similarity_and_beta_diversity/links/56589fde08ae1ef9297df08e/Compositional-similarity-and-beta-diversity.pdf
- [40] Santos, T.P., Cutrim, M.V.J., da Cruz, Q.S., Cavalcanti-Lima, L.F., dos Santos Sá, A.K.D. and de Azevedo-Cutrim, A.C.G. (2024) Zooplankton Community Heterogeneity and Trophic Interactions in Response to Environmental Drivers in a Mesotidal Estuary on the Brazilian Equatorial Margin—Lençóis Maranhenses National Park. *Freshwater Biology*, **69**, 1261-1277. <https://doi.org/10.1111/fwb.14303>
- [41] Camara, M. and Keita, A. (2016) Variations spatio-temporelles des principales Ca-

- ractéristiques du zooplancton côtier de l'Afrique de l'ouest: Cas de la baie de Taboun-sou (Conakry, République de Guinée). 137 p.
<https://www.scirp.org/reference/referencespapers?referenceid=4100775>
- [42] Liaudanskas, M., Brunevičiūtė, R., Gaivelytė, K., Viškelis, J., Viškelis, P., Kviklys, D., *et al.* (2016) Seasonal Variation of Qualitative and Quantitative Composition of Phenolic Compounds and Antioxidant Activity in Apple (*Malus Domestica* Borkh.) Fruits. *International Journal of Biochemistry Research & Review*, **14**, 1-13.
<https://doi.org/10.9734/ijbcrr/2016/28856>
- [43] Tabunschik, V., Gorbunov, R., Bratanov, N., Gorbunova, T., Mirzoeva, N. and Voytsekhovskaya, V. (2023) Fatale River Basin (Republic of Guinea, Africa): Analysis of Current State, Air Pollution, and Anthropogenic Impact Using Geoinformatics Methods and Remote Sensing Data. *Sustainability*, **15**, Article 15798.
<https://doi.org/10.3390/su152215798>
- [44] Modéran, J. (2010) Charente Estuary: Community Structure and Trophic Ecology of Zooplankton, Ecosystem Approach to Metal Contamination. Ph.D. Thesis, University of La Rochelle, 1-2. <https://www.researchgate.net/publication/281658667>
- [45] Deloffre, J., Lafite, R., Lesueur, P., Lesourd, S., Verney, R. and Guézennec, L. (2005) Sedimentary Processes on an Intertidal Mudflat in the Upper Macrotidal Seine Estuary, France. *Estuarine, Coastal and Shelf Science*, **64**, 710-720.
<https://doi.org/10.1016/j.ecss.2005.04.004>
- [46] Pritchard, D.W. (1967) What Is an Estuary: Physical Viewpoint. In: Lauff, G.H., Ed., *Estuaries*, American Association for the Advancement of Science, 149-176.
<https://www.scirp.org/reference/referencespapers?referenceid=2262701>
- [47] Dalrymple, R.W., Zaitlin, B.A. and Boyd, R. (1992) Estuarine Facies Models; Conceptual Basis and Stratigraphic Implications. *Journal of Sedimentary Research*, **62**, 1130-1146. <https://doi.org/10.1306/d4267a69-2b26-11d7-8648000102c1865d>
- [48] Perillo, G.M.E. (1995) Chapter 2 Definitions and Geomorphologic Classifications of Estuaries. *Developments in Sedimentology*, **53**, 17-47.
[https://doi.org/10.1016/s0070-4571\(05\)80022-6](https://doi.org/10.1016/s0070-4571(05)80022-6)
- [49] Dyer, K.R. (1997) Estuaries: A Physical Introduction. Wiley, 140 p.
<https://books.google.com/books/about/Estuaries.html?id=l84PAQAIAAAI>
- [50] Cadenasso, M.L., Pickett, S.T.A., Weathers, K.C. and Jones, C.G. (2003) A Framework for a Theory of Ecological Boundaries. *BioScience*, **53**, 750-758.
[https://doi.org/10.1641/0006-3568\(2003\)053\[0750:affato\]2.0.co;2](https://doi.org/10.1641/0006-3568(2003)053[0750:affato]2.0.co;2)
- [51] Cloern, J. (2001) Our Evolving Conceptual Model of the Coastal Eutrophication Problem. *Marine Ecology Progress Series*, **210**, 223-253.
<https://doi.org/10.3354/meps210223>
- [52] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., *et al.* (1997) The Value of the World's Ecosystem Services and Natural Capital. *Nature*, **387**, 253-260. <https://doi.org/10.1038/387253a0>
- [53] Baran, E. (1999) Rôle des estuaires vis-à-vis de la ressource halieutique côtière en Guinée. In: Domain, F., Chavance, P. and Diallo, A., Eds., *La pêche côtière en Guinée: ressources et exploitation*, Editions IRD, 137-157.
<https://www.scirp.org/reference/referencespapers?referenceid=3136186>
- [54] Devreker, D., Forget-Leray, J. and Souissi, S. (2012) Ecology of the Copepod *Eurytemora affinis*: A Species at the Center of the Estuarine Trophic Network, 59 p.
<https://www.seine-aval.fr/publication/fasc-eurytemora-affinis/>
- [55] Baran, É. (1995). Spatio-Temporal Dynamics of Estuarine Fish Communities in

- Guinea: Relationships with the Abiotic Environment. 236 p.
<https://www.researchgate.net/publication/32972641>
- [56] Gill, C.W. (1986) Suspected Mechano- and Chemosensory Structures of *Temora Longicornis* (Copepoda: Calanoida). *Marine Biology*, **93**, 449-457.
<https://doi.org/10.1007/bf00401113>
- [57] Drits, A.V., Pasternak, A.F. and Kosobokova, K.N. (1994) Physiological Characteristics of the Antarctic Copepod *Calanoides Acutus* during Late Summer in the Weddell Sea. In: Ferrari, F.D. and Bradley, B.P., Eds., *Ecology and Morphology of Copepods*, Springer, 201-207. https://doi.org/10.1007/978-94-017-1347-4_27
- [58] Turner, J.T. (1984) The Feeding Ecology of Some Zooplankters That Are Important Prey Items of Larval Fish. 34 p. <https://repository.library.noaa.gov/view/noaa/5581>
- [59] Gee, J.M. (1989) An Ecological and Economic Review of Meiofauna as Food for Fish. *Zoological Journal of the Linnean Society*, **96**, 243-261.
<https://doi.org/10.1111/j.1096-3642.1989.tb01830.x>
- [60] Cascella, K. (2014) Impact of Global Warming on Krill in Polar Environments: Thermotolerance and Hsp70 Response. Ph.D. Thesis, Université Pierre et Marie Curie, 284 p. <https://hal-emse.ccsd.cnrs.fr/THESES-UPMC/tel-01151589>
- [61] Domain, F. and Bah, M.O. (1993) Sedimentological Map of the Guinean Continental Shelf. 26 p.
https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_5/notexp/39526.pdf
- [62] Camara, M., Ivanof, L.I. and Cravchenko, B. (1988) Tides of the Coastal Zone of the Republic of Guinea.
<https://www.tide-forecast.com/locations/Conakry-Guinea/tides/latest>
- [63] Diop, S. (1990) The West African Coast, from Saloum (Senegal) to Mellacorée (Republic of Guinea). ORSTOM Studies and Theses Collection, 379 p.
<https://www.researchgate.net/publication/32980810>
- [64] Rose, M. (1933) Pelagic Copepods. Fauna of France, 6-377.
[https://faunedefrance.org/bibliotheque/docs/M.ROSE\(FdeFr26\)Copepodes-pe-lagiques.pdf](https://faunedefrance.org/bibliotheque/docs/M.ROSE(FdeFr26)Copepodes-pe-lagiques.pdf)
- [65] Trégouboff, G. and Rose, M. (1957) Manual of Mediterranean Planktonology. National Centre for Scientific Research, 544 p.
<https://books.google.com/books?id=pbU0wPfiim0C&dq=editions:OCLC10470923&hl=fr>
- [66] George, W. and Chris, L.J. (2001) Marine Zooplankton of West Africa. 120 p.
<https://www.scrip.org/reference/referencespapers?referenceid=4100769>
- [67] Lynne, M.W. (2004) Practical Guide to Identifying Freshwater Crustacean Zooplankton. 2nd Edition, Cooperative Freshwater Ecology Unit, 50 p.
<https://laurentian.ca/research/centres/cfeu>
- [68] Sajina, L.L. (1986) Tableau de poids des principaux organismes zooplanctoniques. MGI. 17 p. <https://www.scrip.org/reference/referencespapers?referenceid=4100767>
- [69] Dauby, P. (1980) Annual Cycle of Surface Zooplankton in Calvi Bay (Corsica). Total Biomass and Copepod Plankton, 6 p. <https://archimer.ifremer.fr/doc/00122/23283/>
- [70] Giry, F., Binet, T. and Keurmeur, N. (2017) Les bénéfices de la protection des mangroves de l'outre-mer français par le Conservatoire du littoral: Une évaluation économique à l'horizon 2040. *Études caribéennes*, **36**.
<https://doi.org/10.4000/etudescaribeennes.10485>

- [71] Akopian, M., Garnier, J. and Pourriot, R. (2002) Cinétique du zooplancton dans un continuum aquatique: De la Marne et son réservoir à l'estuaire de la Seine. *Comptes Rendus. Biologies*, **325**, 807-818. [https://doi.org/10.1016/s1631-0691\(02\)01483-x](https://doi.org/10.1016/s1631-0691(02)01483-x)

Websites

http://www.obs-vlfr.fr/~gaspari/copepodes/cop_doc.htm.

Accessed on 11/03/2024.

http://www.plancton-du-monde.org/module-formation/phyto_02.html.

Accessed on 07/04/2024.

<http://educatif.eau-et-rivieres.asso.fr/pdf/plancton-generalites.pdf>.

Accessed on 05/07/2024.

<http://atelierpeche.free.fr/3-Habitants/zooplancton.pdf>. Accessed on 09/03/25.