Advances in
Biotechnology & Microbiology
ISSN 2474-7637

Juniper Publishers
key to the Researchers

Research Article
Volume 16 Issue 4 - August 2021
DOI: 10.19080/AIBM.2021.16.555941

Adv Biotechnol Microbiol


# Phytoplankton structure and *cyanobacteria* specific composition of Foum-Gleita Lake, Mauritania

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**Submission:** July 27, 2021; **Published:** August 23, 2021

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**Abstract**

In order to study the structure and the relative abundance of *phytoplankton* and the specific composition of *cyanobacteria* in the Foum-Gleita Lake, the surface waters of this Lake were subject of a regular monthly sampling extending over 12 months, from September 2017 to August 2018. Analysis of the phytoplankton by inverted microscopy method identified 28 taxa distributed over six phyla (*Chlorophyta, Cyanobacteria*, *Bacillariophyta, Cryptophyta, Miozoa* and *Euglenozoa*). However, analysis of the *Cyanobacteria* by same method showed that this phylum is specifically composed of eight genera (*Microcystis, Gloeocapsa, Chroococcus*, *Dolichospermum*, *Oscillatoria*, *Planktothrix*, *Lyngbya*, and *Arthrospira*), five of them are recognized as potentially toxic (*Microcystis, Dolichospermum*, *Oscillatoria*, *Planktothrix* and *Lyngbya*) and are mainly dominated by the species *Microcystis aeruginosa* and *Dolichospermum flos-aquae* during the hot season (May to September).

**Keywords:** *Phytoplankton*; *Cyanobacteria*; Abondance; Lake; Foum-Gleita; Mauritania

## Introduction

The surface waters are often subject to eutrophication, mainly due to the various sources of pollution and to the natural process of soil erosion providing various elements, which can be at the origin of the deterioration of quality of these waters [1]. This growing phenomenon is manifested by massive proliferation of phytoplankton, in particular the blooms of *cyanobacteria* which have very wide geographic and ecological distributions [2]. In Mauritania, the state of the lakes is very little studied while they receive an increasing volume of waste, in particular nutrients especially phosphorus (P) and nitrogen (N). For a long time, the Foum-Gleita Lake has been subject of significant demographic pressure due to arrival of the nomad's victims of growing drought in the Sahel. After several years of domestic, agricultural and industrial use of this lake, previous surveys have shown that its waters are evolving towards eutrophication [3]. The objective of this work is to study the structure and the relative abundance of phytoplankton and the specific composition of *cyanobacteria* in the surface waters of Foum-Gleita Lake (Mauritania).

## Materials and Methods

### Studied area and sampling

Foum-Gleita Lake is geographically encamped in southern part of Mauritania between latitudes 16°15' N and 16°03' N and longitudes 12°39' W and 12°32' W (mean altitude: 32 m). Precisely, it is located in the Gorgol region, at the department of M'bout, 120 km east of Kaédi (capital of the region), and 520 km southeast of Nouakchott (capital of the country). Its water body is 160 $km^2$ (normal area) and 50 $km^2$ (minimum area) and has a storage capacity of 1 billion m3 of water. The watershed of studied lake is located between latitudes 15°50' N and 17°40' N and longitudes 11°40' W and 12°35' W, with a total area of approximately 21,000 $km^2$ and a 180 km long; The watershed crosses soft (clayey) but also hard (rocky) formations. The watershed climate is characterized by a long dry season (8 months), high temperatures (22 to 44°C), low rainfall (180 to 400 mm/year), long sunshine period (290 days/year), permanent winds (3 to 7 m/s) and the presence of a phosphate mine (94,500 ha). Socio-economically, Foum-Gleita Lake plays a key role in the irrigation of cultivated areas (11,200 ha), the supply of drinking water (26,500 inhabitants), the animals drinking (53,300 heads) and in the practice of continental fishing for a production of 800 tonnes/year. Ecologically, this lake plays an important role for birds (nesting and migrating), mammals, reptiles and insects. In this lake, the sampling was carried out between September 2017 and August 2018 in four different sites (S1, S2, S3 and S4) chosen according to their accessibility (Figure 1), at the rate of a monthly sampling per site. The samples were taken from the surface (0.1-0.5 m). The phytoplankton concentrates were sampled using a plankton net with a 20-µm mesh gap according to the method described in Briand et al. [4]. Upon arrival at the laboratory, the samples are stored at 4°C until analysis.

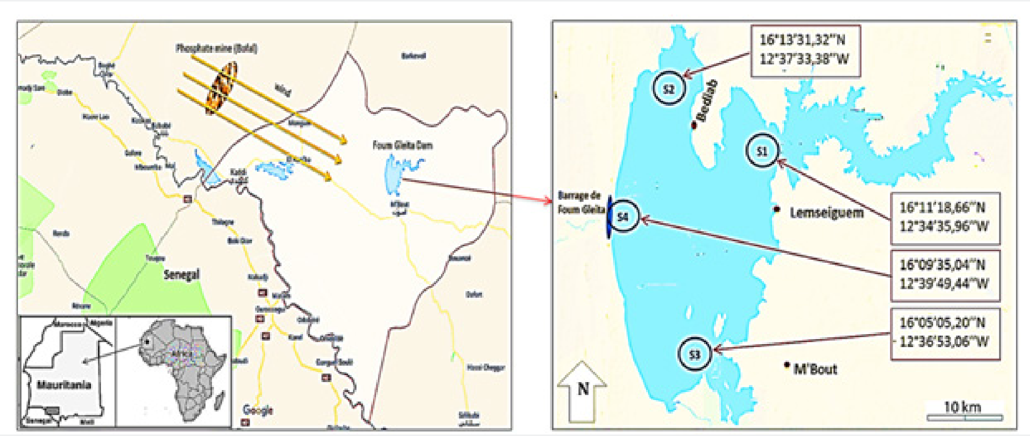


**Figure 1:** Localization of all sampling sites (S1, S2, S3 and S4) in the surface water of Foum-Gleita Lake.

## Phytoplankton analysis

Identification and enumeration of phytoplankton was performed using inverted microscopy following Utermöhl's method [5]. For each preserved phytoplankton sample, 10 mL aliquots were settled for 24 hours on a gridded chamber before being visually scanned on an inverted microscope (Leitz, Fluovert) at 20x and 40x. The two dominant *cyanobacteria* taxa have been identified at the species level, while the other minor ones have been identified only at the genus level, using universally accepted taxonomic keys [6-9], and then all have been quantified with a minimum of 100 units counted per sample. The biovolume (mm3/L) of *Microcytis sp*., *Dolichospermum sp*., *Oscillatoria sp*. and *Planktothrix sp*. was then estimated. Briefly, the mean number and the dimension of cells from 50 Microcystis colonies and 50 *Dolichospermum* filaments per sample were estimated. For *Oscillatoria* and *Planktothrix*, the average length and width of 50 filaments per sample were also estimated. The biovolume of each taxa was calculated by assuming each cell as sphere for *Microcystis* and *Dolichospermum* and each filament as a cylinder for *Oscillatoria* and *Planktothrix species*. The number of cells per liter for Microcystis and *Dolichospermum species* and filaments per liter for *Oscillatoria* and *Planktothrix* species were then multiplied by the average cell and filament biovolume [10]. Other phytoplankton groups were identified according to the morphological characteristics described in Bourrelly, Reynaud, Laloë, and Olenina [11-15], and then quantified as cell per liter with a minimum of 100 units counted per sample.

## Results

### Structure and relative abundance of phytoplankton in Foum-Gleita Lake

The monthly monitoring of the evolution of phytoplankton in Foum-Gleita Lake, allowed us to identify 28 taxa spread over six phyla among which we cite *Chlorophyta, Cyanobacteria, Bacillariophyta, Cryptophyta, Miozoa* and *Euglenozoa* (Table 1). The qualitative analysis of phytoplankton present in the water samples from the four sampling sites made it possible to obtain the specific composition shown in Figure 2. Within this composition, *Chlorophyta* is the most present phylum. It represents 42 to 50% of the total number of phytoplankton species. This phylum is mainly dominated by *Desmidiales*, in particular the genera *Closterium*, *Staurodesmus* and *Staurastum*. Site 1 has the highest density of *Chlorophyta* compared to sites 2, 3 and 4, respectively. *Cyanobacteria* represents the second phylum (17 to 32%) with higher densities at sites 4 and 3 than at other sites 2 and 1, respectively. Principally, this phylum is represented by the genera *Microcystis*, *Gloeocapsa, Chroococcus, Dolichospermum, Oscillatoria, Planktothrix, Lyngbya*, and *Arthrospira*. *Bacillariophyta* phylum occupies the third position after *Chlorophyta* and *Cyanobacteria* where they represent 11 to 13%. It is essentially dominated by *Pennatophycidae*, in particular the genera *Pinnularia, Fragilaria* and *Gomphonema*, with higher densities on site 2 compared to other respective sites: 1, 3 and 4. *Cryptophyta phylum* represents the fourth class (7 to 9%).


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This phylum is mainly represented by the genera *Cryptomonas* and *Rhodomonas*. Miozoa phylum represented by the genera *Prorocentrum* and *Symbiodinium* come in fifth position where it represents 5 to 6% of the total number of *phytoplankton species*. Euglenozoa phylum constitutes only 3 to 5% of the phytoplankton encountered and is dominated by the genus Euglena.

**Table 1:** Inventory of phytoplankton in Foum-Gleita Lake.

| Phyla | Orders | Genera Or Species |
|---|---|---|
| *Chlorophyta* | *Chlorochoccales* | *Scenedesmus spp.* |
| | | *Monoraphidium spp.* |
| | | *Oocystis spp.* |
| | | *Pediastrum sp.* |
| | | *Kirchneriella spp.* |
| | *Desmediales* | *Closterium spp.* |
| | | *Cosmarium sp.* |
| | | *Staurastrum spp.* |
| | | *Staurodesmus sp.* |
| | *Zygnématales* | *Mougeotia sp.* |
| *Cyanobacteria* | *Nostocales* | *Dolichospermum flos-aquae* |
| | *Chroococcales* | *Microcystis aeruginosa* |
| | | *Chrococcus spp.* |
| | | *Gleocapsa spp.* |
| | *Oscillatoriales* | *Oscillatoria sp.* |
| | | *Planktothrix sp.* |
| | | *Lyngbya sp.* |
| | | *Spirulina spp.* |
| *Bacillariophyta* | *Cymbellales* | *Gomphonema sp.* |
| | *Fragilariales* | *Fragilaria sp.* |
| | *Naviculales* | *Gyrosigma sp.* |
| | | *Nitzchia sp.* |
| | | *Pinnularia sp.* |
| *Cryptophyta* | *Cryptomonadales* | *Cryptomonas sp.* |
| | | *Rhodomonas spp.* |
| *Miozoa* | *Prorocentrales* | *Prorocentrum sp.* |
| | *Suessiales* | *Symbiodinium sp.* |
| *Euglenozoa* | *Euglenales* | *Euglena sp.* |


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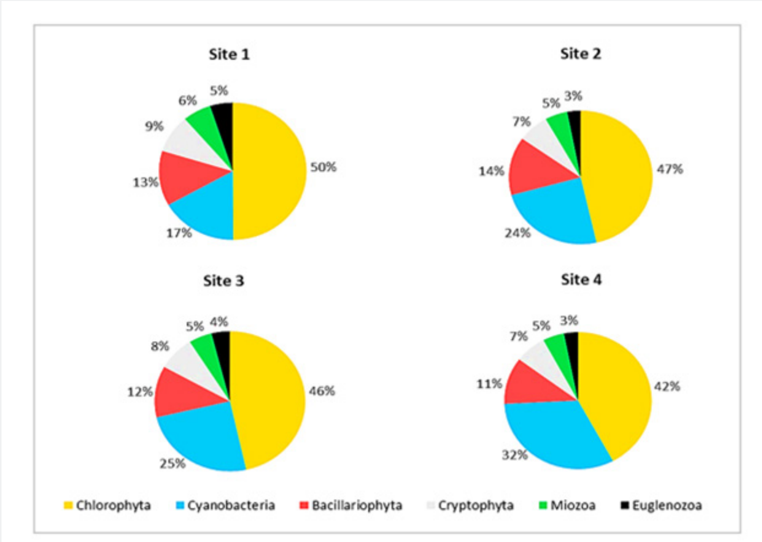


**Figure 2:** Structure of *phytoplankton* in the surface water of Foum-Gleita Lake.

In addition, the analysis of spatiotemporal evolution of relative abundance of the different phytoplankton phyla (Figure 3), revealed the dominance of *cyanobacteria* on sites 3 and 4 during the hottest months of the study period (August, September and October).

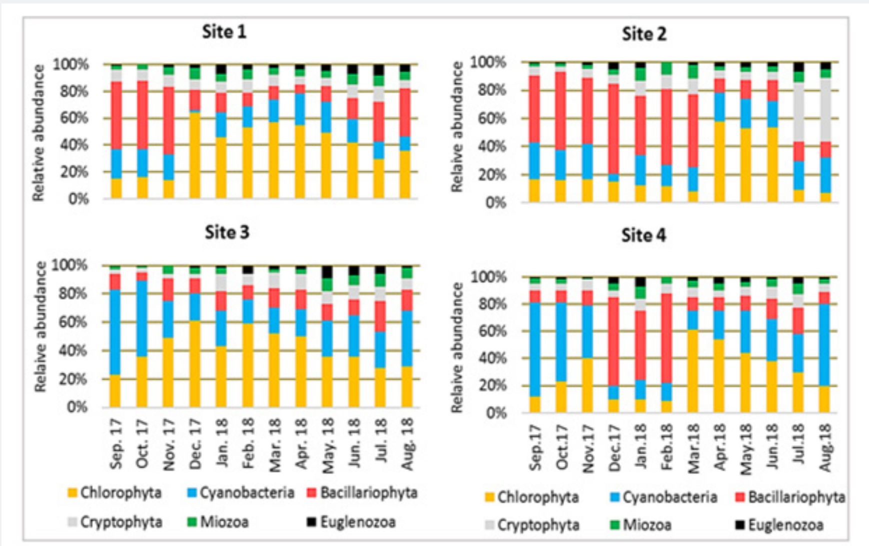


**Figure 3:** Spatiotemporal variations of the relative abundance of *phytoplankton* in Foum-Gleita Lake.

## Specific composition of cyanobacteria in Foum-Gleita Lake

The *cyanobacteria* observed in Foum-Gleita Lake during the period of this study consisted of 8 genera (Figure 4), three having a colonial form (*Microcystis, Gloeocapsa* and *Chroococcus*) and five having a filamentous form (*Dolichospermum, Oscillatoria, Planktothrix, Lyngbya,* and *Arthrospira*). The two genera, Microcystis and *Dolichospermum*, which represent respectively 38 and 48% of total number of the *cyanobacteria* species, however, showed a constant presence in the different sampling sites throughout the study period. They were exclusively represented by the species *Microcystis aeruginosa* and *Dolichospermum flos-aquae*, respectively. The two genera *Gloeocapsa* and *Chroococus*, which respectively constitute 8.3% and 5.3% of the total number of cyanobacteria, also remained present throughout the study period, but with fairly low average densities. However, the two genera *Oscillatoria* and *Planktothrix*, which total only 0.4% of the total number of cyanobacteria, showed an irregular monthly presence. The genus *Oscillatoria* only appeared in samples from


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all four sites during the first three months of the study. The genus *Planktothrix* was only present at sites 2, 3 and 4, with very low irregular densities. The two genera *Arthrospira* and *Lyngbya*, which together represent only 0.02% of the total number of *cyanobacteria*, accidentally appeared only once at site 3, with low densities.

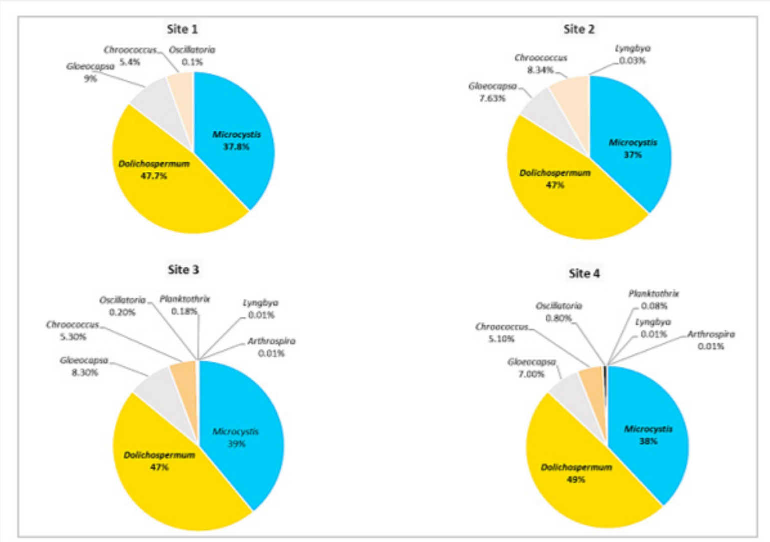


**Figure 4:** Specific composition of *cyanobacteria phylum* in Foum-Gleita Lake.

In addition, we note in the Foum-Gleita Lake the massive presence of potentially toxic *cyanobacteria* detected from monthly samples over an annual cycle. Analysis of their occurrence in this lake (Table 2) showed that the first two genera, Microcystis and *Dolichospermum*, were ubiquitous, the third, *Oscillatoria*, and the fourth, *Planktothrix*, were irregular. While the last one, *Lyngbya*, was accidental.

However, the analysis of natural samples during the periods of strong development of these toxic *cyanobacteria* showed that the main species responsible for the blooms in the prospected lake were Microcystis *aeruginosa* and *Dolichospermum flos-aquae*. Its blooms appear in summer to reach their maximum proliferation in September with significant annual variability in biomass. The highest biovolumes of these two dominant species, *D. flos-aquae* and *M. aeruginosa*, were observed when the DIN/TP ratio was less than 10 and the water temperature reached 30°C (Figure 5).

**Table 2:** Occurrence of toxic cyanobacteria in Foum-Gleita Lake.

| Genera | Species | Occurrences | Observations |
|---|---|---|---|
| *Microcystis* | *Microcystis aeruginosa* | 100% | Omnipresent |
| *Dolichospermum* | *Dolichospermum flos-aquae* | 100% | Omnipresent |
| *Planktothrix* | *Planktothrix sp.* | 21% | Irregular |
| *Oscillatoria* | *Oscillatoria sp.* | 15% | Irregular |
| *Lyngbya* | *Lyngbya sp.* | 1% | Accidental |

## Discussion

The structure of phytoplankton and the spatiotemporal variations in phytoplankton densities observed in the Foum-Gleita Lake during the period of this study is a logical response to the seasonal change in the physicochemical conditions of the environment, where the growth of phytoplankton depends on temperature, nutrients and light. Microscopic analysis of the water samples showed that the phytoplankton of Foum-Gleita Lake was mainly composed of a *Chlorophyta/Cyanobacteria* assemblage, with some genera of Bacillariophyta. Other phyla such as *Cryptophyta*, Miozoa and Euglenozoa were also present but with much less importance, although local short-term developments can sometimes observed, as for *Cryptophyta* phylum at site S2


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in July-August. Globally, *the phytoplankton* in Foum-Gleita Lake was quantitatively dominated by *Cyanobacteria* phylum during the rainy period (July-September) especially in sites S3 and S4 where anthropological pollution was most important with high concentrations of Dissolved Inorganic Nitrogen (6.53 and 8.22 mg/L, respectively) and Total Phosphorus (0.56 and 0.59 mg/L, respectively) combined with elevated water temperature (30.4 and 30.7°C , respectively) [3]. However, when the water temperature begins to drop during the dry season months (November-April), *Chlorophyta* become the dominant phylum in these sites (S3 and S4) although *cyanobacteria* are still present as the second phylum with relative abundances of 17-29%. In the other two sites, S1 located at mouth of the Gorgol Noir River and S2, far from any anthropogenic pollution, the phytoplankton community was characterized by a distinct abundance succession of *Bacillariophyta/Chlorophyta*. However, *Cyanobacteria* were always present in third position except in the S2 site in July-August where they were present in fourth position after *Cryptophyta*. These results are in accordance with other studies, which have shown that phytoplankton succession in tropical aquatic ecosystems is characterized by a distinct change between dry and rainy seasons: *Chlorophyta/Cyanobacteria* in Lake Tanganyika in Tanzania [16], *Bacillariophyta/Cyanobacteria* in Lake Victoria in Kenya [17] and in Lake Guiers in Senegal [18]. While in temperate regions such as North Africa, phytoplankton communities were dominated by *Bacillariophyta* phylum in winter and *Chlorophyta* phylum in spring-summer, succeeded by *Cyanobacteria* phylum in autumn [19,20].

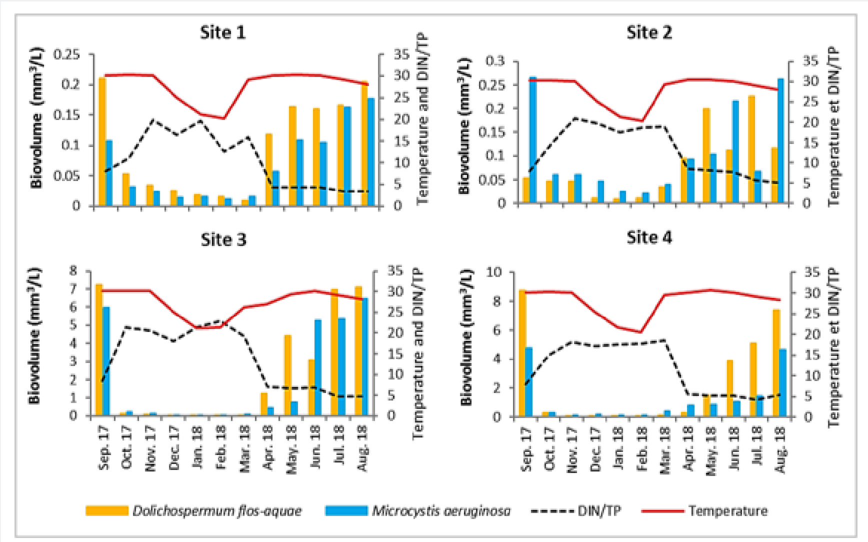


**Figure 5:** Abundance of *Dolichospermum flos-aquae* and *Microcystis aeruginosa* in Foum-Gleita Lake as a function of temperature and DIN/TP ratio.

In other regions such as Europe and America, an analysis of data from 143 lakes showed that *cyanobacteria* biomass increases sharply with temperature in lakes with high rates of light absorption [21]. In addition, Jankowiak et al. [22] reported that *cyanobacteria* abundance in Lake Erie (international border between Canada and United States) increased dramatically in response to an increase in nitrogen, with large increases combined at high concentrations of nitrogen and phosphorus, and water temperature. In contrast, Almanza et al. [23] showed that certain genera of *cyanobacteria* such as *Aphanizomenon, Aphanocapsa, Aphanothece* and *Dolichospermum* can form blooms in the freshwater ecosystems of south-central Chile at low temperatures in autumn and winter (10,8- 15.6 °C), which suggests that eutrophication is the main factor in the proliferation of these genera regardless of water temperature.

The cyanobacterial community of Foum-Gleita Lake was mainly composed of *Dolichospermum flos-aquae* and *Microcystis aeruginosa*, which were known among the most microcystin-producing (MCs) and bloom-forming species in the world [24]. The growth trend of these two dominant species followed the same pattern at all four sites (S1 to S4); showing low abundance between December and February when the water temperature was a little lower (around 22°C). However, the biovolume of both species begins to increase in parallel with temperatures from March to peak in August and September when the water temperature reaches 30°C. In non-limiting Nitrogen and Phosphorus ecosystems like our lake, high water temperatures can promote the development of *cyanobacteria* by maximizing their growth rates compared to other phytoplankton phyla [25]. Although the growth trend of *Dolichospermum flos-aquae* and *Microcystis aeruginosa* in this lake was similar in the four sampling sites, their biovolume was approximately 30 times higher in sites S3 and S4. This difference in spatial dynamics could be explained by the fact that S3 and S4 were the sites most exposed to anthropogenic pollution.


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## Conclusion

The present study has contributed to understanding, for the first time, the structure and the seasonal variations of phytoplankton community of the surface waters of Foum-Gleita Lake. It showed that the phytoplankton taxocenosis of this lake is poorly diversified (28 taxa spread over six phyla). It also revealed a period of strongest phytoplankton development extending from May to September. In addition, this study identified 8 taxa of *cyanobacteria* dominated in summer-autumn by the two toxic species, *Microcystis aeruginosa* and *Dolichospermum flos-aquae*. This situation is probably linked to the urbanization, the agricultural activities, the phosphate mines present in the watershed of the lake and the increase in water temperature due to the global change. The massive presence of *Microcystis aeruginosa* and *Dolichospermum flos-aquae*, which are potentially toxic, in this lake, clearly demonstrates the need for regular monitoring of *cyanobacteria* and cyanotoxins in the waters of this lake.

## Acknowledgment

J.L. Gomez Pinchetti thank the support of the European Territorial Cooperation Program PCT-MAC 2014-2020 through the project REBECA-CCT (MAC/1.1.B/269).

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