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SPATIOTEMPORAL STRUCTURE AND DYNAMICS OF ZOOPLANKTON COMMUNITIES IN SMALL RESERVOIRS LAKES IN CENTRAL CÔTE D'IVOIRE, WEST AFRICA

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ABSTRACT

Objective: This study aimed to determine the seasonal distribution of zooplankton in relation to the environmental characteristics of small-reservoir lakes in central Côte d'Ivoire.

Methods and results: Sampling was conducted from June 2016 to June 2018 at Raviart, Allomambo and Kongobo during the dry and rainy seasons. Organisms were collected by filtering 50 L of water through a plankton net with a 20-µm mesh size. In total, 49 taxa belonging to 24 families and 36 genera were recorded, including 32 rotifers, 8 cladocerans, 4 copepods and 5 other organisms. Rotifers dominated the community, accounting for 79.03% of total abundance, with Brachionus quadridentatus as the dominant taxon. Taxonomic richness was significantly higher in the rainy season (24–35 taxa) than in the dry season (11–23 taxa). Zooplankton abundance increased during the rainy season at Raviart and Allomambo, whereas the opposite trend was observed at Kongobo. Canonical correspondence analysis revealed associations between taxon distribution and environmental variables, particularly conductivity, temperature, pH and dissolved oxygen.

Conclusion and application: Zooplankton communities in the three small reservoirs showed marked seasonal variation, whose magnitude and direction differed among stations. The predominance of rotifers, particularly Brachionidae, highlights the value of zooplankton for ecological monitoring of these environments. These findings provide a basis for seasonal monitoring of the ecological quality of small reservoirs in central Côte d'Ivoire.

Keywords: Zooplankton, Diversity, abundance, Small-reservoir lakes in central Côte d'Ivoire, Anthropogenic activities, Seasonal distribution

1 INTRODUCTION

Small reservoirs lake are essential surface-water storage structures that meet the water-resource needs of small communities, particularly in rural areas. In Côte d'Ivoire, these structures are widespread, with more than 500 units distributed throughout the country; a substantial proportion is located in the central region, which contains approximately 23.6% of them (Traore, 1996). Initially designed for a single purpose, these reservoirs are now intensively used for various domestic, agricultural and recreational activities (Marzouk, 1989; Oweis et al., 2001). However, this increased use, combined with human activities such as fishing, swimming, laundry and agriculture, causes the gradual degradation of these aquatic environments, affecting their ecological quality and biodiversity (Idessa, 1992; Tchapgnouo, 2012). The uncontrolled expansion of activities in these small-reservoir lakes therefore raises major management and conservation concerns.

In the face of these pressures, accurate scientific data on aquatic organisms are essential, particularly for zooplankton, which is a key indicator of the ecological condition of these environments. Zooplankton occupies a central position in aquatic food webs, transferring matter and energy from primary producers to higher trophic levels (Levinsen and Nielsen, 2002). Through its responses to environmental change and its sensitivity to disturbance, it is also considered an effective indicator of climate change and water quality (Brassard, 2009). Zooplankton monitoring can therefore be used to assess the ecological health of aquatic ecosystems at different levels of organisation, from communities to individual organisms (Fernando et al., 1993).

In Côte d'Ivoire, several studies have investigated the spatiotemporal dynamics of zooplankton communities (Pagano and Saint-Jean, 1994; Aka et al., 2000; Kouassi, 2001; Pagano et al., 2004; Ouattara et al., 2007; Etilé et al., 2009; Monney et al., 2016; Fofana et al., 2019). However, no study of this kind had previously been conducted in the country's small reservoirs in the central region.

The present study aims to address this gap by providing the first in-depth investigation of the spatiotemporal dynamics of zooplankton communities in small-reservoir lakes in central Côte d'Ivoire.

2 MATERIALS AND METHODS

2.1 Study area

The three small-reservoir lakes investigated are located in central Côte d'Ivoire. The sampling stations were Raviart (7°24′N, 4°53′W), Allomambo (7°46′N, 4°53′W) and Kongobo (7°45′N, 5°28′W) (Figure 1). Fishing, laundry and swimming take place in the small-reservoir lakes at Kongobo and Allomambo. The Raviart reservoir is used for agriculture, laundry and swimming. The climate of central Côte d'Ivoire is humid tropical, with two seasons: a dry season from November to March and a rainy season from April to October (Cecchini, 2020).

2.2 Measurement of environmental characteristics

Physicochemical characteristics were measured before biological sampling. The physicochemical parameters—temperature, dissolved oxygen, pH, conductivity and total dissolved solids—were measured in situ in the upper 50 cm of the water column at each station using digital multiparameter instruments.

2.3 Sampling and identification of zooplankton organisms

Sampling was carried out at three stations from June 2016 to June 2018 during the dry season (March and November) and the rainy season (June and August). Zooplankton was collected during four campaigns at each site, between 08:00 and 15:00. Five buckets with a capacity of 10 L each (a total volume of 50 L) were filled at three points in each water body and filtered through a plankton net with a 20-µm mesh size. The resulting concentrate was collected in a 250-mL vial. The organisms were treated by adding sucrose, neutral red and liquid soap, and were fixed with 5% formaldehyde. In the laboratory, taxa were counted in a Bogorov counting chamber under a MOTIC stereomicroscope at magnifications of ×160, ×250 and ×400, following the technique described by Cassie (1968).

Taxa were identified using the following identification references: Amoros (1984), Saint-Jean (1985), Pourriot and Francez (1986), Baribwegure and Segers (2000), Hamaidi et al. (2008), De Manuel (2000), Dussart and Defaye (2001), Sharma (2010), and Kotov et al. (2012).

2.4 Data analysis

Taxonomic richness, percentage occurrence, the Shannon index and evenness indices were used to describe the structure and dynamics of the zooplankton community. Percentage occurrence (F) was calculated as $F = (Si / St) \times 100$,

where Si is the number of stations at which taxon i was recorded and St is the total number of stations sampled. Taxa were classified according to their percentage occurrence following Dajoz (2000): F ≥ 50% = constant taxon; 25% ≤ F < 50% = accessory taxon; and F < 25% = accidental taxon.

Canonical correspondence analysis (CCA) was used to relate environmental variables to zooplankton taxa in the small-reservoir lakes. Mann–Whitney U and Kruskal–Wallis tests were performed to assess variation in zooplankton densities and physicochemical parameters according to season and station.

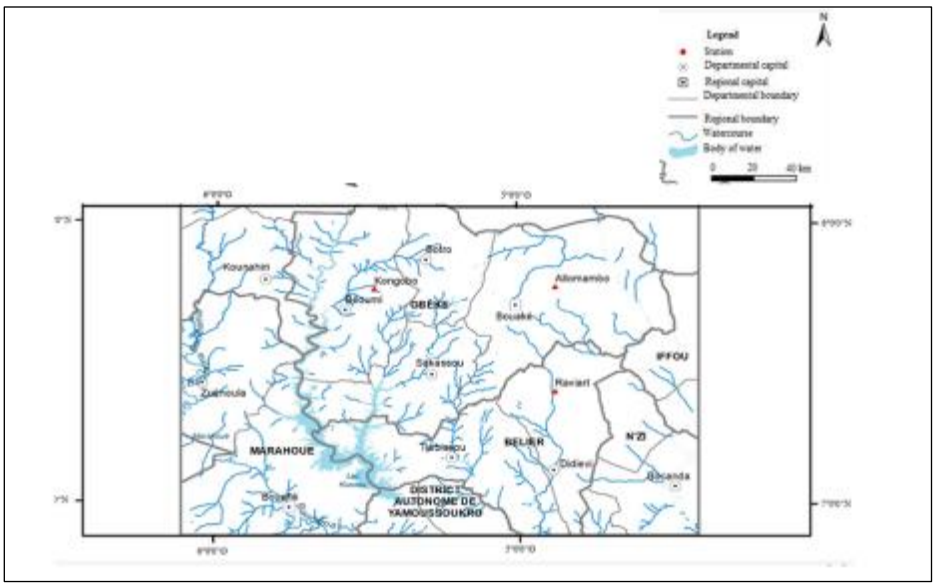


Figure 1: Sampling stations in the small-reservoir lakes investigated in central Côte d'Ivoire from June 2016 to June 2018.

3 RESULTS

3.1 Seasonal variations in physicochemical parameters

Table 1 presents the means and standard deviations of the physicochemical parameters measured during each season at each sampling station in central Côte d'Ivoire from June 2016 to June 2018.

The physicochemical parameters measured in the small reservoirs of central Côte d'Ivoire varied seasonally, but the differences were not statistically significant. Mean dissolved oxygen (DO) ranged from 2.35 ± 0.07 to 8.45 ± 0.63 mg/L in the rainy season and from 2.05 ± 0.07 to 10 ± 0.70 mg/L in the dry season. Dissolved oxygen concentrations tended to be higher during the dry season, but this difference was not significant (Mann–Whitney U test, $p > 0.05$).

Mean water temperature ranged from 27.80 ± 0.70°C to 33 ± 1.27°C in the dry season, compared with 27 ± 0.70°C to 28.80 ± 2.40°C in the rainy season. Temperature was higher in the dry season, although the difference was not statistically significant ($p > 0.05$).

Measured pH values ranged from 7.32 ± 0.19 to 8.06 ± 0.08 in the dry season and from 7.12 ± 0.67 to 7.85 ± 0.14 in the rainy season. All values were above 7, indicating slightly alkaline conditions. No significant seasonal difference was observed ($p > 0.05$).

Total dissolved solids (TDS) ranged from 39.50 ± 4.94 to 143.50 ± 51 mg/L in the rainy season and from 50.50 ± 0.70 to 99.50 ± 0.70 mg/L in the dry season. Electrical conductivity, which is correlated with TDS, ranged from 78 ± 8.45 to 288 ± 103.23 µS/cm in the rainy season and from 101 ± 1.41 to 194.50 ± 6.36 µS/cm in the dry season. Statistical analyses showed that these variations between seasons were not significant.

Table 1: Mean values and standard deviations of physicochemical parameters measured during the dry season (DS) and rainy season (RS) at each sampling station in central Côte d'Ivoire from June 2016 to June 2018. O_2 = dissolved oxygen; Temp = water temperature; pH = potential of hydrogen; TDS = total dissolved solids; Cond = conductivity.

ENVIRONMENTAL VARIABLES						
Stations	Seasons	O_2 (mg/l)	Temp (°C)	pH	TDS (mg/l)	Cond (µS/cm)
Raviart	DS	2.05 ± 0.07	31.25 ± 0.35	8.06 ± 0.08	99.50 ± 0.70	194.50 ± 6.36
	RS	2.35 ± 0.07	28.80 ± 2.40	7.12 ± 0.67	143.50 ± 51	288 ± 103.23
Allomambo	DS	10 ± 0.70	33 ± 1.27	7.32 ± 0.19	50.50 ± 0.70	101 ± 1.41
	RS	8.45 ± 0.63	27 ± 0.70	7.76 ± 0.69	39.50 ± 4.94	78 ± 8.45
Kongobo	DS	5.85 ± 0.07	27.80 ± 0.70	7.85 ± 0.07	67 ± 3.53	133.50 ± 0.70
	RS	5.55 ± 0.77	27 ± 0.57	7.85 ± 0.14	66.50 ± 9.89	133.50 ± 2.12

3.2 Taxonomic richness of the zooplankton community and percentage occurrence

Table 2 presents the zooplankton community recorded during this study in the small-reservoir lakes of central Côte d'Ivoire. A total of 49 zooplankton taxa were identified, including 32 rotifers, 8 cladocerans, 4 copepods and 5 other organisms. These 49 taxa belonged to 24 families and 36 genera. The most diverse families were Brachionidae (10 species), followed by Lecanidae (6 species), Trichocercidae (4 species), and Filinidae, Mytilinidae and Daphniidae (3 species each). Cyclopidae and Chydoridae each contained two taxa; the remaining families were represented by a single species.

Of these taxa, 18 were constant, 11 accessory and 18 accidental.

Taxonomic richness did not differ significantly among stations (Kruskal–Wallis test, $p > 0.05$). It ranged from 29 taxa at Kongobo to 40 at Allomambo. Taxonomic richness was significantly higher in the rainy season (24–35 taxa) than in the dry season (11–23 taxa) (Mann–Whitney U test, $p < 0.05$).

The following table preserves the station-presence records and occurrence percentages reported in the source. "+" indicates that a taxon was recorded at the station. Taxon names are retained as written in the revised French manuscript and have not been independently re-identified.

Table 2: Composition of the zooplankton community collected in the small-reservoir lakes of central Côte d'Ivoire from June 2016 to June 2018.

Groups	Families	Taxa	Raviart	Allomambo	Kongobo	Occurrence (%)
Copepods	Cyclopidae	*Thermocyclops decipiens*	+	+	+	100
Copepods	Cyclopidae	*Mesocyclops ogunus*	+	+	+	91.66
Copepods	Undetermined	Nauplii	+	+	+	91.66
Copepods	Undetermined	Copepodites	+	+	+	58.33
Rotifers	Epiphanidae	*Epiphanes macrourus*	+	+	+	58.33
Rotifers	Filinidae	*Filinia opoliensis*	+	+	+	50
Rotifers	Filinidae	*Filinia terminalis*	+	+		41.66
Rotifers	Filinidae	*Filinia longiseta*	+	+		50
Rotifers	Brachionidae	*Brachionus angularis*	+	+	+	75
Rotifers	Brachionidae	*Keratella tropica*	+	+	+	50
Rotifers	Brachionidae	*Brachionus falcatus*	+	+	+	83.33

Rotifers	Brachionidae	*Brachionus caudatus*		+	+	41.66
Rotifers	Brachionidae	*Brachionus calyciflorus*	+			33.33
Rotifers	Brachionidae	*Platyias quadricornis*	+	+		25
Rotifers	Brachionidae	*Brachionus bennini*		+		8.33
Rotifers	Brachionidae	*Brachionus quadrientatus*	+	+	+	33.33
Rotifers	Brachionidae	*Plationus patulus*	+			16.66
Rotifers	Brachionidae	*Brachionus sericus*		+		8.33
Rotifers	Synchaetidae	*Polyarthra vulgaris*	+	+	+	41.66
Rotifers	Lecanidae	*Lecane bulla*	+	+	+	66.66
Rotifers	Lecanidae	*Lecane papuana*	+	+	+	25
Rotifers	Lecanidae	*Lecana leontina*	+	+	+	33.33
Rotifers	Lecanidae	*Lecane styrax*		+		8.33
Rotifers	Lecanidae	*Lecane quadrientata*	+			8.33
Rotifers	Lecanidae	*Lecane luna*	+	+	+	50
Rotifers	Colurellidae	*Lepadella ovalis*		+		8.33
Rotifers	Mytilinidae	*Mytilina acanthophora*		+		8.33
Rotifers	Mytilinidae	*Mytilina ventralis*	+		+	16.66
Rotifers	Mytilinidae	*Mytilina mucronata*	+	+		16.66
Rotifers	Testudinellidae	*Testudinella patina*	+		+	25
Rotifers	Hexarthridae	*Hexartha mira*			+	8.33
Rotifers	Trichocercidae	*Trichocerca vernalis*		+		16.66
Rotifers	Trichocercidae	*Trichocerca cylindrica*		+	+	25
Rotifers	Trichocercidae	*Trichocerca bicristata*		+		8.33
Rotifers	Trichocercidae	*Trichocerca longiseta*		+		8.33
Rotifers	Asplanchnidae	*Asplanchna priodonta*	+			8.33
Cladocerans	Daphniidae	*Ceriodapnia cornuta*		+	+	58.33
Cladocerans	Daphniidae	*Ceriodapnia affinis*		+	+	25
Cladocerans	Daphniidae	*Scapholeberis mucronata*			+	8.33
Cladocerans	Macrothricidae	*Streblocerus sericaudatus*	+	+		33.33
Cladocerans	Moinidae	*Moina micrura*	+	+	+	83.33
Cladocerans	Sididae	*Diaphanosoma excisum*	+	+	+	33.33
Cladocerans	Chydoridae	*Alona weltneri*	+			8.33
Cladocerans	Chydoridae	*Pseudochydorus globosus*		+		8.33
Other organisms	Undetermined	*Ostracods*	+	+	+	66.66
Other organisms	Centropyxidae	*Centropyxis acuelata*	+	+	+	50

Other organisms	Chironomidae	Chironomid larvae	+	+	+	66.66
Other organisms	Chaoboridae	Chaoborus larvae		+		8.33
Other organisms	Undetermined	Other insect larvae	+	+	+	75

Table 3: Seasonal variation of diversity indices in small reservoir lakes in central Côte d'Ivoire

Metric	Seasons	Raviart	Allomambo	Kongobo
Total taxa	—	33	40	29
Taxonomic richness	Dry season	11	23	22
Taxonomic richness	Rainy season	30	35	24
Shannon index (H′)	Dry season	1.02	0.74	1.22
Shannon index (H′)	Rainy season	0.84	2.11	2.17
Evenness index (E)	Dry season	0.42	0.23	0.39
Evenness index (E)	Rainy season	0.24	0.59	0.68

3.3 Quantitative analysis of the community

Figure 2 shows the relative contribution of the zooplankton community collected in the three small-reservoir lakes. Rotifers dominated numerically (79.03%), followed by copepods (18.81%), cladocerans (1.73%) and other zooplankton organisms (0.43%).

In terms of density, the rotifer community was dominated by Brachionus quadrientatus (52.3%), followed by Filinia longiseta (21.13%). Among cladocerans, Moina micrura was dominant (60.92%), followed by Ceriodaphnia cornuta (25.53%). Among copepods, copepod nauplii (64.56%) and Thermocyclops sp. (21.39%) were the most abundant taxa. Ostracods (40.3%) dominated the group of other organisms.

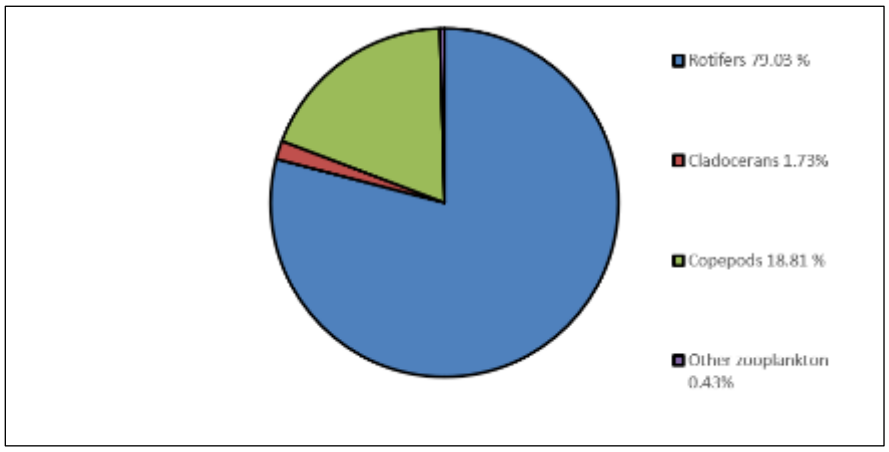


Figure 2: Relative contribution of the zooplankton community collected in three small-reservoir lakes in central Côte d'Ivoire from June 2016 to June 2018.

Zooplankton densities varied among stations. The highest value was recorded at Raviart (388.78 individuals/L) and the lowest at Kongobo (119.37 individuals/L) (Figure 3). However, the Kruskal–Wallis test revealed no significant difference in total zooplankton abundance among stations ($p > 0.05$).

Rotifers were particularly dominant at Raviart, accounting for 97.82% of individuals; Brachionus quadrientatus alone represented 57.94% of the total collected at this station. Ceriodapnia cornuta was the dominant species in Lake Kongobo (75.91%), while copepod nauplii dominated at Allomambo (78.48%).

Seasonal variation in total zooplankton abundance showed higher values during the rainy season, ranging from 150.68 to 567.35 individuals/L, and lower values during the dry season, ranging from 36.88 to 210.21 individuals/L, particularly at Raviart and Allomambo (Figure 4). In contrast, the highest densities at Kongobo occurred during the dry season. The Mann–Whitney U test indicated that these seasonal variations were significant for all the small lakes studied ($p < 0.05$).

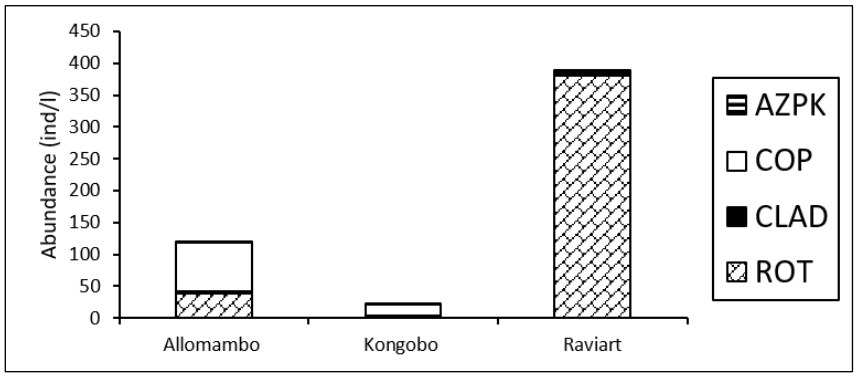


Figure 3: Spatial variation in mean total zooplankton abundance in three small-reservoir lakes in central Côte d'Ivoire from June 2016 to June 2018. AZPK: Other zooplankton; COP: Copepods; CLAD: Cladocerans; ROT: Rotifers.

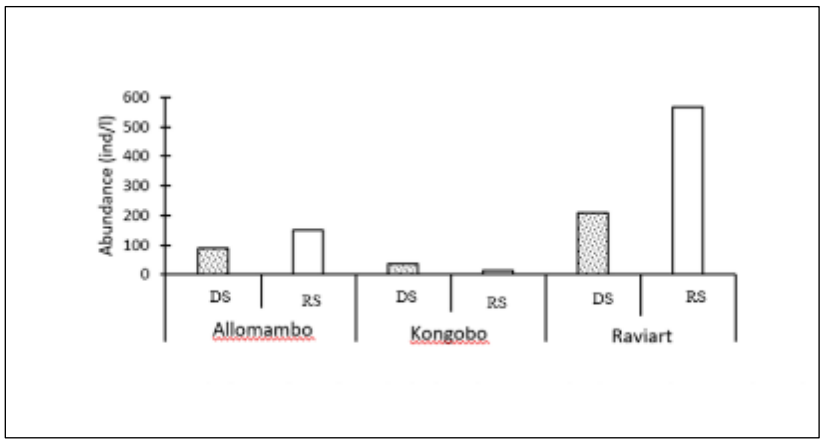


Figure 4: Seasonal variation in total zooplankton abundance in three small-reservoir lakes in central Côte d'Ivoire from June 2016 to June 2018.

3.4 Diversity indices

Analysis of the Shannon index showed that, except at Raviart, the highest values were recorded during the rainy season, ranging from 2.11 to 2.17 bits/individual (Table 2). During the dry season, the index reached its lowest values, from 0.74 to 1.22 bits/individual, at all stations. With regard to evenness, except at Raviart, higher values were recorded during the rainy season (0.59–0.68) than during the dry season (0.23–0.39). However, the Mann–Whitney U test showed no significant seasonal differences in the Shannon and evenness indices across all stations ($p > 0.05$), suggesting that the observed variations were not statistically significant.

3.5 Correlations between environmental variables and zooplankton taxa

Relationships between environmental variables and the distribution of taxa in the small-reservoir lakes of central Côte d'Ivoire were investigated using canonical correspondence analysis (CCA). The CCA results, based on zooplankton organism densities and environmental variables in the dry season (A) and rainy season (B), are presented in Figure 4. The analysis indicates that environmental variables influenced zooplankton species distribution in all three small-reservoir lakes in both seasons. The first two axes together explained more than 80% of the total variance in the CCA for both seasons.

During the dry season (Figure 4A), CCA ordination along axis 1 separated Raviart from the other stations. The first group included copepodites and the taxa Brachionus angularis, Filinia longiseta, Moina micrura and Epiphanes macrourus. This group was positively correlated with axis 1 and associated with Raviart, a site characterised by high conductivity, total dissolved solids, pH and water temperature.

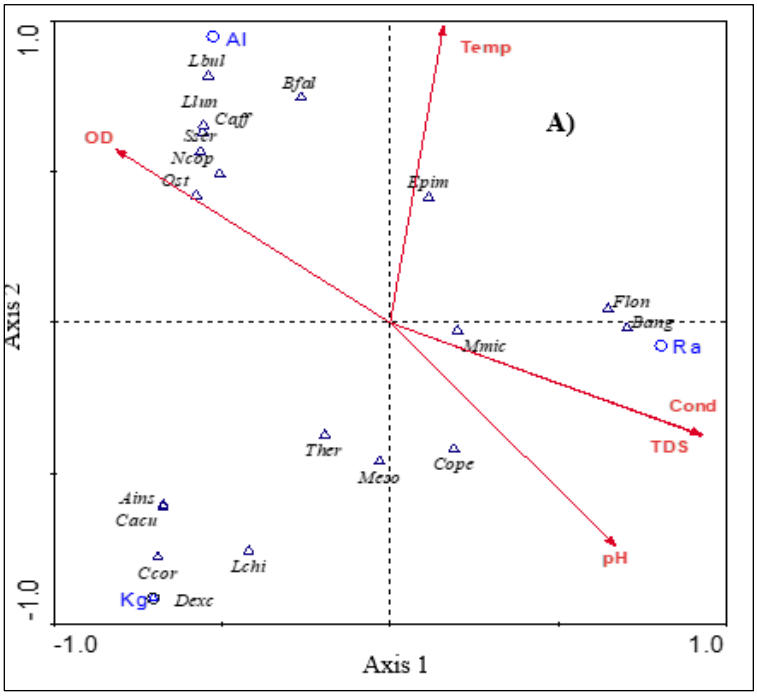
Group 2 comprised Lecane bulla, Lecane luna, Ceriodaphnia affinis, Streblocerus sericaudatus, Brachionus falcatus, copepod nauplii, Ostracods sp., Centropyxis acuelata, Ceriodaphnia cornuta, other insect larvae, Mesocyclops sp., Thermocyclops sp., Diaphanosoma excisum and chironomid larvae. This group was negatively correlated with axis 1 and associated with Allomambo and Kongobo, where total dissolved solids, conductivity, temperature and pH were lower.

Ordination along axis 2 also separated the taxa into two groups. The first group consisted of Streblocerus sericaudatus, Brachionus falcatus, copepod nauplii, Ostracods sp., Lecane bulla, Lecane luna and Ceriodaphnia affinis. It was positively correlated with axis 2 and associated with Allomambo, a station characterised by high dissolved oxygen. The second group consisted of Centropyxis acuelata, Ceriodaphnia cornuta, other insect larvae, Mesocyclops sp., Thermocyclops sp., Diaphanosoma excisum and chironomid larvae. It was negatively correlated with axis 2 and associated with Kongobo, where dissolved oxygen concentrations were low.

During the rainy season (Figure 4B), CCA ordination along axis 1 also separated Raviart from the other stations. The main taxa recorded at Raviart were Ostracods sp., Filinia longiseta, Lecane bulla, Brachionus quadrientatus, Brachionus falcatus, Testudinella patina, Lecane leontina and Lecane luna. These taxa were positively correlated with axis 1 and associated with high conductivity, total dissolved solids and water temperature.

Taxa associated with Allomambo and Kongobo included Filinia opoliensis, Centropyxis acuelata, Ceriodaphnia cornuta, chironomid larvae, other insect larvae, Mesocyclops sp., Thermocyclops sp., copepod nauplii, Trichocerca cylindrica, Brachionus angularis, Lecane papuana, Keratella tropica, copepodites, Brachionus caudatus, Diaphanosoma excisum, Polyarthra vulgaris, Filinia terminalis, Moina micrura and Mytilina mucronata. These taxa were negatively correlated with axis 1.

Ordination along axis 2 separated the taxa into two groups. The first comprised Filinia opoliensis, Mesocyclops sp., Thermocyclops sp., copepod nauplii, Trichocerca cylindrica, Centropyxis acuelata, Ceriodaphnia cornuta, chironomid larvae and other insect larvae. These taxa were positively correlated with axis 2 and associated with Kongobo. The second group comprised Brachionus angularis, Diaphanosoma excisum, Polyarthra vulgaris, Filinia terminalis, Lecane papuana, Keratella tropica, copepodites, Brachionus caudatus, Moina micrura and Mytilina mucronata. These taxa were negatively correlated with axis 2 and associated with Allomambo, where pH and dissolved oxygen were high during the rainy season.



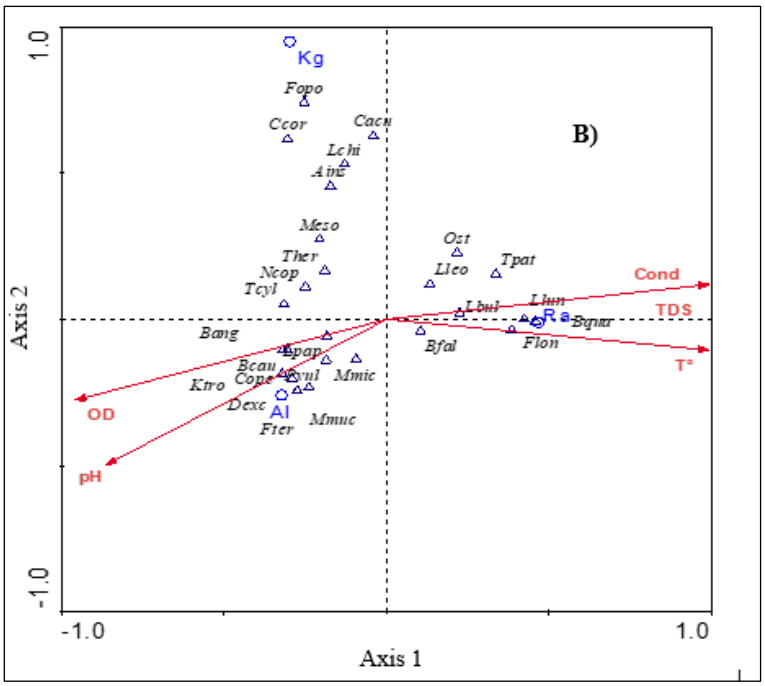


Figure 4: Canonical correspondence analysis of environmental variables and zooplankton taxon densities in the small-reservoir lakes of central Côte d'Ivoire during the dry season (A) and rainy season (B).

Fopo, Filinia opoliensis; Cacu, Centropyxis acuelata; Ccor, Ceriodaphnia cornuta; Lchi, chironomid larvae; Ains, other insect larvae; Meso, Mesocyclops sp.; Ther, Thermocyclops sp.; Ncop, copepod nauplii; Tcyl, Trichocerca cylindrica; Bang, Brachionus angularis; Lpap, Lecane papuana; Ktro, Keratella tropica; Cope, copepodites; Bcau, Brachionus caudatus; Dexc, Diaphanosoma excisum; Pvul, Polyarthra vulgaris; Fter, Filinia terminalis; Mmic, Moina micrura; Bfal, Brachionus falcatus; Lleo, Lecane leontina; Oest, Ostracods sp.; Flon, Filinia longiseta; Lbul, Lecane bulla; Llun, Lecane luna; Bqua, Brachionus quadrientatus; Bfal, Brachionus falcatus; Tpat, Testudinella patina; Caff, Ceriodaphnia affinis; Sser, Streblocerus sericaudatus; Epim, Epiphanes macrourus; Mmuc, Mytilina mucronata.

4 DISCUSSION

4.1 Physicochemical characteristics

Water temperature is an important factor in ecosystem functioning and is particularly affected by changes in air temperature. In the small-reservoir lakes studied in central Côte d'Ivoire, mean water temperature ranged from 27.8°C to 33°C during the dry season and from 27°C to 28.8°C during the rainy season. These values are broadly similar to those reported by Kouassi et al. (2007) for Taabo Reservoir, Ossey et al. (2008) for Buyo Reservoir and Koné et al. (2022) for Kossou Lake, where temperatures ranged from 25°C to 33°C. According to Kouassi et al. (2007), the temperature of Ivorian watercourses rarely falls below 25°C. Water temperature in the reservoirs studied was higher during the dry season than during the rainy season, consistent with observations by Koné et al. (2022) at Kossou Reservoir. Factors such as solar exposure, latitude, substrate composition, rainfall, wind and, particularly, vegetation cover may influence water-temperature variation in aquatic ecosystems (Welcomme, 1985).

Mean pH values ranged from 7.32 to 8.06 during the dry season and from 7.12 to 7.85 during the rainy season. These values fall within the WHO guideline range of 6.5–8.5 (WHO, 2004). They indicate that the waters of the studied small reservoirs are slightly alkaline and within the cited guidelines for drinking water. In general, the manuscript reports average water pH values of 7.4–7.8 across the two seasons. The pH values recorded in the reservoirs were close to those measured in Ayamé I Lake, where values ranged from 7.1 to 7.8 (Konan et al., 2013). During the dry season, pH was high at Raviart and Kongobo but low at Allomambo. The decrease in pH observed at Allomambo during the dry season may be explained by substantial organic-matter decomposition (Odjohou et al., 2020).

Mean dissolved oxygen concentrations in the small-reservoir lakes of central Côte d'Ivoire ranged from 2.23 to 9.13 mg/L. A similar result was reported by Traoré (1996) at Kossou Lake, where dissolved oxygen values ranged from 2 to 10 mg/L. The waters at Allomambo were better oxygenated (9.13 mg/L) than those at Raviart (2.23 mg/L) and Kongobo (5.63 mg/L). According to WHO (2004), good-quality water should have a dissolved oxygen concentration above 7 mg/L; on this basis, the manuscript characterises the water at Allomambo as being of good quality.

Electrical conductivity in the studied lakes was relatively high, ranging from 78 to 288 µS/cm. These results differ from those reported by Kouassi et al. (2007) and Aliko et al. (2010), who recorded mean values between 85.16 and 96.64 µS/cm. According to Welcomme (1985), conductivity provides a useful indication of the chemical richness of an environment. Conductivity at Raviart was higher during the rainy season (288 µS/cm) than during the dry season (194 µS/cm). In contrast, conductivity at Allomambo and Kongobo was higher during the dry season. The results for Allomambo and Kongobo are similar to those reported by Koné et al. (2022) for Kossou Lake. The increase in conductivity and total dissolved solids during the dry season may be explained by evaporation combined with a lack of water inputs. N'Goran (1989) showed that these processes can cause ion accumulation and thereby increase conductivity. The same observations apply to total dissolved solids because the two parameters are positively correlated.

4.2 Biological characteristics

This study recorded 49 zooplankton taxa in three small-reservoir lakes in central Côte d'Ivoire. The taxonomic richness was comparable to that reported for the Bandama Basin by De Ridder and Pourriot (1984), who recorded 53 species.

The total zooplankton richness recorded in this study was higher than that reported for small reservoirs in northern Côte d'Ivoire (Aka et al., 2000; 30 taxa), the Comoé River in the Comoé National Park sector (Yao et al., 2015; 20 taxa), the Bagoé River (N'Da et al., 2015; 38 taxa) and Kaby Lake (Fofana et al., 2019; 31 taxa).

The higher taxonomic diversity observed in the present study may largely be explained by the use of a finer mesh size (20 µm) than those used in previous studies, allowing smaller microorganisms and rotifers to be captured more effectively.

In terms of abundance, the zooplankton community was strongly dominated by rotifers (79.03%). Rotifer dominance has also been reported by Aka (2000) in small reservoirs in northern Côte d'Ivoire, by Monney (2017) in four coastal rivers in southeastern Côte d'Ivoire, and by Fofana et al. (2019) in Kaby Lake. Rotifers are the most abundant zooplankton group in freshwater (Margalef, 1983). They can ingest small particles, including bacteria and organic detritus, which are often abundant in eutrophic environments. Consequently, according to Margalef (1983), a high proportion of rotifers in freshwater may be considered a biological indicator of a high trophic state.

Total zooplankton taxonomic richness in the small-reservoir lakes of central Côte d'Ivoire was higher during the rainy season than during the dry season. This result agrees with findings by Fofana et al. (2019) in Kaby Lake and Gouton et al. (2024) in the Okpara River.

Nutrient enrichment during floods and the inflow of rainwater carrying effluents from human activities may explain the high zooplankton richness observed during the rainy season.

At the Allomambo and Raviart reservoirs, zooplankton abundance was higher during the rainy season than during the dry season. This observation is consistent with reports by several authors, including Masundire (1994) for Lake Kariba in Zambia and Zimbabwe, Okogwu and Ugwumba (2006) for Ologe Lagoon in southwestern Nigeria, and Soro et al. (2019) for the upper Bandama River. Increased zooplankton density during the rainy season may be associated with the inflow of rainwater containing various nutrients. Nutrient-rich water supports the development of phytoplankton and zooplankton (Makaoui et al., 2005; Somoue et al., 2013). By contrast, zooplankton abundance in the Kongobo reservoir was higher during the dry season. Similar results were obtained by N'Da et al. (2015) in the Bagoé River. This dry-season abundance may be explained by higher temperatures or increased nutrient availability. High temperatures during the dry season, combined with abundant food, may promote zooplankton population growth (Strecker et al., 2008; Gray et al., 2021).

The lowest taxonomic richness and mean total abundance were recorded at Kongobo, which also had the lowest temperatures. This pattern suggests that physicochemical parameters, particularly temperature, may influence zooplankton diversity and abundance. The higher mean abundance at Allomambo and Raviart may be related to their higher temperatures. Temperature affects feeding activity, metabolism, and the development and reproduction cycles of zooplankton. De Azevedo and Bonecker (2003) also showed that increasing temperature accelerates growth, sexual maturation and reproduction in zooplankton species.

The CCA results separated Raviart from Allomambo and Kongobo. The high zooplankton density observed at Raviart in both seasons may be explained by its comparatively high temperatures in both seasons. The increase in zooplankton density during the rainy season may also be related to the reservoir's proximity to plantations and its use for agriculture. These human activities may enrich the water with nutrients, favouring zooplankton development. Filippelli (2008) and Morée et al. (2013) reported that nutrient inputs are associated with agricultural activities requiring nitrogen- and phosphorus-based fertilisers, livestock production and its organic waste, and domestic discharges.

The zooplankton community at Raviart was characterised by the dominance of rotifers, particularly Brachionus quadrientatus. Rotifer dominance may be associated with eutrophication and could help explain the low dissolved oxygen concentrations in this reservoir. According to Dorgham (2014), taxa of the genus Brachionus are frequently found in eutrophic tropical waters because of their high tolerance of eutrophication.

Dissolved oxygen appears to be an important factor influencing zooplankton communities at Allomambo and Kongobo during the dry season. During the rainy season, the communities may be influenced by dissolved oxygen and pH. These better-oxygenated sites were characterised by copepod abundance during the dry season. The low zooplankton density at Kongobo may be associated with its lower water temperature. Water temperature may also influence the variation of other parameters, such as oxygen content and pH (Mbaye, 2015; Jeyid, 2016; Badji, 2018).

This study identified 49 zooplankton taxa belonging to 24 families and 36 genera, indicating substantial diversity in the small-reservoir lakes of central Côte d'Ivoire. The predominance of families such as Brachionidae (10 species) and Lecanidae (6 species) highlights the importance of particular rotifer groups in the aquatic food web. Families with fewer taxa but several species, including Trichocercidae, Daphniidae and Cyclopidae, point to a complex zooplankton community structure that may be influenced by local environmental conditions.

Occurrence analysis showed that 18 taxa were constant, indicating consistent occurrence across the sampled habitats, while 11 were accessory and 18 accidental, suggesting variability in their occurrence. This pattern may reflect habitat dynamics, with some taxa occupying stable niches while others are more transient or opportunistic.

No significant difference in taxonomic richness was observed among stations (Kruskal–Wallis test, $p > 0.05$). The discussion in the source reports a range of 31–39 taxa, suggesting relative homogeneity among zooplankton communities despite numerical variation. However, taxonomic richness was significantly higher during the rainy season (24–35 taxa) than during the dry season (11–23 taxa) (Mann–Whitney U test, $p < 0.05$). This finding is consistent with literature generally reporting increased aquatic biodiversity during rainy periods, potentially because of increased nutrient inputs, habitat availability and organism dispersal.

These results highlight the seasonal influence on zooplankton composition and diversity in the studied small reservoirs and emphasise the importance of seasonality in aquatic community dynamics. Relative stability among stations may indicate ecological homogeneity or a limited influence of local anthropogenic factors, although further studies are needed to test these hypotheses.

5 CONCLUSION

This study characterised the structure and seasonal dynamics of zooplankton communities in three small-reservoir lakes in central Côte d'Ivoire. A total of 49 taxa belonging to 24 families and 36 genera were recorded, indicating notable taxonomic diversity. Rotifers were the dominant group, accounting for 79.03% of total abundance, and Brachionus quadrientatus was the most abundant taxon across all samples. The results revealed significant seasonal variation in taxonomic richness, which was higher during the rainy season than during the dry season. Abundance followed contrasting patterns among stations: densities were generally higher during the rainy season at Raviart and Allomambo, whereas Kongobo showed the opposite trend. These differences highlight the importance of considering seasonality together with local environmental characteristics when interpreting zooplankton dynamics. Canonical correspondence analysis revealed associations between taxon distribution and several physicochemical variables, particularly conductivity, temperature, pH and dissolved oxygen.

Overall, this study provides baseline data on zooplankton diversity and seasonal dynamics in small reservoirs in central Côte d'Ivoire. It highlights the value of integrating zooplankton communities and physicochemical parameters into ecological monitoring programmes for these water bodies.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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[1] Bibliographic entries are retained in their original published language and form. This is standard practice in scientific manuscripts: translating a reference title can make the cited publication harder to identify. The

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