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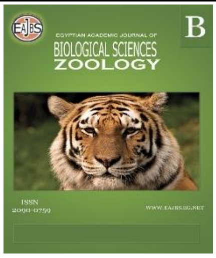

Phytoplankton Biodiversity and Its Relationship with Aquatic Environmental Factors in Lake Sidi Mhamed Benali of the Wilaya of Sidi Bel Abbes (North-West of Algeria)

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ABSTRACT

Our work consists in characterizing the phytoplanktonic biodiversi of lake Sidi Mhamed Benali, also, biotic parameters were employed to asse lake trophic conditions, by Multivariate Analysis and by the ecological indice during the period which extends from March to May 2021.The results of t phytoplankton analysis allowed us to list 89 species divided into 6 class (Diatoms, Chlorophyceae, Euglenophyceae, Cyanophyceae, Cryptophyceae ar Dinophyceae).The general composition of the phytoplankton of the lake dominated by Diatoms with 34 taxa, or 36.62% of the phytoplankto community, represented mainly by the following genera: Cyclotella, Nitzsch and Fragilaria, followed respectively by Chlorophyceae with 25 taxa, or 31.81 of the total population, they are represented mainly by Oocystis, Tetraspora ar Closterium, Eugenophyceae with 13 taxa, a proportion of 12. 82%, tl Cryptophyceae: groups 5 taxa, with a proportion of 10.44%, the Cyanophycea counts 9 taxa, with a proportion of 6.88%, the Dinophyceae which groups 3 tax with a proportion of 1.42%. Moreover, the waters of the lake are classified waters of average quality and are in as hypereutrophic state.

INTRODUCTION

Phytoplankton not only play important role in aquatic ecosystems but also serve as key indicators for water quality assessment (Cadotte,2014).
Phytoplankton is the primary producer in lake ecosystems, producing oxygen and organic matter through photosynthesis (jiang, 2011).

Seasonal changes in plankton communities have been found (Lv, 2011), which are performed not only as changes in species number, density, biomass and diversity but also as seasonal changes in community structure (Vallina, 2017). Moreover, the dominant species of phytoplankton may also change between different seasons within a year (Ye, 2014).

These changes are mainly influenced by physical-chemical (bottom-up effects) and predation (top-down effects) through the aquatic food web (Doi, 2013). The factors that regulate phytoplankton seasonality can be difficult to predict due to the many biotic and abiotic interactions that act singly or in concert, and influence population growth, dispersal, and survival (Reynolds, 2006). As with most organisms, specific phytoplankton populations are more likely to dominate assemblages when environmental factors favor their key natural-history requirements Emon Butts 2017; in extreme cases (Carrick and Review, 2011), these peak conditions can lead to the occurrence of seasonal blooms, phytoplankton blooms have shown to be induced by physical factors such as water column light availability and stability (Millie *et al*. ,2014) Seasonal phytoplankton blooms and sensitivity to changing climatic conditions have been documented in both marine and freshwater ecosystems (Winder *et al* ., 2012).

MATERIALS AND METHODS

1-Presentation of the Study Area:

Located 1.7 km northwest of the city of Sidi-Bel-Abbès (in western Algeria), on a plateau at an altitude of 460 m, Lake Sidi M'hamed Benali (35°23' North and 0°64' West) (Bouzidi *et al*., 2010), because of its biological richness and its natural functions, it constitutes an exceptional natural heritage of this city (Fig.1).

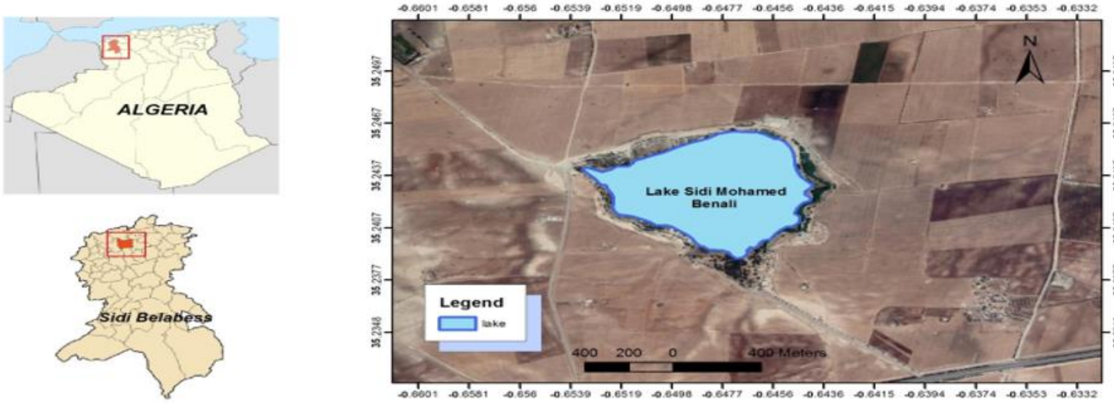

Fig. 1: presentation of the study area

This lake has a strictly anthropic origin. It is fed in large part by the canal created in the 1940s between the Wadi Mekerra and the Wadi Sarno (Mhamdia, 2016).

In full water, the lake extends on about fifty hectares. Its maximum depth is around 30 m. It has a capacity of 3 million m3 and its depth reaches 30 meters (Baki, 2016). The Sidi Mhamed Benali Lake is one of the most important natural reserves of the Algerian West which is subjected to urban and rural impacts which involve a certain imbalance and a visible degradation from where the interest and the choice of this study (El badaoui, 2016). The lake is surrounded by agricultural land that receives large doses of fertilizer and carries abundant livestock. In addition to the pollution generated by these activities, there is also pollution related to the lake's tourist attraction (Chiali and Cherifi, 2019). Nevertheless, in recent years, the waters of the dams and lakes are threatened by pollution problems of anthropic origin (urban discharges, industrial activities, agriculture, etc.) (Mc Kinney, 1984).

2-Methodology and Equipment Used:

Water sampling was performed using a 1-liter PVC Van Dorn bottle, remotely controlled from a boat.Temperature (°C), pH (pH unit), dissolved oxygen (mg/l), and conductivity (µSiemens/cm) was measured with a Loviband multi-parameter. Transparency is measured in the field by the Secchi disc disappearance depth.The hydrometric title (°F) is realized by an ammonia determination.The complete alkalimetric title (°F) by a determination with hydrochloric acid.

As for the nutrients, the nitrates (mg /1) are measured by photometric determination of a phosphomolybdic complex after reduction with ascorbic acid.

The determination of ammonium contents (mg l/l) is carried out by mineralization with sulfuric acid, distillation and colorimetry with indophenol blue.

Orthophosphate concentrations are determined by colorimetry with sulfomolybdic reagent (Rodier, 1984).

Chlorophyll (a) content (μg/l) is estimated by the spectrophotometric method, after extraction of the pigment with 90% acetone (Lorenzen, 1967).

3-Choice of the Sampling Principle:

Sampling can be done by a number of principles: the sampling of water point by point, in order to analyze the different Physico-chemical parameters of the water as well as the determination of the different phytoplanktonic communities.

3.1-Water Sampling:

Water and phytoplankton samples are taken during each surface survey, in the different stations. Different physical parameters were taken on site: temperature (air and water), pH, electrical conductivity, salinity and dissolved oxygen. All these parameters are measured in situ with a multi-parameter analyzer type WTW 340 I.

In addition, the transparency of the Secchi disk measures the light penetration in a lake, which is reduced by: turbidity, color, algae (C.C.M.E, 2011).

In the laboratory, the same water samples were subjected to different analyses in order to measure the concentration of nutrient salts: Nitrates (NO3-), Nitrites (NO2-), Phosphates (PO43-) and ammoniacal nitrogen (NH4+).

3.2-Conservation and Analysis of Water Samples:

The samples are placed in clean bottles and kept at a low temperature of 4°C in coolers. Analyses are done in the aquatic ecosystem laboratory of the CNRDPA, according to Rodier *et al.*, 2005 (Rodier *et al.*, 2005). L'analyse for the determination of nutrient salts.

4-Study of Phytoplankton:

4.1-Phytoplankton Sampling:

The phytoplankton studied were collected at the surface using a phytoplankton vacuum net with a mesh size of 20 μm.

4.2-Preservation of the Samples:

The phytoplankton sample was fixed with a solution of lugol to obtain a final concentration of 1% in the sample.

4.3-Preparation of the Sample:

The sample and the material used (sedimentation chamber) are put at the same room temperature in order to allow random sedimentation of the phytoplankton in the sedimentation chamber. The sample is then gently shaken about ten times to homogenize its content and then poured into the sedimentation chamber. A 10 ml chamber is used, the chamber thus filled, is left in the dark, in a place without vibration to allow correct sedimentation of the sample.

The sedimentation time is 4 hours per cm of height of the sedimentation column for a freshwater sample fixed with Lugol. A 10 ml sample should sediment for 4 hours (CEMAGREF, 2011).

4.4-Identification and Counting of Biological Parameters:

The analysis of phytoplankton is done according to the recommendations of the standard guide for the enumeration of phytoplankton by inverted microscope (said to be inverted because the objectives point upwards); standard NF en 15204 of December 2006, corresponding to the method of Utermohl (UTERMOHL, 1958). under an inverted microscope. The results are expressed in the number of algae and cells per liter of raw water.

Settlement Organization and Structure:

To evaluate the phytoplankton community structure of the study area, the following ecological indices were used: Species richness, species density, abundance, relative frequency, Shannon diversity index H', equitability index E and Rank-frequency diagrams.

RESULTS AND DISCUSSION

1-Summary of Abiotic Parameters:

The quality of the waters of Sidi Mhamed Benali Lake has been evaluated according to the Physico-chemical parameters studied previously, it is determined by comparing our results to the limits of the water quality grid of the natural water bodies of SEQ (France) which are shown in Table (1).

According to Table (1), the averages of the abiotic parameters during the period of study, show that the waters of Lake Sidi Mhamed Benali are also of Average quality.

Table 1: Water quality standards of natural water bodies (SEQ-EAU) and the averages found in the studied site during the year 2021.

Quality elements(=Alterations) Parameters		Lower limits					Lake Sidi Mhamed Benali
		Bad	Médiocre	Medium	Good	Very good	
Oxygen balance	Dissolved Oxygen (mg/l)	< 3	3	4	6	8	4,65
Materials phosphorus (mgP/l)	Phosphates	>1	1	0.5	0.2	0.05	1.2
Matter Nitrogenous (mgN/l)	Nitrates	>16.94	16.94	11.3	5.65	1.13	4,76
	Nitrites	>0.3	0.3	0.16	0.09	0.03	0, 3
	Ammoniacal nitrogen	>3.9	3.9	1.56	0.39	0.078	1,88
Température	Température	>28	28	25	21.5	20	8 (°C)
Acidification	pH	>4.5	4.5	5.5	6	6.5	7,80

2-Multivariate Analysis of the Physico-chemical Data of The Water:

To visualize more easily the influence of environmental parameters on the growth and phytoplankton dynamics of the waters of Sidi Mhamed Benali Lake, principal component analyses were performed by considering the data of Physico-chemical parameters separately.The figures obtained are based on the correlation coefficient. In our analysis, we retained 9 Physico-chemical parameters. The PCA was done on centered data and reduced with respect to their average. The use of normalized data allows for getting rid of the measurement units which are heterogeneous in our case. The correlation matrix (Fig. 2) shows the distribution of the Physico-chemical parameters on two factors (F1 and F2). The coordinates of the variables on the axes are the correlation coefficients between the variables and the factors. This matrix shows that,the F1 axis percentage of inertia 60.17% for the Sidi Mhamed Benali Lake describes essentially the following parameters: phosphates, conductivity and salinity, dissolved oxygen, nitrates, ammonium, chlorophyll "a" and O2 saturation rate (%), which are negatively correlated with, water transparency and temperature, pH and nitrites.The F2 axis percent inertia 24.64% describes the following parameters: chlo "a", ammonia nitrogen dissolved oxygen and water temperature and pH which are negatively correlated with transparency, conductivity salinity, saturation rate (O2%), nitrite, nitrate and phosphates.

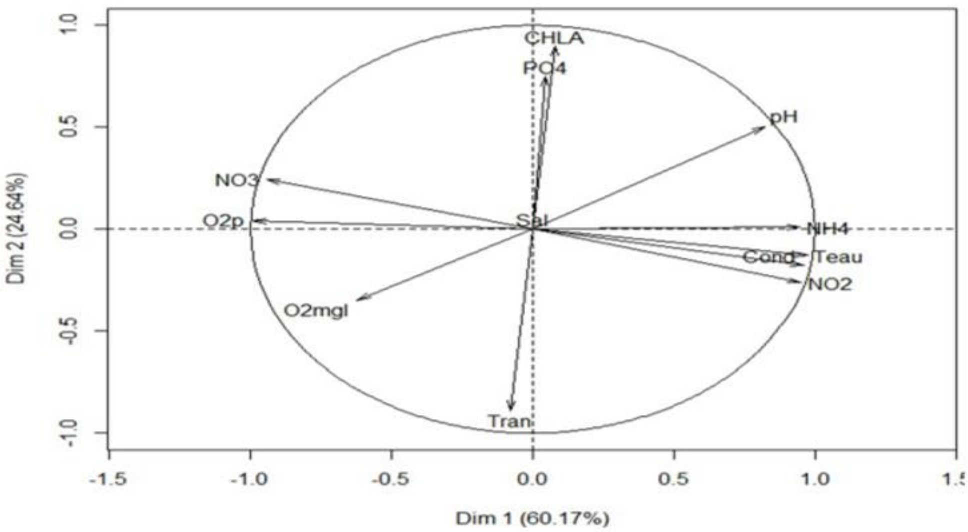

Fig.2: PCA of Physico-chemical variables (factors 1 and 2) % Total inertia: 84.81.

3- Evaluation of The Trophic Status:

According to the criteria established by the O.C.D.E. (1982), based on Secchi depth and chlorophyll "a" concentration, the trophic status of our study site can be deduced. According to the classification table of the trophic state (Table 2), we notice that the Sidi Mhamed Benali Lake is in a hypereutrophic state.

Table 2: Trophic state of the Sidi Mhamed Benali Lake according to the criteria of the O.C.D.E. (1982).

Classification	Average In-Lake Total P (ug P/L)	Average Secchi Depth (m)	Average Planktonic Algal Chlorophyll (ug/L)
Oligotrophic	< 7.9	> 4.6	< 2
Oligotrophic-mesotrophic	8-11	4.5-3.8	2.1-2.9
Mesotrophic	3.0-6.9	3.7-2.4	3.0-6.9
Mesotrophic-eutrophic	28-39	2.3-1.8	7.0-9.9
Eutrophic	>40	<1.7	>10

Study of the Phytoplanktonic Population:

A Qualitative Study of The Population:

After the cellular enumeration of phytoplanktonic species with a diameter greater than 20 µm, we have listed.We have listed 89 species divided into 6 classes (Diatoms, Chlorophyceae, Euglenophyceae, Cyanophyceae, Cryptophyceae and Dinophyceae) which are, according to their abundance (Fig. 3)

Diatoms or Bacillariophyceae: form the most diverse group, and comes in the first position with 34 taxa, 36.62% of the phytoplankton community, they are represented mainly by the following genera: Cyclotella, Nitzschia and Fragilaria.

Chlorophyceae: it is also diversified, coming in the second position with 25 taxa, or 31.81% of the total population, they are represented mainly by Oocystis, Tetraspora and Closterium.

The Euglenophyceae: have 13 taxa, that is to say, a proportion of 12.82%, dominated by the genera: Trachelomonas, Phacus and Euglena.

Cryptophyceae: includes 5 taxa, or a proportion of 10.44%, represented only by the genus: Cryptomonas.

Cyanophyceae: includes 9 taxa, or a proportion of 6.88%, dominated by the genera: Oscillatoria, Microcystis and Merismopedia.

Dinophyceae: includes 3 taxa, a proportion of 1.42%, represented mainly by the genus: Peridinium.

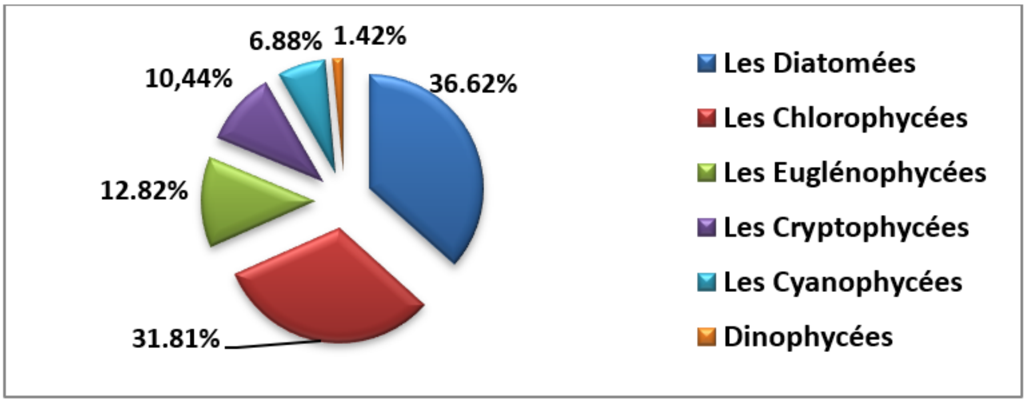

Fig. 3: Variation in abundances of phytoplankton groups.

The 89 species determined are demonstrated in the following lists:

Diatoms or Bacillariophyceae:

cf. Cyclotella	Cyclotella cf. choctawhatchee	Cyclotella meneghiniana
Cyclotella sp1	Cyclotella cf. meneghiniana	Cyclotella ocellata
cf. Fragilaria	Cyclotella cf. ocellata	Cyclotella sp2
Cyclotella choctawhatchee	Cyclotella sp3	cf. Nitzschia
Cyclotella sp4	cf. Nitzschia sp	Licmophora sp
Surirella sp	cf. Navicula	Nitzschia cf. palea
Fragilaria cf. capucina	Navicula cf.	Nitzschia palea
Fragilaria cf.ulna	Navicula cf.Cryptotenella	Nitzschia sp 1
Fragilaria sp	Navicula cf.gregaria	Nitzschia sp 2
Fragilaria ulna	Navicula minima	Nitzschia sp 3
Raphidiopsis cf.Curvata	Stephanodiscus cf.	neoa Surirella cf.Ovalis

Chlorophyceae:

cf. Crucigenia	cf.Oocystis sp	Closterium acutum
cf.Chlorella	cf.Oocystis	Closterium cf. acerosum
Cf.Closterium	cf.Scenedesmus	Closterium cf.setaceum
cf.Cosmarium	Closteriopsis sp	Chlamydomonas sp1
Chalamydomonas sp2	Scenedesmus fluxuosus	Coelastrum sp
Oocystis cf.choctawhatchee	Cosmarium granatum	Oocystis lacustris
Scenedesmus sp1	Cosmarium sp	Oocystis marssonii
Scenedesmus sp2	cf.fenestrata	Tetraspora gelatinosa

Cryptophyceae:

Cryptomonas sp Cf.	Cryptomonas

Cyanophyceae:

Anabaena cf. circinalis	cf.Merismopedia	Microcystis aeruginosa
Anabaena cf. delicatula	Oscillatoria cf.rubescens	Oscillatoria sp
Oscillatoria rubescens	Raphidiopsis sp	Anabaenopsis circularis

Euglenophyceae:

cf. Phacus	Trachelomonas hispida	Euglena sp
cf.Trachelomonas	Trachelomonas regulosa	Phacus pleuronectes
Euglena acus	Euglena oxyuris	Trachelomonas
Euglena candata	elomonas sp	
Euglena gracilis	Trachelomonas globularis	

Dinophyceae:

Peridinium cinctum	Peridinium sp1	Peridinium sp2

The Quantitative Study of The Population:

Spatial and Temporal Variation of The Algal Population:

After the cell count of phytoplankton, we noticed a variation in the density of phytoplankton groups:

The most abundant group is Diatoms with a density of 95.18 ×105 alg/l (Fig. 4) and an abundance of 36.6% (Fig. 5). The most abundant genera are Cyclotella and Nitzschia and Fragilaria.

The importance of this group is related to the richness of the environment in nitrogenous nutrients (Berdalet, 1996; Carlsson, 1999), and climatic conditions (temperature and light) (Daly, 1998).

The Chlorophyceae come in second place. They are organisms that dominate environments that are rich in nitrogenous nutrients28-29. With a density of 82.67× 105 alg/l and 31.81%. The most abundant genera: Oocysts, Tetraspora and Closterium.

Their presence results from the enrichment of the environment with nutrients (Sane, 2006). The third group is the Euglenophyceae with a density of 33.31 ×105 alg/l dominated by an abundance of 12.85%. The most abundant genera: are Trachelomona and Phacus.

In the fourth position, the Cryptophyceae represents a density of 27.14 ×105alg/l with an abundance of 10.44%, represented mainly by the genus Cryptomonas.

In the fifth group, the Cyanophyceae represents a density of 17.89×105alg/l and an abundance of 6.88%. The abundant genera are: Oscillatoria, Microcystis and Merismopedia

They move in the water column according to the illumination and the concentrations of nutritive salts, which justifies their presence in the aphotic layers (Chorus & Bartram, 1999) and especially in the summer period.

Dinophyceae is a rare class with a density of 37.02× 104 alg/l and an abundance of 1.42%, represented by the genus Peridinium.

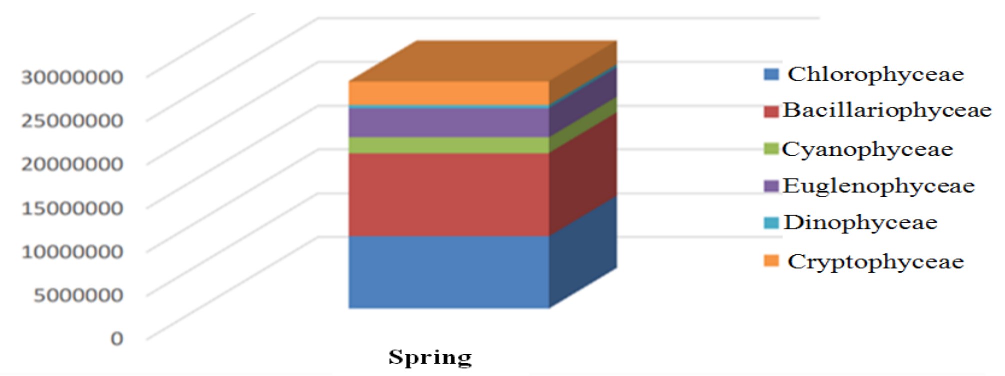

Fig.4: Variation of phytoplankton densities in Sidi Mhamed Benali Lake during the spring period.

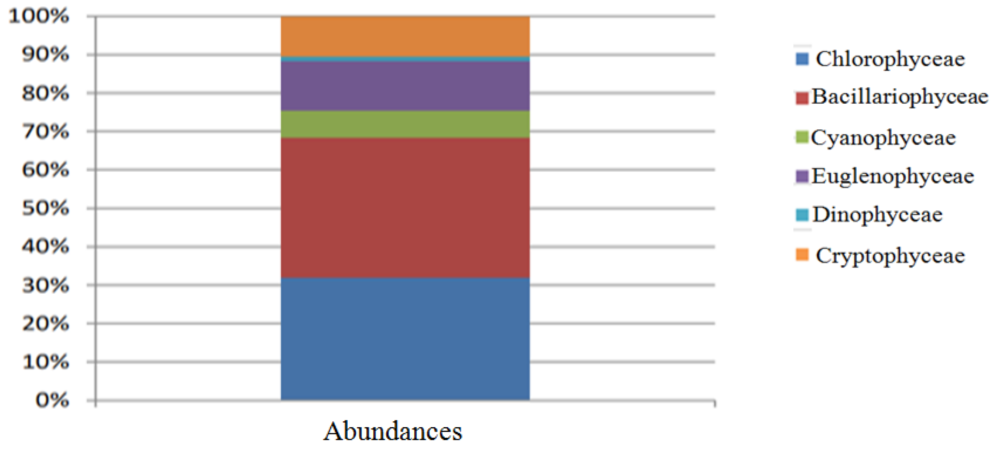

Fig. 5: Variation of abundances of phytoplanktonic groups in Sidi Mhamed Benali Lake during the spring period.

Spatial and Temporal Evolution of The Specific Diversity:
Shannon index (H ') and Equitability (E):

In the Sidi Mhamed Benali Lake, the Shannon index is 5.44 bits/ind (Fig.6). These values are explained by the remarkable dominance of the species cf. Cyclotella. The species richness during this period reaches its maximum of 90 species.

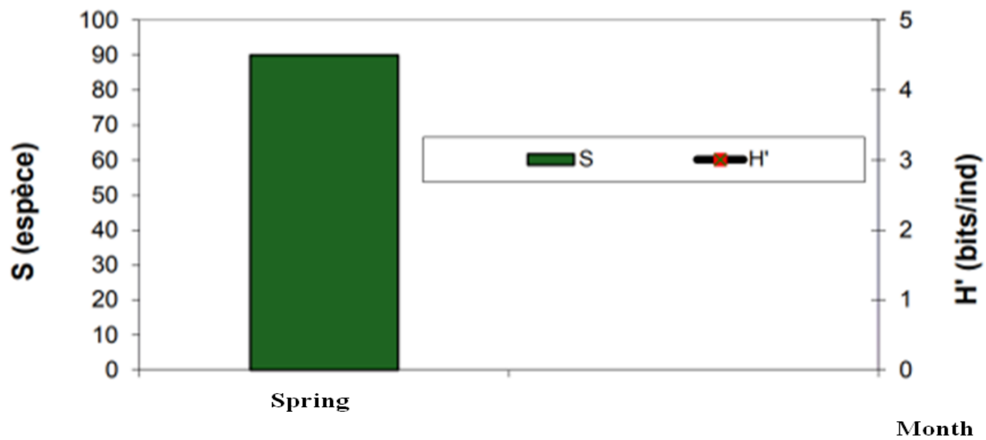

Fig.6: Variation in species richness (S) and Shannon index (H') in Lake Sidi Mhamed Benali.

These high values reveal that the population is composed of a large number of species with a balanced distribution. Overall, a specific diversity index characterizes the organization and evolution of a stand. The results obtained (Fig. 6), show that in general, a specific diversity is very important during this period. When the equitability is minimal (close to 0) almost all the individuals are concentrated on one species (cf. Cyclotella), this phenomenon was observed during the month of April with R= 0,22.

Table 3: Values of the Shannon diversity index and equitability of phytoplankton species found at the level of Lake Sidi Mhamed Benali.

	Lake Sidi Mhamed Benali		
month	**S**	**R**	**H'**
spring	90	0,221	5,445

Analysis of the Frontier Diagram (Rank Frequency Diagram):

To complete the parameters studied previously, the rank-frequency diagrams (RFD) are used to visualize the distribution and the overlap of the different taxa (Fig.7).

Rank-frequency diagrams offer a synthetic representation of a community (Frontier and Etienne, 1990). The analysis of the DRF curves, for the Sidi Mohamed Banali Lake, allows describing the evolution of the algal settlement structure. Figure 06 shows that the DRF curve is completely convex, which corresponds to stage 2 indicating mature and balanced ecosystems.

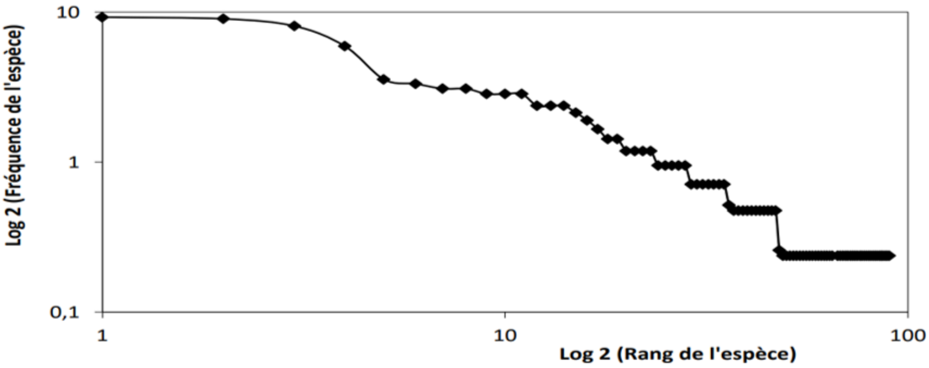

Fig.7: Variation of the curve Rank Frequency of Lake Sidi Mhamed Benali.

Conclusion

The study of the Physico-chemical and phytoplanktonic characteristics of the waters collected in lake Sidi Mhamed Benali reveals high concentrations of certain parameters. This phenomenon favors the proliferation of pollutant-resistant organisms such as Diatomophyceae, Chlorophyceae and Cyanophyceae which represent the quasi-totality of the algal population. This proliferation leads to a decrease in transparency and dissolved oxygen which are also signs of eutrophication. From a general point of view, the water quality of this lake, affected by this phenomenon, is bad, which causes a decrease in biodiversity. In total, only 89 species were recorded during the study, grouped into 6 functional classes according to the classification of Bourrelly 1972, 1981 and 1985.

The knowledge of the trophic state of a dam is not enough. Further studies should allow a more precise approach to the existing interactions between the phytoplankton compartment and the adjacent levels of the food web and the impact of Physico-chemical parameters. The rapid evolution of phytoplankton communities in response to environmental changes reinforces the interest in their ecological monitoring because of the importance of this dam from the point of view of these multiple uses.

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