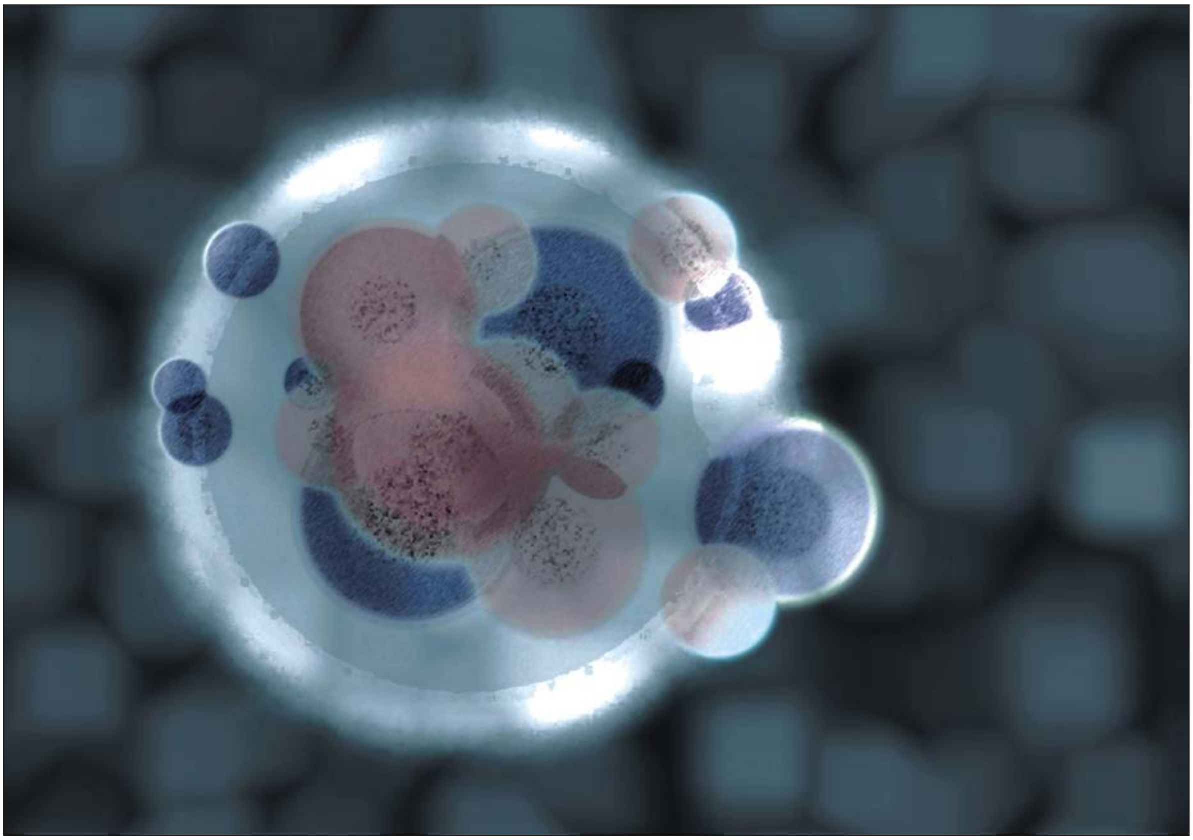

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Diversity, Abundance and Seasonal Dynamic of Zooplankton Community in a South-Saharan Reservoir (Burkina Faso)

[1]Adama Ouéda, [1]Wendengoudi Guenda, [2]André T. Kabré, [3]Frédéric Zongo and [1]Gustave B. Kabré
[1]Laboratoire de Biologie et Ecologie Animale, UFR/SVT,
Université de Ouagadougou 03 BP 7021 Ouagadougou 03
[2]Institut du Devélopement Rural, Université Polytechnique de Bobo-Dioulasso,
01 BP 1091 Bobo-Dioulasso 01
[3]Laboratoire de Biologie et Ecologie Végétale, UFR/SVT,
Université de Ouagadougou 03 BP 7021 Ouagadougou 03

Abstract: From May 2004 to April 2005, the zooplankton of the Loumbila reservoir was subject to a 14 days periodicity follow-up. This study attempt to describe the diversity, abundance and seasonal dynamic of zooplankton community in a south-saharian reservoir. Plankton community was sampled with horizontal tows of a plankton net of 100 μm mesh size. The samples analysis permitted to identify 7 species of Cladocera and 2 species of the Copepoda. The overall Rotifers observed belong to 14 genera. The Cochran's Q-test together with various methods of variance analyses and the Redundancy Analysis (RDA) allowed to highlight the seasonal dynamics of zooplankton settlement. The most significant factor in this dynamics is water movement i.e., water gain or loss in the reservoir. This factor evolves together with some physicochemical parameters favourable to plankton development and simultaneously opposes some other unfavourable factors such as high conductivity. Crustaceans are more sensitive to the season impacts than Rotifers. Besides this seasonal variability the zooplankton community of Loumbila reservoir also shows variability according to depth.

Key words: Zooplankton, seasonal dynamics, physicochemical parameters, Burkina Faso

INTRODUCTION

As a sahelian country, Burkina Faso does not enjoy much surface water; which has led to the implementation of a surface water control policy. According to SOCREGE (2003) approximately 200,000 ha of surface water are available in the rivers, ponds and dams of the country in the full rainy season. The numerous dams built throughout the country contribute to the development and preservation of biological diversity. However, studies on the dynamics and the biological diversity of these ecosystems are rare if or non-existent.

Many studies have dealt with the aquatic organisms of West Africa. As a matter of fact, Déjoux *et al*. (1983) and Guenda (1996, 1997, 2000) have contributed to improve our knowledge of the insects of this region, whereas Zongo and Guinko (1999a, b) and Ouattara *et al*. (2000, 2001) have contributed in extending our knowledge of West African phytoplankton.

However, regarding the zooplankton, studies are sparse and restricted to mere short term taxonomic observation reports without any real quantitative analysis of neither the distribution nor the abundance of the zooplankton. That is why further study in the field of zooplankton is needed, owing to the importance of the zooplankton in the trophic network of the aquatic ecosystems. Present study provides qualitative and quantitative analysis of the zooplankton dynamics in a south-saharian reservoir located in Burkina Faso. This reservoir is so submitted to the very harsh climate, characteristic of the North-central region of Burkina Faso.

MATERIALS AND METHODS

Study site: Sampling was carried out in the man made lake of Loumbila (Fig. 1). This reservoir is located in the Loumbila village, 20 km to the North-East of Ouagadougou (Burkina Faso). Its geographical co-ordinates are: 12° 29' 34" N and 1° 24' 5" W. It was built in 1947 and several times modified and restructured so as to serve as feed basin for fresh water production for the city of Ouagadougou. Its current capacity is estimated at 42 million m^3. (area, 1500 ha; maximum depth, 6.6 m; pH 8.0). The socio-economic activities connected to the

Corresponding Author: Adama Ouéda, Laboratoire de Biologie et Ecologie Animale, UFR/SVT,
Université de Ouagadougou 12 BP 170 Ouagadougou 12 Tel: (226) 76 41 45 09

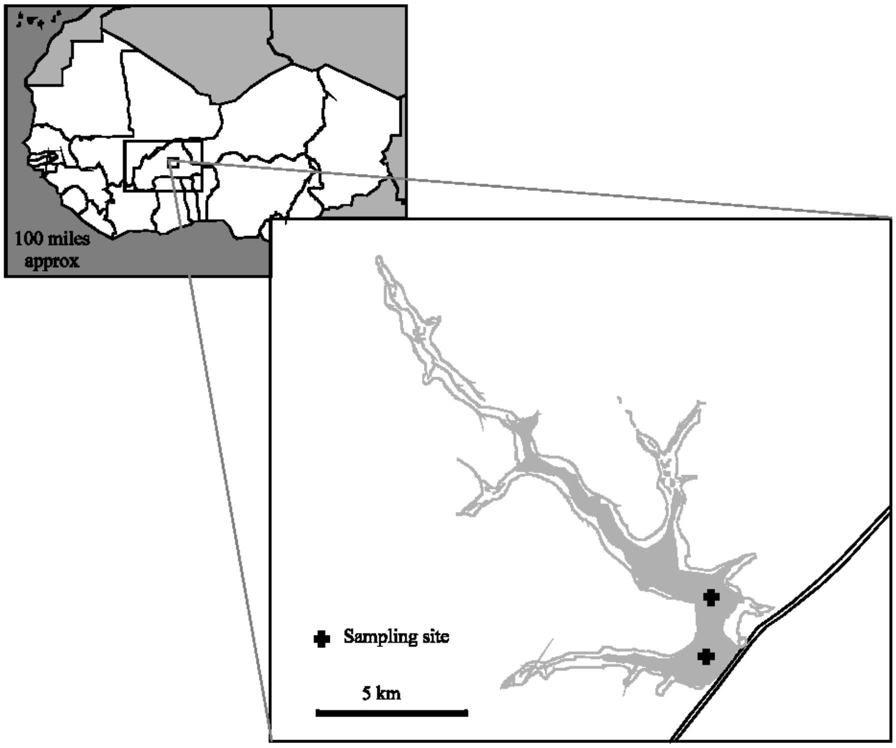

Fig. 1: Localisation of the study site, in Burkina Faso (West Africa)

dam are agriculture, breeding, fishing and trade (Nébié, 2003: ONEA and CASST, 2004). Loumbila is located in a climatic zone of Northern Sudanian type (Guinko, 1984) characterized by a dry season, from November to May and a rainy season, from June to October. The rainfall is irregular and can drastically vary from one year to another. For the years 2002 and 2003, the average temperature was of 29.05° under shade. The highest averages were recorded in April (33.6°C). The evaporation is 8.5 mm day^{-1} on average, with maximal values observed in March (12.64 mm day^{-1}) and minimal ones in September (5.37 mm day^{-1}).

Sample collection and analysis: Because of the shallowness of the reservoir (less than 2 m of average depth, in dry season), the zooplankton samples were taken by doing horizontal tows over a distance of 540 m. The plankton net used is a conical nitex net with 100 µm of mesh size and a mouth of 25 cm diameter. The prospection lasted a whole year, from May 2004 to April 2005. The sampling was 14 days in periodicity and was taken each time at two different depths: 0.3 and 1 m. The samples were preserved in 5% formalin.

The samples were analysed under inverted microscope. The identification of species was done on the basis of several works on zooplankton taxonomy (Dussart and Gras, 1966; Streble and Krauter, 1973; Pontin, 1978; Voigt and Koste, 1978; Dussart, 1980; Goy, 1980; Pourriot, 1980; Rey and Saint-Jean, 1980; Idris, 1983; Korìnek, 1999). The quantitative analysis was done each time on a 10 times diluted sub-samples. Counting was done on 2 to 5 aliquots of 1 mL according to the density of the sample. Knowing the distance covered during each sample and therefore the volume of filtered water, the density of each zooplankton species in the storage reservoir can be inferred.

Seasonal dynamics analysis: In order to better understand the structure of temporal distribution, the study time was divided into periods by taking account of the factors season, quantity of water and water movement. We distinguished two seasons, the dry season (November to May) and the rainy season (June to October). According to the quantity of water in the reservoir, the year was divided into two periods too: The period of low water and the period of high water, or rising period. The factor water movement too leads to dividing the year into two periods: A period of water loss and a period of water profit.

Statistical analysis: Cochran's Q-test was used to check the independence of the distribution of the species according to time. This analysis was based on the species presence-absence matrix. A Mann-Whitney U-test based on the matrix of species abundance was run to check the differences between distributions according to season, water movements and water level. The canonical analysis thanks to CANOCO for Windows (Canonical Ordination of the Communities, version 4.0) was used to divide the period of study into sub-periods and to highlight the factors that account for a possible non-independent distribution of the population. To perform this canonical analysis we had used two distribution matrix. The first matrix is those showing the species densities and the second matrix represents physicochemical parameters evolution within the year. The DCA (Detrended Correspondence Analysis) gave a Length of Gradient lower than 4. Such Length of Gradient decides us to opt for a linear analysis method: RDA (ReDundancy Analysis, also called reduced-rank regression). The Wilcoxon's test was used to check the significant differences between the months within the same sub-period. Kruskal-Wallis' ANOVA was used to check the significant differences between the sub-periods identified. The Wilcoxon's test and the Kruskal-Wallis' ANOVA were based on the specific richness and the Shannon's index of diversity of months. With the exception of the canonical analysis, all the other statistical analysis were carried out with STATISTICA 5.5.

RESULTS

Community structure, diversity and abundance: Twenty-six species were identified in the 52 samples from Loumbila: 7 species of Cladocera, 2 species of Copepoda, 17 species of Rotifera. Along with these 26 species, is the macro-zooplankton represented here by larvae of Chaoboridae, jellyfish and small fishes. The species met are the following:

- For Cladocera: *Alona rectangula* Sars, 1962; *Ceriodaphnia affinis* Lilljeborg, 1900; *Ceriodaphnia cornuta* Sars, 1885; *Daphnia barbata* Weltner, 1898; *Diaphanosoma excisum* Sars, 1885; *Macrothrix spinosa* King, 1852; *Moina micrura* Kurz, 1874,
- For the Copepoda: *Mesocyclops leuckarti* Claus, 1857; and *Tropodiaptomus incognitus* Dussart and Gras, 1966,
- For Rotifera: *Brachionus caudatus* Barrois, 1894; *Brachionus falcatus* Zacharias, 1898; *Brachionus quadridentatus* Hermann, 1783; *Filinia longiseta* Ehrb., 1834; *Filinia opoliensis* syn. *Tetramastix opoliensis* Zacharias, 1898; *Keratella tropica* Apstein, 1907; *Lecane luna* Müller, 1776; *Platyas quadricornis* Ehrb., 1832; *Pompholyx complanata* Gosse, 1851; *Asplanchna* sp., *Collotheca* sp., *Epiphane* sp., *Gastropus* sp., *Hexarthra* sp., *Polyarthra* sp., *Trichocerca* sp. and *Trichotria* sp.

An average of 15.38 species have been listed in each sample and an average of 20.58 species each month. For the cumulated data per month, the minimal specific richness (17 species) has been observed in June and February and the maximum richness (27 species, including macro-Zooplankton) in July. In accordance with Legendre and Legendre (1984), the rank-frequency diagram (Log-Log) in Fig. 2 shows that the settlement of zooplankton of the Loumbila reservoir has a great diversity. However, the ten most abundant species alone represent 95.6% of the individuals. They include *K. tropica*, *M. leuckarti* (nauplies and copepodid), *T. incognitus* (nauplies and copepodid), *B. falcatus*, *B. caudatus*, *F. opoliensis*, *Gastropus* sp., *M. micrura*, *D. excisum* and *Hexarthra* sp. The seventeen least abundant species represent 3.2% of the total individual density, which is far below 1% for each one. Rotifera are the most abundant with a percentage of 60.4% of the population; they are followed by of the Copepoda 32.3% and Cladocera 7.3%.

H'0.3m, H'1m and H'P, in Fig. 3, represent the evolution of Shannon's index of diversity (H) for the samples taken respectively at 0.3 m of depth, 1 m of depth and a mixture of both. H'0.3m vary between 2.2 and 3 while H'1m vary between 2.3 and 3.3. Diversity has greater variability in the rainy season. It is more or less stabilized at a rather low level by the end of the rainy season and significantly increase at the beginning of the dry season. H'0.3m is always lower than or equal to H'1 m, except for two samples taken in May and June, respectively. The Wilcoxon's test confirms the significativity of the difference between the evolutions of the index of diversity according to depth ($p<0.0009$).

Seasonal dynamics: Table 1 shows the p values of the Cochran's Q-test. With a threshold of probability of 0.05, it can be retained that the whole population of

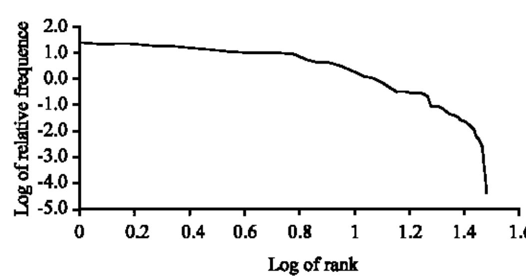

Fig. 2: Loumbila zooplankton species' rank-frequency diagram (Log×Log)

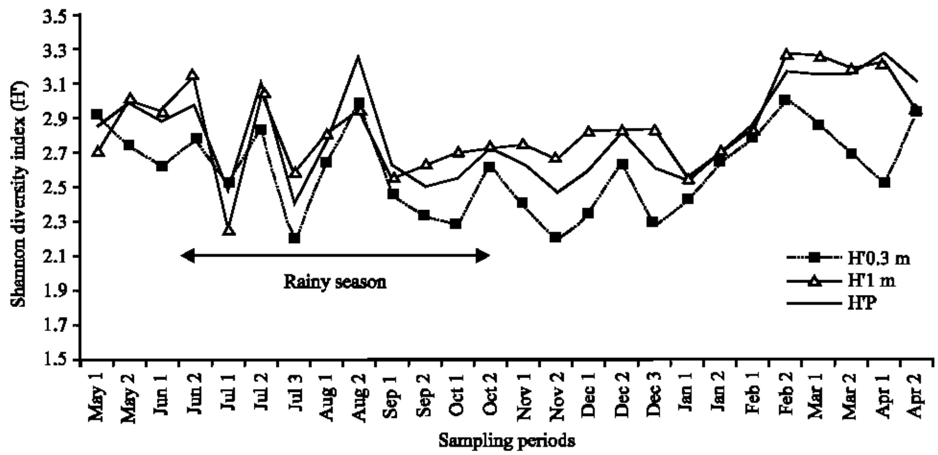

Fig. 3: Variations of Shannon diversity index (α) among sampling periods. (H'0.3 m, H'1m et H'P are, respectively α values for samples taken at 0.3 and 1 m and whole samples

Table 1: p-values for Cochran Q-test on species presence-absence matrix

Factors			Whole samples	0.3 m samples	1 m samples
For whole study time and population			0.014*	0.005*	0.627
Periodic factors	Season	Dry season	0.293	0.103	0.379
		Rainy season	0.074	0.063	0.892
	Water movements	Water profit	0.156	0.007*	0.483
		Water loss	0.296	0.407	0.952
	Water quantity	Low	0.093	0.040*	0.649
		High	0.027*	0.046*	0.480
Groups	Crustaceans	Both season	0.0028*	0.0004*	0.0014*
		Rainy season	0.608	0.515	0.749
	Rotifers	Both season	0.294	0.384	0.390

* = Significant p-value (p<0.05), implying non independent distribution

zooplankton is not independently distributed through time. This is also true for the samples collected at 0.3 m of depth. However, for the samples taken at 1 m, the distribution can be regarded as independent.

Considering the factor season and excluding one season or the other from the analysis, we notice that the distributions can be regarded as independent within each season. The same goes with factor water movement: The distributions are independent within each subset water loss and water profit. However, for the factor water quantity, the distribution becomes independent if we discard the samples of low waters. This implies that variability in distribution may not be directly related to the factor water quantity, it is related to water movement. Therefore the factor season could account for the dynamics of the population of zooplankton. The season may then act much more through water movement rather than its quantity in the reservoir.

Regarding the two groups of organisms, Crustacean and Rotifera, we note that the distribution of Rotifera is independent, whether for the whole of the samples or the two subsets of samples (0.3 and 1 m). As for Crustaceans distribution, it is not independent in any of the three cases. These results show that the Crustacean zooplankton have very important seasonal variability in contrast with Rotifers.

Figure 4 and 5 show variations in the abundance of Crustaceans and Rotifers according respectively to months and to seasons. Cladocerans, Copepods and macro-zooplankton elements appear to be, respectively 1.85, 2.26 and 2.77 times more abundant in the rainy season than in the dry season. Rotifers are 1.32 time more abundant in dry season.

The analyse of the Table 2 shows that only Cladocerans present a distribution significantly different according to the factor season. This population presents a drastic increase in July and then decreases to relatively low levels from October. However, the zooplankton population as a whole and the Cladocera and Copepoda populations as well showed distributions significantly different according to the factor water movements. Populations abundant increase when there is incoming water in the reservoir. Only Copepods population fluctuate significatively according to factor water level. There is more Copepods in High level period.

The influence of environmental factors: Figure 6a presents the ranking of the months resulting from the RDA. It enabled us, to divide the year in four distinct sub periods which are: Sub-period 1: May and June, Sub-period 2: July and August, Sub-period 3: September,

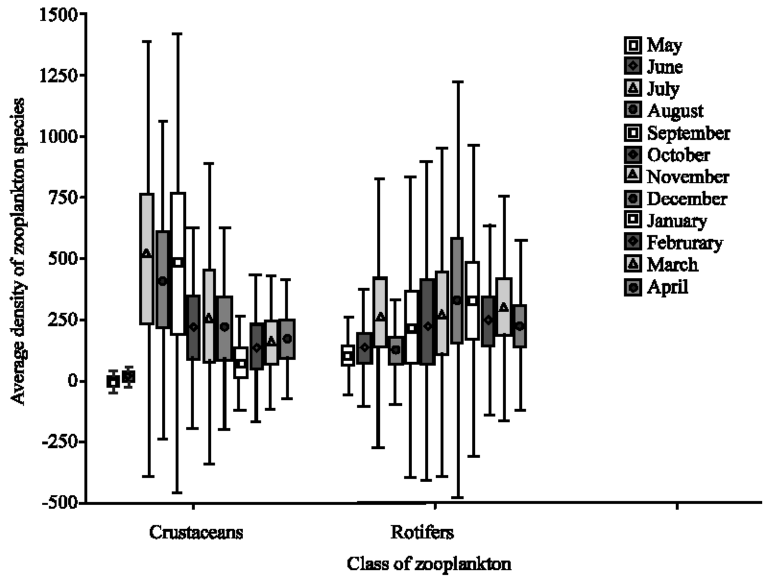

Fig. 4: Box whisker representing Crustaceans (Cladocerans and Copepods) and Rotifers distribution among the year (densities are expressed as number of individuals m^{-3} species^{-1}) (Point = Mean, Box = Mean±Standard Error, Whisker = Mean±Standard Deviation)

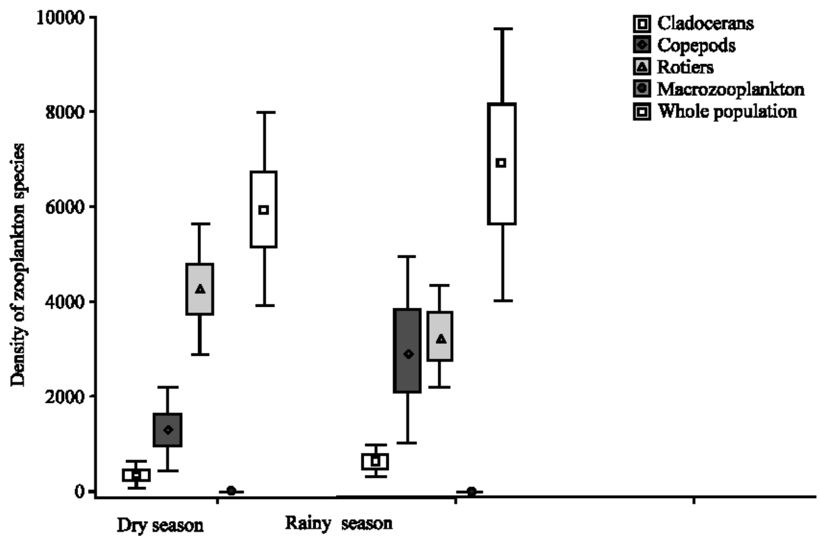

Fig. 5: Box whisker showing the seasonal variation of the average densities (number of individuals m^{-3}) of zooplankton taxa in Loumbila reservoir (Point = Mean, Box = Mean±Standard Error, Whisker = Mean±Standard Deviation)

October, November and December and Sub-period 4: January, February, March and April. These 4 sub-periods correspond respectively to the periods of:

- Severe low water level (very low water levels),
- Beginning of rising water,
- Maximum rising followed by the beginning of water loss,
- Low water level.

Table 2: p-values for Mann-Whitney U-test on sub-periods, according to group of organisms and factors (Season, Water movements and Water level)

Groups	Season	Water movements	Water level
Cladocerans	0.024*	0.009*	0.472
Copepods	0.186	0.021*	0.038*
Rotifers	0.204	0.436	0.111
Whole population	0.517	0.041*	0.090

* = significant p-value (p<0.05), indicative of difference between sub-periods

There is no significant difference between months in the same sub-period pair by pair. Because the smallest p-value (Wilcoxon's test) for couple of months

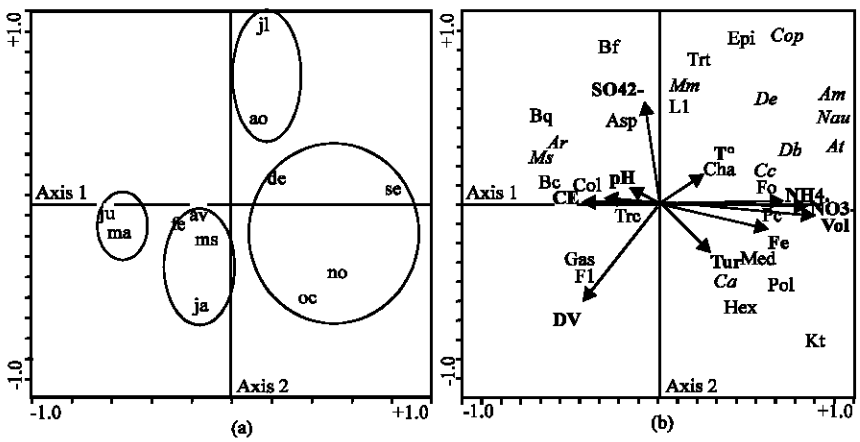

Fig. 6: RDA results a) Months distribution: Sub-periods are underlined by circles. b) Zooplankton taxa and the environment data ordination. The bold characters are used for environmental variables; we have used a forwarded selection to choose the most expressive variable to represent. Crustaceans are shown in italic characters. Months codes: ma = May, ju = June, jl = July, ao = August, se = September, oc = October, no = November de = December, ja = January, fe = February, ms = March, av = April. Physico-chemique data codes: CE = Electric conductivity, DV = Water movements (V1-V2), Fe = Total iron, NH4+ = Ammonium, NO_3^- = Nitrates, SO_4^{2-} = Sulphates T° = Water temperature, Tur = Turbidity Vol = Water volume. Zooplankton taxa codes: Al = Alevin, Am = Mature of *M. leuckarty*, Ar = *A. rectangula*, As = *Asplanchna* sp., At = mature of *T. incognitus*, Bc = *B. caudatus*, Bf = *B. Falcatus*, Bq = *B. quadridentatus*, Ca = *C. affinis*, Cc = *C. cornuta*, Ch = Chaoboboridae larvae, Co = *Collotheca* sp., Cop = Copepodid, Db = *D. barbata*, De = *D. excisum*, Ep = *Epiphane sp.*, Fl = *F. longiseta* Fo = *F. opoliensis*, Ga = *Gastropus* sp., He = *Hexathra* sp., Kt = *K. Tropica*, Ll = *L. luna*, Me = Jellyfish, Mm = *M. micrura* Ms = *M. spinosa*, Nau = Nauplii, Pc = *P. complanata,* Po = *Polyarthra* sp., Tr = *Trichotria* sp., Tri = *Trichocerca* sp.

of the same sub-period, observed for the couple of months May-June is superior to 0.05 ($p = 0.062$). According to the specific richness and the Shannon's index of diversity, the Kruskall-Wallis's ANOVA confirm the difference between the 4 sub-periods ($p = 0.005$ for specific richness and $p = 0.029$ for Shannon's index of diversity).

In Fig. 6b we have the biplot of the species and environmental data. The results of RDA show that the first two factorial axes represent 82.5% of the variance explained by the overall variables. The environmental variables presenting the greatest correlations with axis 1 are: the volume of water in the reservoir ($R = 0.79$), the ammonium rates ($R = 0.75$), the nitrate rates ($R = 0.63$) and the quantity of loosed water ($R = -0.41$; DV = initial volume-final volume). Axis 2 is tightly correlated with the quantity of loosed water ($R = -0.54$), the sulphate rate ($R = 0.52$) and the potassium rate ($R = 0.41$).

DISCUSSION

The zooplankton of Loumbila Reservoir is mainly represented by Rotifera, Copepoda and Cladocera. Rotifera are the most abundant and the most constant. With 26 species belonging to 22 genera, this settlement has rather great specific richness and high diversity. The index of regularity lies between 0.5 and 0.8 for all the samples during our study time. A spatial variability is noticed in the settlement, which appears much more stable, richer and more diversified in depth (1 m) than on the surface.

The settlement of zooplankton in the storage reservoir of Loumbila presents a seasonal dynamics, which can be better explained by the variation of the water level in the reservoir than its quantity. According to this variability, the year can be divided into 4 distinct sub-periods whose characteristics are summarized in Table 3. This variability is related to water movement and to a lesser extent to water quantity. Ouattara *et al.* (2001) reached similar conclusions for algal settlement in the Bia River in Côte d'Ivoire. Indeed, in the rainy season, water arriving in the reservoir drives a great quantity of organic and inorganic matters (Kabré, 2001) dissolved or in suspension, which brings about an expansion of phytoplankton and bacteria. These matters together with the phytoplankton and the bacteria constitute the essence of the food of the zooplankton, which accounts for the significant development of the

Table 3: Characterization of the 4 sub-periods defined by the RDA

Sub-periods	Physicochemical characteristics	Ecological characteristics
Very low water level May June	Water loss accentuated High conductivity Low ammonium and nitrates rates	Water volume and dissolved materials are very weak, zooplankton population is reduced to species that resistant to drought: *B. caudatus*, *A. rectangula*, *M. spinosa* and some Rotifers.
Begiuning of flooding July August	Abrupt increases of turbidity and water level High concentration of nitrates, sulphates and potassium	The important incomes of nutritive elements lead to higher specific richness and higher abundance. We have the first apparition of species such as *C. cornuta*, *D. barbata*, *L. luna*, *P. complauata*, *Trichocerca* sp., *Trichotria* sp. *Polyarthra* sp. mature Copepods, alevins, jellyfishes and the Chaoborus larva. Samples are dominated by Copepods
Maximum flooding followed by the begiuning of water loss September, October, November December	Highest water volume Turbidity maintained Increasing iron and ammonium rates.	Abundance and specific richness stabilize to mean levels. *K. tropica* and the Copepods dominate the samples. Macrozooplankton became important
Advanced water loss January Febmary March April	Important reduction of water volume Extreme temperatures	Water impoverishment, concomitant to its losses lead to a decrease of Copepods and Cladocerans densities. On the other hand, other species know a relative development in this period; these are Rotifers such as *B. caudatus*, *F. opolieusis*, *F. longiceta*, *Hexarthra* sp. and *Gastropus* sp.

zooplanktonic Crustaceans at this period (Wetzel, 1983; Dussart, 1980; Rey and Saint-Jean, 1980; Pontin, 1978; Pourriot, 1980). However, the seasonal variability of the distribution is less important at 1 m of depth.

This obvious seasonal distribution also varies with the group considered. Cladocera and Copepoda are more clearly distributed according to the season. Cladocera are more abundant in the rainy season and present a dynamics clearly related to water movements in the reservoir. The Copepoda are more or less equally related to the water movement and water quantity. Rotifera probably sensitive to some limiting factors (pollution and predation) on the other hand present a relative decrease in abundance in the rainy season.

Along with the factors water movement and water quantity, the chemical factors accounting the most for the model of zooplankton species distribution in Loumbila reservoir are, according to the RDA, nitrate rate, ammonium rate, turbidity, sulphate rate, full iron rate, electric conductivity, water temperature and pH.

The extreme temperatures (measured at 0.3 m in depth) are 18 and 32°C. The average temperature is 27.29°C. Nitrates, nitrites and ammonium are the main source of nitrogen for the phytoplankton (Wetzel, 1983). Therefore, the abundance of these elements may be the cause of the development of the phytoplankton, which in turn may be the cause of the development of zooplankton. However, according to the classification suggested by Nisbet and Verneaux (1970), the rates of nitrates, nitrites and ammonium in the Loumbila reservoir indicates a state of significant insidious pollution (nitrates: 102 mM, nitrites: 0.8 mM and ammonium: 45 mM). This pollution is probably due to the anthropic activities, namely market gardening, the principal activity of the residents in the dry season. Thus, the inclusion of the ammonium and nitrate rates in the explanatory model of the dynamics of the population might not be accounted for only by an obvious cause-effect relation but also by the clear connection between these rates and the actual factors: which are water quantity and water movement. Indeed, most of the nitrates and ammonium of surface water come from the drainage of surface waters and rainfalls (Wetzel, 1983).

The high turbidity of water in the Loumbila reservoir (25.32 NTU) is explained by the drainage of surface waters, which is rich in suspended matters. This phenomenon, according to Zongo (1991) may account for the tendency to the eutrophication of the aquatic environment and whose sign may be the development of zooplankton fauna (Ryding and Rast, 1993). As a matter of fact, Roman (1977, 1979) had remarked the rarity of the zooplankton in his samples.

Water conductivity in Loumbila lies between 47 and 116 μS cm^{-1}. The importance of this factor in the dynamics of the zooplankton (strong negative correlation) can be explained by the fact that the presence of dissolved electrolysable salts contributes to induce a strong osmotic pressure on the fauna and the flora, thus inducing migrations or mortality of some living orgamisms (Sacchi and Testard, 1971).

With a pH between 7.8 and 8.2, the water of the reservoir in Loumbila is fairly alkaline (Nisbet and Verneaux, 1970) and according to Zongo (1991) this water is favourable to good productivity of the phytoplankton and the zooplankton. According to Wetzel (1983), the iron rate can, under some restricted conditions, be a limiting factor for photosynthesis. The high iron rates may thus indirectly induce a growth of the zooplankton. With a rate lower than 100 mM the sulphate concentration in Loumbila reservoir reflects a normal situation (Nisbet and Verneaux, 1970).

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