Environmental Research Journal 7 (1): 9-14, 2013
ISSN: 1994-5396

Dynamic Densities and Specific Cyanobacteria Biomass of Oubeira Lake (National Parc of Elkala, Algeria)

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Abstract: Oubeira is an endorheic freshwater lake rich in organic substances and therefore it is considered as an ecosystem very favorable to the proliferation of potentially toxic cyanobacteria. The aim of the present study is to investigate the specific dynamics of cyanobacteria with an estimated production of biomass. The obtained results showed that Oubeira is highly favorable for the development and growth of cyanobacteria. Such class is dominated by species *Aphanizomenon flos-aquae* in the station North and center station with densities of 14×10^5 and 10^7 cell mL^{-1}, respectively. They are relatively high compared to other species of cyanobacteria. At the South station, the densities seem unaffected by the season's variations and remain constant at about 10^6 cell mL^{-1}. The species *Microcystis aeruginosa*, *Chroococcus turgid*, *Oscillatoria rubescens* and *Anabaenopsis elenkini* displayed similar densities at whole station with a slight dominance of *Anabaenopsis elenkini*. The contribution of cyanobacteria seems under the domination of *Microcystis aeruginosa* where its biomass is much higher than the other species. The maximum production was observed in the Southern station during July with 120 μgC L^{-1}. Whereas the biomass is much lower in the North and center stations where they reach 70 μgC L^{-1}. Moreover, the genus of cyanobacteria that dominate the Oubeira Lake are *Microcystis*, *Aphanizomenon* and to a lesser extent *Anabaenopsis*.

Key words: Biomass, cyanobacteria, density, Oubeira Lake (EL-Kala, Algeria), North

INTRODUCTION

Oubeira Lake is located in the North East of Algeria (36°50'N-08°23'E) at 25 m above sea level and only 4 km from the Mediterranean sea. It is qualify as wetland of international importance under the Ramsar Convention since, 1983 withconsiderable biological richness. The organic matter inputs by runoff, promote the enrichment of the water. In early 1990, the pumping of lake water was allowed because of the severe drought that led to the draining of the lake.

However, the introduction without prior study in the lake of two planktivorous fish species, *Hypophthalmichthys molitrix* and *Aristichthys nobilis* led to the perturbation of this aquatic ecosystem. This imbalance has mortgaged the few attempts to exploit for breeding and rearing fish.

In addition to the environmental problem, researchers observed much proliferation point of cyanobacteria with occasional blooms. According Bensouilah, the cyanobacteria produce toxins that may appear in Spring and Summer. Because of the shallowness of the Oubeira, operations for fishing, irrigation and drinking water production have been failed. Following this water needs, it is necessary to monitor rigorously the waters, especially to track quantitative and qualitative toxic species of cyanobacteria.

The objective of this research is to estimate the densities of cyanobacteria, species composition and a first attempt to determine the specific biomasses of cyanobacteria in Lake Oubeira during an annual cycle (January to December 2010).

MATERIALS AND METHODS

Study site: Lake Oubeira

Morphometry: Oubeira Lake is located in the North East of Algeria. Table 1 shows that is a freshwater lake with

Table 1: Morphometric characteristics of Lake Oubeira

Characteristics	Values
Area	22.9 km^2
Maximum length	6 km
Maximum width	5 km
Maximum depth	2.5 m
Average depth	1.5 m
Volume	22.031.078,82 M^3
Water balance	15,080,387.81 m^3 $year^{-1}$

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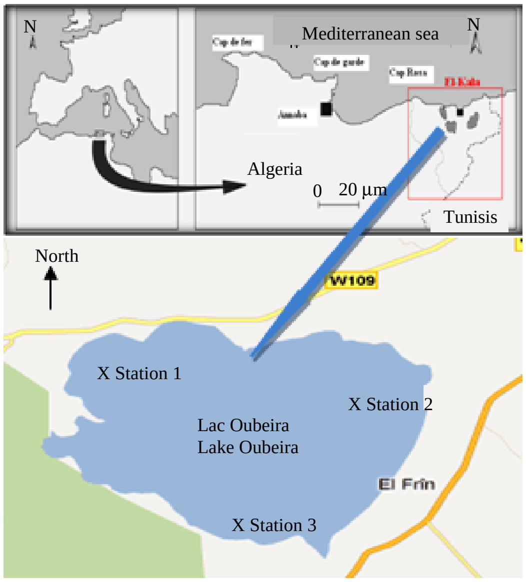

Fig. 1: Location of Lake Oubeira: location of sampling stations. (Station (O1), Station (O2), Station (O3))

a large area, approximately 30 km^2 and a depth of 1.5 m. Moreover, it is raised above the sea. Oubeira Lake is exposed to prevailing winds which could influence the spatiotemporal distribution of cyanobacteria.

Sampling stations and frequency: Three stations were selected based on their position on the continental inputs, on the wind influence from North to South (Fig. 1) and water circulation. Station 1 is placed in the North-West part of the lake does not undergo any major human influence except the river of Demnet El-Rihane stream. Station 2, located in the East of the lake which is directly subjected to contributions of the two small rivers (Boumarchen and Degrah). However, station 3, located in the South is rather under the direct influence of excess intake of surrounding wetlands and the flows of Messida river which considered as the main tributary of the Oubeira Lake (Fig. 1).

However, the agricultural activity, the River Boumarchen and Messida also bring different chemical pollutants including phosphates and nitrogen originated from the fertilizers used in agriculture of the surroundings farms. Samples are collected monthly in triplicate from January to December 2010.

Physical measurements: Measurements of water pH and temperature were performed using a probe field (PHYWE 0713900). The conductivity was measured with a JENWAY 4071 conductivity meter. Water measurements were made at a depth of about 80 cm.

Quantitative and qualitative analysis of cyanobacteria quantitative analysis: Three samples were taken at each station. After homogenizing, a fraction of 100 mL was fixed with concentrated Lugol, stored in the dark at 4°C and then allowed to settle for 24 h in tanks counting. Cyanobacteria species were counted and identified using an inverted microscope according to Utermohl method. The count was performed on 30 microscopic fields (Rott, 1981). The number of individuals per milliliter was determined by microscopic field with the objective 40 (490 µ or 0.49 mm of diameter). The surface of the settling tank with a diameter of 2.5 cm and a sedimented volume were calculated according to the following equation:

$$N = Nc \times Sc/So \times 1/Vs$$

Where:

N = Number of individuals per milliliter
Nc = Number of individuals counted
Sc = Surface of the tank
So = Observed surface
Vs = Volume sedimented (Rott, 1981)

Qualitative analysis: Cyanobacteria species identification was based on the observation of morphological (shape, size, color, etc.) and anatomical characteristics. However, the identification was made according to many references such as Bourrelly.

Biovolumes and biomasses calculations: The biovolume of the different cyanobacterial species was estimated using the method of Bratbak (1985) and using the geometric equation best suited to the cell shape (Smayda, 1978; Rott, 1981).

The geometric shapes may be spherical, cylindrical or pyramidal. The individual biovolume was calculated from the Greatest Axial Linear Dimension or GALD proposed by Reynolds (1984) based on the geometric dimensions and the average measured over hundred individuals Reynolds (1984). The total biovolume of species was calculated from its density as Abundance x biovolume.

The biomass (µgC L^{-1}) was estimated using the biovolume conversion factor of carbon equivalent, assuming that 10^6 μm^3 is equal to 1 µg of fresh material. The biomass of organic carbon represents 12% of the fresh material (Amblard *et al*., 1995).

RESULTS AND DISCUSSION

Physical parameters: Figure 2 shows that the temperature changes in a normal manner and with seasonal low temperatures during Winter reaching 9°C in the North station 1 during January and about 11°C in the center 2 and in the South 3 stations. In Summer time, the

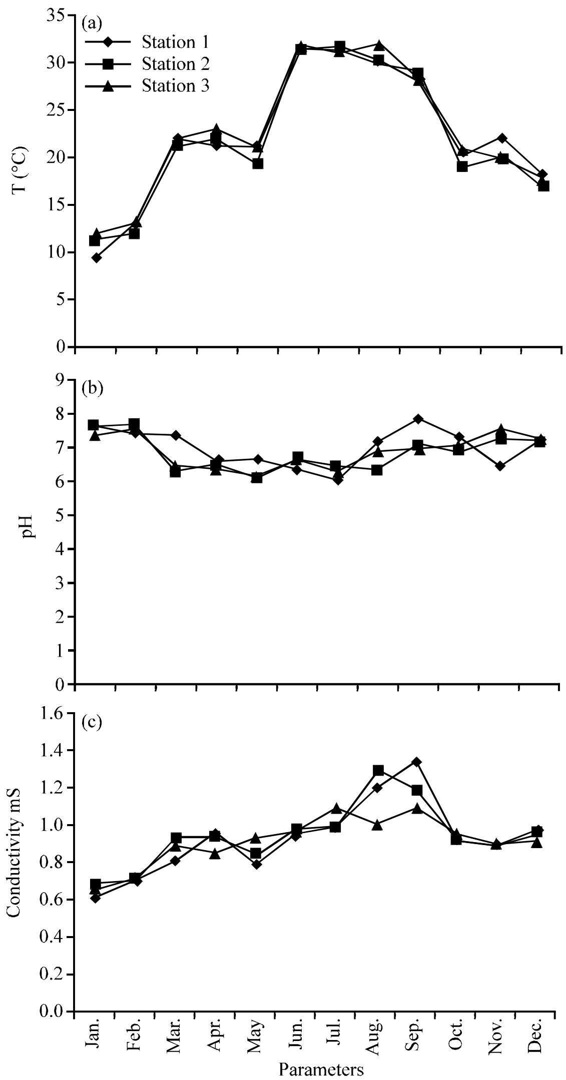

Fig. 2: Evolution of the parameters temperature, pH and conductivity in the three study sites of lake during the study period

temperature was >30°C in the three stations. The Autumn and Spring were the periods of optimal temperatures with an average of about 21°C.

The pH values, recorded during the study period were in general low. They vary between 6.1 and 7.9 during the period of March to August where they were slightly acidic (Fig. 2). From September to February, the values were >7. According to Stumm and Morgan (1996) in freshwater the natural environments are generally buffered to a pH of 7-8.

The conductivity of Oubeira water varied very little during the study period. It ranges from 0.5-1.5 mS cm^{-1} with an average of about 1 mS cm^{-1} in almost all sampling stations (Fig. 2).

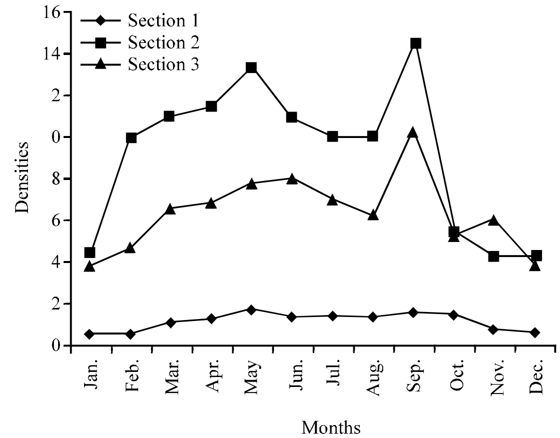

Fig. 3: Total densities evolution (10^4 ind. L^{-1}) of cyanobacteria in the three stations during the study period

Cyanobacteria of Oubeira Lake

Seasonal dynamic: Cyanobacteria are present in the Oubeira on a regular basis whole the year and their evolution seems to follow the same path especially in the center of the lake were they develop the densities of about 14×10^6 cell mL^{-1} in May. Moreover, the seasons of Spring and Summer were the most favorable to the development of cyanobacteria in the lake (Fig. 3).

Spatiotemporal distribution of the species: Researchers were able to identify essentially, seven species of cyanobacteria with a varied spatio-temporal distribution. Table 2 shows the list of species observed in terms of presence absence in all stations. Some species are encountered on a regular basis whatever the season in all stations this is the case of *Aphanizomenon flos-aquae* (L.) Ralfs, *Microcystis aeruginosa* Kutz, *Anabaenopsis elenkinii* (Miller) and *Oscillatoria rubescens* De Condolle. In contrast, at stations 1 and 2, the species *Microcystis elachista*, *Microcystis flos-aquae*, *Anabaena* sp. were observed. In addition some species have been observed sporadically with a very low density (not exceeding 10^3 cell mL^{-1}). Contrary in stations 1 and 2 some common species were observed as *Microcystis elachista*, *Microcystis flos-aquae* and *Anabaena* sp.

Total biomass of cyanobacteria: The maximum biomass production by cyanobacteria at station 3 in July was 130 μgC L^{-1} whereas the biomasses were significantly lower at station 1 and 2 where they reach a maximum of 70 μgC L^{-1} (Fig. 4). As shown in Fig. 4, North station was one that produces less biomass in this lake.

Table 2: List of cyanobacteria species observed according to the sampling stations of Lake Oubeira

Species/Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Chroococcus turgidis (Kuetz) Naegeli	1.3	3	1.3	1.2.3	1.2.3	1.3	1.2.3	1.3	1.3	3	1.3	1.3
Microcystis aeruginosa Kutz	1.3	1.3	1.3	1.3	1.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3
Anabaenopsis elenkinii Miller	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3
Oscilatoria rubescens De Candolle	-	-	3	1.3	1.3	1.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	-
Aphanizomenon flos-aquae (L.) Ralfs	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3	1.2.3

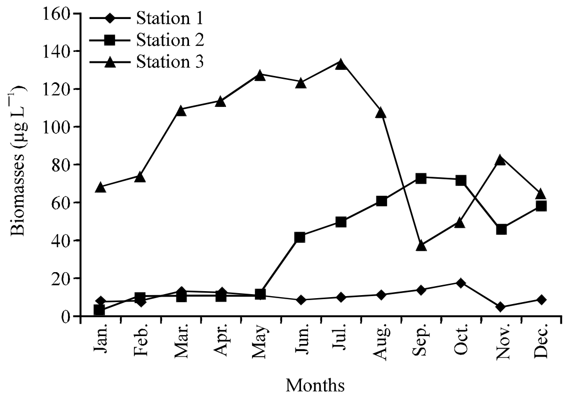

Fig. 4: Total biomass evolution (µgC L^{-1}) of cyanobacteria in the Oubeira Lake

Cyanobacteria specific biomass: Cyanobacteria contributed weakly in the biomass of station 1 with values not exceeding 20 µgC L^{-1}, regardless of the month with a slight dominance of the genera *Aphanizomenon* and *Anabaenopsis*. As for the stations 2 and 3, the biomass was slightly important reaching a maximum of 4 and 6.2 µgC L^{-1} but they were always the same genuses that dominate in the lake. In general, the maximum biomass has occurred during the seasons of Spring and Summer, stimulated by the rise of temperature (Olrik, 1994). Also, the genuses of cyanobacteria that dominate the Oubeira are *Microcystis*, *Aphanizomenon* and to a lesser degree *Anabaenopsis* (Fig. 5). In percentage term, the species *Microcystis aeruginosa* dominates whatever the station with >90% except for the period January to may in the center of the lake were there was a biomass produced mainly by the species *Aphanezomenon flos-aquae* is 42%), *Anabaenopsis* sp. 33%) and *Chroococcus turgidis* about 20% (Fig. 5).

The results demonstrate clearly that the North station was less populated while the stations of the center and the South were higher in cyanobacteria density and thus in the biomass. Indeed, these stations are subject to various inputs of freshwater effluent and the rivers of Messida and Boumarchen which bring the by products (phosphates and nitrogen) of agricultural activity. Also, the vast watershed formed by the mountains of El-Kala from the East and those of El-Frine from the South was causing significant inputs of allochthonous organic matter and of microorganisms that contribute to lake enrichment.

However, fluctuations in densities differ following physical conditions of the environment, including temperature which was a determining factor in the development of cyanobacteria. Temperature variations can have a direct impact on the development of certain phytoplankton species which according to Arrignon (1991) held at preferential thermal intervals more easily knowing that the Oubeira is a shallow lake.

Table 2 shows that some species of Cyanobacteria are present in a regular manner. These species are *Microcystis aeruginosa*, *Anabaenopsis elenkini*, *Aphanezomenon flos-aquae*. In Oubeira Lake during winter, cyanobacteria develop high densities. In Southern station, the highest densities have been recorded with a monthly average of 3.1×10^7 Cell mL^{-1} compared to those of station 2 (2.6×10^7 Cel mL^{-1}). Indeed, the temperature increase during spring allows a resumption of the phytoplankton activity in the center of the lake with a consequent higher biomass. In the South station from March until September, the biomass values were higher, supported mainly by the cyanobacteria.

The biomass varied very little at the station 1 with a minimum of 36 µgC L^{-1} during November with a maximum of production was always recorded during spring period with 87.6 µgC L^{-1}. The character of the region's subtropical climate induces little seasonal variation in abundance, biomass and productivity of phytoplankton species with a marked low succession (Lewis, 1978; Smayda, 1980; Richerson and Carney, 1988). These authors noted however that biological processes may fluctuate endogenously in the absence of external environmental fluctuations.

The introduction of the *Hypophthalmichthys molitrix* in Oubeira Lake was probably the cause of cyanobacteria dominance because there was a reduction in N/P ratio which according to Sanders *et al.* (1980) enables atmospheric nitrogen-fixing cyanobacteria to proliferate (Zehr *et al.*, 2001) and then dominate in aquatic systems where the N:P ratio was 5:1 (Findlay *et al.*, 1994) and or the pH was >8 (Prescott *et al.*, 1995). According to Chorus and Bartram (1999), the presence of cyanobacteria in considerable amount was usually accompanied by an increase in biomass and therefore a high production of toxins that could generate poisons to animals and humans. The biodiversity and the irregularity in the frequency of occurred species in the Oubeira might be explained according to Bourrelly by a specific feature for

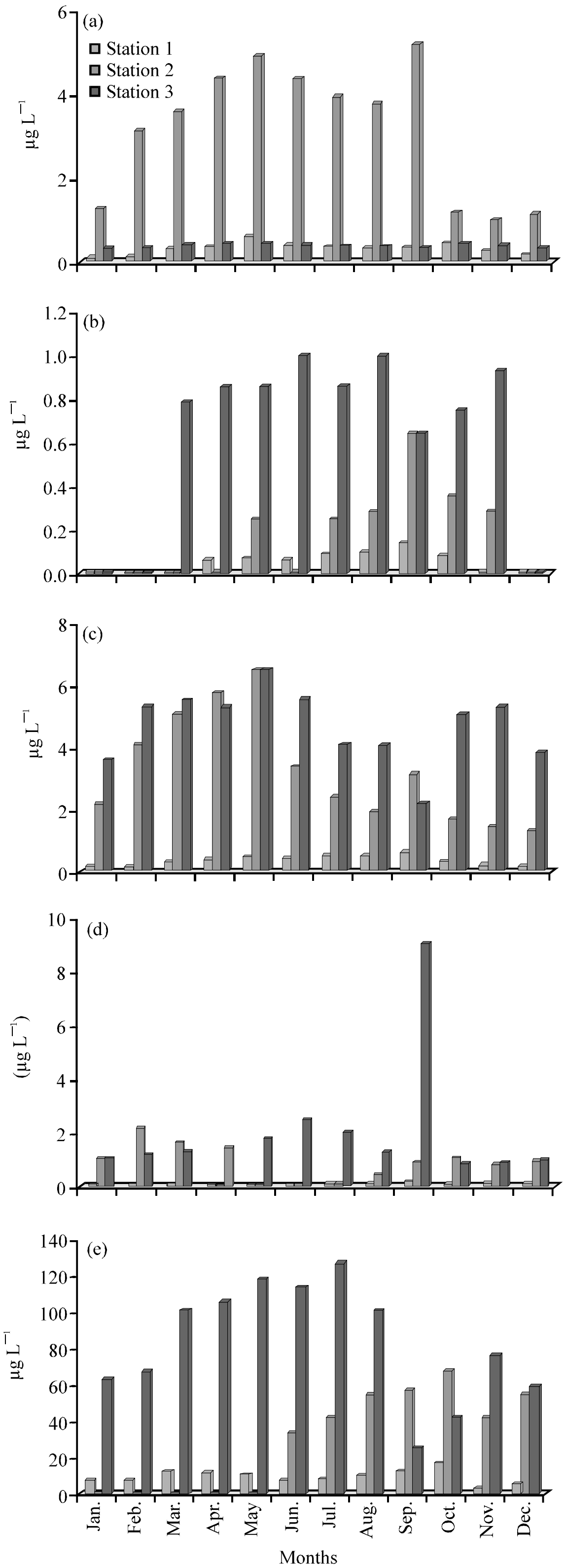

Fig. 5: Evolution of biomass of different species of cyanobacteria in the three stations of the Oubeira

each aquatic ecosystem. It proves that every genus shows different adaptive capacities in relation to local different environmental conditions. Temperature is the factor that regulates the cyanobacteria success in tropical and subtropical lakes (Huszar *et al.*, 2000; Komarkova and Tavera, 2003) and in Mediterranean areas (Lopez-Archila *et al.*, 2004; Romo *et al.*, 2005). However, counted a maximum of 3×10^6 Cell mL^{-1} of cyanobacteria in April with a predominance of the genus *Microcystis* followed by the genus *Anabaena* and *Oscilatoria* which has been confirmed by the actual study. According to Murphy *et al.* (1976) some species of the genus *Anabaena* and *Microcystis* can be dominant because they secrete a chelating agent which increases their growth or prevents directly those of the competing algae or both effects simultaneously.

Moreover, the water high temperature (25°C) of Oubeira Lake could support the algal growth according to Robarts and Zohary (1987). These researchers reported that direct effects of temperature were secondary compared to the indirect effects of nutrients for the determination of cyanobacteria bloom (very punctual in the Oubeira Lake). In many lakes there has been the dominance of cyanobacteria in high temperatures during summer period (Albay and Akcaalan, 2003; Chen *et al.*, 2003; Roelk *et al.*, 2004). Thus, the domination and regular presence of cyanobacteria could mean a real presence of toxins. Algal blooms, therefore, constitute a real threat to public health because according to Kotak *et al.* (1996) there is a strong correlation between the abundance of cyanobacteria in water and the concentration of cyanobacterial toxins (Kotak *et al.*, 1996).

CONCLUSION

It can be said that Lake Oubeira presents very favorable conditions for the development of cyanobacteria. The continuous presence of cyanobacteria and their occurrence in large quantities requires the establishment of a monitoring program. Such a program may allow continuous monitoring of water with regular control of water physico-chemical parameters. The quantities and the spatio-temporal dynamics of cyanobacteria must be controlled especially during the bloom period. Thus, the potential risk they may pose to public health will be achieved.

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