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Study of the physicochemical parameters of water and phytoplankton in Lake Tonga (wetland of the national park of El Kala, North East of Algeria)

Aicha Djabourabi*, Hassen Touati, Nadira Sehili, Mariem Imen Boussadia, Mourad Bensouilah

Department of Biology, Faculty of Sciences, Badji Mokhtar University, Annaba, Algeria-Laboratory of Ecobiology formarine environments and coastal areas, Algeria

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Abstract

This work aims to study the impact of the variation of physicochemical parameters on the dynamic of the phytoplankton community on lake Tonga, a wetland of El Kala National Park (Nord east of Algeria).Temperature, pH and dissolved oxygen are measured *in situ* using a field's multi parameters; the analysis of the nutrients is carried out by colorimetric method (nitrate with the Aoac method), the chlorophyll a with the method of Lorenzen and suspended matter with the differential weighing method, the sampling of micro-algae is achieved by a phytoplankton net.All measurements of biotic and abiotic variables showed seasonal variation. The maximum phytoplankton density was recorded in spring (3 million ind/l). Dinoflagellates and diatoms density assessment during the two cycles and in two stations shows that the lowest values are recorded during summer and autumn(200 000ind/l) while the highest ones are detected during winter and spring with about 2 million ind/l. However, cyanobacteria proliferate in autumn and summer season. The spearman coefficient reveals that chlorophyll a is correlatedpositivelywith densities of cyanobacteria and diatoms and dissolved oxygen is negatively correlated with the dinoflagellates density. The Principal Component Analysis (PCA) show that the cyanobacteria evolve positively with ammonium and chlorophyll a and that the dinoflagellates follow a negative outcome with the temperature of the water. In Tonga lake the phytoplankton is influenced by changes in the physicochemical parameters of water, hydrodynamic, rhythm of the seasons and climate change.

* **Corresponding Author:** Aicha Djabourabi ✉ djabourabiaicha@yahoo.fr

Introduction

The quality of an aquatic ecosystem is dependent on the physico-chemical qualities of water and the biological diversity of the system (Irfanullah, 2006).Several studies show that the phytoplankton community is strongly influenced by changes in the physicochemical parameters of water (Hari Muraleedharan, 2010; Coutinho et *al.*, 2012; George et *al.,* 2012), the rhythm of the seasons (Radji et *al.*, 2013; Hamaidi et *al.* 2009) and other aspects of climate change, such as wind, air stream and precipitation, can also affect the phytoplankton community in various ways (Jurgensone et *al.*, 2011).

Many studies have been carried out on the phytoplankton of dams, lackes or rivers in Algeria; that we mention works of Nasri et *al.* (2007, 2008); Amri *et al.*, (2010); Boussadia *et al.*, (2015) ;Saoudi. et *al.* (2015, 2017); were interested mainly to Cyanophyceae in the North East of Algeria. Other studies (Al Asadi *et al.*, 2006; Branes *et al.,* 2007; Chaib *et al.*, 2011; Hmaidi *et al.*, 2013; Djabourabi *et al.*, 2014) relate to populations of phytoplankton of many other Algerian areas.

In the present study, we investigated the composition, diversity and abundance of phytoplankton, to get a general view of the physicochemical condition of the water and then correlate the physicochemical parameters of the water to the phytoplankton distribution and abundance.

The objective of this study is to determine the impact of the physicochemical parameters of water on the dynamic of the phytoplankton community of Tonga.

Materials and methods

Presentation of the study area

Lake Tonga located in El Kala national park which is situated in the extreme North-East of Algeria, is a "pond" type of water, less than 6 m deep, located 5 km southeast of the town of El-Kala and 65 km East-southeast of the town of Annaba, which communicates with the sea through the artificial canal of Messida. Its geographical coordinates in the center are 36 ° 51 '511 North - 8 ° 30' 100 East. Its surface area in open water is about 2300 ha. It is significantly reduced in summer due to evaporation.

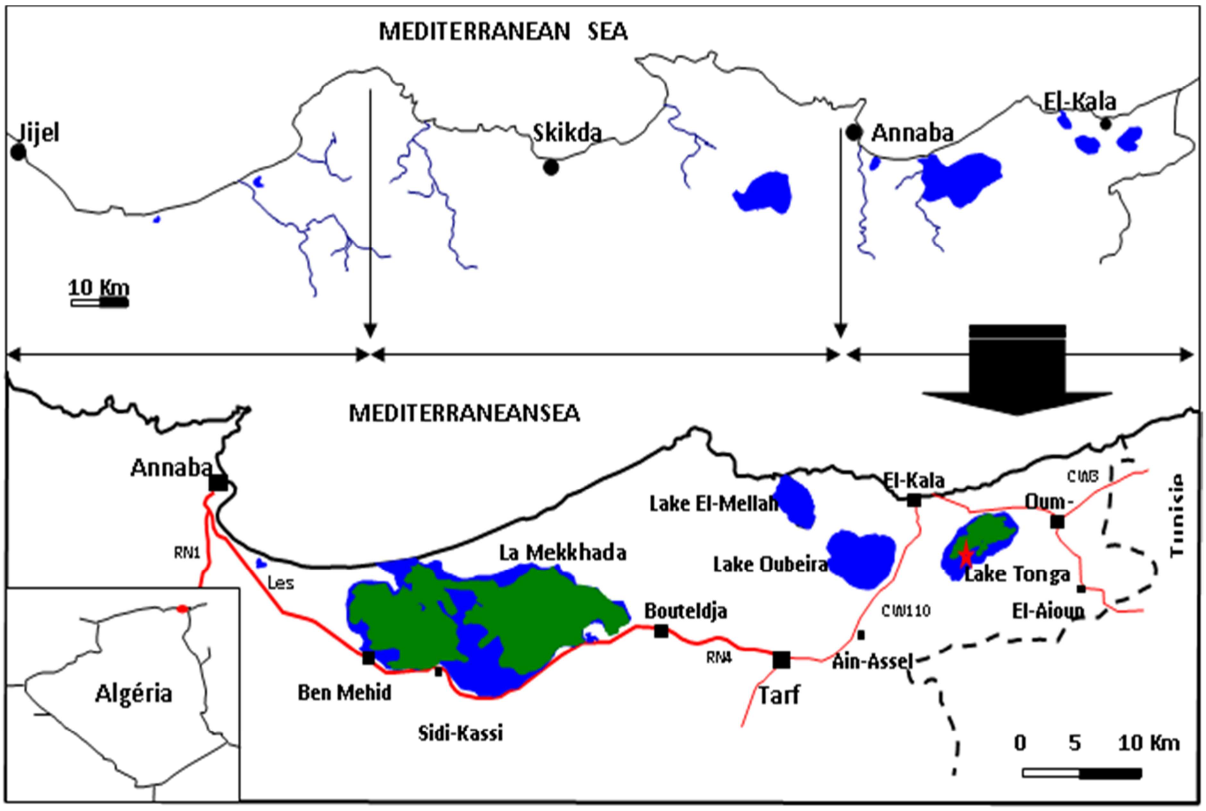


Fig. 1. El-Kala National Park and location of Tonga Lake

The excavated areas are located to the west and to the whole of the southern part of the lake.

Lake Tonga is fed by many tributaries, the most important of which are: Oued El Hout and Oued El Eurg. The lake also receives groundwater from the groundwater in the land surrounding it (Fig. 1). In Tonga Lake, two sampling stations were selected, the first at the level of the valves and the second in the center of the lake.

Sampling

Water withdrawals and measurements are carried out monthly over a period of two years, from January 2007 to December 2008.The "*in situ*" temperature measurements, pH and dissolved oxygen are carried out using a multi parameter (Consort, 535) using several probes.The determination of nitrites, ammonium and phosphates is carried out using a colorimetric method.

The determination of the suspended matter in water is carried out by the application of the differential weighing method after filtration (Aminot and Chausspied, 1983); the nitrate is assayed by the method described by Aoac (2002).

The determination of chlorophyll a is carried out according to the monochromatic method of Lorenzen (1967) using 90% acetone as solvent.The phytoplankton is harvested using plankton net (20 μm of mesh void). The generic identification is based on the observation of morpho-anatomical characteristics according to retained identification keys of Bourrelly (1985; Couté (1995). For the counting of phytoplankton, we used 100 ml of filtrate preserved in 10% formaldehyde, According to the method of Leitao et *al.* (1983).

Statistical analysis

Statistical analysis of the data was performed under R (R Development Core Team, 2014 Version 3.1.2) developed by Ross Ihaka (1996). The normality condition of the distributions was checked beforehand by applying the Shapiro-Wilk (not shown). Distributions, being usually of asymmetric time, forced us to choose non-parametric alternatives for the statistical analysis.

Results and discussion

Physicochemical characterization of Tonga lake water

Temperature (T°C):

In Tonga Lake, the temperature difference between the coldest month (December) and the hottest month (July and August respectively during Cycle I and II) is about 19°C and 16.40 ° C during Cycle 1 and 2 respectively (Fig. 2A).

Dissolved oxygen (DO)

Dissolved oxygen levels ranged from 7 to 14 mg/l from December to May and decreased to 6 mg/l in the other months of Cycle 1.

On the other hand, with the exception of the January peak (11.52 mg / L) dissolved oxygen contents do not exceed 7 mg/l and show significant fluctuations from one month to another during Cycle 2(Fig.2B).

Hydrogen potential (pH)

The pH is between 7 and 9 from January to June and fluctuates between 6.5 and 7 during the other months of the cycle 1; With respect to cycle 2, the pH does not exceed the value 7 except for the peaks of April (7.26) and June (8.05) (Fig. 2C).

In general, physicochemical parameters, including nutrient concentration, temperature, pH, DO, in the water bodies studied were favorable for microalgae proliferation(Boussadia *et al.*, 2015).

Nutrients

Nitrite levels fluctuated between 0.1 and 0.4 μM/l during 6 months of the cycle 1 and ranged from 0.1 to 1.49 μM/l for 7 months of cycle 2. Maximum levels were recorded during the month of July (0.44 μM/l) in Cycle 1 and February (1.49 μM/l) in Cycle 2. (Fig.2D).

It is during Cycle 1 that the nitrate contents are the highest; the maximum value (135 µg/l) is recorded in January; The levels fluctuate between 38 and 57 µM/l during the summer period and show peaks of 11 and 19 µM/l in February and April respectively. However, the presence of nitrates is limited to 4 months of cycle 2 at levels ranging from 0.2 to 0.6 µM / l (Fig.2E).

Ammonium shows a presence in July (0.56 µM/l) during Cycle 1 and during the summer period of Cycle II at concentrations between 0.4 and 8 µM/l. (Fig. 2F).

Chlorophyll a

The lowest levels of chlorophyll a were recorded in May (5.60 µg/l) in cycle 1 and in June (1µg/l) in cycle 2. Peaks, greater than 60 µg/l, are encountered during 6 months of the cycle 1 and only 2 months of cycle 2. However, it is during the summer period of both cycles that the chlorophyll a contents are the highest (Fig.2H).

In an ecosystem functioning logic, estimation of chlorophyll content provides an overall and integrating indication of the phytoplankton community's response to fluctuations in its environment (Harris, 1986).

Suspended matter

Suspended matter shows the lowest levels during the winter period of the cycle 1 and summer of cycle 2. Suspended matter levels above 30 mg/l are encountered from July to October of cycle 1 and from November to January of cycle 2. The maximum level (81mg/l) is recorded in August of cycle 2. (Fig.2I).

Organic matter is the most important fraction of suspended solids. Phytoplankton production can be an important source of organic matter (Lesel, 1980).

The results of the Spearman coefficient calculation (Tab. 1) show that: in cycle 1, suspended matter is positively correlated with chlorophyll a (r = 0.5) and water temperature (r = 0.5) and has a negative correlation with dissolved oxygen (r = -0.8). Nitrites are negatively correlated with water temperature (r = -0.5). In the second cycle (Tab. 2), chlorophyll a is positively correlated with the ammonium content (r = 0.5) and negatively with the suspended matter (r = -0.5). Water temperature in Tonga Lake is positively correlated with ammonium (r = 0.5) and nitrite (r = 0.6)

Quantitative and qualitative variation of phytoplankton

Generic Diversity of phytoplankton

In Tonga Lake, the phytoplankton population comprises 76 and 80 genera in Cycle 1 and 2, respectively, according to annual statistics. The whole phytoplankton population consists of 41 to 44 genera of Diatoms, 20 to 22 genera of Dinoflagellates and 15 to 14 genera of Cyanophyceae (Fig.3).

Phytoplankton Overall average density

During Cycle 1, the overall phytoplankton density varies most often between 1 and 2.5 million in d/l with peaks ranging between 3, 4 and 3.5 million ind/l respectively on February, April and May (Fig.4).

Table 1. Results of the spearman coefficient (cycle1).

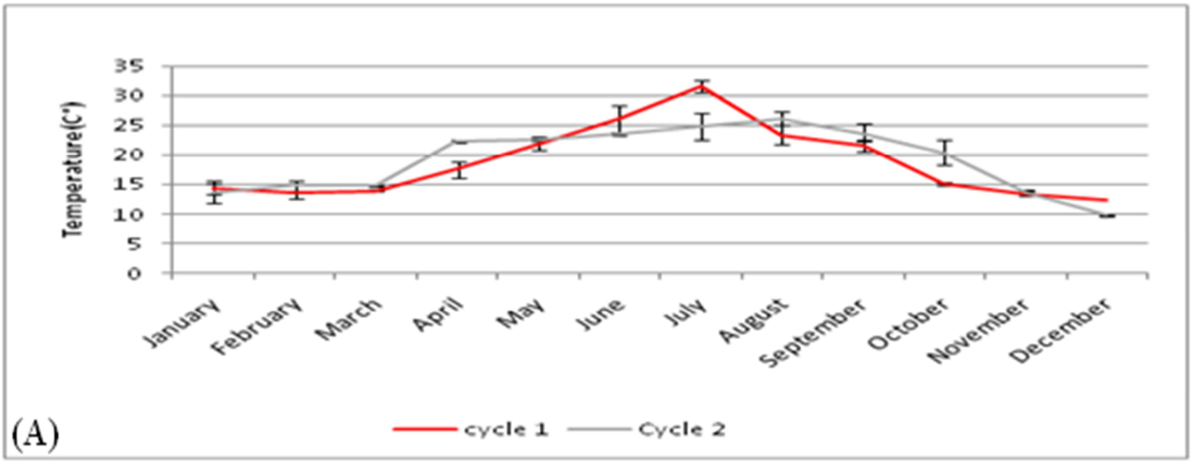
	Chl.a	Cyan	Diat	Dino	H3PO4	MES	NH4	NO2	NO3	DO	pH	T
Chl.a	**1.0000**											
Cyan	**0.6087**	**1.0000**										
Diat	-0.2885	-0.0255	**1.0000**									
Dino	-0.3012	-0.1359	**0.7720**	**1.0000**								
HPO4	0.0504	0.0192	0.1519	0.1734	**1.0000**							
MES	**0.5531**	**0.5551**	-0.3236	-0.3756	0.0413	**1.0000**						
NH4	0.3466	0.3465	-0.2562	-0.1357	0.3476	0.2415	**1.0000**					
NO2	-0.0111	-0.2711	-0.0043	-0.1167	0.3125	-0.2851	0.3599	**1.0000**				
NO3	0.4309	0.3654	-0.1710	-0.0169	-0.0293	0.2548	0.2888	-0.2323	**1.0000**			
DO	-0.3882	-0.3826	0.4530	0.4617	-0.1425	**-0.8451**	-0.3466	0.1446	0.0110	**1.0000**		
pH	0.1449	-0.2479	0.2406	0.2669	0.2771	-0.3015	0.1657	0.2171	0.0380	0.2539	**1.0000**	
T	0.3249	0.3816	0.0770	0.2220	0.1238	**0.5615**	0.3165	**-0.5532**	0.4413	-0.4570	0.0248	**1.0000**

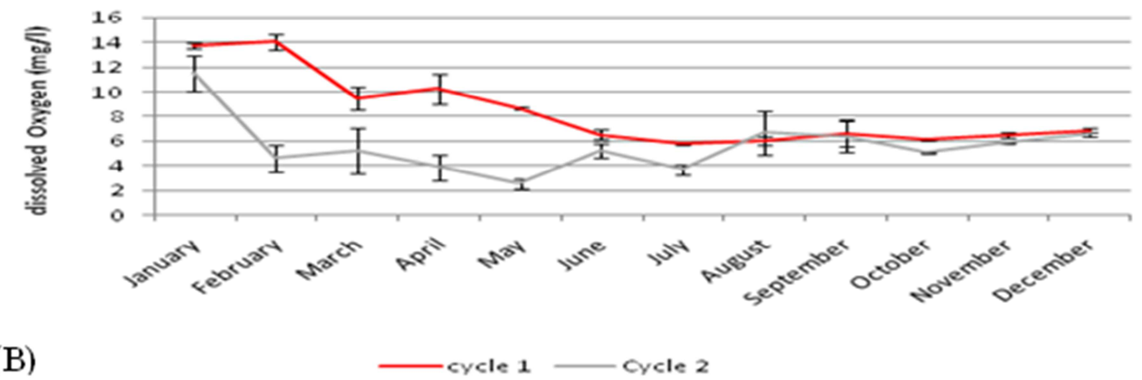
r≥0,

Table 2. Results of the spearman coefficient (cycle2).

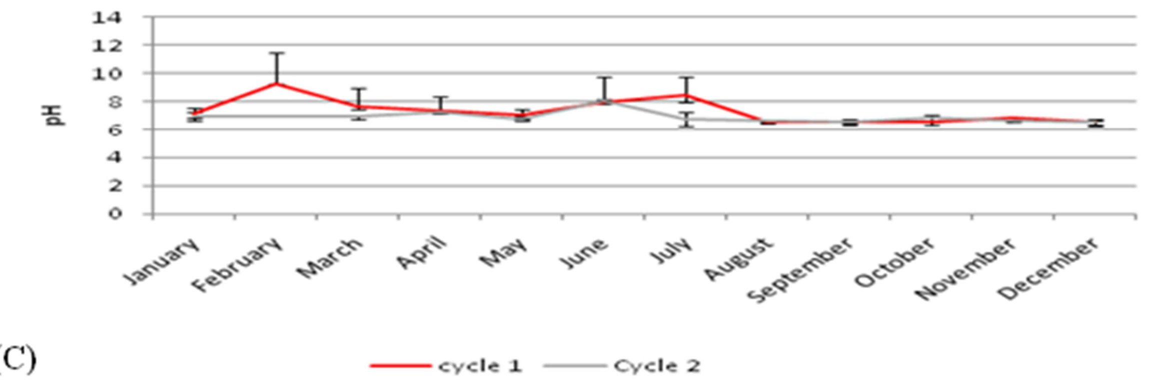
	Chl.a	Cyan	Diat	Dino	H3PO4	MES	NH4	NO2	NO3	OD	pH	T
Cyan	0.2183	1.0000										
Diat	**-0.6073**	0.2063	1.0000									
Dino	-0.3911	0.0631	**0.7260**	1.0000								
H3PO4	0.2849	0.1123	-0.1267	0.0481	1.0000							
MES	**-0.5381**	-0.3997	0.3025	-0.0168	-0.2422	1.0000						
NH4	**0.5306**	0.2216	-0.4111	-0.2150	0.4849	-0.4603	1.0000					
NO2	0.3378	0.3870	0.1954	0.3249	0.2375	-0.3478	0.2931	1.0000				
NO3	0.1733	-0.1112	-0.2588	0.0257	0.0683	-0.0529	0.2121	-0.1997	1.0000			
DO	0.2136	-0.1553	-0.3576	**-0.5824**	-0.0428	0.1114	0.0886	-0.4919	0.1715	1.0000		
pH	-0.4190	-0.3410	0.3513	0.3233	-0.0979	0.3331	-0.3532	0.1618	0.1239	-0.1815	1.0000	
T	0.3151	0.2871	0.0009	0.1833	0.4289	-0.3145	**0.5967**	**0.6023**	-0.0640	-0.3031	0.0422	1.0000

r≥0,5

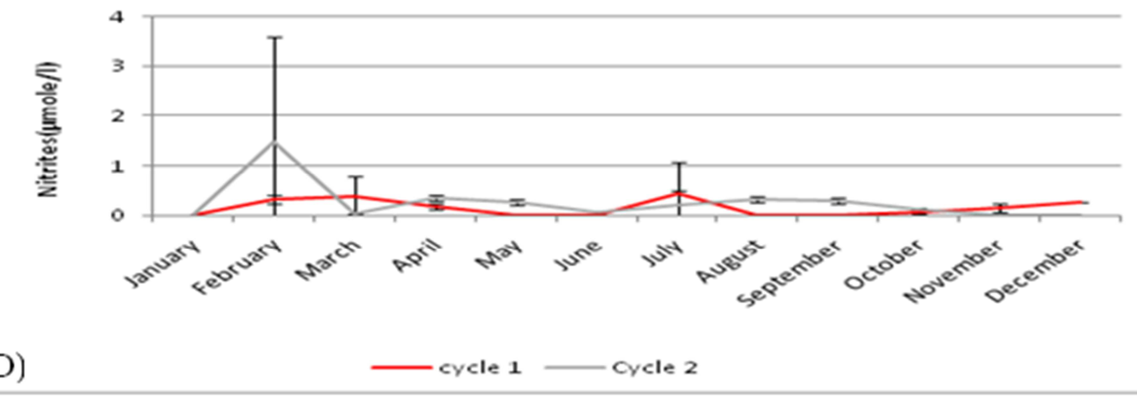



dissolved Oxygen (mg/l)
16
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
cycle 1
Cycle 2

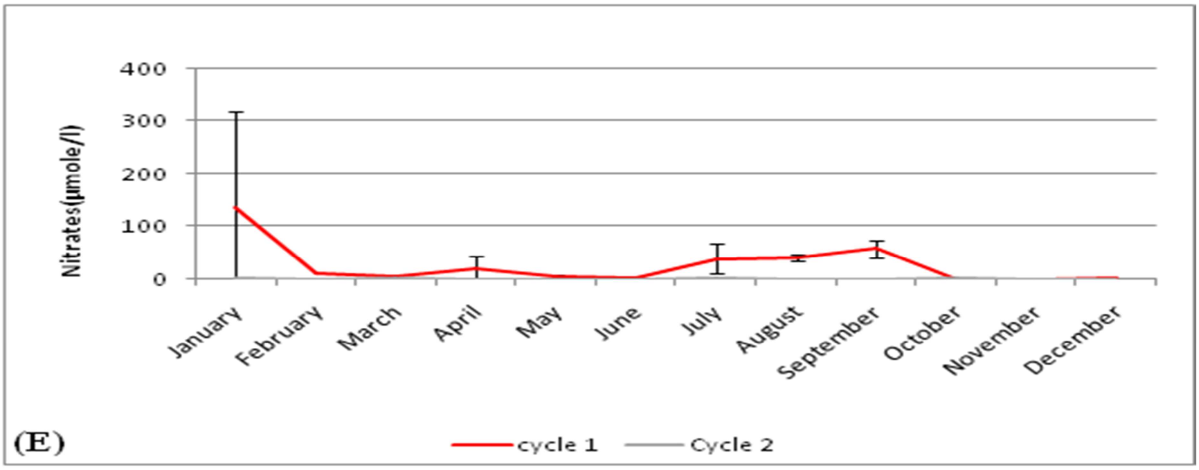
(B)

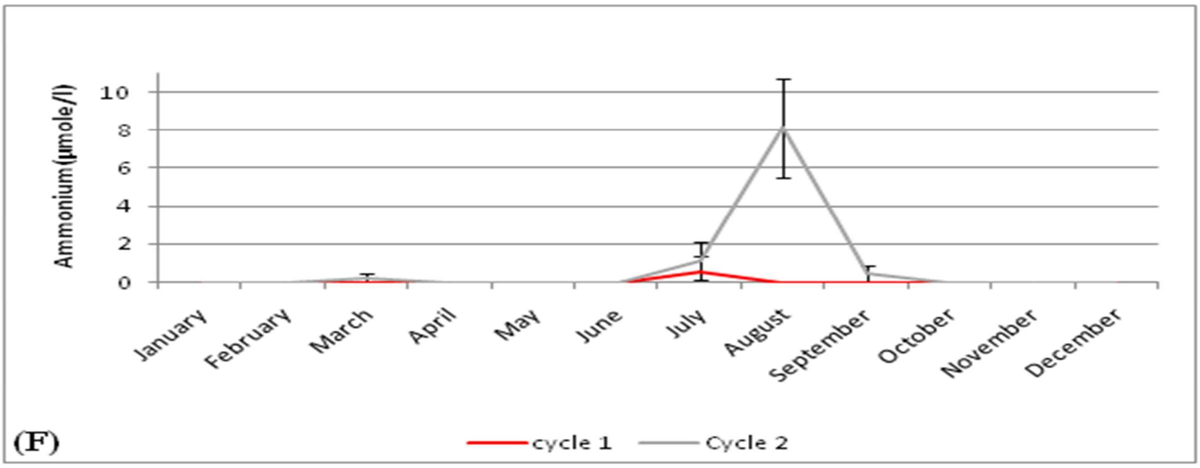

pH
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
cycle 1
Cycle 2

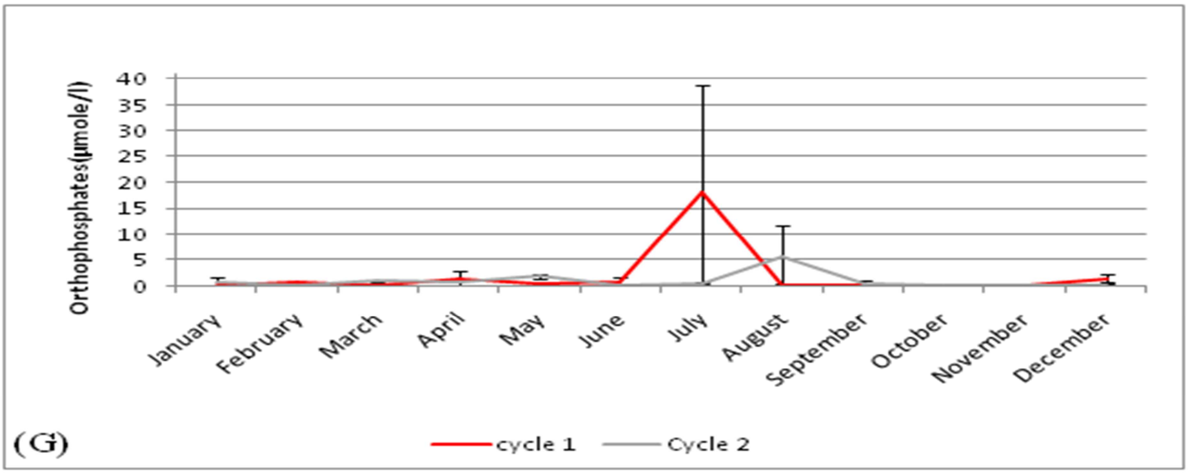
(C)

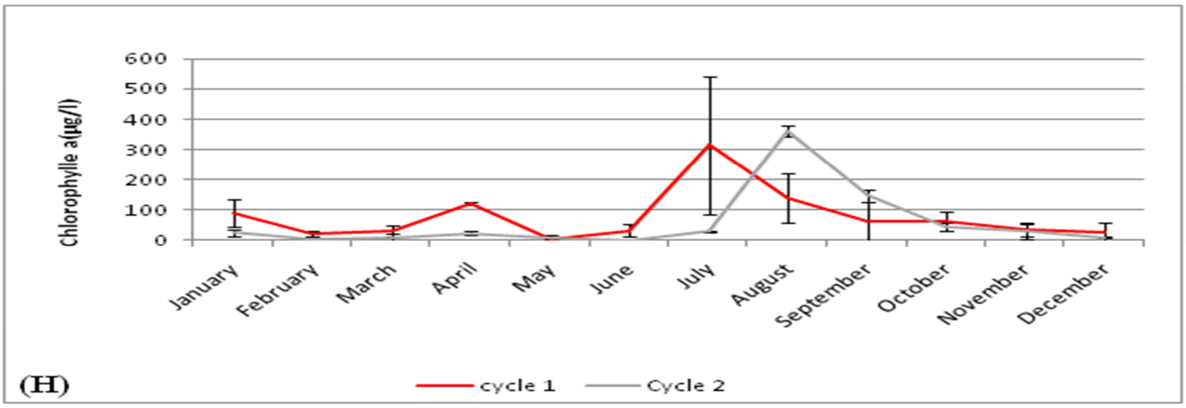

Nitrites(µmole/l)
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December
cycle 1
Cycle 2

(D)


Nitrates(µmole/l)
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December
(E)
cycle 1
Cycle 2


Ammonium(µmole/l)
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
(F)
cycle 1
Cycle 2


Orthophosphates(µmole/l)
40
35
30
25
20
15
10
5
0
January
February
March
April
May
June
July
August
September
October
November
December
(G)
cycle 1
Cycle 2


Chlorophylle a(µg/l)
600
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December
(H)
cycle 1
Cycle 2

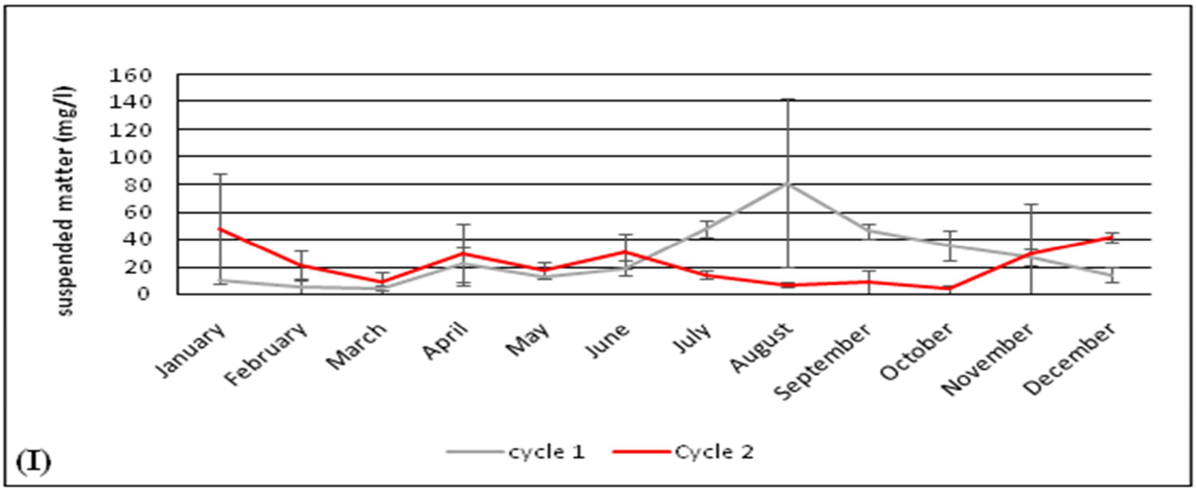


Fig. 2. Monthly fluctuations of the physicochemical parameters of Tonga Lake(A)temperature, (B)dissolved oxygen, (C)pH, (D)Nitrites, (E)Nitrates, (F)Ammonium, (G)Orthophosphates, (H)Chlorophyll a, (I)Suspended matter.

On the other hand, during Cycle 2, the overall density usuallyfluctuates between 2 and 3 million ind / l, reaching peaks of more than 3 and 5 million ind / l in autumn and spring season, respectively.

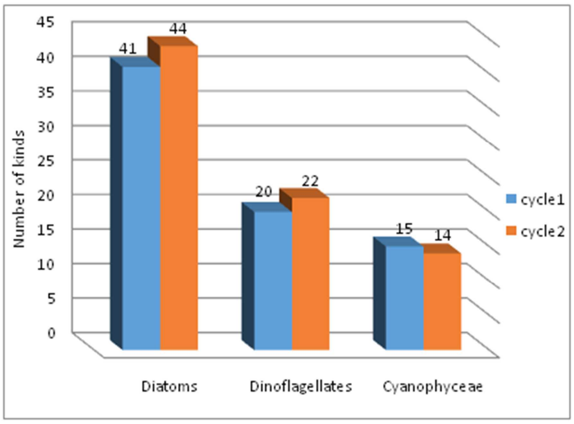


Fig. 3. Generic diversity of the microalgae community of Tonga Lake.

Proportion of phytoplankton classes

According to the evolution of the ratio of the phytoplankton classes, both diatoms and Cyanophyceae dominate during Cycle 1 and 2 (Fig.5). The dinoflagellates reveal the lowest proportions during the two cycles.

Huszar and Giani, (2004) point out that the phytoplankton community may present different distribution models depending on the capacity of the algae to regulate their position by specific adaptation strategies.

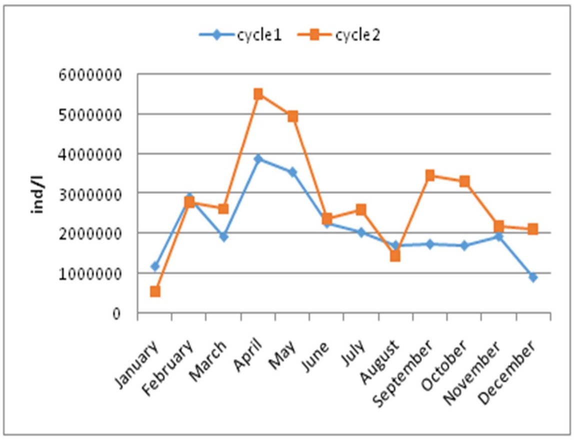


Fig. 4. Monthly variation of the phytoplankton overall average density harvested in Tonga Lake.

spatio - temporal distribution

Diatomaceous

Diatoms in Figure 6 show, according to the sampling site, similarities in their temporal dynamics. The highest densities are recorded in the spring and autumn season at the valves (800 000 to 1 300 000 ind / l) and in winter and spring at the center (from 800 000 to more than 3 million ind / l). It is during the summer period that the diatoms show the lowest densities at the two stations. However, El Haouati*etal.*,(2015), reports that strong diatom proliferations was in spring in Reghaia Lake in northern Algeria.

Dinoflagellates

During both cycles and at the two stations, dinoflagellates reveal densities of more than 500 000 ind / l from February to June (Fig. 7).During the rest of the year two peaks are recorded, one on October at the level of valves (more than 1 million ind / l) and the other on September at the center (600 000 ind / l during the Cycle 2). Chellapa *et al.* (2008), report,in the public reservoir of Cruzeta (Brazil), a strong dominance of Bacillariophyceae in September.

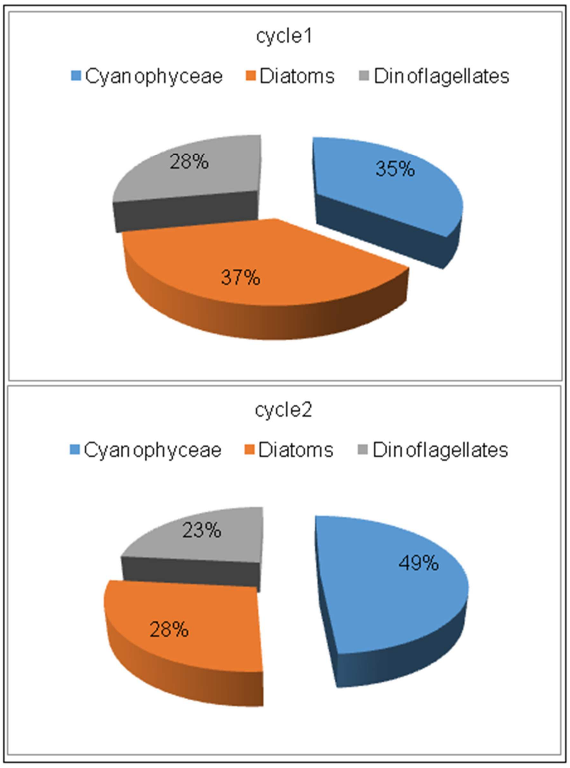


Fig. 5. Ratio of each phytoplankton class surveyed in Tonga Lake.

Cyanophyceae

At valves, according to the study cycle, cyanophytes show 3 and 7 peaks over 1 million ind / l during summer and autumnre spectively in cycle I and II (Fig.8); However, at the center, more than 7 peaks over 1 million ind / l are recorded in cycle II against only a single autumnal peak in the cycle I. Similar results were observed in Oubeira Lake, where summer and autumn show the highest values (Djabourabi *et al.* 2014, Boussadia *et al.,* 2015).

Impact of changes in environmental parameter on the phytoplankton community

In order to determine the relationship between the variation of environmental parameters and the phytoplankton in Lake Tonga we evaluated the non-parametric Spearman correlation coefficient (*r*);it shows that during the first cycle cyanobacteria is correlated with chlorophyll a and suspended matter.(Tab. 1)

During cycle 2, negative correlation was evaluated between density of diatoms and chlorophylla and between dinoflagellate and dissolved oxygen (Tab. 2) The use of Principal Component Analysis (PCA) as a preliminary and exploratory descriptive approach, allowed to visualize the structure of temporal and spatial variation in Tonga Lake, as a function of some measured biotic and abiotic variables. The ACP also made it possible to check for possible similarities between the different months and stations.

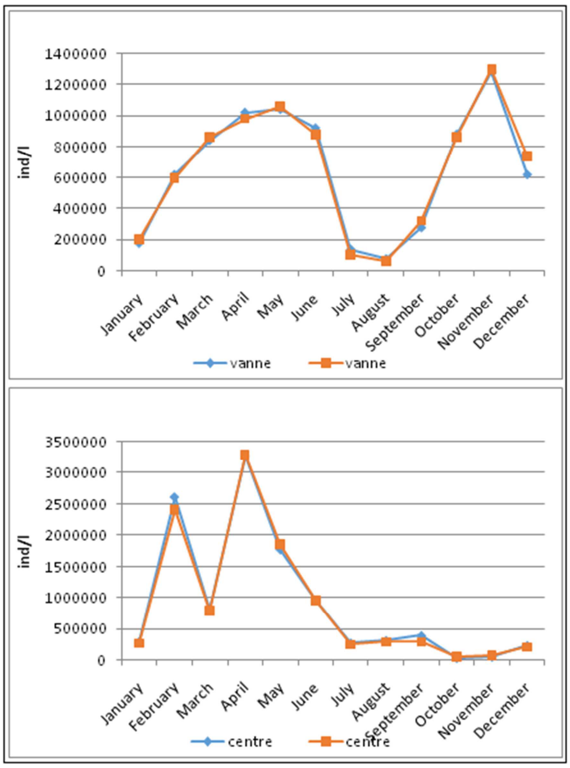


Fig. 6. Diatoms Spatiotemporal Distribution in Tonga Lake.

Monthly changes in biotic and abiotic parameters for cycle1

Our Principal Component Analysis (PCA) shows that the first two main planar components (1-2), of the PCA performed on 13 biotic and abiotic variables returned 63.67% of the information (Inter month variability). Axis 1 accounts for 41.55% of the total variability was associates with temperature (r = 0.63), ammonium (r = 0.94), and chlorophyll a (r = 0.93) and density of cyanobacteria (r = 0.62) which are the most positive Significant in the construction of axis 1.Kangro *et al., (*2007) and Vahtera *et al., (*2007) suggest that proliferation of cyanobacteria is promoted by the increase of inorganic nitrogen contents because they have the power to fix this element.

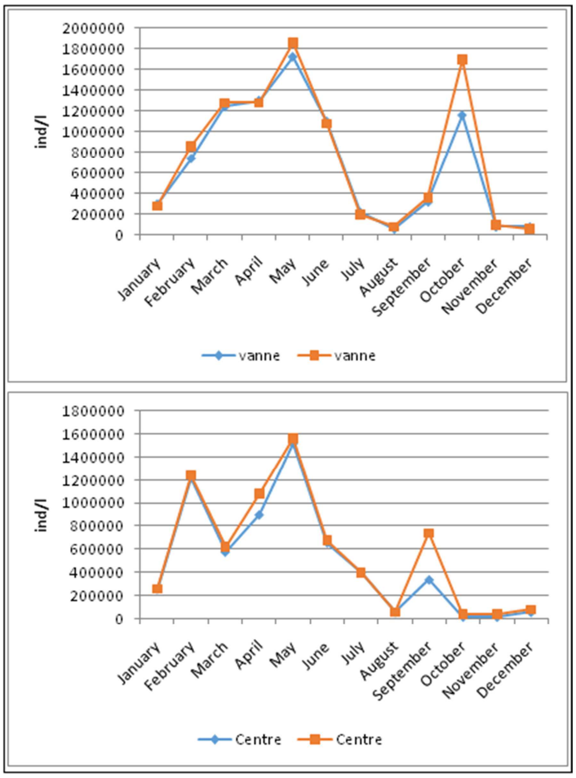


Fig. 7. Dinoflagellates spatiotemporal Distribution in Tonga Lake.

Axis 1 shows a clear difference between the cold months (January, February, March and December) and the warm months (July and August). Axis 2 explains, only 22.12% of the total variation, this axis allowed us to identify the specificity of the month of July compared to the other months, because it is built essentially by environmental variables (dissolved oxygen variables r = 0,73 and nitrite (r = 0.60). However, it is negatively correlated with the suspended matter variable (r = -0.7) and the water temperature (r=-0.53).

Monthly variations of the biotic and abiotic parameters of cycle2

The first two main components account for 52.88% of the total inter-month variability of the biotic and abiotic variables matrix. Fig. 10 shows the factorial plane (1,2) of our ACP, the first two axes which explain respectively: 34.96% and 17.92%. (Fig. 10).

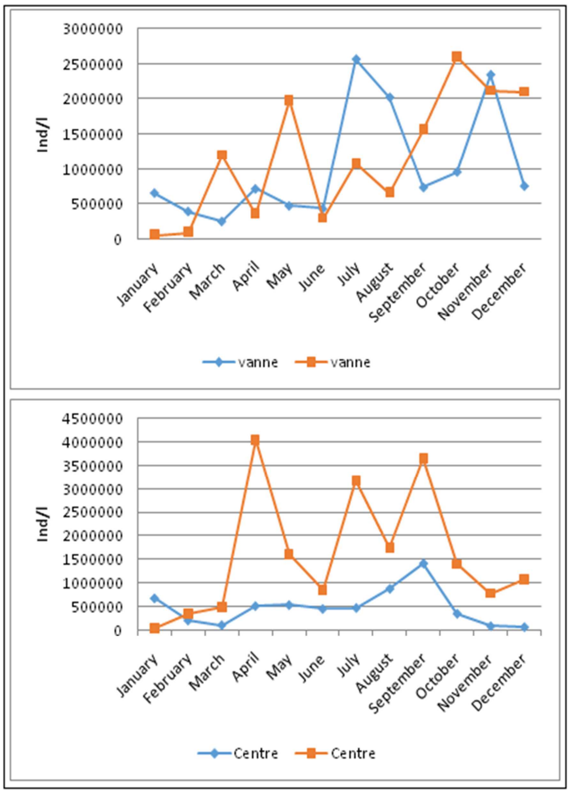


Fig. 8. Cyanophyceae Spatiotemporal Distribution in Tonga Lake.

Axis 1 shows the specificity of the month of August compared to the other months. This more or less seasonal structuring could be explained by the positive correlation, with this axis, of the water temperature variable (r=0.59). The orthophosphate variables (r = 0.83), ammonium (r = 0.93) and chlorophyll a (r=0.93) are the most important in the construction of axis 1which contributes significantly to its construction. The axis 2 is essentially constructed by the dissolved oxygen variables (r = 0.83). However, this axis is negatively correlated with the density of the dinoflagellates (r = -0.54,) and the water temperature (r = -0.53).

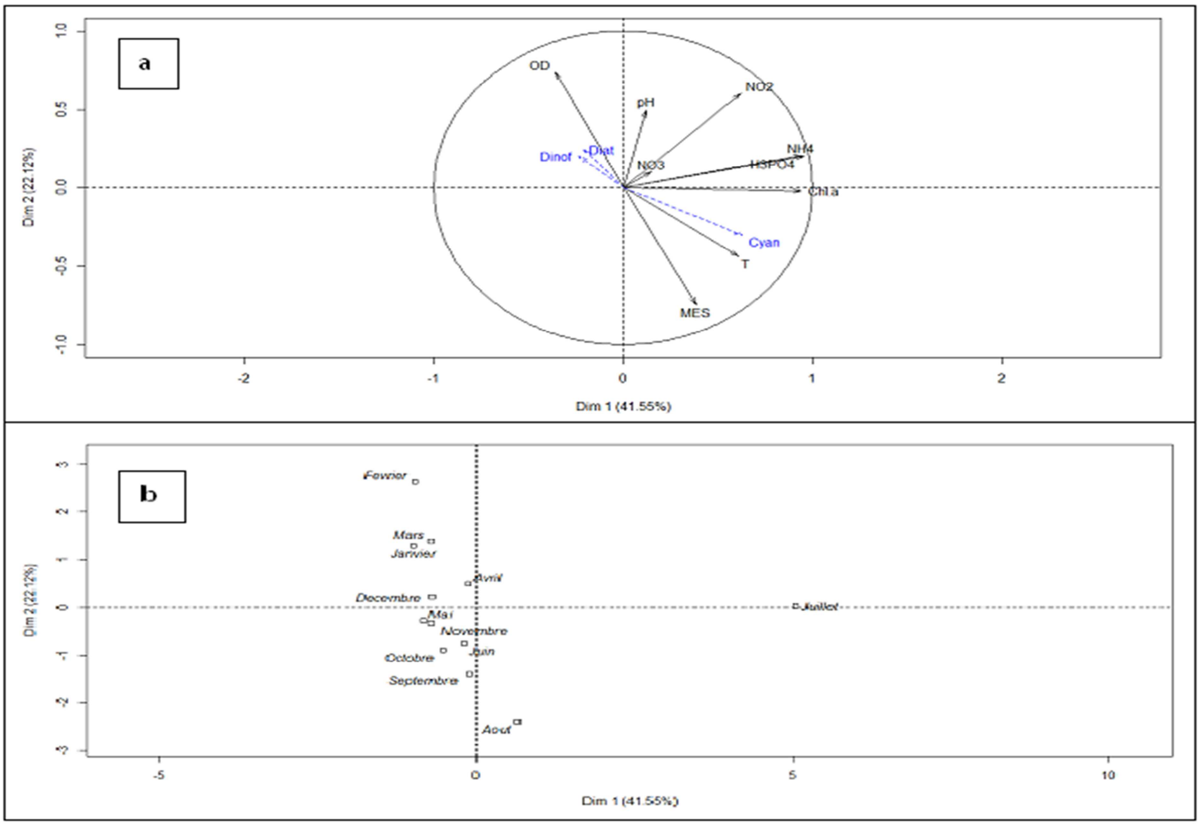


Fig. 9. Principal component analysis (cycle1) based on monthly variations in Tonga lake. Factorial design (1, 2): axis 1: 41.55 %, axis 2: 22.12 %. a) Correlation circle of biotic and abiotic variables with the first two principal axes. b) Projection of months on the first two principal axes.

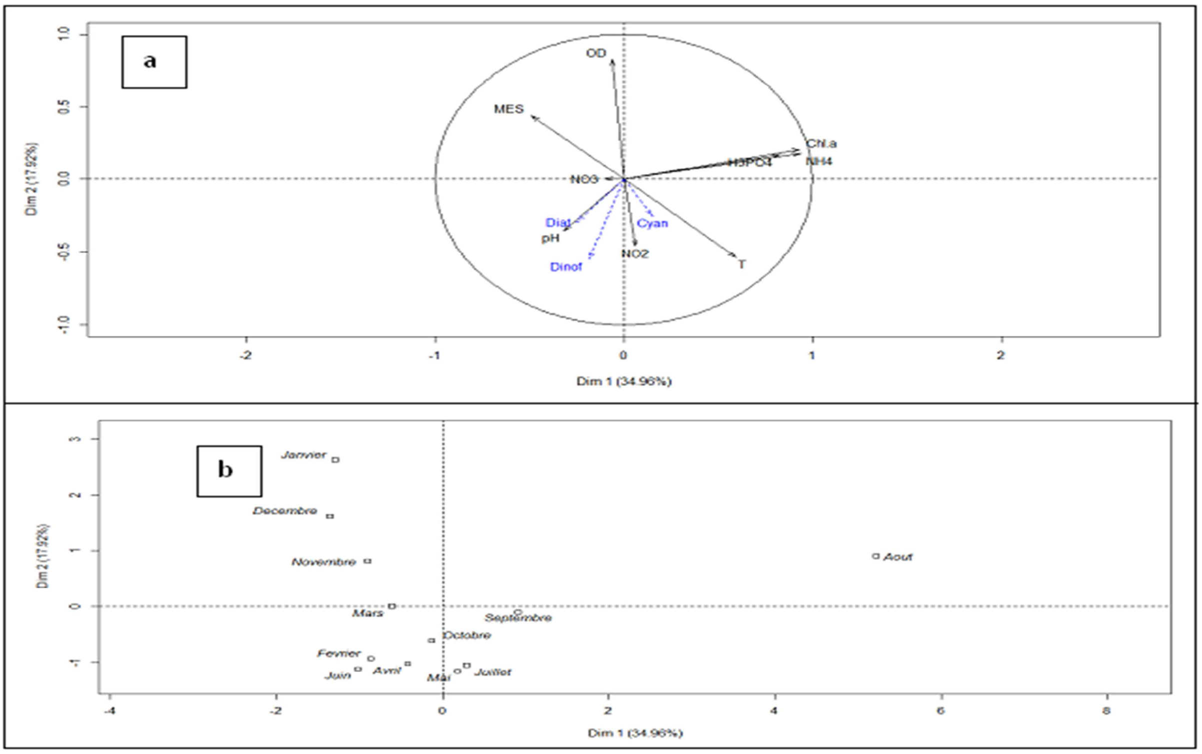


Fig.10. Principal component analysis (cycle2) based on monthly variations in Tonga lake cycle1. Factorial design (1,2): axis 1: 34.90 %, axis 2: 17.92 %. a) Correlation circle of biotic and abiotic variables with the first two principal axes. b) Projection of months on the first two principal axes.

Conclusion

Our results indicate that as a result of the increasing urbanization of the Tonga Lake watershed, a significant enrichment of the natural waters strategy plan could occur, that led not only to a change in the specific composition but also to the proliferation of toxic microalgal blooms.

The lake's phytoplankton community is dominated generically by the diatoms class; however in terms of density, it is the class of cyanobacteria that predominates.

In our study, we show the impact of some physicochemical parameters on the density and distribution of the microalgal community, favoring phytoplankton efflorescence because this shallow lake is characterized by a particular hydrodynamic and rich in nutrients.

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