International Journal of Aquatic Biology (2015) 3(3): 161-171
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.NPAJournals.com

Original Article

Structure and seasonal dynamics of phytoplankton and zooplankton in Lake Azili, small Lake of the pond of River Ouémé, Benin

Arsène Mathieu Houssou*[1], Hyppolite Agadjihouédé[1, 2], Elie Montchowui[1, 2], Clément Agossou Bonou[3], Philippe Lalèyè[1]

[1]Laboratory of Hydrobiology and Aquaculture, University of Abomey-Calavi, BP 526 Cotonou, Republic of Bénin.
[2]National High School of Agronomics and Technics Sciences of Kétou, University of Agriculture of Kétou, BP 95 Kétou, Republic of Bénin.
[3]Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, BP 2009 Cotonou, Republic of Bénin.

Abstract: The early reaction of the plankton communities to environmental changes makes it a useful tool for monitoring the pollution of aquatic environments. Lake Azili is a small water body, the majority of which is strongly influenced by river Ouémé during the floods time. Its ecosystem is one of the most important for the country, due to its rich biodiversity, especially that of halieutics. By following the evolution of its health, due to the strong anthropological pressure, this study aims to estimate the structure and the dynamics of its planktonic biodiversity and to assess its current state. It was carried out for seven months between May to November, 2012, according to the hydrological seasons of Benin. Plankton samplings were monthly, taken in a vertical sense from the lake, from all depths, using plankton net. The diversity indices were calculated for the compartment of zooplankton, that of phytoplankton being a preliminary evaluation. A total of 51 species of phytoplankton and 36 zooplankton species were inventoried. Instability is observed in the seasonal structure of both communities, especially for the period of transition between the floods and the floods recession. Due to the specific composition and the diversity, the ecosystem of Lake Azili is perturbed.

Article history:
Received 2 November 2014
Accepted 22 April 2015
Available online 25 June 2015

Keywords:
Cyanobacteria
Eutrophication
Ecological Health
Plankton

Introduction

The aquatic biodiversity has been used for several decades as an ecological health and environment pollution indicator. In this regard, several studies estimated the distribution of the aquatic flora and fauna to understand the environmental changes. Nowadays, in all of Africa's waters, the monitoring of quality is much more based on the assessment of macroscopic organism (mainly halieutic fauna), although the microscopic organisms are more sensitive to the environmental variations. In continental waters, sensibility of microorganisms is more notable due to strong human influence (Groga, 2012). The distribution of these organisms is dictated by the auto-ecological processes that result from the global changes and the anthropological factors (Dolédec et al., 1999). Several algorithms and other statistical designs currently exist and are developed based on the plankton structures at specific abundance levels to assess the quality of the aquatics environments. But these tools are developed in temperate conditions, and it is necessary to adapt them on the tropical environments. This adaptation requires a good knowledge of the structure of microorganisms (phytoplankton and zooplankton) as well as their ecology. Thus, several African countries began the exploration of the planktonic populations in their waters. But in Benin, little study regarding plankton was carried out, while the country has several water bodies, among which Lake Azili forms a particular ecosystem. Some populations depend on this lake, in particular the village "Agonvè", surrounded with water and forming a small island within the country. Over the past few years, a

* Corresponding author: Arsène Mathieu Houssou
E-mail address: arsenehous@yahoo.fr

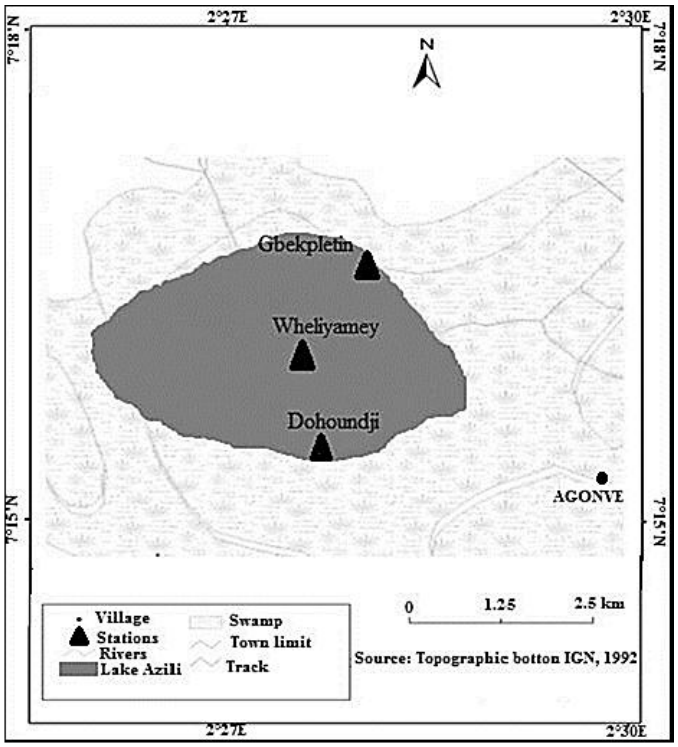

Figure 1. Localization of the sampling sites in Lake Azili.

continuous process of degradation of the ecosystem has been recorded (Aklinon, 2005). Therefore, it is important to involve different disciplines to evaluate its current state and to identify ways of rehabilitation. Hence, this study aims to estimate the phytoplankton and zooplankton communities of the Azili Lake and to establish a base for future works of quality assessment.

Materials and Methods

Study sites and sampling stations: This study was carried on Lake Azili, which is a small flood lake of Ouémé River in the municipality of Zangnanado, situated in the center of Benin. The Lake Azili extends in period of flood recession from 7°15' to 7°20' N and from 2°20' to 2°30' E. Its area is 200 ha of water and reach 300 ha of permanent deep swamp. It measures an average 1.7 km from North to South and 2 km from East to West. Its volume is regularly influenced by the Olougbé River and the channel Houan. The latter is a tributary and outflow for Azili Lake, at the same time. Along 5 km, the channel Houan links the lake with the Ouémé River which, during the overflow between July and October pours a part of its waters in the Lake through the channel. The Oulugbé River is 15 km long and 2-3 m wide, and it is a permanent tributary of the lake. The high water of Lake Azili is essentially caused by those of Ouémé River.

Three sampling stations (Fig. 1), with a different level of human impact and representing the various housing environments, were chosen so as to represent the lake area. Sampling have been made from upstream to downstream, as follows: Dohoundji (07°15'N, 002°27'E), Whéliyamey (07°15'N, 02°27'E) and Gbekpletin (07°15'N, 002°27'E).

Sampling methods: The sampling was carried out monthly, according to the hydrological seasons of Benin. It covered the period from May to November, 2012. The period of recession was represented by three months (May, June and July) and the flood season by the period from August to November. To ensure the good representation of the various species, the composite sampling protocol was retained. A composite sampling unit was a mixture of three vertical lines (Lake full vertical sampling) at the same station. The sampling effort was thus nine hauls a month. The samples are then immediately fixated in 5% formalin solution. Both organisms groups were sampled by the same conical net with a mesh size of 30 µm. Thus, the study allowed to estimate exactly the zooplankton diversity, while regarding the phytoplankton, the diversity is not precisely estimated due to the fact that several species are smaller than 30 µm.

The hydrological and physico-chemical conditions during the sampling are presented in Table 1. A Hanna multi-parameter and a Voltcraf oximeter have been used to survey the physico-chemical parameters of water, while the hydrology was evaluated using a Secchi disc (diameter 30 cm) and a graded and weighted rope.

Laboratory analysis: In the laboratory, all the samples were concentrated in the same volume of 100 ml before observation on photonic microscopy. The fifth aliquots of every sample were analyzed by taking, after homogenization, 1 ml of water sample

Table 1. Physico-chemical parameters recorded during the study.

	Low water time			Flood time			
	May	June	July	August	September	October	November
Température (°C)	30.7 ± 0.1	28.4 ± 0.1	26.2 ± 0.1	27,5 ± 0.2	27.7 ± 0.1	28.2 ± 0.3	29.37 ± 0.3
Dissolved oxygen (mg.L^{-1})	6.1 ± 0.1	5.6 ± 0.2	3.8 ± 0.1	3.4 ± 0.1	3.6 ± 0.1	4.0 ± 0.3	4.2 ± 0.3
pH	6.8 ± 0.1	6.8 ± 0.03	6.9 ± 0.2	6.6 ± 0.1	6.3 ± 0.2	6.8 ± 0.02	6.6 ± 0.04
TDS (ppm)	19.0 ± 0.1	17.5 ± 0.0	26.2 ± 2.0	25.5 ± 1.3	28.7 ± 0.3	28.5 ± 2.2	26.3 ± 0.3
Conductivity (µS.cm^{-1})	43.7 ± 4.2	34.5 ± 0.9	51.3 ± 3.5	51.8 ± 2.3	55.0 ± 0.9	56.3 ± 4.2	51.5 ± 0.5
Secchi depth (m)	0.7 ± 0.01	0.5 ± 0.05	0.6 ± 0.04	0.37 ± 0.0	0.40 ± 0.02	0.34 ± 0.02	0.19 ± 0.0

(1 ml pipette fixed). The species identification, based on the morphological characters, was carried out for phytoplankton compartment based on Nogueira-Correia and Ferreira (2000), Tsukii (2005), Kinross (2007) and Oyadomari (2011). The identification of zooplankton species implied according to Beauchamp (1965), Smith and Fernando, (1978), Pourriot and Francez (1986) and Lynne (2004). After identification, the individuals of every species were counted per compartment, on counting cell. For the algal group, three categories of species were considered in the enumeration, i) the species found in abundance in all the fields, which were counted in 20 compartments, ii) the frequent species, counted in 40 fields and iii) the rare species which were counted on all the cell. As zooplanktons, the individuals were counted in all the compartments. During the counting for both communities, only the individuals having a whole structure are considered.

Data analysis: After enumeration of the individuals of species identified in 20 ml (1/5 of sample), the abundances related to the filtered water volume were obtained with the following formulas: For phytoplankton species, the abundance by milliliter of sample was first calculated by: N = (n * 196 / X), where N is the total number by ml observed; n the number of individuals counted by ml, 196 total number of compartment on the counting cell and X number of observed compartment. Then, the density of every species in the Lake, as well for the phytoplankton as for zooplankton was calculated by:

$$D=\left[100^{*}\sum_{i=1}^{20} Ni\right]/[20*3*He*Sbf]$$

Where D is the density (ind.m^{-3}), Ni the total number of individuals by ml for the species i, He the depth of the lake, Sbf the basic area of the plankton net, 3 number of hauls by sample and 20 number of aliquot of 1 ml observed.

After calculation of the abundances, the data were transformed before any treatment with log (X+1) to stabilize the variances of biological over-dispersal (Frontier, 1973). These data were projected in the factorial design of the principal components analysis (PCA) to study the seasonal dispersal. The univariate diversity was also studied only for zooplankton by calculating the indices below. It is not calculated for phytoplankton considering that all the species of the lake are not certainly represented. The diversity of Shannon-Wiener, to discriminate the various populations. It is obtained by:

$$H' = -\sum\left[\left(\frac{ni}{N}\right)*\log 2\left(\frac{ni}{N}\right)\right]$$

Where H' is the index of diversity expressed in bit/individual, ni the number of the species, N the total number of individual constituting all the species, log2 the logarithm on base 2. The diversity index of Simpson. It is obtained by:

$$SP = 1 - \sum\left[\frac{ni*(ni-1)}{N*(N-1)}\right]$$

Where SP is the diversity index, ni the specific effective and N the total number of individual in the sample merged all species. The diversity index of Margalef, expressed by:

$$Marg = \frac{Ns-1}{\ln(n)}$$

Where Ns is the total species number and n the total abundance. The Evenness index to estimate the regularity between the species. It is obtained by:

$$\text{Evenness} = \frac{H'}{\text{Log2Ns}}$$

Where H' is the Shannon index, Log2 the logarithm on base 2 and Ns the specific richness.

The ANOVA one ways test is finally used to study the temporal variations in the zooplankton and phytoplankton abundance.

Results

Populating composition and occurrences: During the study, a total of 51 phytoplankton species, share out in five classes (Table 2) are inventoried including, Diatomophyceae represented by 24 taxa, Cyanophyceae by eight taxa, Chlorophyceae by 12 taxa, Euglenophyceae by six taxa and Pyrrophyceae by one species. As indicated in the methodology, this diversity represents probably not all the phytoplankton in lake due to the used net. Nevertheless, it represents a preliminary result of this diversity study. As the presence/absence, of the diatoms species during the shallow depths season, all taxa were identified except *Aulacodiscus* sp. The latter was identified only during the floods, contrary to *Navicula* sp., which was absent in the samples only during recession period. About the Cyanobacteria taxa, all were identified as well in flood as during the recession. In the Chlorophytes group, it was noted the absence of *Cladophora* sp. during the flood recession while it appeared in the floods time. An opposite distribution pattern was observed for *Cosmarium* sp. As the Euglenophytes, all the species were represented in both seasons with the exception of *Trachelomas* sp. which had the same distribution as *Cosmarium* sp. The only one Pyrrophyceae species was identified during both seasons. According to the occurrence percentages of various taxa regarding all the algal population, it is obtained a net dominance of the diatoms *Melosira* genera in the lake.

As regard to zooplankton, 36 taxa made up 30 species of rotifers, three copepods and three cladocerans (Table 2) were recorded. The presence/absence showed that three rotifers taxa, including *Brachionus patulus*, *Lepadella* sp. and *Proales daphnicola* were appeared in the lake during the floods time. In addition, two other rotifers i.e. *Lecane leontina* and *Lecane* sp. were disappeared with the floods. As copepods, just *Acartia* sp. was found only during the high depths. The cladoceran *Bosmina* sp., contrary to *Moina dubia*, had the same distribution similar to the previous copepod species. The occurrence percentage of each rotifers species regarding whole group and both seasons showed the dominance of species as *Anuraeopsis navicula*, *Anuraeopsis* sp., *Asplanchna brighwelmlii*, *Brachionus falcatus*, *Cephalodella giba*, *Keratella tropica*, *Polyarthra vulgaris* and *Testudinella* sp.. As the copepods, *Mesocyclops* sp. was dominant, while *Daphnia* sp. dominated the cladoceran population.

Plankton population's abundance: The total phytoplankton harvested with the net, during both hydrologic seasons, knew globally a distribution in which the floods time was unfavorable (Fig. 2A). The best densities were obtained between May and July with the peak in June, which was followed by a progressive decrease until October showing a slight rise in November. This temporal variation was significantly different between June and October ($P<0.05$). Regarding the zooplankton (Fig. 2B), the distribution of the abundance was similar with that of phytoplankton, except in September. The two lowest densities of total zooplankton observed in October and November was significantly different and from that of all other months ($P<0.05$). In addition, the total zooplankton in May (relatively low) was significantly different from that of the other months with the exception of September.

Seasonal distribution of phytoplankton: The abundances data of various phytoplankton taxa, according to the months, both hydrological seasons, reduced and centered by a factorial analysis of the main components are represented on Figure 3. With eigenvalue of 5.61, the first factor explains 80.15% of the results. It is essentially formed by the low-water period and the month of August, representing the floods inception. All the variables are negatively selected and well-represented on it. This period (May-August) is correlated to the strong representat-

Table 2. Phytoplankton and zooplankton species occurrence according to the hydrological seasons.

Phytoplankton	Code	Water level			Zooplankton	Code	Water level		
		Low	Flood	%			Low	Flood	%
DIATOMOPHYCEAE					**ROTIFERS**				
Aulacodiscus sp.	D1	-	+	0.03	*Anuraeopsis navicula*	R1	+	+	4.21
Caloneis sp.	D2	+	+	0.36	*Anuraeopsis* sp.	R2	+	+	11.51
Cocconeis sp.	D3	+	+	2.27	*Asplanchna brightwelmlii*	R3	+	+	14.25
diatoma trenuis	D4	+	+	0.13	*Asplanchna girodi*	R4	+	+	2.93
Eunotia bilunaris	D5	+	+	2.03	*Asplanchna* sp.	R5	+	+	2.57
Eunotia sp.	D6	+	+	0.05	*Brachionus caudatus*	R6	+	+	0.71
Gomphonema amoenum	D7	+	+	0.42	*Brachionus falcatus*	R7	+	+	4.73
Gomphonema sp.	D8	+	+	1.63	*Brachionus patulus*	R8	-	+	0.15
Gomphonema vibrio	D9	+	+	1.13	*Brahionus quadridentatus*	R9	+	+	0.49
Melosira ambigua	D10	+	+	29.86	*Brachionus* sp.	R10	+	+	2.31
Melosira granulata	D11	+	+	2.90	*Cephalodella giba*	R11	+	+	20.27
Melosira sp.	D12	+	+	27.39	*Colurella uncinata*	R12	+	+	0.33
Melosira varians	D13	+	+	5.16	*Filinia longiseta*	R13	+	+	1.25
Navicula sp.	D14	+	-	0.002	*Filina opoliensis*	R14	+	+	1.92
Nitzchia paradoxa	D15	+	+	0.14	*Habrotrocha* sp.	R15	+	+	1.84
Nitzschia reversa	D16	+	+	0.27	*Hexarthra intermédia*	R16	+	+	0.50
Nitzschia sigma	D17	+	+	5.26	*Keratella tropica*	R17	+	+	4.75
Pinnularia cardinalis	D18	+	+	0.08	*Lecane leontina*	R18	+	-	0.21
Suriella capronii	D19	+	+	0.02	*Lecane* sp.	R19	+	-	0.01
Suriella linearis	D20	+	+	1.57	*Lepadella patella*	R20	+	+	0.78
Synedra acus	D21	+	+	2.68	*Lepadella* sp.	R21	-	+	0.01
Synedra splendens	D22	+	+	1.40	*Lindia* sp.	R22	+	+	2.17
Thalassiosira rotula	D23	+	+	0.08	*Ploesoma* sp.	R23	+	+	2.59
Thalassiosira sp.	D24	+	+	0.74	*Proales daphnicola*	R24	-	+	0.46
CYANOPHYCEAE					*Proales decipiens*	R25	+	+	1.60
Microcystis flos-aquae	CY1	+	+	0.62	*Proales* sp.	R26	+	+	1.86
Microcystis sp.	CY2	+	+	0.29	*Polyarthra vulgaris*	R27	+	+	5.58
Microcystis wesenbergii	CY3	+	+	0.27	*Pompholyx sulcata*	R28	+	+	1.42
Oscillatoria sp.	CY4	+	+	0.02	*Rotaria* sp.	R29	+	+	1.13
Raphidiopsis méditerranea	CY5	+	+	0.80	*Testudinella* sp.	R30	+	+	7.46
Spirulina sp.	CY6	+	+	0.02	**COPEPODS**				
Stigonema sp.	CY7	+	+	0.75	*Acartia sp*	CO1	-	+	1.12
Synechocystis aquatilis	CY8	+	+	0.89	*Afrocyclops* sp.	CO2	+	+	4.95
CHLOROPHYCEAE					*Mesocyclops* sp.	CO3	+	+	9.95
Binuclearia eriensis	CH1	+	+	5.11	Nauplui	N	+	+	83.97
Cladophora sp.	CH2	-	+	0.003	**CLADOCERA**				
Closterium aciculare	CH3	+	+	0.61	*Bosmina* sp.	CL1	-	+	12.85

+ Presence, - Absence

Table 2. Continued.

Phytoplankton	Code	Water level			Zooplankton	Code	Water level		
		Low	Flood	%			Low	Flood	%
Closterium parvulum	CH4	+	+	0.62	*Daphnia* sp.	CL2	+	+	87.00
Cosmarium sp.	CH5	+	-	0.01	*Moina dubia*	CL3	+	-	0.15
Gonatozygon sp.	CH6	+	+	0.06					
Micrasterias sp.	CH7	+	+	0.06					
Scenedesmus quadricauda	CH8	+	+	0.13					
Scenedesmus sp.	CH9	+	+	0.03					
Staurastrum sp.	CH10	+	+	0.02					
Stigeoclonium aestivale	CH11	+	+	0.37					
Tetraedron sp.	CH12	+	+	0.07					
EUGLENOPHYCEAE									
Euglena sp.	E1	+	+	0.48					
Phacus caudatus	E2	+	+	0.15					
Phacus longicauda	E3	+	+	0.68					
Strombomona sp.	E4	+	+	0.33					
Trachelomas bituricensis	E5	+	+	0.03					
Trachelomas sp.	E6	+	-	0.01					
PIRROPHYCEAE									
Peridinium bipes	P1	+	+	0.07					

+ Presence, - Absence

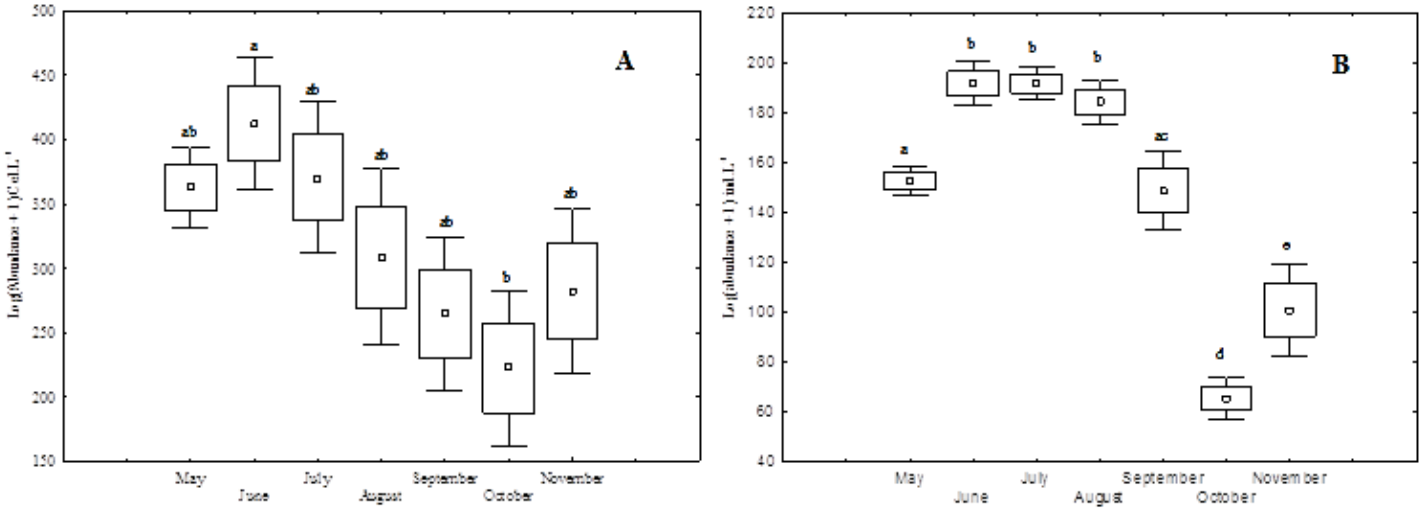

Figure 2. Temporal evolution of total phytoplankton (A) and total zooplankton (B) of Lake Azili (The mustache boxes with no common letters are significantly different (P<0.05)).

-ion of diatoms (*Melosira granulata*, *Melosira varians*, *Melosira ambigua*, *Melosira* sp., *Nitzschia sigma*, *Gomphonema* sp., *Synedra acus*,*Cocconeis* sp. and *Suriella linearis*) and of Chlorophytes (*Binuclearia eriensis*), in opposition to diatoms (*Nitzschia paradoxa*, *Navicula* sp., *Pinnularia cardinalis*, *Suriella capronii* and *Aulacodiscus* sp.), cyanobacteria (*Oscillatoria* sp.), chlorophytes (*Cladophora* sp., *Cosmarium* sp., *Scenedesmus* sp., *Staurastrum* sp.), and Euglenophytes (*Trachelomas* sp.).

The high-water time (October and November) and

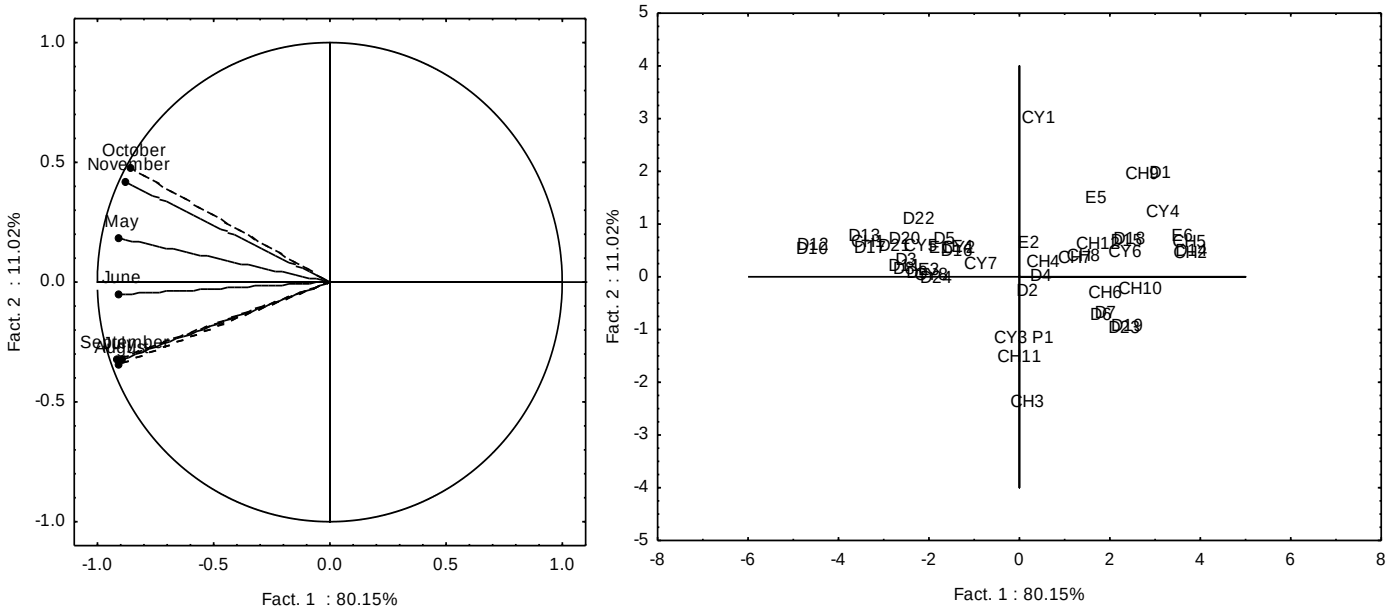

Figure 3. Projection of phytoplankton species and the sampling time in the factorial design of Principal Component Analysis.

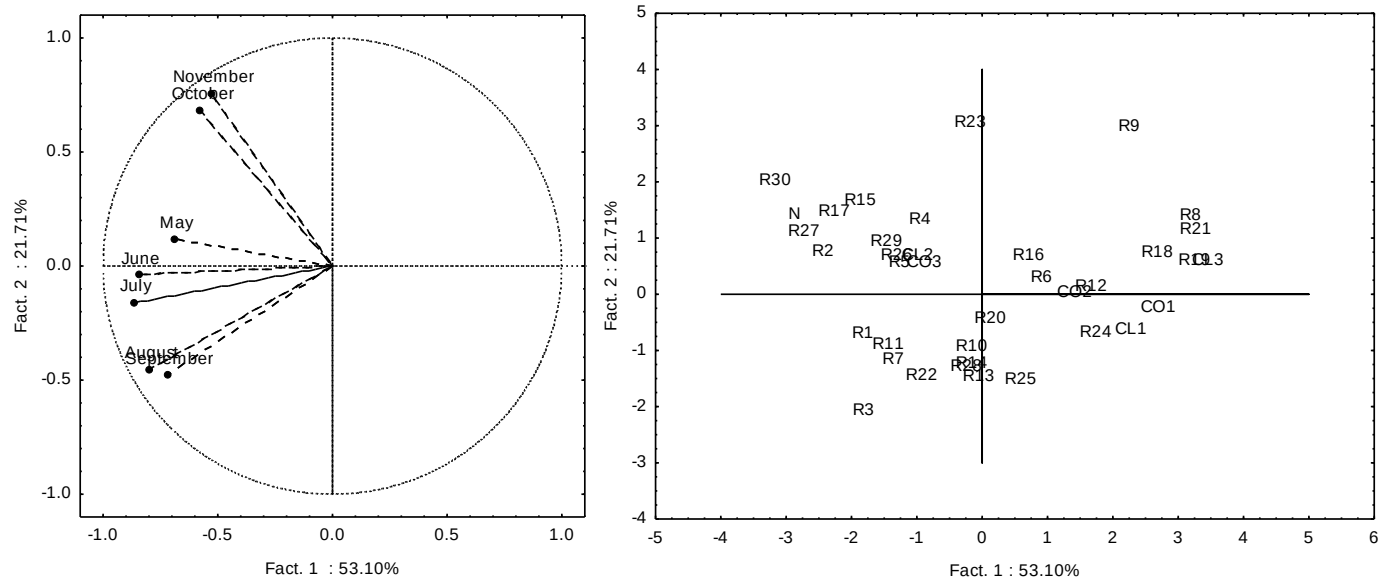

Figure 4. Projection of zooplankton species and the sampling time in the factorial design of Principal Component Analysis.

August compose the second axis, which explains 11.02% of the distribution. It opposes the floods period, which is positively selected with regard to the average depths. The species such as the diatoms *Aulacodiscus* sp., the cyanobacteria *Microcystis flos-aquae*, the chlorophyte *Scenedesmus* sp. and the euglenophyte *T. bituricensis* are well-represented during the floods, contrary to the species as *Eunotia* sp., *Gomphonema amoenum*, *Thalassiosira rotula* (diatoms), *Microcystis wesenbergii* (cyanobacteria), *Closterium aciculare*, *Stigeoclonium aestivale* (Chlorophytes) and *Peridinium bipes* (Pirrophyte). The phytoplankton distribution in the factorial design of PCA, following the quality representation of various species, show that those of diatoms are represented well in both hydrological seasons, the flood recession period; however being more favorable. On the other hand, the period during which the lake receives the first influxes of River Ouémé (August-September) knew the best

Table 3. Monthly variation of the diversity index and the dominance degree of zooplankton species.

	RS	SP	H'	Evenness	Marg	Dominants species	%D
May	25	0.95	3.09	0.88	3.95	*Brachionus falcatus, Cephalodella giba*	12.8
June	28	0.96	3.28	0.95	4.28	*Asplanchna girodi, Cephalodella giba*	10.3
July	27	0.96	3.28	0.98	4.12	*Polyarthra vulgaris, Testudinella* sp.	8.9
August	29	0.96	3.29	0.92	4.46	*Anuraeopsis navicula, Asplanchna brightwelmlii*	10.3
September	27	0.95	3.20	0.91	4.30	*Filina opoliensis, Asplanchna brightwelmlii*	12.4
October	19	0.93	2.74	0.82	3.46	*Habrotrocha* sp., *Testudinella* sp.	21.2
November	18	0.93	2.74	0.82	3.02	*Keratella tropica, Testudinella* sp.	18.9

RS: specific Richness, SP: Simpson diversity, H': Shannon diversity, Marg: Margalef diversity

representations of other groups (Cyanobactera, Chlorophytes, Euglenophytes and the only Pirrophyte species). The high-water months there were not so selective.

Seasonal distribution of the zooplankton: Zooplankton distribution submitted to analysis in principal components is presented on Figure 4. First axis which explains 53.10% of the results is characterized by the shallow depths season, all the variables being negatively correlated; it is composed by June, July and August. September is also well represented on it. Therefore, it explains the microfauna distribution during the recession and a part of that of the transition period between both seasons. It includes the species such as rotifers *Testudinella* sp., *Anuraeopsis* sp., *Keratella tropica*, *Polyarthra vulgaris* and nauplii of copepods, which oppose their strong representation of shallow depths to that of: i) *Brachionus patulus*, *Brahionus quadridentatus*, *Lecane leontina*, *Lecane* sp. and *Lepadella* sp. (rotifers), ii) *Acartia* sp. (copepod) and iii) *Bosmina* sp. and *Moina dubia* (cladoceran).

The second axis, which expresses 21.71% of the results, is formed by the floods period (September, October and November). It selects positively the last two months and negatively September, the latter being very well-represented in the factorial design. It includes essentially the rotifer species, among which *Filinia longiseta*, *Filina opoliensis*, *Pompholyx sulcata*, *Brachionus falcatus*, *Asplanchna brightwelmlii*, *Proales decipiens* and *Lindia* sp. are strongly correlated to September. They oppose their spread to *Testudinella* sp., *Ploesoma* sp., *Brahionus quadridentatus* and *Habrotrocha* sp., which are selected by the floods period. According to the quality representation of various zooplankton species, selected and not selected by one or the other one, both axes of the PCA design, it was observed that rotifers were distributed well on both seasons. Nevertheless, August (at the floods beginning) was favorable to the abundance of several species. The same period was the one with the best representations of two other zooplankton groups (copepods and cladoceran), while the high depths were unfavorable.

Zooplankton specific diversity and dominance: The diversity indices of zooplankton populations are presented in Table 3. Several indices were calculated to assess the diversity. In none of the studied months, the specific richness was equal to the total value observed on the lake. Thus, the ecological preference of the different species varied over the sampling period. Regarding the diversity indices, no high variations have been observed between both hydrological seasons, nor between constituent months. In that, the specific richness varied between 18 and 29 species, while the Simpson diversity is near of unity for all the study period. The Shannon Wiener index is varied between 2.74 bit.ind^{-1} and 3.29 bit.ind^{-1}, the highest value coinciding with the biggest specific richness of August, the biggest Simpson diversity and also that of Margalef (29, 0.96 and 4.46, respectively). The samples uniformity measured by Evenness, remained very high during both seasons. All the index consideration, shows a good diversity of zooplanktonic population in the

lake. The best diversifications were recorded during the transition period (August-September) while lower diversities were recorded during the high depths (October-November). This diversity has resulted in low levels of dominance by the next most represented species in the different months of the study (Table 3). Thus, the percentage of dominance varied between 8.9% and 21.2%. The lowest dominance does not correspond exactly to the most diversified, but altogether the tendency remains the same.

Discussion

Although the study of the phytoplankton compartment is a preliminary evaluation of the diversity of the microflora of Lake Azili, a significant number of species was identified. Totaling 51 species, the found richness is widely below that of other watercourses of the sub-region (111 and 192 species, respectively on the Lake Guiers in Senegal (Ngansoumana, 2006) and in the coastal river of Ivory Coast (Niamien-Ebrottié et al., 2013)). The microflora sampled in the present study showed a structure dominated by diatoms, similar to Onozeyi (2013) on Ogun River in southwest of Nigeria. Azili Lake is a particular ecosystem with its important vegetation cover and the strong anthropological pressure; it has a muddy bottom due to the organic decomposition. This, therefore, justifies the important presence of diatoms species, which, in continental environment, knows good diversifications due to the organic mineralization and re-suspension caused by human activities (Groga, 2012). In the diatoms group the species selective of polluted environment were identified. The strong representation of the genera *Nitzschia*, *Gomphonema*, *Navicula*, *Pinnularia*, *Caloneis*, *Eunotia*, etc., shows that the ecosystem is perturbed and rich in organic elements. The cyanobacteria presence, generally characteristic of high nitrogenous and phosphated mineral concentration in thermal conditions from 25 to 30°C (Erkaya et al., 2011), is not characteristic of the lake, even if the thermal conditions are filled all year (tropical environment). Some identified species were more representative during the transition period between recession and floods. This dynamics gives two hypotheses. Given that in this period, the lake receives the influxes of its tributary (the river Ouémé), whether it had a direct contribution in specimens by the river or the mineral conditions were improved by its jet. The first hypothesis would give more a gradient upstream-downstream in the species distribution, not being the case in the results of this study. The second hypothesis thus remains the most convincing even if a more spatial study remains to be carried out. It would thus be a mineralized material re-suspension and a nutriment contribution while the physico-chemical conditions of the river are poor (Hounsou, 2011). Nevertheless, the presence and temporal distribution selective species for high eutrophication conditions (Erkaya et al., 2011), shows the ecosystem disturbance even if a planktonic bloom is not observed at present. In addition, the chlorophytes have presented an ecological preference for the big floods period selecting particularly the transition period. Thus, the arrival of new species and the disappearance of others previously inventoried species can be observed, which was the case in four phytoplankton phyla, the most representative of inventoried population. An instability in the algal community structure in the lake due to exchanges with its tributary is subsequently noted.

Regarding the zooplankton populations, the biodiversity of the lake is globally cosmopolitan. *Filinia longiseta*, *Filina opoliensis*, *Testudinella* sp., *Brachionus caudatus*, *Keratella tropica*, etc. are generally well-represented in diverse environments (Bozkurt and Akin, 2012). Its wealth is important, being slightly superior than that of Cross River of Nigeria (Offem et al., 2009). It presents a characteristic structure of tropical fresh water by the wide dominance of rotifers. The seasonal structure of this community shows a tendency towards the transition period for several species. The diversity is also unstable due to the exchanges with the Ouémé River, a classic structure being, nevertheless,

observed with the peak abundance shortly after that of phytoplankton. In the population of inventoried rotifers, many species are characteristic of polluted environment. Selecting the strongly eutrophic ecosystems (Bozkurt and Akin, 2012), the distribution and temporal dominance of the species from the genera *Filina* and *Lepadella*, as of some phytoplankton species, show that the lake is in a degradation process. The health of an aquatic ecosystem can be estimated by several methods one of them being the calculation of the diversity index. It is recognized that species diversity increases with succession, while the characteristics of different species vary the spatial and temporal distribution according to the classification level of the food chain. A diversity index to explain the community characteristics will thus have to consider the functional structure of this one both at a spatial and temporal level. The work which we realized has a temporal consideration reduced and is valid only for the considered period. Therefore, for all the calculated indices, the population presents an average diversity. The Shannon index, dependent on the size of samples and on the type of habitat (Grall and Coïc, 2005), interpreted with Evenness, classifies the lake in the category of the moderately polluted ecosystems during the floods recession and the transition period and strongly polluted during the floods, on the scale of the sandy/muddy ecosystems according to Simboura and Zenetos (2002), showing again the impact that the Ouémé River has on the Azili Lake. The plankton biodiversity of the Lake is a classic population of tropical environment with an unstable structure due to the rejection of the tributary Ouémé River. Considering the ecosystem established by the lake, pressures which are exercised and its planktonic biodiversity, a tendency to eutrophication is observed.

The distribution of species along the two hydrological seasons, submitted with the classification of the lake on the Simboura and Zenetos (2002) pollution scale, highlighted in both group of phytoplankton and zooplankton, some species potentially bio-indicators of pollution. Therefore, *Aulacodiscus* sp., *Microcystis flos-aquae*, *Scenedesmus* sp. and *Trachelomas bituricensis* are phytoplankton species candidates for bio-indication in the lake Azili subject to a further study in this direction. Regarding the zooplankton group, those are species such as: *Filinia longiseta*, *Filina opoliensis*, *Pompholyx sulcata*, *Brachionus falcatus*, *Asplanchna brightwelmlii*, *Proales decipiens*, *Lindia* sp., *Testudinella* sp., *Ploesoma* sp., *Brahionus quadridentatus* and *Habrotrocha* sp. A complementary study assessing the actual state of the lake pollution and the direct effects of pollutants on these species so will confirm or refute species as bio-indicator of pollution in the lake Azili environment.

Acknowledgements

We are grateful to all person who contributed to the good realization of this work. A particular thought to Mr. Yaovi René for his contribution in the data collection and to the teams of the Laboratories of Hydrobiology and Aquaculture of Faculty of Agronomic Sciences and Research in Applied Biology of Polytechnic School of Abomey-Calavi.

References

Aklinon S.Y. (2005). Contribution of the evaluation of the wetlands of the center of Benin: case of Lake Azili, Thesis of agricultural engeneer, University of Abomey-Calavi, Benin, 111 p.

Beauchamp D.E.P. (1965). Classify of Rotifers. In: J.R. Durant, C. Levêque (Eds.). Aquatic flora and fauna of Africa Sahel soudanniane, Office of Technical and Scientific Research of overseas Press, Paris, pp 227-234.

Bozkurt A., Akın S. (2012). Zooplankton fauna of Yeşilırmak (between Tokat and Black sea), Hasan Uğurlu and Suat Uğurlu Dam Lakes. Turkish Journal of Fisheries and Aquatic Sciences, 12: 777-786.

Dolédec S., Statzner B., Bournaud M. (1999). Species traits for future biomonitoring across ecoregions: patterns along a human-Impacted river. Fresh Biology, 42: 737-758.

Erkaya I.A., Özer T.B., Akbulut A., Abel U., Udoh A.U., Yıldız K. (2011). The abundant and wide-spread species of algae in the algal flora of the lower Euphrates Basin wetlands. Turkish Journal of

Fisheries and Aquatic Sciences, 11: 55-62.

Frontier S. (1973). Statistical study of zooplankton dispersion. Journal of Experimental Marine Biology and Ecology, 12: 229-262.

Grall J., Coïc N. (2005). Summary of quality assessment of coastal benthos methods, European University Institute of the Sea, Ifremer, 91 p.

Groga N. (2012). Structure, function and dynamics of phytoplankton in Lake Taabo, Côte d'Ivoire, PhD thesis, University of Toulouse, France, 224 p.

Hounsou M.B. (2011). Spatio-temporal evaluation of the water quality in the watershed Ouémé river outfall Bonou, PhD thesis, University of Abomey, Benin, 257 p.

Kinross J. (2007). Summary investigation on the phytoplankton of the Rivers Almond and Creran, Available at http://www.algalweb.net/algweb1.htm (accessed June 26th, 2012).

Lynne M.W. (2004). Practical Guide to Identifying Freshwater Crustacean Zooplankton, Laurentian University Press, Ontario, Canada, 60 p.

Ngansoumana B.A. (2006). The phytoplankton community of Lake Guiers (Senegal): types of functional associations and experimental approaches to regulatory factors, PhD Thesis, University of Cheikh Anta Diop, Senegal, 155 p.

Niamien-Ebrottié J.E., Konan K.F., Edia O.E., Ouattara A., Gourène G. (2013). Composition and spatial and seasonal variation of algal assemblage of coastal rivers of South-eastern Côte d'Ivoire. Journal of Applied Bioscience, 66: 5147-5161.

Nogueira N.M.C., Correia F.M.M. (2000). Cyanophyceae / Cyanobacteria in red mangrove forest at mosquitos and coqueiros estuaries, são luís, state of maranhão Brazil. Brazilian Journal of Biology, 61: 1519-6984.

Offem B.O., Samsons Y.A., Omoniyi I.T., Ikpi G.U. (2009). Dynamics of the limnological features and diversity of zooplankton populations of the Cross River System SE Nigeria. Knowledge and Management of Aquatic Ecosystems, 393: 02.

Onozeyi D.B. (2013). Monthly spatial occurrence of phytoplankton and zooplankton in River Ogun, Abeokuta, Southwest Nigeria. International Journal of Fisheries Aquaculture, 8: 193-203.

Oyadomari J. (2011). Diatom Gallery. Keweenaw Waterway at MTU Surface plankton tow. Available at http://www.keweenawalgae.mtu.edu/index.htm (acce ssed June 26th 2012).

Pourriot R., Francez A.J. (1986). Rotifères. Practical introduction to the systematic of organisms of French continental water, Monthly bulletin of linnéenne society of Lion, France. 19 p.

Simboura N., Zenetos A. (2002). Benthic indicators to use in ecological quality classification of Mediterranean soft bottom marine ecosystems, including a new biotic index. Mediterranean Marine Sciences, 3: 77-111.

Smith K., Fernando C.H. (1978). A guide to the freshwater calanoid and cyclopoid copepod Crustacea of Ontario. University of Waterloo, Canada, 74 p.

Tsukii Y. (2005). Gomphonema vibrio Ehrenberg, cell body. Available at http://www.protist.i.hosei. ac.jp/protist menuE.html (accessed July 12th 2012).