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Floristic diversity and Ecology of EpilithicDiatoms of the ChottChergui wetland (North-West of Algeria)

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Abstract

This study is a phytoecological approach aimed to improve the knowledge on diatoms and their ecology in the wetland of ChottChergui in the northwesternregionof Algeria.For this work, 60 samples of solid substrates containing the epilithic diatom flora were collected in the field using a subjective method. The identification of diatom taxa was carried out according to a standard protocol while using pertinentliteraturethat specialized guides. At the level of the 5 sampling sites, water physicochemical parameters that could influence the distribution of diatoms were measured. The results obtained made it possible to recognize 36 diatom taxa belonging to 12 families, of which, the most dominant were *Naviculaceae*, *Surirellaceae* and *Bacillariaceae*. The calculated biodiversity indices (Shannon's H and equitability revealed a low taxonomic richness which will probably be explained by the dominance of the typical brackish water taxa such as *Mastogloiabraunii*, *Campylodiscusclypeus* ,and *Navicymbulapusilla*. We were also able to characterize the distribution of identified taxa according to the physicochemical parameters of each site. Furthermore, the attraction of the diatomic communities to saprobia shows the predominance of the two classes: α-mesosaprobic and β-mesosaprobe during the two seasons of fall and spring. Canonical correspondence analysis revealed that the distribution of diatom communities is positively correlated with conductivity and temperature. Some species like *Navicymbulapusilla*, show a significant resistance to anthropogenic eutrophication.

Keywords: Algae, Epilithic Diatoms, Ecology, ChottChergui,Tiaret, Wetland.

Introduction

Diatoms (*Bacillariophyceae*) are major group of unicellular algae that have been widely used over the past fifty years as bioindicators in the ecological assessment of rivers around the World. Diatoms are very sensitive to changes in nutrient concentrations and organic pollution (Prateek et al., 2016).The taxonomy of diatoms is complicated and their mode of reproduction is particular because reproduction is generally sexual. However,there can be individual division,causing a subtle alteration in shape. In general, they are identified through the morphology of cells which are characterized by geometric shape and their internal structures.

Work on Algerian diatoms began more than a century ago (Montagne, 1846; Ehrenberg 1854).Some studies were carried out during the 1970s (Baudrimont, 1970-1974) on the inventory of freshwater diatoms. Recent studies conducted by (Lange-Bertalot et al., 2009; Chaïb et al., 2011, 2012; Nehar et al., 2015; El Haouati et al., 2015; Negadi et al., 2018) have made it possible to relatively gain moreunderstanding of this flora.

Unlike the vascular flora, there is a paucity in the study oftheNorthAfrican cryptogamic flora, primarily those in Algeria (Ait Hammou, 2015). Research and field data on diatomsare still incomplete, especially their taxonomy and ecology (Negadi et al, 2018). For this reason,ourstudyseeks to characterize the diversity and ecology of the epilithic diatoms existing in the ChottChergui wetland in the north-west of Algeria.This region is very rich in salt, brackish and hot thermal water resources and constitutes the largest natural wetland of this type in North Africa after the ChottDjerid in Tunisia.The study of the diatoms diversity of this region is likely to increase the interest of conservation and protection of this wetland as part of an environmentally sustainable agenda. Furthermore, the obtained dataon the ecology of these taxa could provide more information on their local and regional distribution.

Study area

The ChottChergui region (0° 45'to 0° 55' E, 34° 25' to 34° 30' N) is located in the North-West of Algeria in the semi-arid steppe highlands. With an area of 855500 km^2 (varies according to precipitation), its width is approximately 160 km, while the maximum altitude is 1108m. Administrative records show that this area primarily includes the southern part of the wilaya (province) of Tiaret, which represents the eastern part of the wetland with an area of around 50000ha (CFT, 2016). The communes of SidiAbd Rahman and that of Chehaima house the majority of the Chott area.

This region is located in a steppe zone comprising salty, brackish water as well as a halophyte flora and fauna well adapted to the semi-arid climate.

Material and methods

Sampling

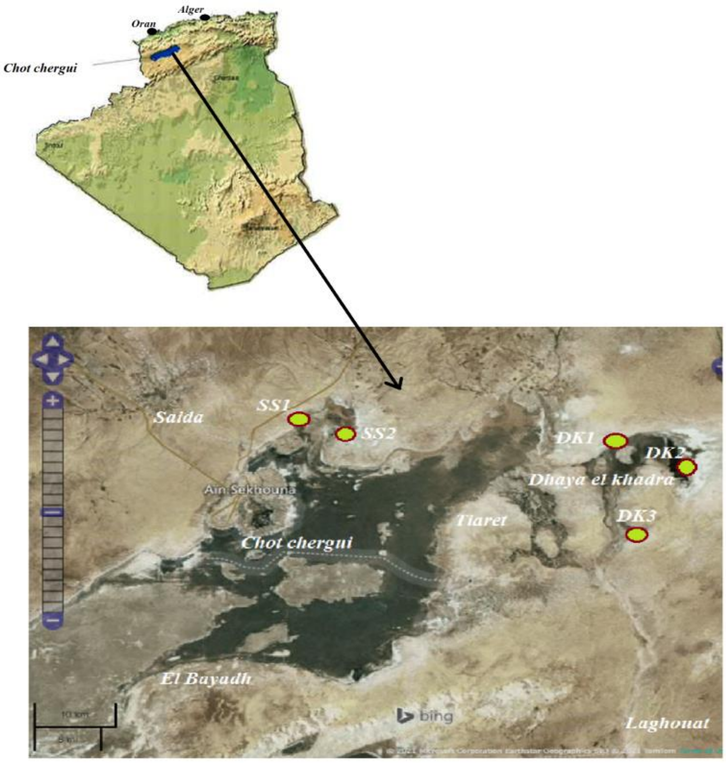

Figure. 1. Geographic location of the studied sites at ChottChergui.

Table. 1. Geographic locationsof studied sites

Station	Latitude	Longitude	Altitude (m)
DK2	34°32'41.16''N	1°20'30.43''E	999
DK1	34°34'14.55''N	1°15'54.32''E	1009
DK3	33°30'48.40"N	1°19'29.74"E	996
SS2	34°34'15.16''N	0°56'51.46''E	900
SS1	34°33'10.44''N	0°52'15.47''E	998

For the study, 60 samples were carried out at 5 sites (Figure. 1, Table. 1) chosen subjectively (Gounot, 1959) according to the environmental conditions (season, accessibility, as well as the presence of the natural submerged support at the level of the site).

These are the following stations*:*

DaitKhadra region (*stations DK1, DK2 and DK3*): is situated in the eastern ChottChergui, 20 km in the southwest of the town of Chehaima. It covers an area of 10000 ha. It contains swamps and Sebkha where the water level is about 50cm on the shores and 180cm in the middle. The water is clear, brackish (saline of: 700-1100mg/l)and used for livestock. The vegetation mainly consists of halophyte plants such as: *Salsolatetrandra, S. vermiculata, Traganumnudatum, Thymeleamicrophylla, Erodiumglaucophyllum, Typhaanguistifolia, Suedafrucutosa, Tamarixafricana, Atriplexhalimus* and *Phragmites sp.*

Saouss region (*stations SS1 and SS2*): this area is part of the large eco-complex of ChottChergui. They are part of the large basin of the Oran highlands, which occupies the eastern wetland of the Chott, near the town of Sidi Abed El Rahmane. The water is soft to brackish and permanent. Its level is generally low with an average depth of 0.5 to 1.5m. The vegetation is also mainly dominated by halophyte plants like that of DaitKhadra.

Sample

Sampling was carried out during two seasons for each of the stations studied (fall and spring). The samples had stones and pebbles covered on the upper face with a brownish biofilm characterizing the presence of diatoms. The depth of the samples taken varied between 20 and 40 cm in depth depending on the turbidity and the water level.

Regarding the water physicochemical parameters at the sampled sites, some of them were measured *in situ* (temperature, pH, conductivity and turbidity) using a Multi-parameter Water Quality Analyzer (Multimeter MM 40 +, Crison Instruments, Spain). The other parameters: dissolved O_2, organic matter (OM), NH_4, NO, Cl, PO_4, Ca, Mg, NO_3, SO_4, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) were measured in the Research Laboratory of Soil and Water, Faculty of Nature and Life Sciences, the University of Tiaret, Algeria.

The measurement of dissolved oxygen was carried out using an electrochemical method by an oximeter (HI 2400- Hanna). The chemical oxygen demand (COD) was measured following a chemical oxidation reaction of the reducing materials contained in the water by excess of potassium dichromate (K2Cr2O7) in a medium acidified by sulfuric acid (H2SO4), in the presence of silver sulfate (Ag2SO4) and Mercury sulfate (HgSO4) whose oxidation is done under boiling for 2 hours (Bartram and Richard, 1996). The determination of the COD concentrations was carried out by aHI-83099 Multi-Parameter Colorimeter instrument (Bountoux, 1993).

According to Rodier (2005), the determination of phosphates in water was based on the formation, in an acidic medium, of a complex with ammonium molybdate and double antimony potassium tartrate; the addition of ascorbic acid makes it possible to reduce the fixing of phosphate ions by giving a complex colored blue which has two maximum absorption values, one at around 700nm, the other greater at 880nm.

The determination of chlorides (Cl-), nitrates (NO3-) and nitrites (NO2-) was carried out according to (Rodier, 1996). The organic matter determination was carried out according to Rodier (1996). The analysis procedure was based on an assay using potassium permanganate in a hot alkaline medium.

Identification

Epilithic diatoms cover the upper surface of substrates with a brownish biofilm characteristic of their high abundance. So, the brushing procedure concerned the upper surface of substrates (natural submerged support) using a Toothbrush.After brushing and rinsing the samples with distilled water, the biofilm was harvested and then a few drops of Lugol solution (Lugol alkaline solution) were added to preserve the epilithic cells in preparation for their study. For the observation of frustules under the microscope, we removed the organic matter from frustulesby adding three volumes of hydrogen peroxide (H_2O_2) at 30%, for 15 to 20 minutes then we added a few drops of 35% HCl to the samples to the diatoms in centrifuge tubes. When the preparations have been diluted by a process, we repeated the process at least three times to remove all traces of oxidant. Finally, the diatoms were dried and fixed on a slide with balsam of Canada (RI = 1.55) for their enumeration and identification. Observations of diatom valves was performed at x 1000 magnification using a light microscope (Optika DM-15, Italy), and photographs were taken (Roper Scientific Photometrics, COOL SNAPTM). In order to observe diatoms randomly and to avoid counting the same specimen twice, the sample was scanned according to a defined slat (PrygielandCoste, 1993).

For this study, we used the following literature: Baudrimont (1974), Krammer and Langebertalotl (1988), Krammer and Lange-Bertalot (1991a), Krammer and Lange-Bertalot (1991b), Keith et al. (2000), Prygiel and Coste (2000), Taylor et al., (2007), Lavoie et al., (2008), Al-Kandari (2009), Al Yamani and Saburova (2019).

Data analyses

Diversity indices

Shannon-Weaver Index (Shannon and Weaver, 1949)

This index makes it possible to quantify the biodiversity of a study environment and observe an evolution over time: H '= -∑si = 1 p_i $\log_2$ pi, where H': Shannon-Weaver biodiversity index; i: a species of the studied environment; p_i: proportion of a species i in relation to the total number of species in the environment; s: number of species.

The Shannon index is often accompanied by the Piélou Equity index (1966), which represents the ratio of H 'to the theoretical maximum index in the stand, i.e. in a stand where all the species would have the same number: (Hmax) E = H '/ H' max

Canonical Correlation Analysis (ACC)

Canonical analysis (CA) is a factorial dimension reduction method for the statistical exploration of two sets of quantitative data observed on the same individuals. Canonical analysis (CA) is a method of multidimensional descriptive statistics that has analogies both with principal component analysis (PCA) for the construction and interpretation of graphs, and with linear regression. Statistical analyses were carried out using Pastversion 3 software (Hammer et al., 2001).

Results and discussion

Floristic diversity

The results obtained allowed us to identify 36 taxa of diatoms in the ChottChergui region (Table. 2). These taxa belong to 21 different genera and 13 botanical families. The majority of the taxa identified are known to be cosmopolitan as it was been verified by Baudrimont (1974). In fact, most of our species were recorded by this authors in his study on the diatoms of arid and semi-arid areas of Algeria. We also found that the majority of our taxa were also recorded by some authors in North Algeria (Petit, 1895; Al-Asadi et al., 2006; Chaïb et al., 2011; Chaïb and Tison-Rosebery, 2012; Nehar et al, 2014; Nehar, 2016).

The number of 36 taxa obtained is considered interesting compared to the other rare studies published in Algeria, in particular that of El Haouati et al (2015) in the Lake of Reghaya near Algiers which counted 24 taxa, but also the study of Nehar and al (2014) in the two sites of El-Hammam stream at Mascara and the estuary of Cheliff river at Mostaganem with a total of 56 taxa.

Other studies such as that of Chaib et al (2014) report a greater number of identified taxa. These authors report 322 taxa for El wed el Kebir in the northeast of the country. However, the literature review conducted by Nehar (2016) on all the recorded Algerian taxa, reported 359 taxa for the whole country; so, this number is to be verified.

Other studies in Morocco also report significant numbers of Diatom taxa identified, in particular Jaghror et al. (2017) in the Sibouwadi with 226 taxa.

Regarding the dominant families, it is the *Naviculaceae* which predominate (25.71%), followed by the *Surirellaceae*(22.86%) and the *Bacillariaceae* (17.14%, Figure. 2).

Table 2. The diatom taxa identified in the study area

			Spring					Fall				
			SS1	***SS2***	***DK1***	***DK2***	***DK3***	***SS1***	***SS2***	***DK1***	***DK2***	***DK3***
Family	**Taxa**	**Code**	+	+	+	+	+	+	+	+	+	+
Achnanthidiaceae	*Achnanthidiumexiguum*(Grunow) Czarnecki (= *Achnanthesexigua*runow in Cleve et Grunow 1880)	AEXI	-	-	+	+	+	-	+	+	-	-
Amphipleuraceae	*Halamphora coffeaeformis* (Agardh) Levkov	HCOF	+	+	+	-	+	-	-	+	+	-
Bacillariaceae	*Nitzschiacommunis*Rabenhorst	NCOM	-	-	+	-	+	+	+	-	-	-
	*Nitzschiadraveillensis*Coste et Ricard	NDRA	+	+	-	+	-	-	-	-	-	-
	*Nitzschiahantzschiana*Rabenhorst	NHAN	-	+	+	+	-	-	-	-	-	-
	*Nitzschialinearis*var. *subtilis* GrunowHustedt	NLIN	+	+	+	+	+	+	+	+	+	+
	Nitzschiapalea(Kützing) W. Smith	NPAL	+	+	+	+	+	-	-	+	+	-
	Tryblionellahungarica (Grunow) DG Mann (=*Nitzschiahungarica*Grunow)	THUN	-	-	-	-	-	+	+	+	-	+
Catenulaceae	*Amphora pediculus*(Kützing) Grunow	APED	+	-	-	+	-	-	-	-	-	-
Centrophycidées	*Coscinodiscus marginatus*Ehrenberg	CMAR	-	-	-	-	-	-	+	+	+	+
Cocconeidaceae	*Campylodiscus clypeus* Ehrenberg	CCLY	+	+	+	+	+	+	+	+	+	+
	*Cocconeispediculus*Ehrenberg	CPED	+	-	-	-	+	-	-	-	-	-
Cymbellaceae	*Encyonemaminutum*Hilse ex Rabenhorst(=*Cymbellaminuta*Hilse ex Rabenhorst 1862)	EMIN	-	+	+	-	-	-	-	-	-	-
	Encyonemasilesiacum(Bleisch) DG Man (=*Cymbellasilesiaca*Bleisch)	ESIL	+	+	+	-	-	-	-	-	-	-
Fragilariaceae	*Ulnaria ulna* (Kützing) Compère (=*Fragilaria ulna* (Nitzsch) Lange-Bertalot 1980)	UULN	+	-	+	+	+	-	-	+	+	+
Mastogloiaceae	*Mastogloiabraunii*Grunow	MBRA	+	+	+	+	+	+	+	+	+	+
Naviculaceae	*Craticulahalophila*(Grunow) DG Mann	CHAL	+	+	+	+	+	-	+	+	-	+
	Gyrosigmaacuminatum(Kützing) Rabenhorst	GACU	+	+	+	+	-	-	+	-	-	-
	*Navicula reidiana*Brébisson (=*Navicula tenellan*Brébisson ex Kützing 1849)	NRAD	-	-	+	+	+	-	-	-	-	-
	*Naviculacryptocephala*Kützing	NCRP	+	+	-	-	-	+	+	+	+	+
	*Naviculacryptotenella*Lange-Bertalot	NCRT	-	-	+	+	-	-	-	+	+	-
	*Navículagottlandica*Grunow	NGOT	-	-	+	+	+	-	-	-	+	+
	*Naviculagregaria*Donkin (=*Naviculagregalis*Cholnoky)	NGRE	-	-	-	+	+	-	-	-	-	-
	*Navicularostellata*Kützing	NROS	+	+	-	+	-	-	-	-	+	+
	Navicymbulapusilla(Grunow) Krammer (=*Cymbellapusilla*Grunow)	NPUS	+	+	+	+	+	+	+	+	+	+
Pleurosigmataceae	*Pleurosigmasalinarum*Grunow	PSAL	+	+	+	+	+	+	+	+	+	+
Stephanodiscaceae	*Cyclotellameneghiniana*Kützing	CMEN	-	-	-	-	-	+	+	-	+	-
	*Cyclotellastelligera*Cleve et Grunow	CSTE	+	+	-	-	-	-	-	-	-	-
Surirellaceae	*Cymatopleurasolea*Brébisson	CSOL	+	+	+	-	+	+	+	-	-	-
	*Cymatopleurasolea*var.*apiculata*(W. Smith) Ralfs	CSAP	-	-	+	+	-	-	-	-	-	-
	Cymbopleuranaviculiformis(Auerswald) Krammer (=*Cymbellanaviculiformis* (Auerswald) Cleve 1894)	CNAV	-	-	-	-	-	-	+	+	-	-
	Stenopterobiacurvula(W. Smith) Krammer	SCRU	+	+	+	+	+	+	+	+	+	-
	*Surirellabrebissonii*var. *brebissonii*Krammer& Lange-Bert.	SBRE	+	+	-	+	+	-	-	+	-	+
	*Surirellacrumena*Brébisson ex Kützing	SCRU	-	-	-	-	-	+	+	-	+	+
	*Surirellaovalis*Brébisson	SOVA	+	-	+	+	-	-	+	+	-	-
Thalassiosiraceae	*Thalassiosirapseudonana*Hasle&Heimdal	TPSE	-	-	+	+	-	-	-	-	-	-

Chaib et al (2011) in their study in wadi el Kebir reported also the dominance of *Naviculaceae*. Otherwise, *Surirellaceae* and *Bacillariaceae* do not usually dominate this type of inventory according to the consulted literature.

The most dominant species

Figure 3 shows the distribution of species across the explored stations. It is found that the diatoms flora of Chott Chergui is mainly dominated by 3 species (*Mastogloiabraunii*, *Navicymbulapusilla* and *Campylodiscus clypeus*).

Mastogloiabraunii present the highest percentages of abundance recorded in spring DK3 (26.6%), SS1 (25%), DK2 (22.31%) and SS2 (21.5%). In this last station, the species presents a high rate also in fall with 28.53%.

The second species (*Navicymbulapusilla*) was also found in abundance, but shows much more dominance in the fall with 40.29%, 38.07% and 26.88% at sites DK2, SS1 and DK3 respectively.

The third taxa (*Campylodiscusclypeus*) is a typical species of dirty water, widespread in this area with a dominance of (A> 20) during spring DK1 (35.83%), DK2 (20.67%) and DK3 (31.41%).

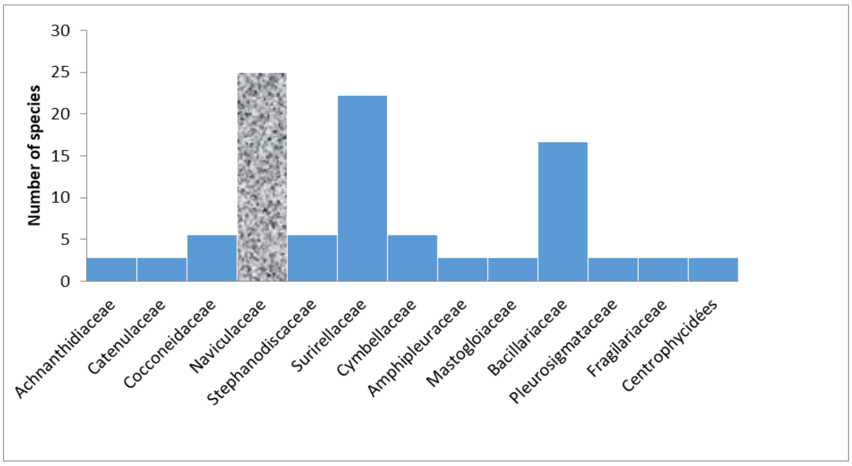

Figure 2. **The most dominant families (number of species-**

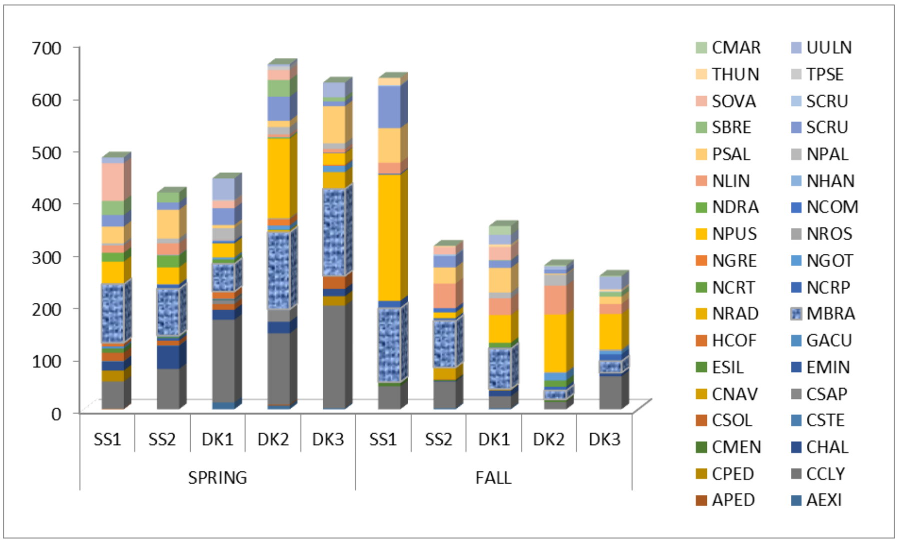

Figure. 3. Distribution and abundance of species across the studied sites during the spring and fall season

Diversity indices

In general, the obtained results show that the specific diversity in the fall season is greater than spring. On the other hand, during spring, there are more individuals (Table.3).This can be explained by the fluctuations of some physico-chemical parameters of the water in relation to the seasons. Indeed, parameters such as pH and salinity changes depending on the season (Farhadian et al. 2015). This is also the case for other parameters (topography, fluctuations in fresh water, tides, discharges and evaporation), which are environmental factors in constant variation according to the seasons (Gastineau, 2012).

Table. 3. Diversity and equity indices (number of taxa and individuals)

	Taxa (Number)		Individuals(Number)		Shannon I		Equity_I	
Season	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**
SS1	21	12	195	562	4,33	4,12	0,74	0,72
SS2	19	17	310	416	3,71	3.98	0,75	0,66
DK1	23	17	281	599	4.27	3,76	0,62	0,55
DK2	23	15	252	663	3,95	3,75	0,77	0,78
DK3	18	13	391	416	2,01	3.89	0,69	0,63

The obtained values from Shannon index confirm that the specific diversity observed during fall in the sampled stations is greater than that observed during the spring. The same results were observed by Farhadian et al., 2015 in Iran. Moreover, some equitability between the stations is quite easily observable, especially between the two seasons.

Ecology of diatoms and water quality in Chott Chergui

According to the classification of Van Dam et al. (1994), the chlorine values between 240 and 939 mg/l reflect the dominance of the medium brackish class. From the physico-chemical analyses results (Table. 4), the measured temperatures varies from one site to another. This makes it possible to classify the diatoms of Chott Chergui in 02 classes: the Euthermesdiatoms which characterize the region of Saouss and Ain Teddese; and the Mesotherms observed especially in DaitKhadra. While based on the pH, it appears that the diatoms encountered are alkaphilic across the majority of sites. On the other hand, the physico-chemical results lead us to conclude that the mineralization is strong in the five studied stations. Indeed, these waters are characterized by the predominance of SO_4 sulphates (255.1-511.6 mg/l), sodium Na^+ (38-343 mg/l), while the very high levels of magnesium exceeding 200 mg/l seems to be due to the drainage of sewage from the nearest commune of Sidi Abed El Rahmen.

Otherwise, in DaitKhadra (DK2, DK3), we observed high concentrations of nitrite and phosphate during the spring. This is due to the agricultural activities (fertilizer and sheep breeding) practiced in the Chehaima region near these stations.

In general, it appears that in ChottChergui, the concentrations of the physicochemical parameters of water, do not change during the two periods (fall and spring) which could be explained, firstly by the lack of precipitation, and then by the high temperatures characterizing the region during the two studied periods.

Table. 4. Water physico-chemical characteristics in the study area.

Site	*Season*	*T°*	*pH*	*CE*	*Tur*	*O_2*	*OM*	*NH_4*	*NO*	*Cl*	*PO_3*	*Ca*	*Mg*	*NO_3*	*SO_4*	*COD*	*BOD*
SS1		37,9	8,4	5798,4	15	40,2	27,2	0,09	0,154	939	0,13	130	271	39,5	448	221	22,1
SS2	*Spring*	32,7	7,55	7354,8	12	60,7	24,3	0,08	0,254	572,99	0,17	343	232	79,2	451	86	8,6
DK1		20,1	7,98	8001,2	12	52,3	26,05	0,26	0,18	553,25	0,09	83	198,5	170	511,6	70	7
DK2		17,4	8,07	8007,9	13	44,12	32,78	0,09	0,327	240	0,09	98	245	51	357,6	77	7,7
DK3		18,9	8,12	7983,7	17	92,12	36,4	0,12	0,145	376	0,02	127	188,7	66	255,1	150	15
SS1		30,7	9,03	7765,1	19	20,14	47,02	0,21	0,231	412,1	0,06	254	197,1	110	313	136	13,6
SS2	*Fall*	31,5	9,65	7549,2	12	27,6	41,1	0,05	0,143	330,2	0,12	143,4	154	87,5	296	79	7,9
DK1		12,3	9,32	8320,2	16	49,2	30,2	1,2	0,121	693,5	0,24	88	196,5	99,1	420	201	20,1
DK2		12,1	8,41	5753,6	14	36,06	20,3	0,05	0,788	698,1	0,31	92,4	242,8	135,7	435	178	17,8
DK3		15,7	9,33	6036,7	13	54,6	30,7	0,09	0,129	563,4	0,9	162,5	244,2	78,2	468	169	16,9

Regarding the attraction of the diatomic community to saprobic conditions, we report the predominance of the α-mesosaprobicclass during fall and spring (Figure. 4, 5). This has been observed in several studies focusing on water quality (Chaib and Tison-Roserbery, 2012; Neharet al 2015; Nehar, 2016). This is also the case concerning the dominance of

Navicymbulapusilla, known by its ecology, preferring oligotrophic waters with a moderate to high content of mineral salts, in particular waters with high concentrations of Ca^{+} and Cl^{-}.

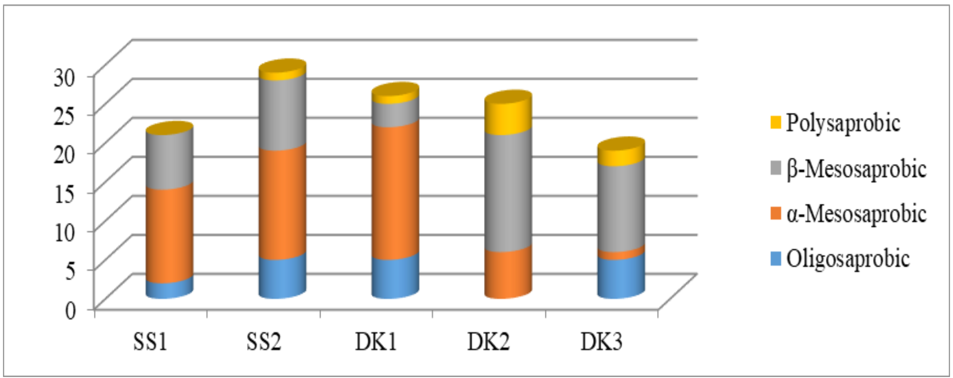

Figure. 4. Affinity of the diatoms community to physicochemical parameters (spring).

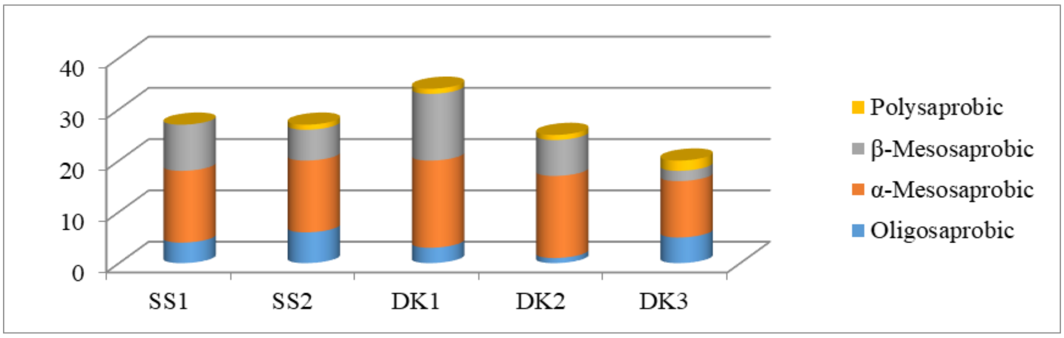

Figure. 5. Affinity of the diatomic community to physico-chemical parameters (fall)

At the DK2 and DK3 sites, we observed the dominance of the class of β-mesosaprobicdiatoms such as *Gomphonemaparvulum* and *Nitzschiapalea* during the spring period. These species have been observed in the agricultural runoff zone (Dait El Khadra) in agreement with the observations of several authors in the USA, Japan, Poland and Germany (Lobo et al., 1995; Leland and Porter, 2000; Köster and Hübener, 2001).

Meso-eutraphentic taxa (*Navicymbulapusilla*, *Campylodiscusclypeus*, *Cocconeispediculus* and *A chnanthidiumexiguum*) are well adapted to moderate concentrations approaching alkaline waters. Contrastly, the species of Eutraphentic class responds strongly to high nutrient enrichment of the environment, where we notice the dominance of some species such as*Mastogloiabraunii* and *Surirellaovalis*.

Table. 5. The pollution classes at the study area

	Station	NH_4	PO_4	NO_3	BOD	Nutrient index				IPO	Pollution classes
Fall	*SS1*	0,09	0,13	39.5	22,1	5	5	3	5	4.5	Low
	SS2	0,08	0,17	79,2	8,6	5	5	2	4	3,75	Low
	DK1	0,26	0,09	170	7	4	5	1	3	3,25	Moderate
	DK2	0,09	0,09	51	7,7	5	5	2	3	3,75	Moderate
	DK3	0,12	0,02	66	15	4	5	2	1	3	Moderate
Spring	*SS1*	0,21	0,06	110	13,6	4	5	2	2	3,25	Moderate
	SS2	0,05	0,12	87,5	7,9	5	5	2	3	3,75	Moderate
	DK1	1,2	0,24	99,1	20,1	3	5	2	1	2,75	High
	DK2	2,05	0,31	135,7	17,8	2	5	2	1	2,5	High
	DK3	0,09	0,9	78,2	16,9	5	5	2	1	3,25	Moderate

According to the organic matter content and the IPO values (Table. 5), the diatoms indicate the degree of weathering of the waters of the study region. This vulnerability of diatoms with respect to organic pollution highlights three classes according to the pollution degree:

- Strong organic pollution (IPO = 2.5 and 2.75) observed in DaitKhadra in spring, confirming the impact of drainage in these places, where permeability is high. This can be explained by the high concentrations of minerals (Na^+, Cl^- and SO_4) linked to urban and agricultural wastewater flowing into these waters.

- Moderate pollution: observed in most of the sites during the two periods with IPO whichvaries between 3 and 3.75, confirming the high rate of saline nutrients.
- Low pollution: Observed in Saouss and Ain Teddese (SS1 and SS2) in the fall, which is explained by the decrease in evaporation following the low temperatures during this period, the low concentration of nutrients in the environment, but also the remoteness of sites from urban areas.

Parameters influencing the distribution of diatoms.

The growth and distribution of algae would be mainly controlled by temperature, light, nutrient concentration, movement of water masses or even salinity (Bussard, 2015).

From the canonical analysis (Figure.6), we can distinguish the Axis 1, which is positively correlated with temperature, separating species from moderately polluted SS1 sites in fall. Temperature is the variable that seems to be more related to the distribution of *Surirellaovalis, Nitzschiadraveillensis, Cyclotellastelligera* and *Encyonemasilesiacum.*

The second important variable among the Axis 1 is the concentrations of dissolved O_2, which includes moderately polluted sites DK1 and DK3, with the presence of two species (*Naviculareidiana* and *Halamphoracoffeaeformis*) characterizing this type of biotope (Triest et al., 2001). In addition, the presence of *Amphora pediculus, Craticulahalophila* and *Campylodiscus clypeus* is positively correlated with conductivity.

Other species such as *Mastogloiabraunii* (most abundant in the 5 sites), *Pleurosigmasalinarum* and *Nitzschiacommunis* present affinity for Cl^- and Ca^+ ions and cations refer to salinity. These species are known by their affinities to biotopes with high saline concentrations, as reported by Leland and Porter (2000). It was shown that the increase in salinity would therefore cause a change in the specific composition within the periphyton, and result in the disappearance of some species most sensitive to this parameter. These species will be replaced by others that are more tolerant, as several studies show (Busse et al., 1999; Ziemann et al., 2001).

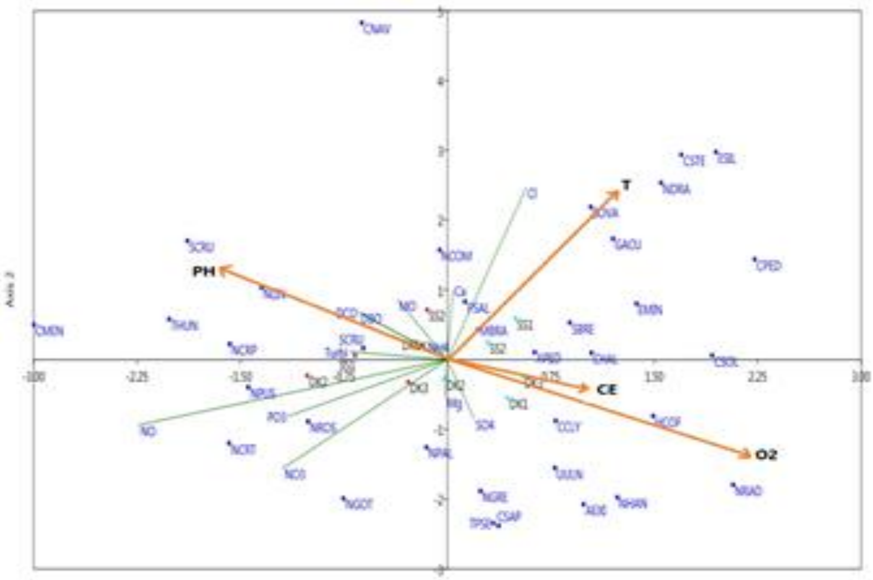

Figure.6. Canonical correlation analysis of diatoms taxa in the study area. The orientation of each of the main variable in relation to each of these axes is presented by an arrow, the length of which indicates the degree of correlation with those axes

On the other side of the Axis 1, *Navicymbulapusilla*, *Naviculacryptotenella* and *Navicularostellata*are positively correlated with NO_2^- PO_3 and NO_3^-. These species are indeed observed in the agricultural runoff areas of DaitKhadra in spring. They are present in water with high mineralization at high concentrations of nitrate and phosphates, as shown by the work of Chaib and Tison-Roserbery (2012), Lobo et al. (2015), Nehar et al (2016) and Rimet (2017, 2018).

The arrangement of the stations on the factorial plane confirms the difference between the stations of Dait El Khadra and those of Saous mainly in terms of water temperature and conductivity. This imposes a different distribution of species between the two regions despite some differences in the specific composition between the two seasons studied.

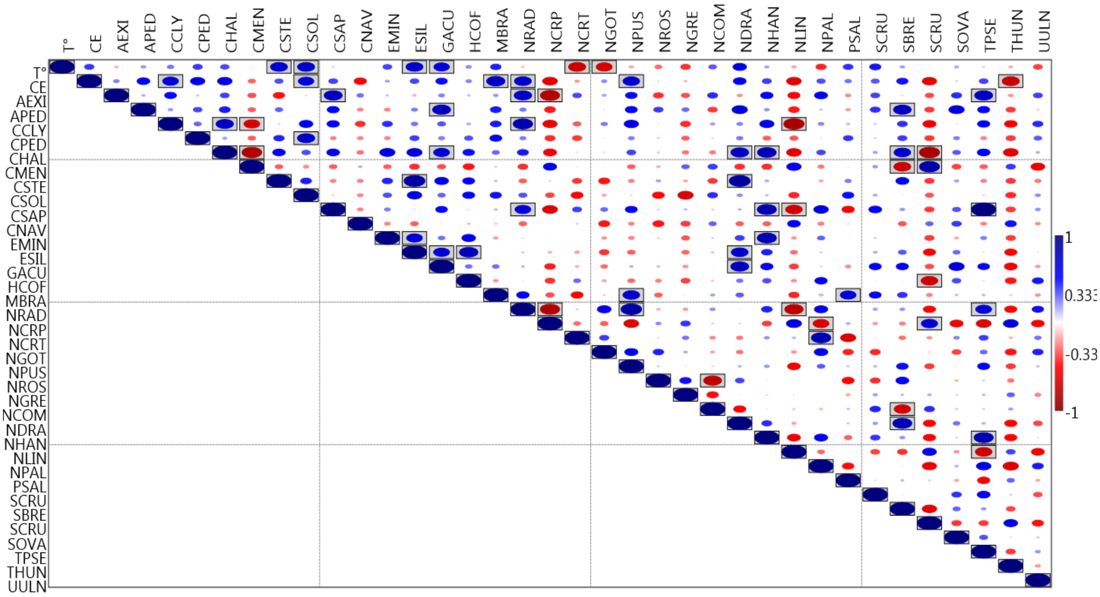

Figure 7. Spearman's correlation between conductivity, temperature and the diatom taxa

Being the main parameters visibly influencing the distribution of diatoms in the study area, Spearmen correlation between these main important parameters (temperature and conductivity) and most abundant diatom taxa such as *Navicymbulapusilla*, *Mastogloiabraunii*, *Naviculareidiana*, *Campylodiscusclypeus*is shown in the figure 7. Spearman correlation coefficient is positive and *Tryblionella Hungarica* correlated negatively with conductivity. On the other part of the plot, we notice *Cymatopleurasolea*, *Cyclotellastelligera*, *Encyonemasilesiacum* and *Gyrosigmaacuminatum* wich are correlated positively with the temperature, while other species such as *Naviculacryptotenella* and *Navículagottlandica* are negatively correlated with this same parameter. In general, Spearman correlation plot confirms that the distribution of the main diatom species in the ChottChergui region is mainly controlled by these two parameters. Any instability or variation of these parameters could contribute to the modification of the specific composition of these stations (Nehar, 2016). In the current context of climate change, the stability of these fragile ecosystems must constitute a priority for organizations responsible for environmental protection.

Conclusion

The results obtained introduce more understanding of the diatom flora in Algeria, where there remains a paucity in the research. This study identifies the diversity in diatom taxa, which has been highlighted in the ChottChergui region, namely 36 taxa belonging to 13 families. Our study found that the distribution of diatom taxa is mainly controlled by temperature and conductivity, which is reflected in the difference in specific composition and number of individuals observed between the two observation periods (fall and spring).

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