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Influence of physico-chemical parameters on the diversity of zooplankton in Kodjoboué lagoon (Bonoua, south-east of Côte d'ivoire)

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Abstract

To maintain the ecological quality of surface waters, zooplankton communities are notable for their varied roles and importance in the food chain. This study aimed to determine the diversity and abundance of zooplankton in the Kodjoboué Lagoon of Bonoua. Sampling was conducted monthly using a plankton net (55 µm mesh size) from April to September 2024. A total of 31 zooplankton taxa were identified, distributed into four main groups: 19 Rotifers, 4 Copepods, 4 Cladocerans, and 4 other organisms. This zooplankton community is quantitatively dominated by Copepods, which represent 45% of the total zooplankton density. Specifically, the taxonomic richness and mean abundance of taxa are highest at stations S1 and S2. Results from the Redundancy Analysis (RDA) show that variables such as temperature, conductivity, dissolved oxygen, and pH are the essential factors influencing the distribution of zooplankton in the Kodjoboué Lagoon of Bonoua. Management of this lagoon based on these parameters would help maintain the diversity and resilience of this ecosystem against various disturbances in aquatic environments.

Keywords: Zooplankton; Kodjoboué Lagoon; Diversity; Environmental Factors; Bonoua

1. Introduction

Water constitutes a natural resource essential for life within any ecosystem. While groundwater is generally favored for drinking water supply, surface waters remain a crucial resource for sustainable development, providing a varied range of goods and services to human societies [1]. In Côte d'Ivoire, the hydrographic network includes a major lagoon system with a total area of 1,200 km^2 [2]. Three main lagoons compose these brackish ecosystems, from West to East: the Grand Lahou Lagoon, the Ebri Lagoon, and the Aby-Tendo-Ehy lagoon system.

Besides these main lagoon systems, other smaller lagoons, such as those of Fresco, Ono, Ouladine, Hébé, and Kodjoboué, also deserve mention. The Kodjoboué Lagoon, naturally influenced by the Comoé River, is subject to significant anthropogenic pressures due to the development of agricultural, agro-industrial, and domestic activities, linked to unchecked population growth [3]. These disturbances are very often felt within biological communities [4], particularly the zooplankton.

Indeed, zooplankton, a fundamental component of plankton, refers to organisms that live suspended in the water and cannot resist currents [5]. Their role in the aquatic trophic chain is indisputable [6], as they act simultaneously as consumers, predators, and prey [7]. They constitute the key element for the transfer of energy and matter in aquatic

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ecosystems [8]. They are also a privileged nutritional source for both fry and adult fish [9]. Moreover, zooplankton, due to its trophic position, high abundance in freshwater, and short life cycle, is particularly sensitive to environmental variations, reacting quickly to changes in its habitat conditions [10].

Despite the alarming degradation of this lagoon and the importance of zooplankton, very few studies in Côte d'Ivoire have focused on the zooplankton of the Kodjoboué Lagoon. It is therefore urgent to establish scientific databases on the aquatic community of this environment to ensure its monitoring and management. This study aims to assess the diversity and abundance of zooplankton in the Kodjoboué Lagoon.

2. Materials and Methods

2.1. Study Environment

The Kodjoboué Lagoon is located in the South-East of Côte d'Ivoire in the South Comoé region, about 4 km South of the town of Bonoua, between longitudes 3°35' 9" W and latitudes 5°14'11" N [11]. This area is contiguous to the Grand-Bassam wetland and covers an area of 3.404 km^2. The Kodjoboué Lagoon extends for about 823 meters long, with a maximum width of 164 meters. It is characterized by a low average depth, not exceeding 2 meters. The Kodjoboué Lagoon benefits from a subequatorial climate characterized by four seasons, including two dry seasons (December to March and August to September) and two rainy seasons [12].

Four stations (S1 to S4) were selected in this environment for data collection (Figure 1). These stations were visited monthly from April to September 2025. Table I summarizes the characteristics of these sampling stations.

2.2. Zooplankton Sampling

At each station, ten 10 L buckets of water (a total volume of 100 L) were collected and filtered using a 55 µm mesh plankton net. The collected water was transferred into sample vials and then treated according to the following protocol:

- Addition of 1 to 2 mg of sucrose to reduce the breakage of Cladoceran shells [13];
- Addition of 2 to 3 drops of neutral red to stain the zooplankton organisms, facilitating their observation under a magnifying glass;
- Addition of 5% concentration formaldehyde to preserve the zooplankton organisms

2.3. Zooplankton Observation and Identification

In the laboratory, each zooplankton sample was concentrated to a volume equal to 50 ml. Zooplankton species were observed using a MOTIC optical microscope at 40x objective. They were subsequently identified based on specific observable morphological characters, using the following identification keys: **[14]**; **[15]**; **[16]**; **[17]**; **[18]**.

2.4. Measurement of Physico-chemical Parameters

Abiotic parameters were measured in situ between 7:00 AM and 10:00 AM before zooplankton sampling. Temperature, dissolved oxygen, pH, conductivity, and salinity were measured using a pre-calibrated multi-parameter meter. The multi-function probe of the device was immersed in the water, within the first 50 centimeters. The values of each parameter were then displayed on the device screen after stabilization and recorded in a notebook. Transparency was measured using a Secchi disk, and depth by the total immersion of a weighted rope until it reached the bottom of the surveyed station. Mesological parameters were measured at each of these stations (Table I).

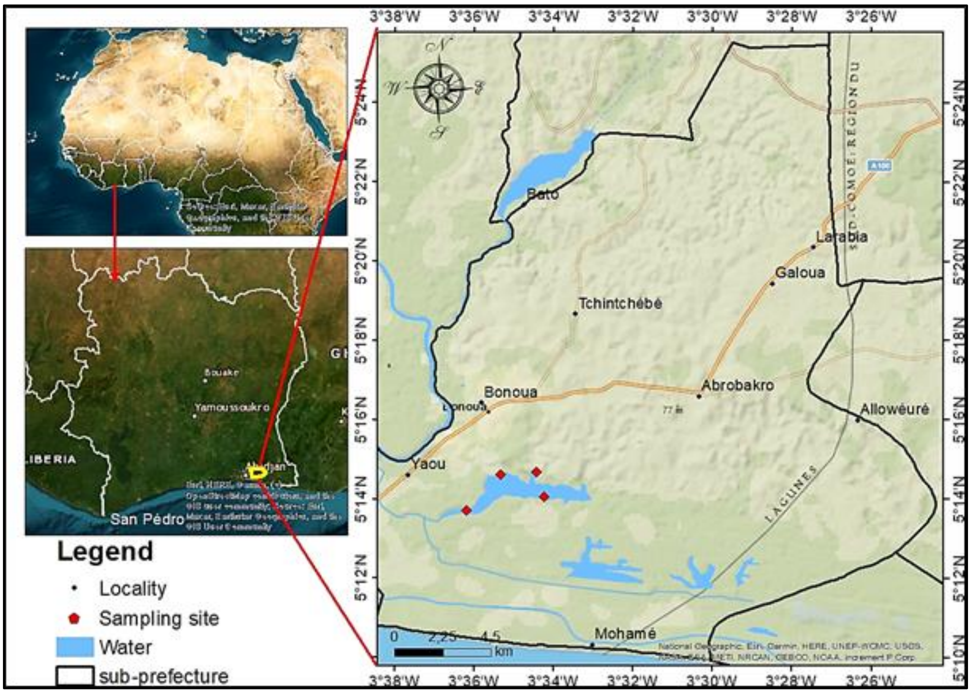


Figure 1 Overview of the sampled stations in the Kodjoboué Lagoon of Bonoua (Côte d'Ivoire) from April to June 2024

Table 1 Mesological data of the sampling stations

Stations	Geographic coordinates	
	Latitude	Longitude
S1	5°14'42.6" N	3°35'12.9" O
S2	5°13'45.3" N	3°36'02.9" O
S3	5°14'01.5" N	3°34'22.0" O
S4	5°14'37.5" N	3°34'21.2" O

Data Analysis: Taxonomic richness, Shannon diversity index, and Evenness index were used to characterize the biological diversity and structure of the zooplankton community in the Kodjoboué Lagoon of Bonoua. Redundancy Analysis (RDA) was employed to correlate environmental variables and zooplankton taxa.

3. Results

3.1. Qualitative Analysis of the Community

A total of 31 taxa, all of continental origin, were collected in the Kodjoboué Lagoon (Table II). Four major zooplankton groups (19 Rotifers, 4 Copepods, 4 Cladocerans, and 4 other zooplankton organisms) distributed across 14 families were identified.

For the Rotifers, the qualitative analysis of taxa indicates a dominance of the Lecanidae family with 6 taxa, representing 31.56%. This is followed by the Filinidae, Brachionidae, Testudinellidae, Trichocercidae, and Mytilinidae, each having two taxa, or 10.53% (Table III, implicitly mentioned as being associated with the rotifer description). The least diversified Rotifer families are Asplanchnidae, Adinetidae, and Euchlanidae, each with one taxon (5.26%).

For the Copepods, the most diversified family is Cyclopidae, with two taxa, representing 50%. These are Mesocyclops sp. and Thermocyclops sp.. The least diversified family is Diaptomidae, with one taxon (25%) (Table II).

Regarding Cladocerans, only the Chydoridae family was recorded, with four taxa, namely, *Alona guttata*, *Alona rustica*, *Eurycercus lamellatus*, and *Biapertura affinis*.

The spatial distribution of taxonomic richness shows that station S2 is the most diverse with 25 taxa. It is followed by station S1, which recorded 21 taxa. Stations S3 and S4 are the least diverse, with 11 and 15 taxa, respectively (Table II).

Copepod Nauplii, (*Asplanchna priodonta*, *Thermocyclops* sp., *Centropyxis aculeata*), Ostracods, Chironomidae larvae, and other insect larvae are common to all four surveyed stations. Two species (*Lecane rugosa* and *Lecane obtusa*) are specific to station S1, while six taxa (*Lecane* sp., *Testudinella* sp., *Trichocerca bicristata*, *Mytilina ventralis*, *Biapertura affinis*, *Dipleuchlanis propatula*) are specific to station S2.

Table 2 Composition of the zooplankton community collected at stations S1, S2, S3, and S4 of the Kodjoboué Lagoon

Groups	**Families**	**Taxa**	**Stations**			
			S1	S2	S3	S4
Rotifers	Filinidae	*Filinia opoliensis*	+	+		
		Filinia terminalis	+	+	+	
	Brachionidae	*Brachionus falcatus*	+	+		+
		Keratella tropica	+	+		+
	Lecanidae	*Lecane bulla*	+	+		
		Lecane rugosa	+			
		Lecane styrax	+	+		+
		Lecane closterocerca	+		+	
		Lecane obtusa	+			
		Lecane sp.		+		
	Testudinellidae	*Testudinella patina*	+	+		
		Testudinella sp.		+		
	Trichocercidae	*Trichocerca similis*		+		
		Trichocerca bicristata	+	+		
	Mytilinidae	*Mytilina ventralis*		+		
		Mytilina mucronata	+	+		
	Asplanchnidae	*Asplanchna priodonta*	+	+	+	+
	Adinetidea	*Adineta grandilis*	+	+		
	Euchlanidae	*Dipleuchlanis propatula*		+		
Cladocerans	Chydoridae	*Alona guttata*		+		+
		Alona rustica				+
		Eurycercus lamellatus	+			+
		Biapertura affinis		+		

Copepods	Cyclopidae	*Thermocyclops* sp.	+	+	+	+
		Mesocyclops sp.		+	+	+
	Diaptomidae	*Tropodiaptomus lateralis*			+	+
	Indeterminate	Nauplii de Copépodes	+	+	+	+
Other	Indeterminate	Ostracodes	+	+	+	+
	Centropyxidae	*Centropyxis aculeata*	+	+	+	+
	Chironomidae	Chironomidae larvae	+	+	+	+
	Undeterminate	Other insect larvae	+	+	+	+
Total	15	31	21	25	11	15

3.2. Quantitative Analysis of the Community

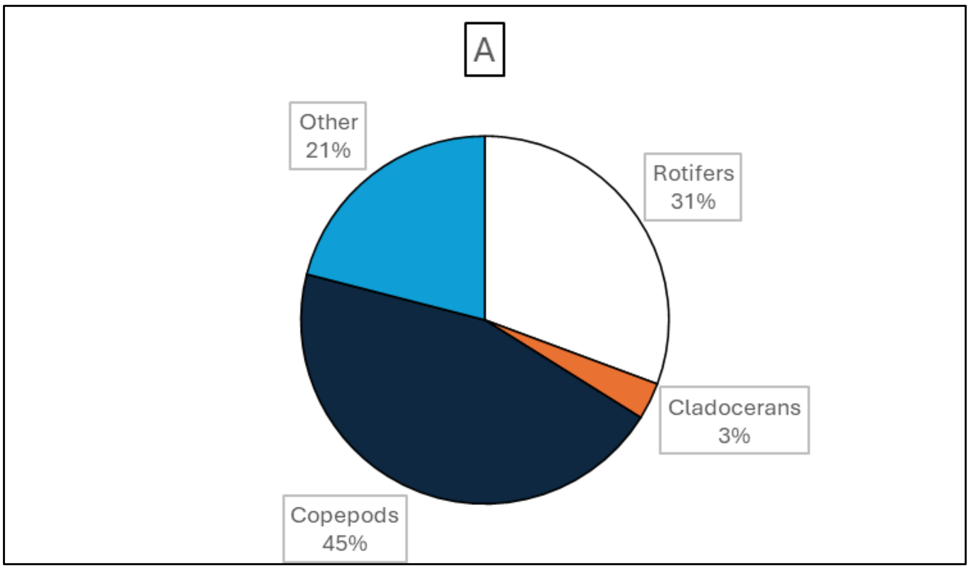
Copepods are the most abundant taxa, representing 45% of the zooplankton community in the Kodjoboué Lagoon. They are followed, respectively, by Rotifers (31%), Cladocerans (3%), and other zooplankton organisms (21%) (Figure 2A).

These Copepods are largely dominated by Copepod Nauplii, with 89% of their density, followed by *Thermocyclops* sp. (5%) and *Mesocyclops* sp. (4%) (Figure 2B).

Rotifers, on the other hand, are dominated by *Trichocerca cylindrica* (22%), followed by *Asplanchna priodonta* and *Keratella tropica* (15%), then by *Testudinella patina* (9%), *Filinia opoliensis* (7%), and finally, *Brachionus falcatus* and *Adineta grandilis* (6%) (Figure 2C).

Regarding Cladocerans, *Alona guttata* presents the highest proportion with 47% of the total Cladoceran density, followed by *Eurycercus lamellatus* (35%) and *Biapertura affinis* (18%) (Figure 2D).

The other zooplankton organisms are dominated by insect larvae, representing 41% of the total density, followed by *Centropyxis aculeata* (27%), Ostracodes sp. (21%), and Chironomidae larvae (11%).



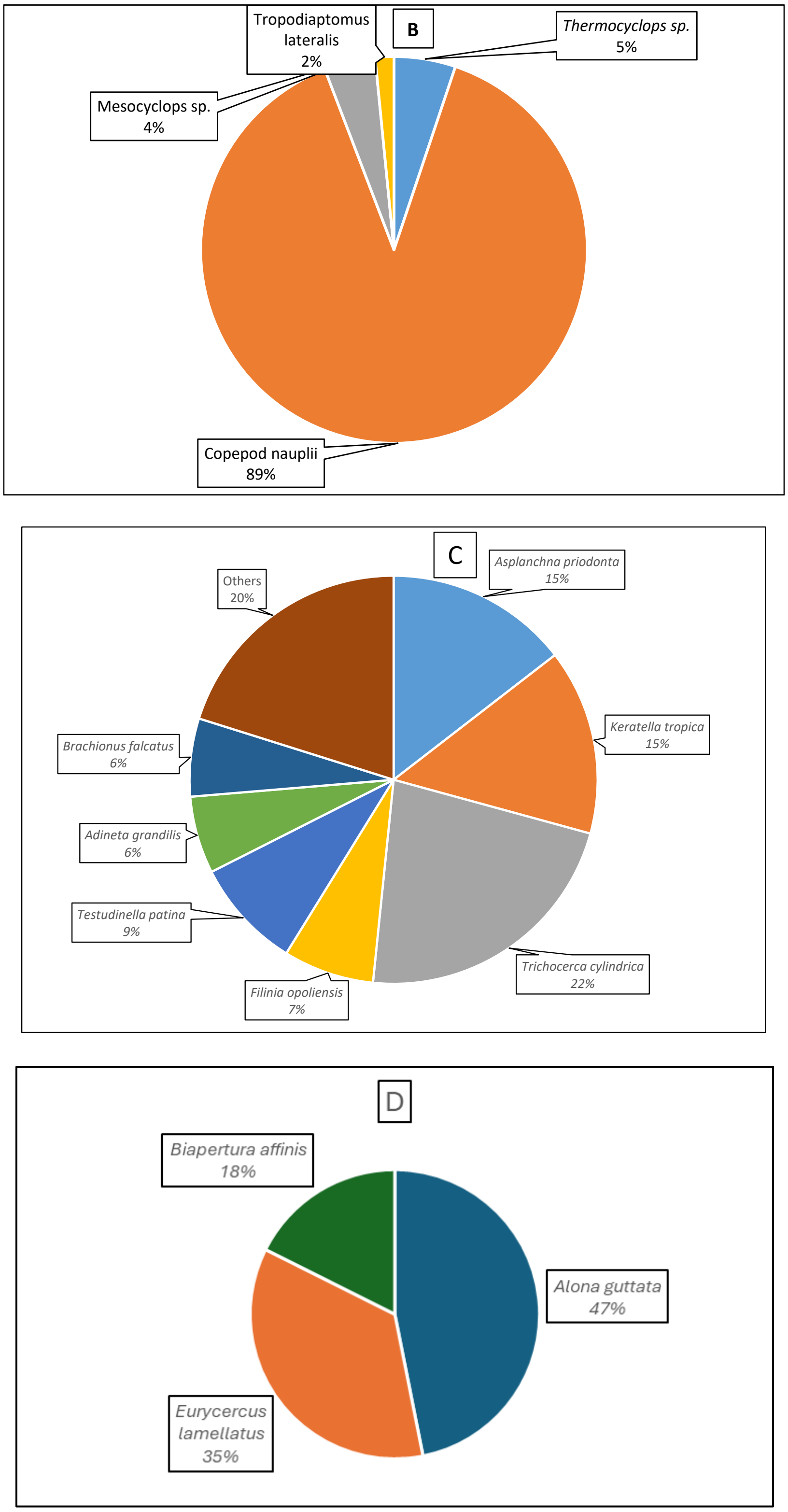


Figure 2 Structure of the total zooplankton (A) and the main taxa of the zooplankton groups sampled in the Kodjoboué Lagoon (Côte d'Ivoire): (B)- Copepods, (C) Rotifers and (D) – Cladocerans

3.3. Spatial Variation of Community Diversity

The Shannon diversity index and Evenness index values are represented in Figure 3. The minimum values for the Shannon index (1.23 bits/ind) and Evenness (0.41) were obtained at station S1, while the maximum values were recorded for the Shannon index at station S2 (2.68 bits/ind) and for Evenness at station S4 (0.90). The Evenness values noted at stations S1 and S2 differ significantly from one station to another (Kruskal-Walli's test, $p < 0.05$).

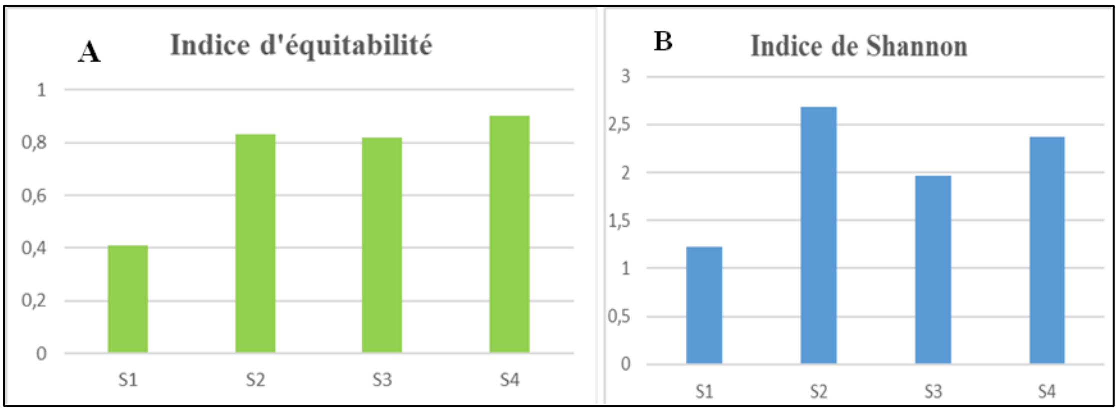


Figure 3 Spatial variation of the Shannon diversity (B) and Evenness (A) indices

3.4. Spatial Variability of Community Density

Contrary to the diversity index values, station S1 recorded the highest average density (2168 ind/m^3) of zooplankton in the Kodjoboué Lagoon, while station S3 recorded the lowest density (499 ind/m^3) (Figure 4). However, the variability of observed densities is only significant between stations S1 and S3 (Kruskal-Walli's test $p < 0.05$).

Copepods constitute the predominant group at station S1, with 74.01% of the total density, whereas at station S2, Rotifers are instead the majority (48.94%). The zooplankton fauna of stations S3 and S4 is dominated by other zooplankton organisms, which alone represent 46.73% and 53.37% of the total zooplankton collected at these stations, respectively.

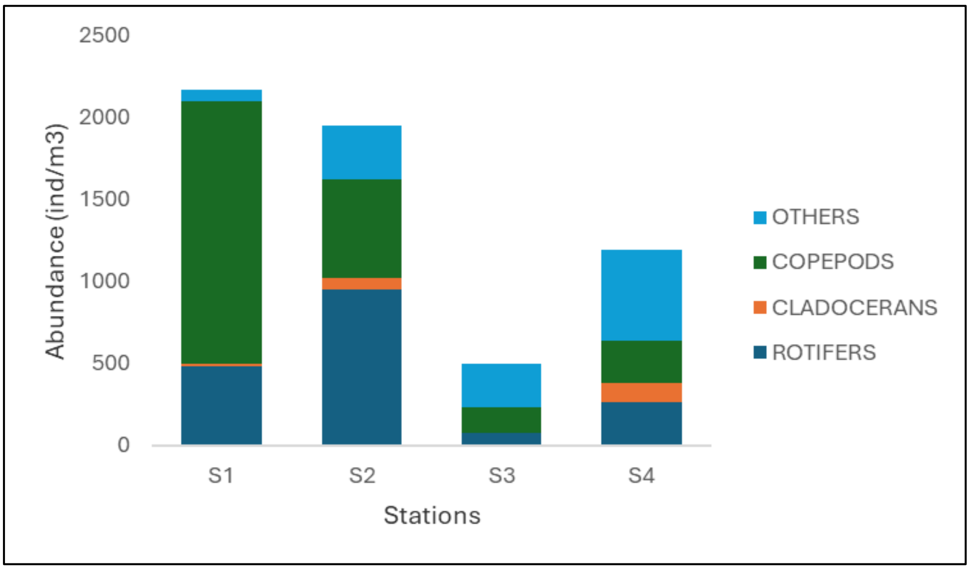


Figure 4 Spatial variation of the total average zooplankton density

3.5. Influence of Environmental Variables on Community Distribution

A Redundancy Analysis (RDA) was performed to establish a correlation between the environmental characteristics of the environment and the spatial distribution of zooplankton taxa in the Kodjoboué Lagoon. The result of this analysis shows that the correlation between environmental factors and zooplankton taxa is mainly explained by factorial axes 1 and 2 (75.2% and 12.8% of the total variance, respectively).

Parameters such as pH and transparency are positively correlated with axis 1. Conversely, conductivity and depth are positively correlated with axis 2, while temperature and dissolved oxygen (DO) are negatively correlated with this axis.

The RDA ordination along factorial axis 1 distinguishes two groups of organisms (Figure 5). Group 1 includes the species *Lecane obtusa, Lecane rugosa, Testudinella patina, Lecane bulla, Filinia terminalis, Trichocerca cylindrica, Filinia* *opoliensis, Adineta grandilis*, which are positively correlated with high values of transparency and conductivity. Group 2, on the other hand, is composed of the species *Thermocyclops sp., Alona guttata, Chironomidae larvae, Keratella tropica, Lecane styrax, Brachionus falcatus*, which are positively influenced by high pH and temperature.

Relative to axis 2, the ordination also indicates the presence of two groups: The first, represented by the species *Lecane obtusa, Lecane rugosa, Testudinella patina, Lecane bulla, Filinia terminalis, Brachionus falcatus, Keratella tropica, Trichocerca cylindrica, Filinia opoliensis, Adineta grandilis, Lecane styrax, Moina micrura, Thermocyclops sp*. and Copepod nauplii, is associated with high values of conductivity, transparency, pH, and dissolved oxygen (DO). As for the second group, it includes the species *Lecane closterocerca*, *Tropodiaptomus lateralis*, other insect larvae, *Asplanchna pridonta*, *Mesocyclops* sp., *Brachionus falcatus*, Ostracods, *Alona guttata* and *Chironomidae larvae*. These are associated with high temperature values.

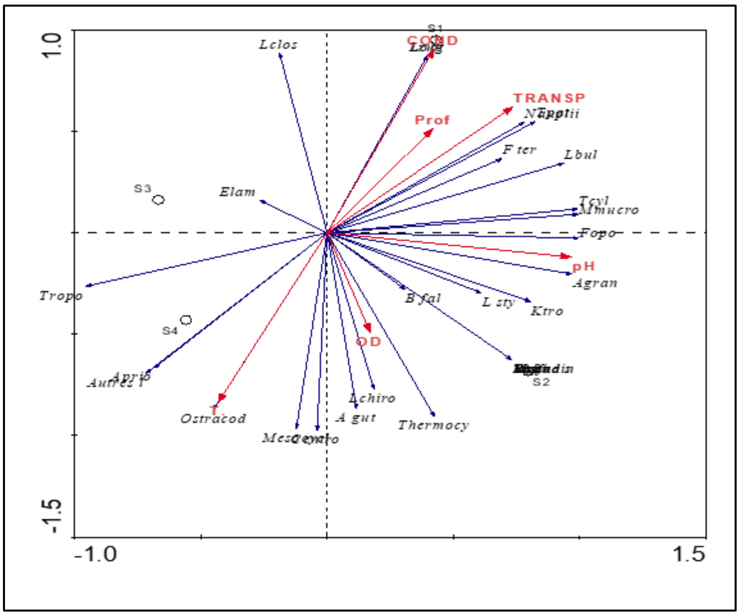


Figure 5 Redundancy Analysis (RDA) showing the relationships between environmental variables, sampling stations, and taxa in the Kodjoboué Lagoon"

4. Discussion

The study of the zooplankton community in the Kodjoboué Lagoon of Bonoua allowed the identification of 31 taxa, all of continental origin. The exclusive presence of continental taxa in the Kodjoboué Lagoon community indicates a brackish environment minimally influenced by saltwater or an ecological management that limits the introduction of marine species. These results differ from those obtained in the Ebri and Grand-Lahou Lagoons, where several studies ([19]; [20]) have identified the coexistence of lagoon, marine, and continental communities, depending on salinity variations.

In contrast, the zooplankton community of the Kodjoboué Lagoon shows a similarity with that of the Ehy Lagoon (freshwater environment) [21], that of the Bia and Agnby rivers [22], as well as that of the small freshwater reservoirs in Northern Côte d'Ivoire [23], highlighting typical characteristics of freshwater environments.

Furthermore, the zooplankton community of the Kodjoboué Lagoon is qualitatively predominated by Rotifers (59%). This predominance would reflect a high concentration of organic matter in the environment. Indeed, the rapid growth of these taxa, key players in the aquatic food chain, is favored by the abundance of bacteria ([24]; [25]). Authors such as [26], [27], [5] and [28] confirm that the qualitative predominance of Rotifers is a frequent characteristic in tropical environments subjected to high pollution or increased eutrophication. However, the high representation of this group is an indicator of a high trophic level [29].

Regarding the quantitative composition of the zooplankton community, Copepods are predominantly represented (45%). The high proportion of this taxon would indicate a good trophic level due to their ecological role as consumers of phytoplankton and bacteria. Moreover, these organisms are perfect, essential prey for many fish and crustaceans [2].

Their abundance indicates that these ecosystems are conducive to the breeding of fish larvae and crustaceans. The fact that the dominant groups, such as Copepods and Rotifers, are used as live food in aquaculture, highlights the economic and ecological importance of the Kodjoboué Lagoon.

Furthermore, the results of the Redundancy Analysis (RDA) reveal that the variables strongly influencing the distribution of the zooplankton community are conductivity, transparency, temperature, and pH. These results align with the assertion of several authors ([22]; [32]), according to which the variables primarily associated with zooplankton segregation in aquatic environments are pH, transparency, temperature, and current velocity.

5. Conclusion

This study, conducted on the Kodjoboué Lagoon, highlights a zooplankton community consisting of 31 freshwater taxa, divided into four groups (Rotifers, Copepods, Cladocerans, and other zooplankton organisms). This community is qualitatively dominated by Rotifers (59%) and quantitatively by Copepods (43%), indicating a high trophic state, due to a high load of organic matter and nutrients.

The taxonomic diversity and abundance were highest at station S1. Conductivity, transparency, temperature, and pH are the variables that primarily influence the distribution of the zooplankton community in the Kodjoboué Lagoon. Management of this lagoon water body focused on these parameters would help maintain the diversity and resilience of this ecosystem against various disturbances in aquatic environments.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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