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Water physicochemical characterization and phytoplankton diversity of arid region in Meggarine Lake, Ouargla, Algeria

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Abstract. *Manamani R, Bensouilah M. 2023. Water physicochemical characterization and phytoplankton diversity of arid region in Meggarine Lake, Ouargla, Algeria. Biodiversitas 24: 1569-1579.* The present study aims to examine the physicochemical parameters, e.g., temperature, dissolved oxygen, pH, conductivity, salinity, nitrites, nitrates, orthophosphates, suspended matter, and chlorophyll (a) content) of Meggarine Lake, located in the Saharian region (Ouargla). Also, to establish the relation with phytoplankton's seasonal dynamics and diversification. From November through May over four years (2016-2019), a spatial and spatiotemporal investigation of phytoplankton composition was conducted. The algae and water samples were collected, preserved, and analyzed from four different sites using standard methods. Canonical Correlation Analysis (CCA) was recorded to explain the correlation between phytoplankton and physicochemical parameters. The results revealed a link between these planktonic populations and their physicochemical properties. Observing the morphoanatomical characters of the phytoplankton genera collected in Meggarine Lake allowed us to identify 29 genera. Diatoms (15 genera), dinoflagellates (03 genera), and cyanobacteria (11 genera) were separated into three groups. The distribution of phytoplankton showed a very high algal density in 2018, with a total of 9,995 cells/L, followed by 2019 and 2017, where the total densities were 5,332 and 5,118 cells/L, respectively. A low total density value was recorded (3,157.067 cells/L) in 2016. The highest value of phytoplankton was noted during the spring season, with 19,778 cells/L. Statistical analyses showed different correlations between the physicochemical parameters and the spatiotemporal variation of algae.

Keywords: Bioindicators**,** environmental factors, Meggarine Lake, physicochemical characterization, phytoplankton diversity

INTRODUCTION

Algae are crucial to lakes and reservoir components because they affect biological diversity (Nasser and Sureshkumar 2014). Microalgae are thought to be responsible for approximately $2x10^9$ tons of the total yearly primary generation of carbon in the world's oceans. In addition, the creation of 80% of the oxygen we breathe is also carried out by them (Verfaillie et al. 2020; Sankaranarayanan et al. 2021). Changes in their physicochemical properties significantly impact the organisms that inhabit ecosystems. The distribution, periodicity, and quantitative and qualitative content of freshwater biota are significantly influenced by seasonal variations in these factors (Sharma et al. 2016). Due to the sensitivity of phytoplankton communities to environmental changes, numerous phytoplankton species are utilized as a nutrient level indicator, based on which lake management strategies are prepared and monitored. It has been performed from very early times to evaluate the water quality by studying phytoplankton groups or other aquatic species (Fakioglu 2013). It is widely recognized that the global population growth and the associated industrialization of coastal regions have continually produced growing pollution, leading to several environmental issues and threats to human health (Diop et al. 2014). Therefore, for improved management of water resources, it's crucial to comprehend the relative effects of natural and human-induced processes on hydrological and biochemical activities through phytoplankton diversity (Arab et al. 2019).

Water quality is one of the factors that should be evaluated in coastal ecosystems since decreased water purity could be catastrophic for marine life (Riani et al. 2014). Following Huang et al. (2022), agricultural production activities have recently impacted and damaged the quantity and purity of the water in lakes. The health of the aquatic ecosystem and changes in water quality can be successfully detected by the phytoplankton's sensitivity to the hydrological environment. Therefore, understanding the alterations in phytoplankton populations in lakes influenced by agriculture may help to decide the best ways to maintain these water resources and serve as a model for additional research. In addition, findings regarding algae and how they respond to specific environmental factors should be investigated and documented because it contributes to determining water quality (Bellinger and Sigee 2015). Several works have been carried out in Algeria on the phytoplankton of dams, lakes, or rivers. We mention studies of Hamaidi-Chergui et al. (2013), Djabourabi et al. (2017), Draredja et al. (2019), Boudjenah and Mokrane (2020).

In Eastern Algeria, the results of works carried out in various water bodies reveal the presence of a certain number of kinds of phytoplankton, of which the majority are recognized as potentially toxic. In southern Algeria, there are several bodies of water or lakes abandoned; these environments are home to biological resources that are very valuable and diverse. We cite, for example, in Ouargla: Lake Temacine, Lake Lala Fatma, Lake Hassi Ben Abdellah, etc. Lake Meggarine is a little-known environment; it is critical to be well-versed in the environment. Unfortunately, the physicochemical characterization of this type of arid environment is not very frequent (Wahed et al. 2015).

Due to the great temporal and geographical heterogeneity of phytoplankton and environmental variables, their interactions are frequently complex and difficult to understand. For example, aspects of the lake, such as nutrition, light, temperature, etc., control the growth of algae (Huang et al. 2022). Therefore, for this reason, the present work aimed to characterize the physicochemical parameters and identify the collected microalgae of Meggarine Lake. This study would also determine the influence of physicochemical parameters on the phytoplankton composition of this Meggarine Lake. A few works were realized in this location, and we noted studies of Gouasmia et al. (2016) and Khellou et al. (2018).

MATERIALS AND METHODS

Study area

Touggourt is the capital of the Oued Righ region, located between the Great Eastern Erg in the southeast and the Chott area in the north, from 600 km southeast of Algiers in the northeastern Sahara. The area is located between latitudes 32.54° and 34.9° North and longitudes 5.30° and 6.20° East. The altitude is close to 70 m, with a Saharan-type climate characterized by a water deficit due to low rainfall, intense evaporation, high temperatures, and high luminosity (Figure 1).

Following Khellou et al. (2018), Meggarine Lake is separated into two small lakes: Lella Fatma and Zerzaim. The first one, "Lella Fatma," is located at latitude 33°12′21″ north and longitude 06°05′54″ East, and Zerzaim Lake is situated at latitude 33°12′12″ North and longitude 06°05′50″ East. The two lakes are connected by a natural trench but are still distinct during the rainy period.

Sampling sites

Four sites in Meggarine Lake were chosen for physicochemical and phytoplankton analyses. This lake is located in the town of Megara, in the middle of a palm grove. Its depth is a few meters, and its area is about 1.25 hectares. Surface waters constitute the main water source, along with drainage water (Figure 1).

Procedures

Sampling

The water samples were taken monthly from December to May between 9:00 a.m. and 12:00 p.m. during the past four years (2016, 2017, 2018, and 2019).

Measurement of the physicochemical parameters of the water

The measurement of the physicochemical parameters of the water was carried out monthly at the time of sampling. The physicochemical parameters studied were: temperature (T, °C), dissolved oxygen content (O_2), pH, conductivity, salinity (with multiparameter instrument HANNA-HI 9829), nitrites, nitrates, orthophosphates (using the colorimetric method of Aminot and Keroule (2004)), suspended matter (based on the differential weighing method of Aminot and Chaussepied (1983)), and chlorophyll (a) content (Monochromatic method of Lorenzen (1967)).

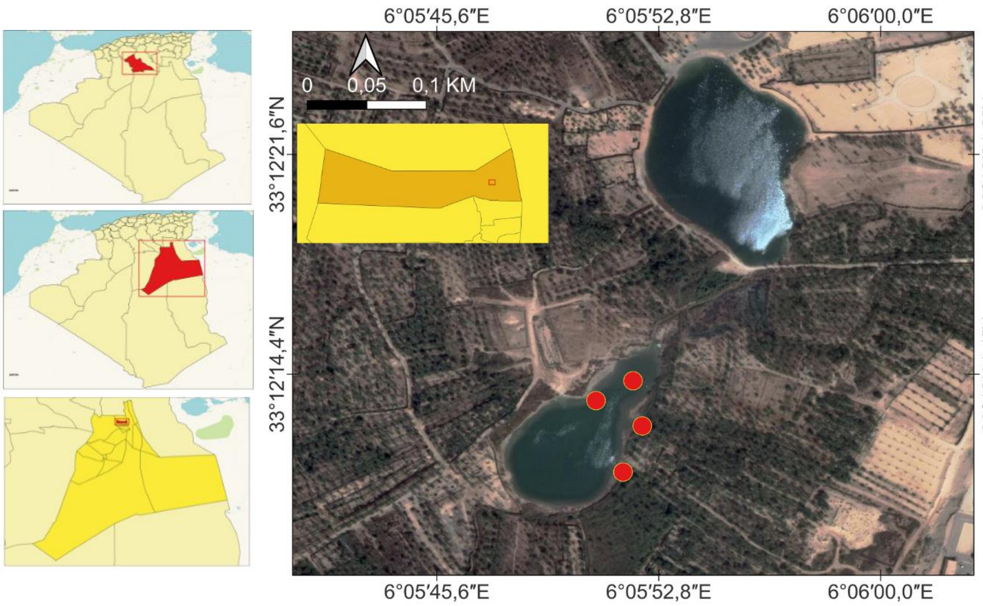

Figure 1. Location of Meggarine Lake, southeast of Algiers indicating the sampling sites

The determination of nutrients (nitrites, nitrates, and orthophosphates) was carried out in the laboratory from one liter of water kept in bottles at a low temperature (in a cooler) using the method of Rodier (2009).

Identification and counting of phytoplankton

A plankton net with a mesh size of 20 m and a collector are used for sampling. The operation consists of filtering the surface water (20 cm below the water surface) and then transferring the contents of the collector to a shaded glass bottle containing 5 mL of 10% ethanol to fix algae placed in a cool, dark refrigerator. The collected genera were determined by observing the morpho-anatomical characters (shape, size, and color) under the optical microscope representing the identification keys retained by Bourrelly (1985).

A precise quantity (20 µL) was carefully homogenized, taken with a micropipette, and laid between the slide and coverslip first. Next, phytoplankton cells were counted using a photonic microscope (Motic) (objective X 10) by scanning the whole surface of the slide. Next, eight slides were counted for each sample to minimize the error.

Data analysis

In each year of the research study, a Canonical Correlation Analysis (CCA) was carried out to assess the link between the water parameters and the amount of phytoplankton with XLSAT, 2014. An axis is determined by the arrows symbolizing each environmental factor variable.

RESULTS AND DISCUSSION

Physico-chemical study

Table 1 presents the physicochemical data recorded in the studied site during the different periods (November to May) from 2016 to 2019.

Temperature

The results obtained during the study period show that the temperature of the water varies at all sites in a similar manner. We found that the monthly values of T°C have maximum values recorded in May (25.42-27.08 °C) and minimum values that vary from 10.86 to 14.44 °C, as recorded in December (2019), January (2016, 2018), and February (2017).

Salinity

During the study period, the evolution of this parameter was similar at all the sampling sites; however, it varies from season to season. For example, the lowest salinity (11.51‰) was recorded in December 2017, and the highest salinity (27.50‰) was recorded in May 2018.

The low salinity recorded is explained by water dilution generated by freshwater inflow originating from precipitation or low water evaporation. Water salinity is high during the spring (April and May) due to the combined action of high temperatures causing high evaporation and a decrease in precipitation, causing a decrease in freshwater inflow. However, the results of Gouasmia et al. (2016) show that Meggarine Lake was classified in the saltwater range; it was the saltier lake with 35.00 ± 0.28 g.L^{-1}. This higher salinity was due to the two salts KCl and NaCl, with a dominance of the first.

pH

The pH of the water in Meggarine Lake is alkaline, generally close to 8. This parameter exhibits a consistent evolution across all sampled sites and periods, except for 2018, where maximum values were noted (13.30 in December and 11.85 in January). According to Chia et al. (2011), the pH values mostly range between 6.5 and 8.5 for most biological activities. The acidic character may have a harmful influence on non-tolerant algal species.

Conductivity

The conductivity of the water during the study period was between 7.35 µs/cm in April and 34.53 and 42 µs/cm as maximum values in May and between 17.87 µs/cm and 20.56 µs/cm in December as minimum values. An irregular conductivity variation during the study period's seasons was noted.

Following Rodier (2009), the conductivity presents the same rhythm as the salinity; it gives an idea of the environment's ionization and hardness. These last two parameters are directly related to temperature variations, precipitation, and evaporation ratios. It is closely related to the concentration of dissolved substances and their nature; mineral salts are good conductors; on the other hand, it is closely related to and varies according to the temperature.

Dissolved oxygen

The dissolved oxygen content of the water varies from month to month in the 04 sites, with minimum values (3.97-4.55 mg/L) in May and maximum values ranging from 11.19 to 13.10 mg/L (January). The fluctuations in dissolved oxygen content are related to temporal variations in temperature; the decrease in oxygen content observed during the spring and May would be related to an increase in air temperature, which limits oxygen solubility.

In addition, according to Gaujous (1995), the origin of oxygen in natural environments is related to the photosynthetic activity of aquatic plants, the dissolution of atmospheric oxygen, as well as the respiratory consumption of fauna and flora, and the degradation of organic matter that result in a biological and chemical demand for oxygen.

Nitrates

The evolution of nitrates monitoring shows identical variations noted by the appearance of a peak during the winter period: December 2016, February 2017, and January (2018 and 2019). The minimum nitrate levels in the water are between 0.086 mg/L (May 2019) and 1.48 mg/L (February 2018).

Nitrates are formed from organic forms by bacteria, and the formation rate seems to be higher than the rate of use, as nitrates enter the nitrogen cycle as the main support for phytoplankton growth. The study of NO_3^- evolution reveals that variations in the content are caused by plants' ineffective use of these elements. The lake presents high values of nitrates during the cold period; this is due, on the one hand, to its weak use by the not very active plants at this period and, on the other hand, to the good oxygenation of the waters noted at this same period. In addition, in winter, surface waters are rich in nutritive salts due to the mixing of waters and the low abundance of plankton (Benmarce 2012).

Nitrites

The determination of nitrites in the waters of Meggarine Lake shows fluctuations in the evolution of levels found in the 04 sites during the seasons, except for 2018, where the values were very important, ranging from 0.062 mg/L (May) to 1.26 mg/L (November). An experimental study indicated that the ammonium oxidization and sulfate reduction efficiencies were increased in the presence of nitrite and nitrate by nitrifying bacteria but also from the reduction of nitrates (Zhang et al. 2019). Gouasmia et al. (2016) noted that nitrite concentrations were generally low during the study period, with a value of 0.13 ± 0.11 mg.L^{-1} was recorded in the cold period in Meggarine Lake.

Orthophosphates

The concentrations of orthophosphates are different from one year to another. They range from 0.023 mg/L (May 2019) to 2.73 mg/L (February 2018). This increase in orthophosphates, noted in March, seems to be linked to the increase in inputs generated by floods and the degradation of organic matter by bacteria. Those regenerate phosphorus but also the turbidity of the water and the phosphorus load absorbed by the sediment.

Suspended matter (SM)

SM varies from season to season and reaches a maximum during April 2016 (2.69 mg/L), April 2018 (2.91 mg/L), May 2017 (1.71 mg/L), and May 2019 (0.93 mg/L). In contrast, during the cold season, SM values are low (December-February).

The increase in SM during the spring season could be related to the high micro-algal density observed during this period and the high chlorophyll (a) content. In addition, the low depth of the aquatic system would favor the transfer of sedimentary particles to the water column; this action is carried out by the waves created under the effect of the wind. Following Draredja et al. (2019), the highest value of suspended matter was recorded in the winter season with up to 38.5 mg L^{-1} (early January). The rest of the year, the concentrations were low, with 3.7 mg L^{-1} (end of September).

Chlorophyll

The chlorophyll (a) assay results obtained from monthly water samples show that the levels of this pigment evolve in the four sites similarly. We note low concentrations during the cold season: February 2016 (0.30 mg/m^3) and December 2018 (0.48 mg/m^3), then a progressive increase from March to May, with the presence of a peak in May 2018 (4.05 mg/m^3). In Mellah Lagoon, Draredja et al. (2019) found that chlorophyll biomass concentration showed two peaks, the first one in late spring and early summer (5.4 ± 0.1 μg L^{-1}) and the second one was observed in autumn (5.3 ± 0.2 μg L^{-1}).

Phytoplankton study

The species composition of the phytoplankton community of the sites is provided in Table 1.

Generic distribution of microalgae

Observing the morphoanatomical characters of the phytoplankton genera collected in Meggarine Lake allowed us to identify 29 genera (Table 1). These are divided into three classes: Diatoms (15 genera or 51%), Dinoflagellates (03 genera or 10%), and Cyanobacteria (11 genera or 38%).

Table 2 shows that the diatom genera were the most representative during the study period (between 43.75 and 75%) except in April 2017, January, and February 2019, when cyanobacteria represented the highest rates of genera. The results of the Khellou et al. (2008) study realized in the same region were assessed in 28 genera of phytoplankton belonging to five classes (Mediophyceae, Coscinodiscophyceae, Bacillariophyceae, Euglenophyceae, and Cyanophyceae).

Frequency of occurrence of collected phytoplankton

The estimated frequency of occurrence of the collected genera by group and year was next.

For Cyanobacteria, Omnipresent: *Microcystis* and *Synechocystis* (2016-2019); Constant: *Aphanizomenon* (2017-2018) and *Chroococcus* (2019); Regular: *Nostoc, Chroococcus* (2017) and *Anabeana* (2019); Accessory: *Anabeana, Oscillatoria, Lyngbya* (2017) *Anabeana, Merismopedia* (2018) *Nostoc* (2019); Rare: *Stephanopyxis* (2017) and *Volvox* (2018).

For Diatoms: Omnipresent: *Synedra* (2016-2017), *Rhizosolenia* (2016), *Pseudonitzshia, Skeletonema* (2017), *Navicula, Pleurosigma* (2017-2019), *Chaetoceros, Pinnularia* (2018); Constant: *Navicula* (2016), *Coscinodiscus* (2017/2019), *Synechococcus* (2017), *Skeletonema, Fragilaria* (2018); Regular: *Skeletonema* (2016), *Melosira* (2018), *Baccillaria* (2019); Accessory: *Pleurosigma* (2016), *Rhizosolenia, Chaetoceros* (2017), *Thalassiossira, Melosira, Synedra* (2019); Rare : *Coscinodiscus, Pinnularia* (2016), *Surirella* (2017), *Skeletonema* (2019).

For Dinoflagellates: Omnipresent: *Gymnodinium* (2018-2019); Constant: *Ceratium* (2018); Regular: *Gymnodinium* (2017), *Prorocentrum* (2018) and *Ceratium* (2019); Accessory: *Ceratium* (2017) and *Prorocentrum* (2019).

Phytoplankton spatial and temporal distribution

The distribution of phytoplankton showed a very high algal density in 2018, which varied between 1,832 and 2,953 cells/L in the four sampling sites with a total of 9,995 cells/L, followed by 2019 and 2017, where the total densities were 5,332 and 5,118 cells/L, respectively. In 2016, a low total algal value was recorded (3,157.067 cells/L) (Figure 2). Phytoplankton variations by sampling site revealed that site 1 scored the highest (i.e., 27% in 2016 and 30% in 2018), while site 2 was the most abundant in 2017 (i.e., 28%) and 2019 (i.e., 37% of the total collected) (Figure 3). While the composition of the phytoplankton varied at each of the examined sites, the phytoplankton abundance generally followed the same trend.

Seasonal fluctuation of algae

Figure 4 shows that algal development varies from one season to another. The highest values were recorded in spring, with 19,778 cells/L, followed by the winter season, with 16,344 cells/L, and the fall season marked a density of 7,255 cells/L. Comparing the seasons shows that the number of microalgae collected in 2017 and 2018 was high in winter and autumn. However, in 2016 and 2019, the most important values were determined in spring (12,168 and 6,137 cells/L, respectively).

Correlation between phytoplankton and water quality

The physicochemical parameters are the primary elements that regulate the dynamics and organization of the phytoplankton in aquatic ecosystems (Pasztaleniec 2016). Therefore, monitoring the physicochemical parameters is crucial for determining how these characteristics affect the distribution of different biodiversity components in headwater streams (Sharma et al. 2016). The findings of Jose and Xavier's study (2022) showed that seasonal variations in physicochemical factors triggered changes in the diversity of algae.

According to the correlation matrix of Pearson, Table 3 and Figure 5 of CCA, the results show that there were positive correlations between: Temperature and: monthly total (r = 0.64; p= 0,0002), salinity (r = 0.88; p< 0,0001), conductivity (r = 0.87; p< 0,0001), suspended matter (r = 0.68; p< 0,0001), chlorophyll (r = 0.67; p< 0,0001); conductivity and: monthly total (r = 0.71; p< 0,0001), salinity (r = 0.93; p< 0,0001), chlorophyll (r = 0.72; p< 0,0001); suspended matter and: salinity (r = 0.79; p< 0,0001), chlorophyll (r = 0.79; p< 0,0001); chlorophyll and: monthly total (r = 0.64; p = 0,0002), salinity (r = 0.75; p< 0,0001). However, negative correlations were noted between dissolved oxygen and: temperature (r = -0.97; p< 0,0001), salinity (r = -0.72; p< 0,0001), conductivity (r = -0.72; p = 0); suspended matter and dissolved oxygen (r = -0.64; p = 0,0002).

Globally, from the table of the correlation matrix of the study period (2016-2019) and the CCA Figure, we distinguished the existence of a positive correlation between total density and temperature, salinity, conductivity, and chlorophyll. The links between physicochemical parameters were positive with temperature and salinity, conductivity, suspended matter, chlorophyll; salinity and conductivity, suspended matter, chlorophyll; conductivity and suspended matter, chlorophyll; suspended matter and chlorophyll. On the other hand, negative correlations were observed between dissolved oxygen and temperature, salinity, electrical conductivity, and suspended matter.

According to Pearson's linear correlation matrix of physicochemical factors in Meggarine Lake, established by Gouasmia et al. (2016), the temperature was positively correlated with salinity and conductivity as well as chloride, sodium, and potassium ions, which manage these two parameters. However, it was negatively correlated with dissolved oxygen in warm periods. This shows the important effect of temperature on all of these factors, especially in Meggarine Lake.

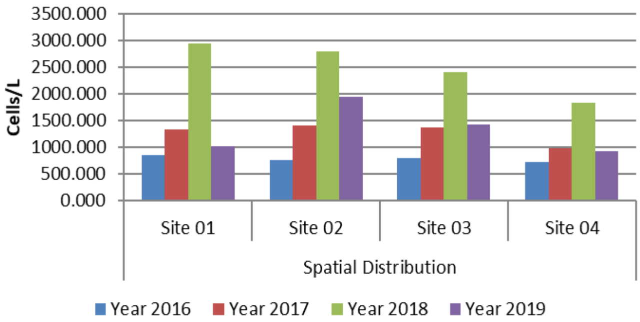

Figure 2. Spatial distribution of phytoplankton

Figure 3. Spatio-temporal distribution of phytoplankton

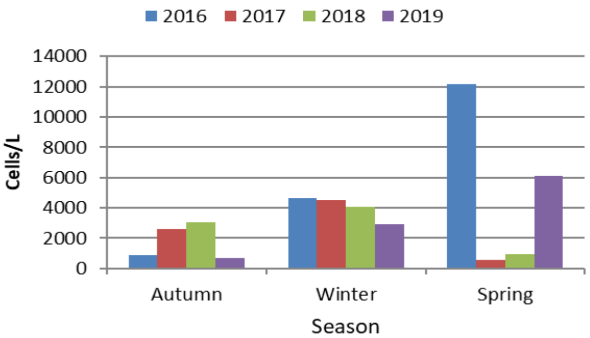

Figure 4. Seasonal development of algae from 2016 to 2019

Table 1. Physicochemical characterization of the lake

Year	Season	Month	Temperature (°C)	Salinity (‰)	pH	Conductivity (µs/cm)	Dissolved Oxygen (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	Orthophosphates (mg/L)	Suspended matter (mg/L)	Chlorophyl (a) (mg/m^3)
2016	Autumn	November	15.550	15.828	8.128	22.933	9.230	1.900	0.029	1.678	0.723	0.823
	Winter	December	14.325	14.100	8.300	17.875	11.393	3.620	0.040	2.498	0.560	0.703
		January	13.293	15.760	8.047	25.325	11.650	1.720	0.036	1.620	0.685	0.478
		February	17.105	17.350	8.675	27.725	10.985	2.200	0.042	1.983	0.450	0.306
	Spring	March	23.265	17.550	7.888	28.700	4.440	1.355	0.033	1.058	0.765	0.515
		April	24.820	26.000	8.040	40.450	4.965	1.700	0.006	0.588	2.698	1.677
		May	27.088	25.568	8.153	42.000	4.298	2.840	0.046	1.543	2.115	4.058
2017	Autumn	November	12.650	12.340	7.908	19.815	9.753	0.928	0.085	0.496	0.520	0.708
	Winter	December	11.173	11.518	7.528	18.388	12.250	0.873	0.028	0.915	0.478	0.690
		January	12.410	13.215	7.603	19.950	11.925	0.940	0.031	1.138	0.570	0.635
		February	10.865	11.880	7.763	18.768	11.825	2.400	0.037	0.363	0.403	0.494
	Spring	March	15.240	13.200	8.225	23.225	6.393	1.058	0.026	0.460	1.063	1.178
		April	20.288	22.775	8.433	28.785	5.583	0.745	0.042	1.715	1.410	1.438
		May	26.753	23.500	7.567	34.533	4.550	0.910	0.017	0.800	1.715	1.728
2018	Autumn	November	19.515	13.218	9.888	20.568	5.185	1.868	1.265	1.348	1.285	0.975
	Winter	December	16.425	13.665	13.305	20.895	6.448	1.967	0.178	0.695	0.743	0.488
		January	14.440	15.450	11.858	23.253	13.100	2.030	0.235	2.140	0.800	0.880
		February	14.463	13.825	8.818	23.278	9.550	1.483	0.139	2.730	0.800	1.038
	Spring	March	24.209	19.600	10.438	27.768	5.013	1.680	0.080	2.170	1.178	1.368
		April	24.200	24.893	8.253	33.528	4.353	1.905	0.082	2.150	2.910	2.340
		May	25.425	27.505	8.740	37.328	5.073	1.650	0.062	1.013	1.670	2.153
2019	Autumn	November	14.023	13.133	8.198	20.605	10.823	1.710	0.105	0.483	0.530	0.668
	Winter	December	12.228	12.710	7.573	18.448	11.195	1.008	0.208	0.536	0.480	0.743
		January	12.660	13.430	8.423	21.318	10.883	4.275	0.033	0.725	0.460	0.710
		February	14.715	14.360	7.450	25.993	10.243	3.213	0.029	1.350	0.415	0.568
	Spring	March	23.233	16.630	8.208	24.133	5.495	2.700	0.026	1.975	0.448	0.775
		April	23.630	20.808	7.603	34.295	5.223	1.240	0.084	0.117	0.580	1.100
		May	25.753	22.615	8.298	40.738	3.978	0.086	0.095	0.023	0.938	1.180

Table 2. Diversity and frequency (F) of occurrence of collected algae in the Meggarine Lake

Year	Season	Month	Number of genera	Identified genera			% of genera per group		
				Cyanobacteria	Diatoms	Dinoflagellates	Cya	Diat	Dino
2016	Autumn	November	06	*Microcystis* Synechocystis*	*Synedra Skeletonema Rhizosolenia Navicula*	-	33.33	66.67	0.00
	Winter	December	06	*Microcystis* Synechocystis*	*Synedra Skeletonema Rhizosolenia Navicula*	-	33.33	66.67	0.00
		January	07	*Microcystis* Synechocystis*	*Synedra Rhizosolenia Navicula Pleurosigmas Pinnularia*	-	28.57	71.43	0.00
		February	04	*Microcystis*Synechocystis*	*Synedra Rhizosolenia*	-	50.00	50.00	0.00
	Spring	March	07	*Microcystis* Synechocystis*	*Synedra Skeletonema Rhizosolenia Navicula Pleurosigma*	-	28.57	71.43	0.00
		April	07	*Microcystis* Synechocystis*	*Synedra Skeletonema Rhizosolenia Navicula Pleurosigma*	-	28.57	71.43	0.00
		May	08	*Microcystis* Synechocystis*	*Synedra Skeletonema Rhizosolenia Navicula Pleurosigma Coscinodiscus*	-	25.00	75.00	0.00
2017	Autumn	November	10	*Microcystis* SynechocystisChroococcus*	*Pseudonitzshia Coscinodiscus Pleurosegma Synedra Navicula*	*Gymnodinium. Ceratium*	30.00	50.00	20.00
	Winter	December	13	*Microcystis Synechocystis Chroococcus Aphanizomenon*	*Pseudonitzshia Coscinodiscus Pleurosegma Synedra Navicula Skeletonema Synechococcus*	*Gymnodinium. Ceratium*	30.77	53.85	15.38
		January	15	*Microcystis Synechocystis Anabeana Chroococcus Nostoc Aphanizomenon*	*Pseudonitzshia Coscinodiscus Pleurosegma Synedra Navicula Skeletonema Synechococcus*	*Gymnodinium. Ceratium*	40.00	46.67	13.33
		February	12	*Microcystis Synechocystis Anabeana Nostoc Aphanizomenon*	*Pseudonitzshia Pleurosegma Synedra Navicula Skeletonema Synechococcus*	*Gymnodinium*	41.67	50.00	8.33
	Spring	March	13	*Microcystis Synechocystis Anabeana Nostoc Oscillatoria Aphanizomenon*	*Pseudonitzshia Coscinodiscus Pleurosegma Synedra Navicula Skeletonema Synechococcus*	-	46.15	53.85	0.00
		April	17	*Microcystis Synechocystis Anabeana Stephanopyxis Chroococcus Nostoc Oscillatoria Aphanizomenon Lyngbya*	*Pseudonitzshia Chaetoceros Coscinodiscus Pleurosegma Synedra Navicula Skeletonema Synechococcus*	-	52.94	47.06	0.00
		May	16	*Microcystis Synechocystis Chroococcus Nostoc Oscillatoria Aphanizomenon Lyngbya*	*Pseudonitzshia Chaetoceros Coscinodiscus Navicula Pleurosegma Surirella Synedra Skeletonema Synechococcus*	-	43.75	56.25	0.00
2018	Autumn	November	12	*Microcystis Synechocystis Aphanizomenon*	*Navicula Pinnularia Skeletonema Chaetoceros Pleurosegma Fragilaria*	*Gymnodinium Prorocentrum Ceratium*	25.00	50.00	25.00
	Winter	December	12	*Microcystis Synechocystis Aphanizomenon*	*Navicula Pinnularia Skeletonema Chaetoceros Pleurosegma Fragilaria*	*Gymnodinium Prorocentrum Ceratium*	25.00	50.00	25.00
		January	14	*Microcystis Synechocystis Aphanizomenon Merismopedia*	*Navicula Pinnularia Melosira Skeletonema Chaetoceros Pleurosegma. Fragilaria*	*Gymnodinium Prorocentrum Ceratium*	28.57	50.00	21.43
		February	15	*Microcystis Synechocystis Aphanizomenon Anabeana Merismopedia*	*Navicula Pinnularia Melosira Skeletonema Chaetoceros Pleurosegma. Fragilaria*	*Gymnodinium Prorocentrum Ceratium*	33.33	46.67	20.00
	Spring	March	16	*Microcystis Synechocystis Aphanizomenon Anabeana Volvox Merismopedia*	*Navicula Pinnularia Melosira Skeletonema Chaetoceros Pleurosegma Fragilaria*	*Gymnodinium Prorocentrum Ceratium*	37.50	43.75	18.75
		April	13	*Microcystis Synechocystis Anabeana Aphanizomenon*	*Navicula Pinnularia Melosira Skeletonema Chaetoceros Pleurosegma. Fragilaria*	*Gymnodinium Ceratium*	30.77	53.85	15.38
		May	08	*Microcystis Synechocystis*	*Navicula Pinnularia Melosira Chaetoceros Pleurosegma*	*Gymnodinium*	25.00	62.50	12.50

2019	Autumn	November	10	*Microcystis Synechocystis Anabeana*	*Coscinodiscus Navicula Pleurosegma Synedra Skeletonema*	*Gymnodinium Ceratium*	30.00	50.00	20.00
	Winter	December	11	*Microcystis Synechocystis Anabeana Chroococcus*	*Coscinodiscus Navicula Pleurosegma Synedra*	*Gymnodinium Ceratium Peridinium*	36.36	36.36	27.27
		January	12	*Microcystis Synechocystis Anabeana Chroococcus Nostoc*	*Coscinodiscus Navicula Pleurosegma Melosira*	*Gymnodinium Ceratium Peridinium*	41.67	33.33	25.00
		February	13	*Microcystis Synechocystis Anabeana Chroococcus Nostoc*	*Navicula Pleurosegma Melosira Pseudonitzshia Baccillaria*	*Gymnodinium Ceratium Peridinium*	46.15	30.77	23.08
	Spring	March	12	*Microcystis Synechocystis Chroococcus Anabeana*	*Coscinodiscus Navicula Pleurosegma Baccillaria Thalassiossira*	*Gymnodinium Ceratium*	41.67	41.67	16.67
		April	09	*Microcystis Synechocystis Chroococcus*	*Coscinodiscus Navicula Pleurosegma Baccillaria Thalassiossira*	*Gymnodinium*	33.33	55.56	11.11
		May	09	*Microcystis Synechocystis Chroococcus*	*Coscinodiscus Pleurosegma Navicula Baccillaria Thalassiossira*	*Gymnodinium*	33.33	55.56	11.11
		Frequency of occurrence of collected phytoplankton							
		Omnipresent		*Microcystis Synechocystis* (2016-2019)	*Synedra (2016-2017) Rhizosolenia* (2016) *Pseudonitzshia Skeletonema* (2017) *Navicula Pleurosigma* (2017-2019) *Chaetoceros Pinnularia* (2018)	*Gymnodinium* (2018-2019)			
		Constant		*Aphanizomenon* (2017-2018) *Chroococcus* (2019)	*Navicula* (2016) *Coscinodiscus* (2017/2019) *Synechococcus* (2017) *Skeletonema Fragilaria* (2018)	*Ceratium* (2018)			
		Regular		*Nostoc Chroococcus* (2017) *Anabeana* (2019)	*Skeletonema* (2016) *Melosira* (2018) *Baccillaria* (2019)	*Gymnodinium* (2017) *Prorocentrum* (2018) *Ceratium* (2019)			
		Accessory		*Anabeana Oscillatoria Lyngbya* (2017) *Anabeana Merismopedia* (2018) *Nostoc* (2019)	*Pleurosigma* (2016) *Rhizosolenia Chaetoceros* (2017) *Thalassiossira Melosira Synedra* (2019)	*Ceratium* (2017) *Prorocentrum* (2019)			
		Rare		*Stephanopyxis* (2017) *Volvox* (2018)	*Coscinodiscus Pinnularia* (2016) *Surirella* (2017) *Skeletonema* (2019)	-			

Note: Omnipresent: F ٪=100٪; Constant: 75≤ F ٪≤ 100; Regular: 50≤ F٪≤75; Accessory: 25 ≤ F ٪≤ 50; Rare: F ٪≤ 25

Table 3. Correlation matrix (Pearson) of the period of study (2016-2019)

Variables	Cyano	Diatoms	Dinofla	MT	TC	Sal	pH	Conduc	DO	Nitra	Nitri	Orthoph	SM	Chlorophyll
Cyano	**1**													
Diatoms	-0.3216	**1**												
Dinofla	**-0.6569**	**-0.5026**	**1**											
MT	**0.4294**	0.3132	**-0.6414**	**1**										
TC	0.1758	**0.4254**	**-0.4992**	**0.6405**	**1**									
Sal	0.2326	**0.4331**	**-0.5572**	**0.5996**	**0.8851**	**1**								
pH	**-0.4357**	0.0419	0.3645	-0.1701	0.0120	-0.0807	**1**							
Conduc	0.2857	**0.4043**	**-0.5828**	**0.7114**	**0.8722**	**0.9354**	-0.1331	**1**						
DO	-0.1600	**-0.3824**	**0.4506**	**-0.5215**	**-0.9077**	**-0.7271**	-0.0600	**-0.7242**	**1**					
Nitra	0.0452	**-0.4067**	0.2825	0.0736	-0.1663	-0.1550	0.1048	-0.1854	0.2507	**1**				
Nitri	**-0.4159**	0.0052	**0.3756**	-0.1736	-0.0031	-0.2035	0.3411	-0.2029	-0.1222	-0.0240	**1**			
Orthoph	-0.0605	-0.1045	0.1385	0.0080	0.0136	0.0391	0.2354	-0.1128	0.1193	0.3525	0.0434	**1**		
SM	0.1702	0.3653	**-0.4463**	**0.4512**	**0.6809**	**0.7926**	0.0178	**0.7017**	**-0.6468**	-0.1136	0.0481	0.1093	**1**	
Chlorophyll	0.1159	**0.4026**	**-0.4264**	**0.6442**	**0.6716**	**0.7554**	-0.0722	**0.7212**	**-0.5892**	0.0008	-0.0533	0.0993	**0.7904**	**1**

Note: Values in bold are different from 0 at significance level alpha=0.05

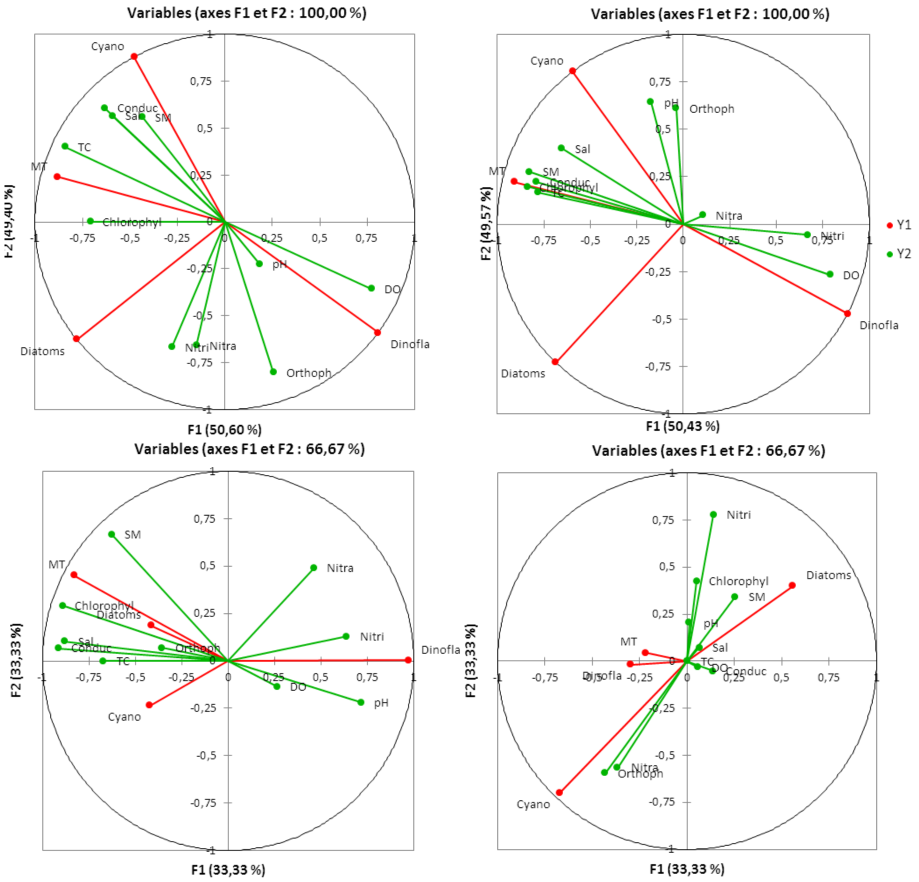

Figure 5. CCA for the physicochemical parameters, the monthly total of algae and algal groups analyzed during the different periods (from 2016 to 2019)

Fluctuations in dissolved oxygen content are related to temporal variations in temperature; the decrease in oxygen content would be related to the increase in the temperature of the air, which limits the solubility of oxygen. The air temperature influence on oxygen dissolution has been reported by many authors who point to a correlation between temperature and oxygen. According to the CCA, dissolved oxygen affected *Microcystis aeruginosa*, alkalinity, and nitrate on phytoplankton abundance, phytoplankton, and Chlorophyta richness (Sharma and Sharma 2021).

Wassie and Melese (2017) observed extremely high phytoplankton densities, and the overall amount of phytoplankton correlated positively with NO_3^-N, PO_4^-P, SiO_2, and chlorophyll (a). Furthermore, phytoplankton abundance increased when nutrient concentrations rose, and vice versa (Litchman et al. 2015). In the study carried out by Sankaranarayanan et al. (2021), it was determined that the relation between total microalgal density and physicochemical properties was positively correlated with temperature (r = 0.825; p = 0.012), salinity (r = 0.848; p = 0.008), Diatoms (r = 0.804; p = 0.016), and Dinoflagellates (r = 0.848; p = 0.008). Dinoflagellates positively connected with total phosphorus and nitrite (r = 0.734, p = 0.038, and 0.752, respectively). Total microalgal population densities were positively linked with nitrate content (r = 0.811, p = 0.15), and Diatoms showed a positive correlation with nitrate (r = 0.774, p = 0.024).

Temperature is an environmental component that significantly impacts phytoplankton, both directly and indirectly, by changing the pace of metabolic responses (Guinder and Molinero 2014). Human activities and rainfall impacted nutrient concentrations and fluctuations in the stoichiometric nutrient ratios (Si/N, N/P, and Si/P) (Yadav and Pandey 2018). As a result, the planktonic system of the lagoon eventually becomes out of balance due to increases in anthropogenic, agricultural, and industrial nutrient discharges. Furthermore, the nutrients N, P, and Si can have different effects on the dynamics of phytoplankton and cause changes in the composition of microalgae at different times of the year (Akagha et al. 2020).

In conclusion, our study has shown that the occurrence and abundance of algae are closely related to their physicochemical characteristics. In addition, most parameters analyzed showed specific temporary and/or spatial variation. The salinity shows great variability, which would be at the origin of a great deal of variability in the planktonic populations according to the seasons. The dissolved oxygen in the lake is determined by its salinity and temperature. On the other hand, the renewal water rate's temperature and salinity strongly influence lake oxygenation. However, the microalgal biomass and chlorophyll mass contribute strongly to the lake's oxygenation and certain periods. Therefore, its shows high dissolved oxygen contents corresponding to the water in oxygen. The pH is rather alkaline, the conductivity is directly linked to the salinity, and the temperature-all three have the same evolution. The suspended matter variation in water would be related to the variation of the microalgae densities and the content of chlorophyll (a).

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