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Evolution of physicochemical parameters and trophic state of three Park National of El-Kala water bodies (North-east Algeria)

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ABSTRACT

The Park National of El-Kala wetland complex is very varied ecosystems; classified as a world protected sites through a renowned international wetland complex. This work was conducted in Northeastern Algeria to study the physicochemical parameters and to determine trophic levels in three water bodies of the Park National of El-Kala wetland complex from January to December 2017. The relationships between phytoplankton density, the main environmental parameters (temperature, salinity, nutrients) and characterization of trophic status based on the references of the Chlorophyll levels were investigated. The monthly fluctuations of the physicochemical parameters of the water showed variations following the seasonal rhythm and are strongly dependent on abiotic factors in the region. The results of the statistical analysis revealed significant correlations between phytoplankton densities and nutrient concentrations and also Chlorophyll concentration.

In conclusion, it was found hyper eutrophication status during the summer period as well as the autumnal period in all studied sites [Chla] > 25 µg/l. By contrast, Mellah lagoon is mesotrophic in winter ([Chla] =7.69 µg/l).

INTRODUCTION

The Mellah lagoon, Tonga and Oubeira Lakes are aquatic ecosystems listed in a register of wetland sites and belong to a biogeographic complex, exceptional by its biological diversity. It is, consists of a mosaic of aquatic habitats including freshwater and brackish water ponds, peat bogs and marshes, as well as lake and lagoon ecosystems **(Djabourabbi, 2014)**.

Lake eutrophication and thus increasing of biologic production associated have major consequences on the physicochemical parameters. However, Phytoplankton represents the basis of food webs and biochemical cycles, and is generally the first

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autotrophic compartment responding to a change of nutrient availability and it forms the basis of the food webs of aquatic ecosystems, represents an important biological component **(Sin *et al.*, 1999)**, and influences greatly the nutrient cycling **(Leruste *et al.*, 2016)**. According to **Ramade (1999)**, chlorophyll a concentrations measurement provides a strong indication of eutrophication level. On the other hand, **Mihnea (1992)** reported an annual average Chl-a of 5 µgl/l for eutrophic zones, whereas Bricker *et al*. (1999) describe as low eutrophised environments those characterized by a maximum Chl-a = 5 µg/l . However, **Galvez-Cloutier *et al.*, 2002** describes a eutrophic water plan starting at 8 µg/l of chlorophyll a concentration.

Anthropogenic eutrophication is widely regarded as one of the major problems affecting both continental and coastal aquatic ecosystems **(Downing, 2014)**. Due to human activities (agriculture, domestic discharges, industrial discharges), an excessive or unbalanced nutrients supply disturbs the community of primary producers, leading to an increase of the eutrophication processes and to drastic changes in the biodiversity of the autotrophic compartment. Thus, it may promote fast-growing opportunistic algae in the first place and finally phytoplankton at the expense of benthic organisms such as macrophytes, and may result in an increase of the frequency of harmful algal blooms **(Livingston, 2000; Le Fur *et al*., 2018; Leuriste *et al*., 2019)**. Increased phytoplankton biomass is the most common symptom of eutrophication among the myriad responses of aquatic ecosystems to anthropogenic inputs of nitrogen and phosphorus **(Glibert *et al.*, 2011; Leuriste *et al*., 2019; Draredja *et al.*, 2019)**. These algal blooms, which alter the physicochemical properties of water, increasing turbidity, decreasing oxygen levels, accumulating reduced elements **(Capblancq and Decamps, 2002)**, are most often also associated with other environmental factors, particularly temperature and luminosity **(Saoudi *et al.*,2015; Djabourabi *et al.*,2017; Leuriste *et al*., 2019; Draredja et *al*., 2019)**. However, High nutrient inputs can also, through an accumulation of macroalgal or phytoplankton biomass, lead to the development of dystrophic crisis and hypoxia and anoxia events, having dramatic impacts on all the living organisms **(Cloern, 2001; Leuriste *et al*., 2019)**. Phytoplankton was extensively studied in northern western Mediterranean lagoons **(Ounissi *et al.*, 2002, Nuccio *et al.*, 2003; Bernardi Aubry and Acri, 2004; Turki *et al.*, 2007; Daoudi *et al.*, 2012; Pulina *et al.*, 2012; Djabourabbi *et al.*, 2014, Leruste *et al.*, 2016; Leuriste *et al*., 2019; Draredja *et al.*, 2019 a, b)**.

Therefore, considering the socio-economic importance of this wetland, this work aims to determining physicochemical parameters and the eutrophication states based on the references of the Chlorophyll concentration of the three water bodies Oubeira, Tanga lakes and El-Mellah lagoon. The relationships between phytoplankton density and the main abiotic parameters (example; temperature, salinity, chlorophyll, nutrients) were investigated to highlight the driving factors.

MATERIALS AND METHODS

Study site

The El-Kala region in northeastern Algeria has mainly three important lakes: Oubeïra, Tonga and El-Mellah (Table 1, Fig. 1), a few kilometers apart. These sites are under the legal protection of the Park National of El-Kala (P.N.E.K). The latter, created on 23 July 1983, is the largest national park in the north of the country. It covers an area of 76,438 ha, i.e. 26% of the area of the wilaya of El-Tarf. Its very varied ecosystems classify it among the world protected sites through an international renowned wetlands complex

Table 1: Geographic coordinates of the Tonga, Oubeira lakes and El-Mellah lagoon.

Study site	Geographical position	Area (ha)	Deep max (m)
Tonga	36° 50' 695 N / 8° 23’ 272 E	2200 ha	4 m
Oubeira	36° 49 - 36° 51' N / 8° 22' - 8° 25' E	2500 ha	2 m
El-Mellah	36°ƒ 53' 565 N / 8°ƒ 19’ 560 E	860 ha	6 m

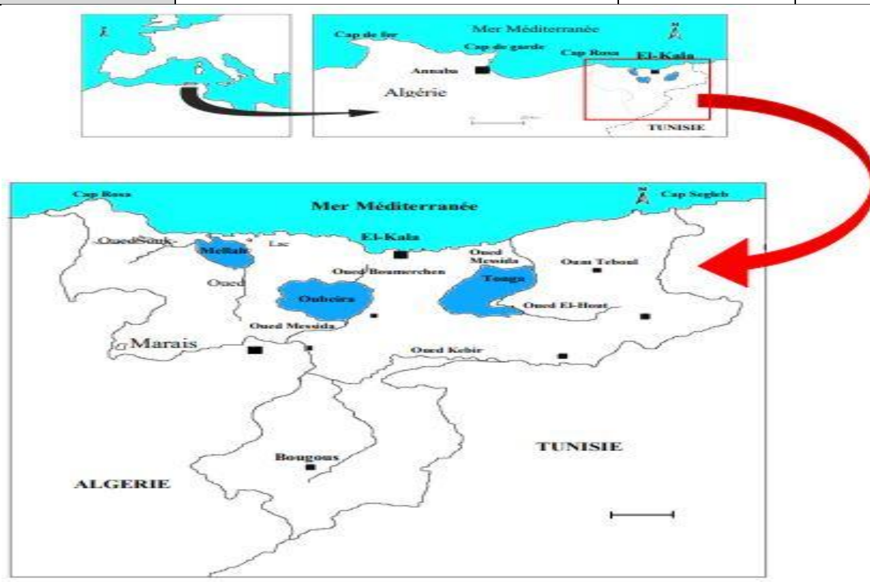

Fig. 1: Geographical location of the wetlands of the Park National of El-Kala **(Benyacoub, 1996)**

Physicochemical parameters

Water samples were taken monthly from January to December 2017. The parameters measured are: temperature, pH and dissolved oxygen. The measurements of the temperature “T °C” and dissolved oxygen (O_2) were carried out *in situ*, using a multi-parameter (Pionner 20 and 30). Concerning the pH measurement, it was performed using a multi-parameter (Consort 535). The use of these instruments consists of immersing the appropriate probe in the water, after calibration, and then waiting a few seconds before reading the result of the measurement, once the display has stabilized.

The chlorophyll α measurement was achieved according to the monochromatic method of **Lorenzen (1967)** using as solvent the acetone 90%. Four nutrients were determined by colorimetric methods (nitrite, ammonia, orthophosphate) **(Aminot and Chaussepied., 1983)** with the exception of nitrate **(Aoac, 2002)**.

Study of phytoplankton population

The phytoplankton was collected using a plankton net (20 µm mesh size) and then fixed in 10% formaldehyde. Phytoplankton cells were counted according to **Leitao *et al.*, (1983)**. Before identification performed according to **Bourelly(1988)**. Trophic status of P.N.E.K wetlands based on the references of the Chllorophyll concentration using norms values of **Galvez-Cloutier *et al.*, 2002**: [*Chl-a*] µg/l < 2.5 Oligotrophic, 2.5 > [*Chl-a*] µg/l < 8, Mesotrophic, 8 > [*Chl-a*] µg/l < 25 Eutrophic, [*Chl-a*] µg/l > 25 Hyper-eutrophic.

Statistical analysis

The Shapiro-Wilk test was used to evaluate the normality of the distribution. The normality of the distributions was verified in advance by applying the Shapiro-Wilk test; since the distributions are asymmetric ($P > 0.05$), we have chosen non-parametric tests for statistical analysis of the data.

Inter site and inter-season comparisons were made using the Kruskal-Wallis test. In addition, the PCA principal component analysis was also used as a descriptive and exploratory method whose objective is to characterize by a multi-varied approach the structuring of our water bodies. Statistical analyzes were performed with R Software (3.5.2. version).

RESULTS

The results of water temperature measurements in the three lakes showed that the monthly temperature varies between 11°C in winter and 30°C in summer. However, the highest dissolved oxygen levels (≥ 10 mg/l) are recorded in January in all the lakes, it is noted that the minimum values are registered in lake Tonga 2.53 ± 0.36 mg/l.

The measured pH varied between 7 and 8 for El-Mellah and Oubeira and between 6 and 7 for lake Tonga. Concerning the salinity, it only characterizes the waters of the El-Mellah lagoon. It reaches its maximum in summer with 39 ± 0.28 g/l and its minimum in winter with 28.48 ± 0.59 g/l. Moreover, Nitrite level is lower than 2 µ mole/l in Tonga and does not exceed 5 µ mol/l for Oubeira and El-Mellah with maximum values of 4.37 ± 0.65µ mole/l and 2.73 ± 0.06 respectively. Nitrate concentrations mark the lowest values in lake Tonga below 1 µ mol/l and show 2 peaks of 1.85 ± 0.24 µ mol/l and 2.80 ± 0.19 in Oubeira and El-Mellah respectively. Ammoniacal nitrogen is only present in summer in the three sampled lakes with 8.09 ± 1.82 µ mol/l in Tonga, 10.30 ± 0.56 µ mol/l in Oubeira and 49.47 ± 8.9 µ mol/l in El-Mellah lagoon.

Maximum levels of orthophosphates were recorded in August in the three study sites, the highest (5.74 ± 1.18 µ mol/l) being in Tonga.

The results of the chlorophyll α analysis, showed the highest levels in Tonga lake in August (360.45 ± 18.87 µg/l), in April, July and September at the Oubeira level with values above 100 µg/l, while in El-Mellah lake, the highest levels were found in June (76.08 ± 9.38 µg/l) and October (66.20 ± 6.49 µg/l).

Suspended Matter varied from site to site and month to month, with the lowest levels measured in Lake Tonga throughout the study period being below 50 mg/l. Maximum values between 150 and 250 mg/l are found during the spring period in Oubeira and El-Mellah (Table 2).

Table 2: Maximum and minimum values of the physico-chemical parameters of the waters of Tonga, Oubeira lakes and EL Mellah lagoon.

Parameters	Lake	Maximum ± Sd	Minimum ± Sd
Temperature (°C)	Tonga	26.15±1.06	9.75±0.07
	Oubeira	30.2±2.14	14.35±1.08
	Mellah	31.05±0.63	11.95±0.07
Dissolved oxygen (mg/l)	Tonga	11.52±1.44	2.53±0.36
	Oubeira	9.46±0.82	4.21±0.25
	Mellah	9.81±1.44	3.61±0.84
pH	Tonga	8.05±0.06	6.51±0.26
	Oubeira	8.6±1.08	7.01±1.11
	Mellah	8.61±0.32	7.58±0.06
Nitrite (µmol/l)	Tonga	1.49±0.39	0
	Oubeira	4.37±0.65	0.34±0.04
	Mellah	2.73±0.06	0
Nitrate (µmol/l)	Tonga	0.64±0.14	0
	Oubeira	1.85±0.24	0
	Mellah	2.80±0.19	0
Ammonium (µmol/l)	Tonga	8.09±1.82	0
	Oubeira	10.30±0.56	0
	Mellah	49.47±8.9	0
Orthophosphate (µmol/l)	Tonga	5.74±1.18	0
	Oubeira	2.86±0.4	0.44±0.1
	Mellah	1.75±0.17	0
Chlorophyll a (µg/l)	Tonga	360.45±18.87	1±0.36
	Oubeira	118.18±14.21	6.67±1.22
	Mellah	76.08±9.38	1.33±0.33
Suspended matter (mg/l)	Tonga	47.5±8.5	3.5±0.5
	Oubeira	185.75±37.7	1.5±0.4
	Mellah	238.5±17.67	10.5±1.5
Salinity (g/l)	Tonga	0	0
	Oubeira	0	0
	Mellah	39±0.28	28.48±0.59

Phytoplankton density

The highest global mean phytoplankton densities are recorded in Oubeira (d = 6 million ind/l) and El-Mellah (d = 5 million ind/l) during summer periods. However, the maximum values are observed in Tonga during spring (d = 3 million ind/ l) (Fig. 2), while mean values are recorded in Tonga and Oubeira (3.5 million ind/l) during autumnal periods.

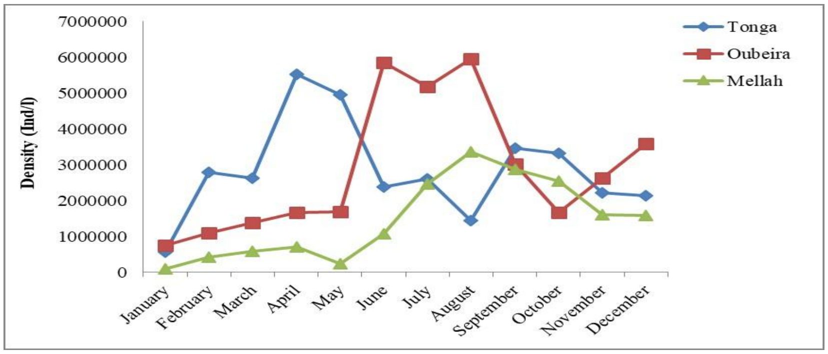

Fig. 2: Monthly variations in phytoplankton density in the waters of Tonga, Oubeira lake-and El-Mellah lagoon.

Trophic status of all P.N.E.K wetlands

Based on the references of the Chllorophyll concentration standards according to **Galvez-Cloutier *et al.*, 2002**. The 3 lakes present a state of eutrophy to hypereutrophy depending on the seasons. Indeed, we notice an hyper eutrophication status during summer and autumnal periods ([*Chla*] > 25 µg/l) in all study sites. However, we record – in winter- an eutrophic ([*Chla*] = 12,83 µg/l) and mesotrophic ([*Chla*] = 7.69 µg/l) status in Tonga lake and Mellah lagoon respectively. Furthermore, in spring, we perceive an eutrophication in Tonga lake ([*Chla*] = 9 µg/l). (Table 3).

Table 3: Trophic status of the wetland complex of the Park National of El-Kala according to **Galvez-Cloutier *et al.*, 2002**.

		Winter	Spring	Summer	Autumn
Tonga	**TS**	Eutrophic	Eutrophic	Hyper-eutrophic	Hyper-eutrophic
	[*Chla*] µg/l	12.83	9	130.4065	74.185
Oubeira	**TS**	Hyper-eutrophic	Hyper-eutrophic	Hyper-eutrophic	Hyper-eutrophic
	[*Chla*] µg/l	32.46	57.83	83.32	61.14
El-Mellah	**TS**	Mésotrophic	Hyper-eutrophic	Hyper-eutrophic	Hyper-eutrophic
	[*Chla*] µg/l	7.69	33.818	51.169	39.022

TS: Trophic status , **[Chla]** µg/l < 2.5 µg/l Oligotrophic, 2.5> **[Chla]** µg/l < 8 µg/l, Mésotrophic, 8 > **[Chla]** µg/l <25 µg/l Eutrophic, **[Chla]** µg/l > 25 µg/l Hyper-eutrophic.

Statistical analysis

Spearman correlation matrix

The calculation of the nonparametric Spearman's correlation, showed that the chl-a is positively correlated with the rate of NH_4^+ (r = 0.62) and NO_2^- (r = 0.51), and that the temperature is positively correlated with the rate of NH_4^+ (r = 0.63). The analysis also highlights, that the micro-algae density is negatively correlated with the level of dissolved oxygen (O_2) (r = -0.65) (Fig. 3).

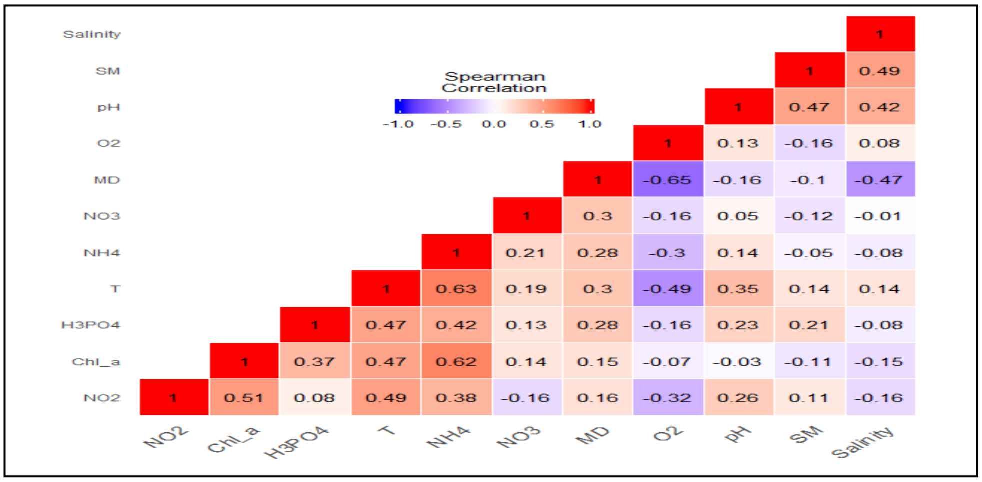

Fig. 3: Inter-variable variation: Spearman correlation coorplot of physico-chemical and biological parameters (11 variables).

Multivariate statistical analysis: the analysis in main PCA component

The principal components analysis (PCA) was used to analyze the spatial and time variations (11), in 3 lacs (Tanga, Oubaira et Mellah): this analysis revealed that 62.14% of the total variation (inter-sites and inter-months) of the physicochemical and biological variables of the matrix, is explained by the first three principal component (Table 4).

Table 4: Eigen values and percentage of the first three principal components.

Axis	Dim.1	Dim.2	Dim.3
Height value	2.63	2.06	1.51
Variance	26.38	20.63	15.12
Accrued	26.38	47.01	62.14

Axis 1 explains **26.38%** of the total variation; it is positively correlated with T (*r* = 0.83), SM (*r* = 0.65), pH (r = 0.54), NO2 - (*r* = 0.**5**3). This first axis separates Mellah lagoon (positive side of axis) from Tonga Lake (negative side of axis). Thus, we can say that Mellah lagoon is mostly characterized by very high levels of NO2-, SM, pH, high temperature and micro-algae density relatively high against the other lake (Tonga) that presents lower rates of NO_2^-, SM, pH and temperature. Consequently, this axis reflect a clear building of spatial variables composed principally by NO_2^-, SM, pH and temperature (Fig. 4 and 6).

This axis present also a clear monthly structuration; indeed, April, August, June, July and May are localized on the positive side of the axis and characterized by high levels of NO_2^-, SM, pH, high temperature and micro-algae density relatively high in comparison with the other months (November, December, January, February and March) that are localized on the negative side of axis and present a lower rates of NO_2^-, SM, pH with lower temperature (Fig. 1 and 3).

Concerning the second axis, it explains **20.63 %** of the total variation; this axis is built mainly by spatio-temporal structuration of the follow variables: H_3PO_4 (r = -0.71), chl_a (r = -0.80) and salinity (r = 0.64). Indeed, we notice that December, March and November (positive side of axis) are characterized by lower levels of H_3PO_4, chl_a and lower salinity; while August, September (negative side of axis) are characterized by high levels of H_3PO_4, chl_a and a low salinity. We remark also, that Mellah lagoon (positive side of axis) have lower rates of H_3PO_4, chl-a and a high salinity in comparing with Tonga lake (negative side of axis) that present high levels of H_3PO_4, chl_a and a low salinity (Fig. 4, 5, 6 and 7).

Lastly, the third axis explain only **15.12 %** of the total variation, built mainly by the strong positive correlation with NO_3^- (r = 0.54) and NH_4^+ (r = 0.53), on a hand; and the negative correlation with NO_2^- (r = -0.74) on another hand. In fact, Oubeira lake (negative side of axis) is characterized by high rates of NO3- et NH4+ and a low concentration of NO_2^-. Furthermore, we highlight a monthly structuration with this parameters; indeed, July, August, September and October (positive side of axis) are characterized by high concentrations of NO_3^- and NH_4^+ but a lower rate of NO_2^-; nevertheless, January, May and April (negative side of axis) are characterized by lower levels of NO_3^- and NH_4^+ but high concentration of NO_2^- (Fig. 5 and 7).

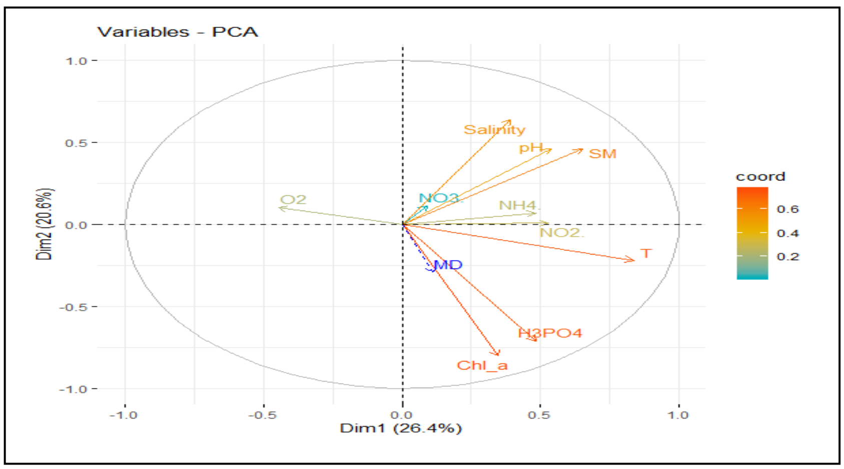

Fig. 4: PCA Correlation Circle (axis 1 and 2).

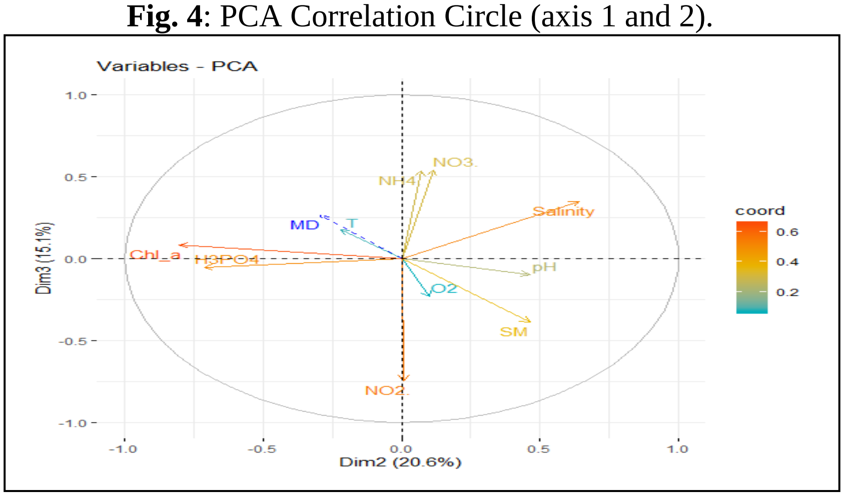

Fig. 5: PCA Correlation Circle (axis 2 and 3).

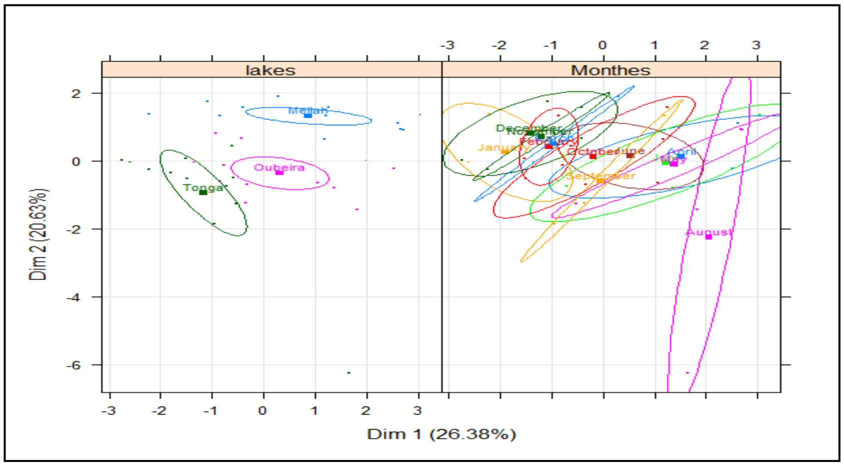

Fig. 6: CPA factor plan (axis 1 and 2).

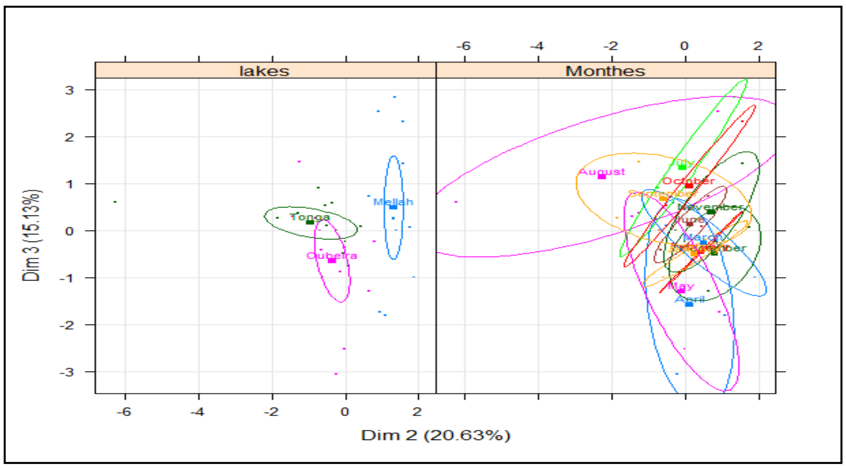

Fig. 7: CPA factor plan (axis 2 and 3).

DISCUSSION

The monthly fluctuations of the physicochemical parameters of the study sites, shows that variations follow a seasonal rhythm and are strongly dependent to abiotic factors in the region.

The calculation of the nonparametric spearman's correlation, showed that the chl-a is positively correlated of NH_4^+ and NO_2^-, and that the temperature is positively correlated with the rate of NH_4^+. The analysis also highlights, that the micro-algae density is negatively correlated with the level of dissolved oxygen (O_2).

The use of principal component analysis (PCA) as a descriptive approach allow to explain the spatio temporal structuration of 11 physico chemical variables and phytoplankton densities.

Our results showed that Mellah lagoon is mostly characterized by very high levels of NO2-, SM, pH, high temperature and micro-algae density relatively high. The other lake (Tonga) presents lower rates of NO_2^-, SM, pH and temperature. Furthermore, we highlight a monthly structuration cleary showed that, summer and autumn are characterized by high concentrations of NO_3^- and NH_4^+; nevertheless, winter and spring are characterized by lower levels of NO_3^- and NH_4^+ but high concentration of NO_2^-.

Finally, Oubeira lake is characterized by high rates of NO3- et NH4+ and a low concentration of NO_2^-.

However, variation in water temperature shows a difference of 20°C between the warm and cold seasons. This difference in temperature is a reflection of the Mediterranean character of the region where the contrasts between the cold and hot seasons are very severe **(Semroud, 1983, Djabourabi *et al.*, 2014; 2017; Nasri *et al.*, 2007; 2008; Draredja *et al.*, 2019 a)**. Concerning the salinity, it only characterizes the waters of the El-Mellah lagoon. It reaches its maximum in summer (39 ± 0.28 g/l)and its minimum in winter (28.48 ± 0.59 g/l).

Fluctuations in this abiotic parameter are related to the atmospheric temperature and water evaporation phenomena, due to the increase in the latter **(Ifremer, 2001)**. However **Draredja *et al.*, 2019** observed significant fluctuations in temperature and salinity in Mellah lagoon in function of the seasons. This was shown in other Mediterranean lagoons and ponds, among them Venice **(Solidoro *et al.*, 2004)**, Orbetello **(Lenzi *et al.*, 2003)**, Di Lagoon, Sacca Goro **(Mistri *et al.*, 2001)** and Thau **(Plus *et al.*, 2003)**. Mellah seems to be sensitive to changes in atmospheric temperature because of its shallow water column (< 5 m).

The pH is an important parameter in the study of aquatic environments and is highly dependent on chemical and biological mechanisms. **Dupont (2004)** reported that the first biological damage appears when the pH varies between 5.5 and 6. This is the range where the most intolerant species disappear.

A reduction in dissolved oxygen in water is an indicator of eutrophication of water bodies. Phtoplanktonic activity, through photosynthesis, is responsible for the higher levels of oxygen found, while decomposition of organic matter explains the zero values of the hypolimnion **(Dodson, 2005)**. The low oxygenation recorded during warm periods is related to the high temperature increase that limits oxygen solubility, which was very well argued during this study by the correlations found between these two parameters.

Indeed, high phytoplanktonic primary production, a sign of nutrient-enriched water, will form a deposit of dead organic matter at the bottom of the aquatic environment **(CCME, 1999)**. **Ounissi *et al.*, 2002; Draredja *et al.*, 2019** recorded that the Mellah lagoon showed less important seasonal variations in dissolved oxygen level. **Mistri *et al.*, 2001** reported dissolved oxygen values (14.5 mg/l) in the waters of the Sacca di Goro lagoon. In contrast to the majority of Mediterranean lagoons, Mellah appears to be the least enriched in nutrients **(Viaroli *et al.*, 1993; Bianchi *et al.*, 2003; Lenzi *et al.*, 2003; Bernardi Aubryand Acri, 2004; Bianchi *et al.*, 2004)**.

Measurements of nutrients (particularly phosphorus and nitrogen) are used to classify water bodies according to their trophic stage. However, other indicators are useful to assess this stage more comprehensively, such as the abundance of aquatic plants **(MDDELCC, 2015)**. Some conventional descriptors of water quality can also be considered, such as conductivity, pH, temperature and dissolved oxygen **(Painchaud, 1997)**.

Lowest levels of suspended matter were measured in lake Tonga and the highest was recorded in Oubeira and El-Mellah during the spring period.**Draredja *et al.*, 2019** observed in El-Mellah lagoon that the highest concentrations of suspended matter were recorded during the river flow in winter season and the rest of the year the concentrations were low in September.

Several studies carried out on lakes and rivers in northeastern Algeria have identified correlations between phytoplankton densities and nutrient concentrations **(Ounissi *et al*., 2002; Nasri *et al.*, 2007; 2008; Amri *et al.*, 2010; Boussadia *et al.*, 2015; Djabourabi *et al.*, 2014; 2017; Saoudi *et al.*, 2015; 2017.; Draredja *et al.*, 2019 a).**

This study used the results of the chlorophyll *α* concentration measurements to determine the trophic levels of all the wetlands in the P.N.E.K, it shows, an hyper eutrophication during the summer and autumn in all studied sites. On the other hand, in winter we report a state of eutrophication in Tonga lake and a mesotrophic state in El-Mellah lagoon. In addition, in the spring, we mark the eutrophication of lake Tonga. **Draredja *et al.*, (2019 a)** have recorded that lagoon El-Mellah, could be classified among mesooligotrophic sites in the Mediterranean basin.

The transition from the mesotrophic to the hyper-eutrophic status in lakes Tonga, Oubeira and El-Mellah is an expression of the imbalance that results from excessive enrichment of the water with nutrients, mainly phosphorus and nitrogen. This naturally occurring phenomenon shows that these water bodies are “aging” and this evolution normally occurs over a relatively long time scale **(MDDELCC, 2015)**.

The trophic level water body varies from ultra-oligotrophic to hyper-eutrophic. It is determined by measuring three lake surface variables: total phosphorus concentration, phytoplankton biomass (chlorophyll α) and transparency. If these variables do not agree, the concentration of chlorophyll *α* can be used. This is a biological description that integrates the physico-chemistry of the water body in its entirety **(Simoneau *et al.*, 2004)**. These changes in the composition of the autotrophic communities impact all the trophic levels, altering the ecosystem functioning **(Cloern, 2001)**.

CONCLUSION

Our study suggest that, the three water bodies Oubeira, Tanga and El-Mellah are experiencing eutrophication problem especially during the summer season, wich is the result of an excessive enrichment of the waters by nutrients, mainly phosphorus and nitrogen. Thus, the phenomenon of ageing of these water bodies occurred naturally with a relatively long temporal evolution.

The monthly fluctuations of the water physicochemical parameters. show variations that follow a seasonal rhythm and are strongly dependent to the abiotic factors in the region.

The results of the statistical analysis reveal correlations between phytoplankton densities and nutrient concentrations, thus reflecting a phenomenon of eutrophication of the different water bodies studied. The use of Principal component confirms the significant relationship between phytoplankton density and Chllorophyll concentration

High nutrient inputs can also, through an accumulation of macroalgal or phytoplankton biomass, lead to the development of dystrophic crisis and hypoxia and anoxia events, having dramatic impacts on all the living organisms. This situation requires the highlighting of a judicial monitoring program to preserve this region.

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