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The influence of environmental factors on the seasonal dynamics of Cladoceran community in the Oubeira Lake (Algeria)

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ABSTRACT

This study aims to inventory Cladocerans communities and determine their seasonal distribution according to certain environmental parameters in a natural shallow freshwater lake (Lake Oubeira) that El Kala National Park shelters. The values of chlorophyll-a and transparency observed during the study period indicate that the water body fluctuated between eutrophic and hypereutrophic status.Occurrence frequency of the 17 listed species revealed the dominance of *Bosmina longirostris* and the constancy of *Ceriodaphnia lacustris*. Among the 15 remaining species, 9 are regular (*Oxyurella tenuicaudis, Alona guttata, Alonella exigua, Pleuroxus aduncus, Eubosmina coregoni, Ceriodaphnia rotunda, Moina brachiata, Diaphanosoma brachyurum, Diaphanosoma lacustris*), 4 are incidental (*Scapholeberis mucronata, Acroperus elongatus, Simocephalus serrulatus, Moina micrura*) and 2 are rare (*Macrothrix rosea, Sida crystallina*). The number of species encountered in Oubeira waters is around 7, 17, 16 and 14 in spring, summer, autumn and winter respectively. In terms of abundance, the 7 species collected in the spring account for more than 88% of the total number of individuals collected. *B. longirostris* represents 9/10 of the overall density recorded by the Cladocerans collected. This species is highly abundant in spring (94% of its overall density) and correlated positively with transparency. *C. lacustris, D. brachyurum, M. micrura, M. brachiata* are absent in spring and are mainly present in summer and autumn; these species show positive correlations with water temperature, chlorophyll-a, nutrients and negative with transparency. It is also interesting to study the temporal dynamics of the various zooplanktonic groups and their interaction with phytoplankton and the fish inhabiting water bodies. Such studies need to be continued because they allow the creation of databases that will be used in biomonitoring programs and management of continental waters.

INTRODUCTION

Freshwater plankton communities are composed of large diversity of organisms contributing, essentially in food networks of lakes. Cladocerans represent an ancient group of Palaeozoic origin, mainly composed of microzooplankton **(Dodson and Frey, 2001; Forro *et al*., 2008)**. Also, Cladocerans (Crustacea: Branchiopoda), commonly known as water fleas, constitute an important element in freshwater lakes; According to **Hessen *et al.* (2003), Mola and Ahmed (2015),** these species largely contribute in zooplankton biomass and play a crucial role in trophic networks of freshwaters**.** As previously reported, Cladocerans were proved to be as important grazers of algae and detritus **(Balayla and Moss, 2004)**, importantly involved in nutrient recycling in aquatic ecosystems **(Hudson *et al*., 1999; Urabe *et al*., 2002)** and considered as water quality indicators **(Pinto-Coelho *et al*., 2005).** The Cladoceran group feeds on bacterioplankton and very small algae **(Nogueira, 2001)** and affects the growth of bacterial population, heterotrophic protozoa, microalgae and even some rotifer species via trophic relationships and competition **(Arnold, 1971; Pace and Vaque, 1994)**. Additionally, it is an important food source for the aquatic organisms feeding on zooplankton **(Christoffersen *et al*., 1993; Rybka and Yuryshynets, 2018)**. Thus, the Cladocerans exhibit an important link in transferring the energy of primary producers to the main consumers **(Nevalainen *et al*., 2019)**. Water fleas are important components of freshwater wildlife, since **Forro *et al*. (2008)** have identified them as particularly important in trophic network of the stagnant waters. In addition, physical and chemical factors, including water temperature, dissolved oxygen concentration as well as nutrient concentrations, linked to the availability of nutritional sources, can influence the structure of the shellfish community **(Lampert and Sommer, 1997)**.

The relationship between composition and abundance of Cladocerans, and the trophic state of the lake has been the subject of numerous studies around the world **(Neves *et al*., 2003; Hart, 2004; De Bie *et al*., 2008; Pinel-Allou and Mimouni, 2013)**. Although, similar research data are rare in Algeria, and, so those done on the continental waters have mainly focused on the inventory of the different groups making up the zooplankton of various water bodies.In this regards, **Cherbi (1984)** has studied the zooplankton populating three lakes of North-east Algerian dam (Boughzoul, Hamiz and Ghrib) and **Samraoui *et al.* (1998)** have inventoried the zooplankton population of several water bodies located in the north east of Algeria; and subsequently, these authors have completed this inventory by samplings carried out in natural lakes, temporary pools, ponds…. (**Samraoui, 2002)**. Similarly, **Cherbi *et al*. (2008)** have studied the zooplanktonic populations of the dam lakes located in sub-humid (Boukourdane) and arid (Foum El Ghorza and Djorf Torba) zones, and **Hamaidi *et al*. (2010)** have studied the zooplankton of Chiffa river and four lake dams (Boukourdane, Lekhal, Taksebt, Ghrib, and Keddara). On the other hand, **Bidi-Akli *et al*. (2014)** have been interested in studying the spatio-temporal dynamic of zooplankton and the effects of biotic and abiotic parameters on their populations. These authors have noted an instability in the composition of both phytoplankton and zooplankton, suggesting therefore, dual effects of abiotic factors of the environment and of predation by fish on the structure of the zooplankton community of this dam. In the Boukourdane reservoir, **Errahmani Brahim *et al*. (2015)** looked at the seasonal variability of the physico-chemical parameters and the dynamics of the plankton structure of the water body.

Therefore, the present study investigates for the first time, the temporal dynamic of Cladocerans, and aims thus to gather the database of Cladocerans community of Oubeira Lake through determining the temporal variations of the species composition and abundance, using various ecological index, and the evaluation of environmental variable effects on Cladocerans community.

MATERIALS AND METHODS

Study area and samples collection

The Oubeira Lake is an endorheic natural fresh water lake located in north eastern Algeria (36° 50' 695 N – 8° 23’ 272 E), within the El-Kala National Park (PNEK) created in 1983 and has an average altitude of 25m above of the sea level (Fig.1). It is the first largest fresh water lake in Algeria, and has an estimated surface area of 2200 ha and a maximum depth of about 4m. In 1984, the lake was included as a wetland under the Ramsar Convention (Ramsar Convention Official Website, 2007, www.ramsar.org). The Oubeira Lake is an important natural reserve for migratory birds and wildfowl species. This site has a great socio-economic importance in terms of fish production and the use of water for irrigation and peanut cultivation. The native Ichthyofauna of the Oubeira Lake is represented by *Barbus callensis*, *Pseudophoxinus callensis*, *Pseudophoxinus guichenoti*, *Pseudophoxinus punicus* and *Gambusia affinis affinis* (Poeciliidae), *Mugil cephalus*, *Liza ramada* (Mugilidae) and eel *Anguilla Anguilla* **(MPRH, 2004)**. The lake is very important for wintering water birds and hosts an interesting aquatic flora including water chestnut (*Trapa natans*), white water lily (*Nuphar alba*) and yellow lily (*Nuphar luteum*).

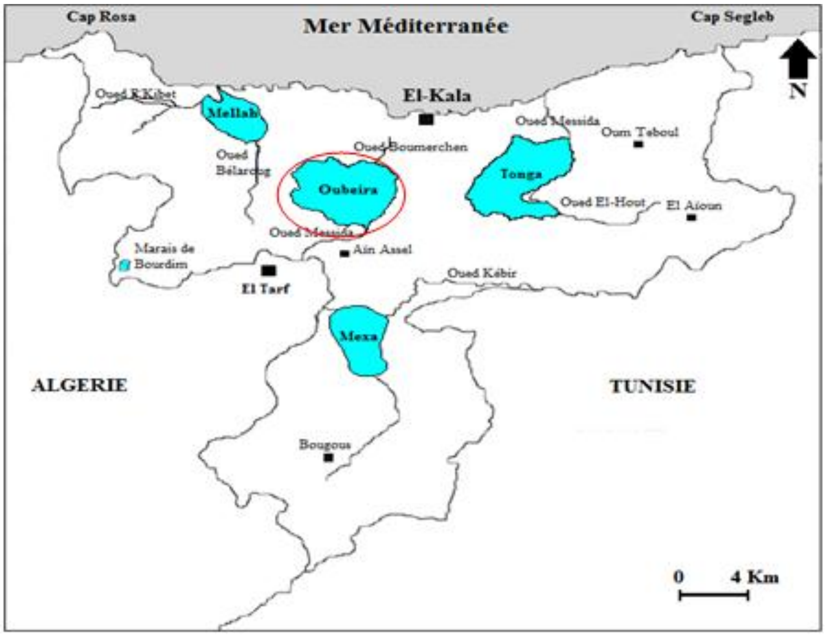

Fig.1. El-Kala National Park and location of Oubeira Lake**.**

Physicochemical measurements

Water and zooplankton samples were collected monthly during the period April 2015 to March 2016. Subsurface water temperature (Tem), dissolved oxygen (DO), pH and conductivity (CON), were performed *in situ* using a multi-parameter provided with probes (Model WTW Multi 340i/SET-82362). The water transparency was estimated with a Secchi disc (diameter 25 cm).

The water samples for nutrient determinations Nitrates (N-NO3), nitrites (N-NO2), ammonium (N-NH4) and orthophosphate (P-PO4) were performed in the laboratory from water samples preserved in cold and dark conditions using the colorimetric techniques for the application of spectrophotometric methods **(Aminot and Chaussepied, 1983)**

The suspended solid matter concentration was determined by measuring the dry weight of the filter before and after filtration of 500 ml of water sample through a Whatman GF/C membrane **(Aminot and Chaussepied, 1983).**

Sub samples (1liter) for quantification of chlorophyll-a, were filtered using Whatman GF/C filters (0.45 μm pore size filter and 47 mm- diameter) and pigment extraction was performed with 90% acetone **(SCOR-UNESCO, 1966)**. The concentrations were determined by the spectrophotometry (Shimadzu UV-1700 Pharma Spec UV-VIS) based on the absorbance at 663,645 and 630 nm.

Zooplankton sampling, identification and enumeration

Cladoceran samples were collected by filtering 100 liters of the subsurface lake water using a hand net made up of nylon cloth with mesh size of 60 μm. The content collected in the plankton tube attached to lower end of the net were transferred to separate polyethylene tubes and after centrifugation a subsample of 30 ml was taken. The Cladoceran organisms were preserved in 4% formalin, added with 4-5 drops of glycerine (organism remain flexible) and 5% sucrose (retain eggs in their brood). The zooplankton were identified and counted under a Leica binocular microscope chamber and results were expressed as the number of individuals per sample volume (ind/l). Identification of the specimens was carried according to **Rey and Saint-Jean (1980)** and to **Dodson and Frey, (1991).**

The zooplankton community structure was studied by calculating the species diversity index (H') using the Shannon–Wiener diversity index (**Shannon, 1949**), Simpson's diversity index (D) (**Simpson, 1949**) and evenness index (Equitability) (J) (**Pielou, 1975**), while frequency index (F %) and the dominance of the major taxa (DI %) was determined according to **Soyer, (1970)** and **Bellan-Santini, (1969)**, respectively. These indexes were calculated from the annual average density of Cladoceran species using (*t*-test statistics).

Statistical analysis

The statistical analysis of the data was performed under R (R Development Core Team, 2014 Version 3.1.2) developed by Ross Ihaka (1996). The normality condition of the distributions was checked beforehand by applying the Shapiro-Wilk (not shown). Then, the inter-seasons comparisons were performed using the non-parametric Kruskal-Wallis test. The correlations between the sets of parameters were evaluated by the non-parametric Spearman correlation coefficient (*r*) to analyze the intensity of relations between parameters. The principal component analysis (PCA) was used (package FactoMine R) to directly explain relationships between biotic and abiotic variables.

RESULTS

Environmental variables

Table 1 shows the values of physico-chemical parameters measured in the water of the Oubeira Lake during the study period.

The water temperature varied from 12°C in winter to 29°C in summer and was close to 20°C during the other seasons. Dissolved oxygen levels were between 6.39 mg/l (in summer) and 10.24 mg/l (in winter); intermediate values (close to 8 mg/l) were noted in spring and autumn. The water was alkaline and pH values varied from 8.4 (spring) to 8.87 (in autumn) and remained close to 8.7 in summer and winter.

Conductivity values fluctuated in the range of 445.18 and 541.18 µS/cm; values above 500 µS/cm are recorded in autumn and winter. Seasonal transparency values are low and do not show large differences (vary between 16 and 11 cm).

Nitrite concentrations range from 1 to 1.33 µmol/l and nitrate concentrations from 3.76 to 5.44 µmol/l; nitrate values are low in winter, high in summer and intermediate in spring and autumn. The N-NH4 contents fluctuate between 2.3 and 6 µmol/l; they exceed 5 µmol/l in autumn and summer and remain below 3µmol/l in winter and spring. Orthophosphates show the lowest concentrations in spring (1.9µmol/l) and the highest in summer (more than 6µmol/l); in autumn and winter, the concentrations are around 2.73 and 2.11 µmol/l respectively.

The highest SS levels are recorded in summer and autumn (over 118 and 105 mg/l respectively); values of 84 and 90 mg/l are recorded in winter and spring respectively. The chlorophyll-a contents are close to 20 mg / l in winter and spring; they more than double in summer (more than 58 mg / l) and reach a peak of 105 mg / l in autumn.

Table 1. Environmental variables recorded in the Oubeira Lake

Parameters	Spring	Summer	Autumn	Winter	mean	sd	cv	Min	media	Max
Chl-a (µg/l)	20.71	58.09	119.29	20.39	54.62	51.17	0.93	2.05	30.43	178.98
COND (µs/cm)	445.18	486.06	516.27	541.18	497.17	45.83	0.09	388	511.5	551
DO (mg/l)	8.34	6.39	8.44	10.24	8.35	2.04	0.24	3.98	8.47	12.05
N-NH4 (µm/l)	3.10	6.07	5.53	2.33	4.25	4.32	1.01	0.21	3.03	25.85
N-NO2 (µm/l)	1.33	1.33	1.28	1.09	1.25	0.66	0.53	0.16	1.17	4.72
N-NO3 (µm/l)	4.39	5.44	4.89	3.77	4.62	1.45	0.31	1.89	4.54	11.49
P-PO4 (µm/l)	1.90	6.16	2.12	2 .73	3.22	4.62	1.43	0.57	1.61	32.98
pH	8.40	8.63	8.87	8.77	8.67	0.39	0.04	7.87	8.67	9.88
SS (mg/l)	90.39	118.15	105.06	84.24	99.46	59.58	0.59	10	85.5	362
Temp (°C)	19.32	29.14	21.81	12.21	20.62	7.05	0.34	11.03	20.61	31.40
Trans (cm)	16.21	12.42	11.06	11.52	12.8	6.12	0.47	5	10	25

Temp – water temperature; DO – dissolved oxygen; Chl-a – Chlorophyll a; COND – conductivity; pH; NO3-N – Nitrates; NO2-N – Nitrites; NH4-N – Ammonium; PO4-P – Orthophosphate; Trans – Transparency; SS – Suspended Solids; (sd- Standard deviation ; CV- coefficient of variation; number of samples n= 132).

Community of Cladocerans

The observation of the morpho anatomical characters of the zooplankton specimens collected in the waters of Oubeir Lake a enabled us to identify 17 species related to 7 families: Aloninae (2), Bosmidae (3), Chydorida (2), Daphniidae (4), Macrothricidae (1), Moinidae (2), Sididae (3) (Table 2).

Calculation of the occurrence frequency of the 17 listed species revealed the dominance of *Bosmina longirostris* and the constancy of *Ceriodaphnia lacustris* (Table 2). Among the 15 remaining species, 9 are regular (*Oxyurella tenuicaudis, Alona guttata, Alonella exigua, Pleuroxus aduncus, Eubosmina coregoni, Ceriodaphnia rotunda, Moina* *brachiata*, *Diaphanosoma brachyurum*, *Diaphanosoma lacustris*), 4 are incidental (*Scapholeberis mucronata*, *Acroperus elongatus*, *Simocephalus serrulatus*, *Moina micrura*) and 2 are rare (*Macrothrix rosea*, *Sida crystallina*).

Concerning the abundance of identified individuals, we note the predominance of those belonging to the family Bosminidae which represent 9/10th of the global density (Table 2).Individuals belonging to the Sididae, Daphniidae and Moinidae account for 8.47% distributed as follows 4.01, 2.23 and 2.23%. The remaining 2% are Chydoridae (1.43%), Aloninae (0.62%) and Macrothrinidae (0.03%).

Table 2. List of Cladoceran species collected from Oubeira Lake

Family	Species	Occurrence frequency		Proportion
A*loninae* Dybowski & Grochowski ,1984	*Acropersus elongatus* Sars, 1862	33.33%	(A)	0.33 %
	Oxyurella tenuicaudis Sars, 1862	50%	(R)	0.29%
Chydoridae Dybowski & Grochowski, 1894	*Alona. guttata* Sars, 1862	66.66%	(R)	0.74%
	Alonella exigua Lilljeborg, 1853	58.33%	(R)	0.69%
Bosminidae Baird, 1846	*Pleuroxus aduncus* Jurine, 1820	50%	(R)	0.30%
	Eubosmina coregoni Baird, 1846	50%	(R)	0.43%
	Bosmina longirostris Müller, 1776	100%	(U)	88.65%
Daphniidae Straus, 1820	*Ceriodaphnia lacustris* Birge, 1893	75%	(C)	1.16%
	Ceriodaphnia rotunda Sars, 1862	66.66%	(R)	0.65%
	Scapholeberis mucronata Müller, 1776	33.33%	(A)	0.18%
	Simocephalus serrulatus Koch, 1841	25%	(A)	0.24%
Macrothricidae Dumont & Silva-Briano, 1998	*Macrothrix rosea* Jurine, 1820	8.33%	(R)	0.03%
Moinidae Goulden, 1968	*Moina brachiata* Jurine, 1820	50%	(R)	1.12%
	Moina micrura Kurtz, 1874	41.66%	(A)	1.11%
Sididae Baird, 1850	*Diaphanosoma brachyurum* Lievin,1848	58.33%	(R)	2.52%
	Diaphanosoma lacustris Korinek, 1981	58.33%	(R)	0.87%
	Sida crystallina Müller, 1776	33.33%	(R)	0.62%

Note *: U: Ubiquitous: FO% = 100%; C: Constant: 75 ≤FO% <100; R: Regular: 50 ≤FO% <75; A: Accessory: 25 ≤FO% <50, Ra; Rare: 0 ≤FO% <25.*

Diversity and ecological Indices

Zooplankton species diversity and evenness indices per season are shown in Table 3. The maximum number of species was observed in summer (S=17), followed by autumn (S= 16) and winter (S=14). Shannon (H'), evenness (J) and Simpson indices of diversity values generally increased in parallel to the number of species (S).

Table 3. Seasonal evolution of ecological indices for Cladoceran community

Season	Indices			
	S	J	H'	D
Spring	7	0.0212	0.0413	0.0105
Summer	17	0.901	2.552	0.906
Autumn	16	0.850	2.356	0.873
Winter	14	0.601	1.586	0.610

Seasonal dynamics of Cladocerans

In Oubeira waters, Cladocerans are strongly present in spring (88% of their overall density).It is, indeed, in spring, and with only 7 species of Cladocerans, that more than 160,000 ind/l are collected. All the 17 species recorded are present in summer, when the density of Cladocerans is around 10 000 ind/l. In autumn and winter, the densities are of the order of 5200 and 6400 ind/l with 16 and 14 species of Cladocerans respectively (Fig. 2).

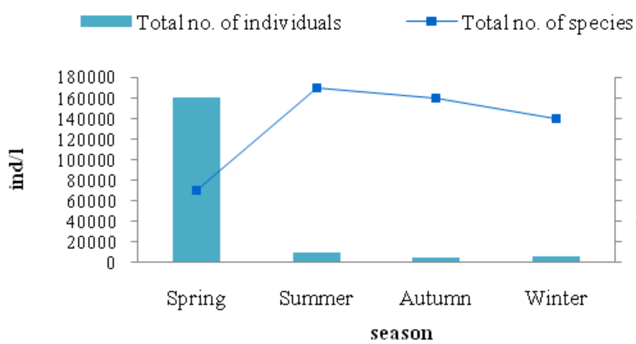

Fig.2. Seasonal variations in species diversity and density of Cladoceran in Oubeira Lake.

Seasonal dynamics of the main Cladoceran species

Bosmina longirostris is present throughout the year; it is highly abundant in spring where 94% of its overall density is noted (Fig. 3A). Seasonal mean densities of *B. longirostris* range from 175 (autumn) to 14300 ind/l (spring); in winter and summer the values are around 466 and 266 ind/l respectively.

Diaphanosoma brachyurum is absent in spring (Fig. 3B), but very strongly present in summer where it accounts for 78% of its overall density. This species shows seasonal mean densities of 112, 165 and 227 ind/l in winter, summer and autumn, respectively.

Moina Brachiata species is strongly present in summer and autumn where it records 82% of its overall density (35 and 47% respectively); the remaining proportions (18%) are recorded in winter as this species is absent in spring (Fig.3C). Seasonal mean densities recorded by *M. brachiata* are close to 60 ind/l.

Moina micrura species reaches 78% in summer and autumn (41% and 37% of its total density respectively); the remaining 22% is recorded in winter due to its absence in spring. Seasonal mean densities of *M. micrura* do not exceed 123 ind/l in summer, 110 ind/l in autumn and 67 ind/l in winter (Fig.3D).

Ceriodaphnia lacustris (Fig.3E) represents more than 42 and 35% of its overall density in summer and autumn (110 and 89 ind/l respectively); it is absent in spring and represents more than 22% in winter (59 ind/l).

The seasonal proportions of other species vary according to the following ascending order: winter (2%)≤ autumn (15%)≤ spring (33%) ≤ summer (50%) (Fig.3F). This group of species shows a seasonal distribution of 172 ind/l in summer, 53 ind/l in autumn, 24 ind/l in winter and 12 ind/l in spring.

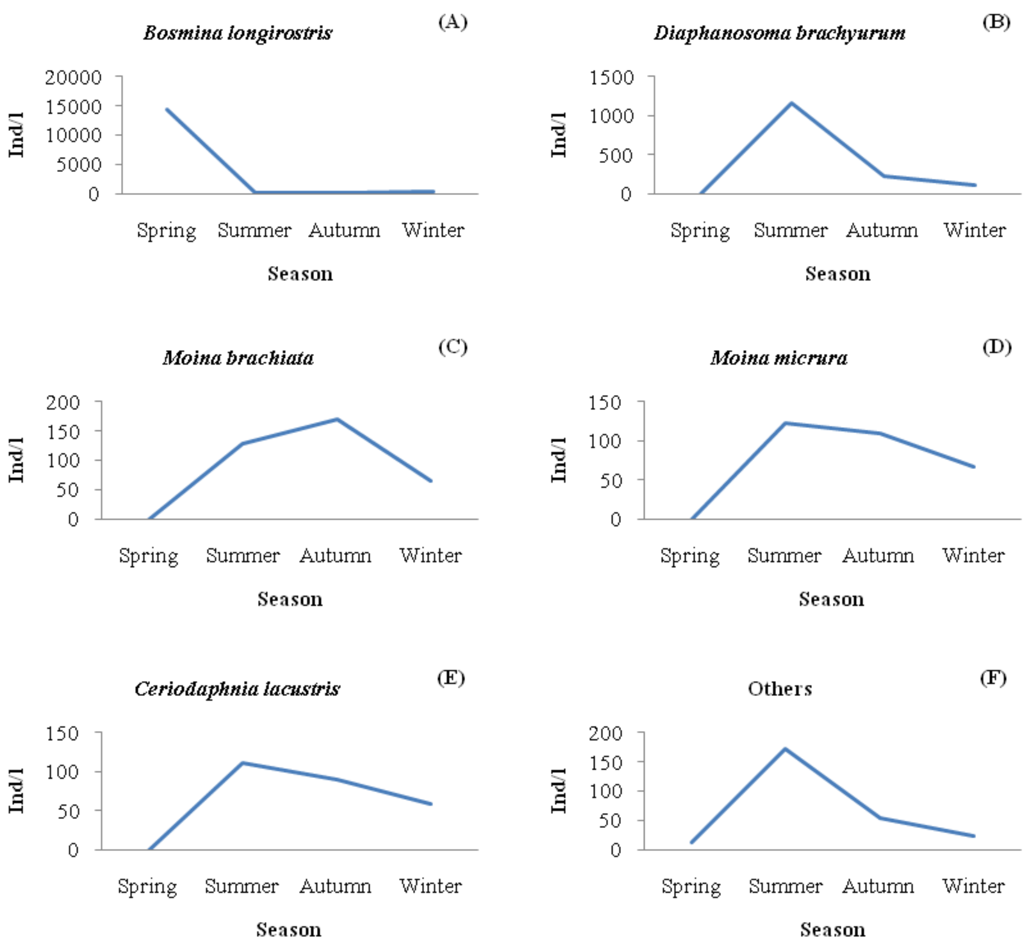

Fig. 3. Seasonal dynamics of the mains species of Cladoceran.

Relationship between environmental variables and main Cladocerans species
Principal Component Analysis (PCA)

The first two main components plan (1-2) of the PCA carried out on the sixteen biotic and abiotic variables restituted nearly 53.01% of data (inter-season variability). The axis 1 shows 30.00 % of the total variability, and is positively correlated with, temperature (r = 0.73, $\cos^2$ = 0.54), nitrate (N-NO3; r= 0.72, $\cos^2$ =0.52), orthophosphate (P-PO4; r=0.71, $\cos^2$ =0.51), ammonium (N-NH4; r=0.64, $\cos^2$ = 0.41), *M. micrura* (r=0.48, $\cos^2$ =0.23), SS (r =0.45, $\cos^2$= 0.20) and *M. brachiata* (r= 0.33, $\cos^2$=0.11) and negatively correlated with the dissolved oxygen (DO; r=-0.78, $\cos^2$ = 0.61). Also, the axis 1 obviously shows a clear difference between groups of warm months (May, June, July, August, September and October) and the group of cold months (January, February, March, April, November and December).

Axis II alone accounts for 23.01% of the total variation (Fig. 4). This axis is negatively correlated with *Bosmina longirostris* and transparency, which contribute strongly to its construction (r=-0.63, $\cos^2$=0.40, r=-0.75, $\cos^2$=0.57 respectively); this axis allowed us to identify the specificity of spring and the high abundance of *B. longirostris*. On the positive part of axis II are projected conductivity (r=0.82, $\cos^2$=0.68), Chl-a (r=0.57, $\cos^2$=0.33), pH (r=0.53, $\cos^2$=0.28) and *Ceriodaphnia lacustris* (r=0.41, $\cos^2$=0.17), *D. brachyurum* (r= 0.31, $\cos^2$=0.10) and N-NO2 (r= 0.28, $\cos^2$=0.08).

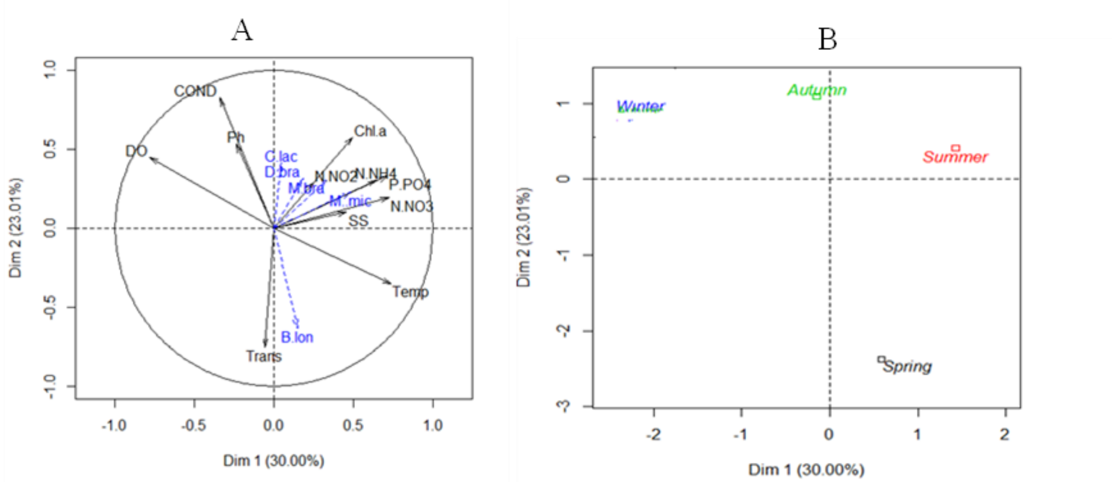

Figure 4: Standardized Principal Component Analysis based on seasons at Oubeira Lake level. Factorial design (1, 2): axis 1: 30.00%, axis 2: 23.01%. (A) Circle of correlations of the environmental variables with the first two axes of the PCA. (B) Projection of seasons on the first two axes of the standardised PCA.

The comparison between seasons by using non-parametric test of Kruskal Wallis reveals significant differences (p<0.05) for each of the measured variables, excluding suspended solids (SS) and phosphorus (P-PO_4).

Simple linear correlations between abiotic and biotic variables are shown in table 4. *Bosmina longirostris* shows a negative correlation with chlorophyll-a and N-NO3 (p< 0.0001), N-NH4 (p< 0.001), N-NO2, P-PO4 (p < 0.01), temperature and conductivity (p < 0.05). This species is positively correlated with transparency (p < 0.05).*Ceriodaphnia lacustris* shows a positive correlation with chlorophyll-a, pH (p <0.0001), conductivity, N-NO2 (p <0.01), N-NH4 and N-NO3 (p <0.05). The correlation of *C. lacustris* with transparency is negative (p <0.0001). The correlation of *Diaphanosoma brachyurum* is positive with temperature (p <0.0001), N-NH4 (p <0.01) and negative with transparency (p< 0.01). *Moina micrura* is positively correlated with temperature, chlorophyll-a (p <0.0001), N-NH4, NO3, P-PO4 (p <0.01), N-NO2 and pH (p <0.05) and negatively with transparency and dissolved oxygen (p< 0.0001). *Moina brachiata* is positively correlated with temperature, chlorophyll-a, N-NO2, N-NO3 (p <0.0001), N-NH4 (p <0.01), P-PO4 (p< 0.05), and negatively with transparency and dissolved oxygen (p< 0.001).

Table 4. Results of Spearman test (p values)

	B.lon	C.lac	Chl.a	COND	D.bra	DO	M.mic	M.bra	N.NH4	N.NO2	N.NO3	P.PO4	pH	SS	Temp	Trans
B.lon																
C.lac	0.0003															
Chl-a	<.0001	<.0001														
COND	0.0348	0.0024	0.3270													
D.bra	0.0023	<.0001	<.0001	0.0570												
DO	0.8025	0.6537	0.4482	<.0001	0.1857											
M..mic	0.0155	<.0001	<.0001	0.0705	<.0001	<.0001										
M.bra	0.0004	<.0001	<.0001	0.5399	<.0001	0.0002	<.0001									
N.NH4	0.0003	0.0344	<.0001	0.0409	0.0035	0.0086	0.0012	0.0032								
N.NO2	0.0013	0.0062	<.0001	0.6057	0.3491	0.1695	0.0338	<.0001	0.0003							
N.NO3	<.0001	0.0412	<.0001	0.0070	0.0527	0.0002	0.0087	<.0001	<.0001	<.0001						
P.PO4	0.0056	0.8493	0.0816	0.6852	0.1871	0.0002	0.0035	0.0236	0.0382	0.0982	0.0002					
pH	0.0513	<.0001	0.0004	<.0001	<.0001	<.0001	0.0452	0.0832	0.6068	0.0928	0.9733	0.1096				
SS	0.5704	0.1570	0.2858	0.3484	0.3394	<.0001	0.2552	0.2767	0.1300	0.1193	0.0875	0.0003	<.0001			
Temp	0.0224	0.37-38	0.0019	<.0001	<.0001	<.0001	<.0001	<.0001	0.0011	0.8927	<.0001	0.0262	0.5974	0.3670		
Trans	0.0351	<.0001	<.0001	<.0001	0.0006	0.1093	<.0001	<.0001	0.3927	0.0015	0.1969	0.0373	0.0911	0.0141	0.0003	

Temp – water temperature; DO – dissolved oxygen; Chl-a – Chlorophyll a; COND – conductivity; pH; N-NO3 – Nitrates; N-NO2 – Nitrites; N- NH4 – Ammonium; P- PO4 – Orthophosphate; Trans – Transparency; SS – Suspended Solids; B.lon - , Bosmina longirostris; C.lac – Ceriodaphnia lacustris; D.bra – Dyaphanosoma brachyurum; M.mic – Moina micrura; M.bra – Moina brachiata* p≤0.05; ** p≤0.01; *** p≤ 0.001.

DISCUSSION

The Oubeira Lake waters were alkaline (pH=8.67) and quite well oxygenated (DO = 8.35 mg/l) and had a mean T° and an average conductivity close to 20°C and 500 µS/cm, respectively. According to the criteria of **Olsen (1950)**, the fact that the water conductivity of Oubeira exceeds 500 µS.cm-1, this lake can be classified as eutrophic **(Djabourabi *et al*., 2014; Bensafia *et al.*, 2020).**

The average contents of nitrogenous elements were about 4.25 mg/l for ammonium, 4.62 mg/l for nitrates and 1.25 for nitrites; whereas the average content of orthophosphates was about 3.22 mg/l. The transparency of the water did not exceed 25cm and the suspended solids matter contents reached an average of 99 mg/l. In Oubeira Lake waters, the average chlorophyll-a levels were around 54.62 µg/l; they were relatively low in winter and spring (close to 20µg/l) and high in summer and autumn (over 58 and 119 µg/l, respectively); very significant positive correlations were noted between chlorophyll-a and N-NH4, N-NO3 and N-NO2 levels ($p<0.0001$). With reference to the diagnostic grid elaborated by the O.E.C.D. and based on transparency values and chlorophyll-a levels, we can classify Oubeira Lake waters as hypereutrophic (**Vollenweider and Kerekes, 1982**).

In Oubeira Lake waters, we collected 17 species belonging to 14 genera. In this same water body, **Samraoui *et al*., (1998)** report the presence of 10 species attached to 7 genera among which only three species are reported in the two studies (*Alona Guttata, Pleuroxus aduncus, Macrothrix rosea*).This difference in composition of Cladoceran community could be explained by the period and effort of sampling. Previous studies report that factors influencing the faunistic composition of a lake are the size of water body (**Dodson and Silva-Briano, 1996; Aka, 2018**), the season and the sampling device and above all the sampling frequency (**Jensen *et al*., 2013; Monney *et al*., 2016**). This seems to be the case, in this study, due to the application of a higher sampling frequency than that used by **Samraoui *et al*., (1998).**

The occurrence frequency of 17 identified species revealed the dominance of *Bosmina longirostris*, the constancy of *Ceriodaphnia lacustris* and the regularity of the species, namely *Oxyurella tenuicaudis, Alona guttata, Alonella exigua, Pleuroxus aduncus, Eubosmina coregoni, Ceriodaphnia rotunda, Moina brachiata , Diaphanosoma lacustris*). Among the 6 remaining species, 4 are incidental (*Scapholeberis mucronata, Acroperus elongatus, Simocephalus serrulatus, Moina micrura*) and 2 are rare (*Macrothrix rosea, Sida crystallina).*

In Lake Boukourdane, located in the same bioclimatic (sub-humid) stage, **Cherbi *et al*. (2008),** report the presence of three Cladocerans species among which *Diaphanosoma brachyurum* records the highest densities.

In the semi-arid zone of the North-Western part of Algeria, **Bouzidi *et al*. (2010)** report the presence of 5 Cladocerans species in Sidi M'hamed Benali Lake; These authors note the predominance of *Moina micrura* and *Diaphanosoma brachyurum* in this water body. In the arid zone, these authors point out the predominance of *Bosmina longirostris* and *Diaphanosoma brachyurum*, in the Foum El Ghorza and Djorf Torba reservoirs **(Feniova *et al*., 2019).**

In spring with the presence of 7 species, we collect more than 160 000 ind/L; wich represents 88% of the overall density collected Cladocerans. In summer, the density is close to 10,000 ind / l and represents only 6% of the overall density; although the 17 species of identified Cladocerans are available. In autumnal and winter period the abundance of 16 and 14 species of Cladocerans species are respectively 5200 and 6400 ind/L.

During the study period, the significant seasonal fluctuations in the Shannon and Weaver index and the equitability of Piélou revealed high instability in the Cladocerans community structure of Oubeira Lake; this indicates the variability of the environmental conditions that prevailed throughout the study. With regard to the Cladocerans diversity, the highest values of the Shannon and Weaver index are noted during the summer (2.55) and the fall (2.35) suggesting therefore a good population distribution between species. The recorded value in winter (1.58) proves the temporary absence of some species, since that revealed in spring (1.04) indicates the low diversity of Cladocerans population during this period of the year. This is well appreciated with the evenness Index (J), which highlights the imbalance of the ecosystem and the poor distribution of species at this time of the year; the low evenness values recorded in spring are due to the high relative abundances of the species *Bosmina longirostris* which account for almost 94% of the individuals collected during this season. As previously reported by **Devaraju (2015)**, Piélou index is low when one or some taxa have a very high relative abundance.

According to **Milan *et al*. (2017)**, the dynamic of Cladocerans is more sensitive to the physico-chemical parameters than that of copepods and rotifers.

The dominance of *Bosmina longirostris* species in spring period could be explained by its preferences for spring temperatures (**Aoujdad *et al*., 2014**). Furthermore, **Balkhi and Yousuf (1996)** consider the species *Bosmina longirostris* to be thermophophobic because high temperatures would cause a reduction in its longevity and fertility (**Varodi *et al*., 2017**). This is supported by the existence of a negative correlation between *B. longirostris* and the water temperature of Oubeira Lake. Many authors report the dominance of *B.*

longirostris in several European lakes with a high trophic status (**Nevalainen *et al*., 2018**). According to **Malgorzata (2016)**, *B. longirostris* prefers eutrophic conditions of water bodies and, would thus, be among the dominant species in a large number of eutrophic lakes. **Saler and Aliş, (2016)** have considered, *B. longirostris* as an indicator of the eutrophication process and this strengthens the existence of a positive correlation ($p < 0.05$) between this species and water transparency of Oubeira Lake.

Cladocerans population would be associated to trophic gradient of lakes and reservoirs; while *Bosmina sp* would be frequent in highly productive waters **(Arcifa, 1984; Sendacz, 1984)** and *Diaphanosoma sp* would be able to survive in lakes of high Cyanobacteria density **(Kerfoot and Kirk, 1991)** or lakes of high suspended solids matter levels **(Pourriot *et al*., 1994; Dejen *et al*., 2004).** What seems to be the case of Oubeira Lake which displays, in summer, suspended solids matter and Chlorophyll-a contents in the order of 118 and 58 mg/l respectively. The species *Diaphanosoma brachyurum* is very strongly present in summer where it accounts for 78% of its overall density; Our results show that this species is positively correlated with, chlorophyll-a, pH and temperature ($p < 0.0001$) as well as N-NH4 ($p < 0.001$). According to **Yousuf and Quadri (1981),** *D. brachyurum* is a summer species and prefers alkaline water (pH> 8) and hot temperature (T°> 20°C). **Lazareva (2012)** reports that *D. brachyurum* survives at a temperature between 20 and 25°C and acquires its maturity in less than four days at 25°C **(Romanovskii and Gilyarov, 1996**).This temperature range would be considered a limiting factor for the development of this species. It is also reported that *D. brachyurum* is very abundant at high trophic levels **(Havens, 1991)**. A positive correlation, between the abundance of *Diaphanosoma* and the chlorophyll-a level, was noticed by **Dejen *et al*. (2004),** during their study investigating the spatio-temporal distribution of microcrustaceans in a tropical lake.

Cerodaphnia lacustris, Moina brachiata and *M. micrura* are strongly present in summer and autumn; they are absent in spring and represent barely 20% of their overall density in winter. A significant positive correlation ($p < 0.0001$) is noted between the water temperature of Oubeira Lake and the species *Moina brachiata* and *M. micrura*. We note, moreover, the existence of positive correlations between the two species of the genus Moina (*M. brachiata* and *M. micrura*) and N-NH4, N-NO3, N-NO2 and P-PO4. According to **Abrantes *et al*. (2009)** and **Rajashekhar *et al*. (2009),** the species of the genus *Moina* develop in waters loaded by organic matter, less oxygenated and withstand organic pollution.

The three species *M. brachiata*, *M. Micrura* and *C. Lacustris* show, however, a very highly significant negative correlation ($p < 0.0001$) with water transparency.

With regard to the species *Ceriodaphnia lacustris*, the latter shows a positive correlation ($p < 0.0001$), with *M. brachiata*, *M. micrura* and chlorophyll-a. In addition, *Ceriodaphnia lacustris* shows positive correlation with pH ($p < 0.0001$), conductivity and N-NO_2 ($p < 0.01$), N-NH_4 and N-NO_3 ($p < 0.05$).

CONCLUSION

Oubeira Lake can be considered as hypereutrophic in reference to the high values of chlorophyll-a level and the very low values of transparency. The PAC showed the singularity of the species *B. Longirostris* evidenced by its high dominance in spring and its negative relation with many factors, including abiotic and biotic factors. Cladocerans population identified in Oubeira Lake would be associated with trophic gradients of waters, many species showed strong positive correlations with chlorophyll-a, temperature and nutrients.

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