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RESEARCH ARTICLE

Phytoplankton abundance and diversity in the coastal waters of Oualidia lagoon, south Moroccan Atlantic in relation to environmental variables

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Abstract

Phytoplankton community in the coastal waters of Oualidia lagoon was characterized from June 2011 to May 2012. Taxonomic composition, abundance and diversity index were determined at six sample sites. A total of 127 species of phytoplankton belonging to two groups viz. bacillariophyceae (81 species) and dinophyceae (46 species) were reported from the all study sites. The results show there is a clear qualitative and quantitative dominance of diatoms, followed by dinoflagellates. Seasonal differences in the quantitative and qualitative composition of the phytoplankton communities in the different sites were marked. The Shannon-Wiener Diversity Index (1,41- 4,41 bits) classified Oualidia lagoon as being not stressed environment. Various water parameters were correlated with phytoplankton diversity. Temperature, dissolved oxygen, salinity and nitrite were found to be important parameters influencing the species composition and succession of phytoplankton at this location.
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INTRODUCTION

Coastal lagoons are, in general, zones of high productivity and they act as a transitional zone between land and sea. But these areas are also sensitive to disturbance, for instance, many are presently threatened by pollution. An increasing interest is being shown in these ecosystems, considered today to be essential elements of the national heritage in a large number of countries. The biological potential of these coastal ecosystems can only be developed through a better understanding of the mechanisms controlling them.

Phytoplankton is the basis of trophic chain as well as the most important biological community in any aquatic system (Monbet, 1992; Sin et al., 1999). It has also an effect on nutrient cycling and a role in global carbon cycle (Fenchel, 1988). One of the main goals of studying phytoplankton ecology is to determine the factors that regulate phytoplankton production and their seasonal succession in aquatic ecosystems (Dominiques et al., 2005). According to Liu et al. (2004), phytoplankton species distribution shows wide spatio-temporel variations due to the differential effect of hydrographical factors on individual species and they serve as good indicators of water quality including pollution.

Literatures on the influence of environmental variables on phytoplankton communities in coastal waters around Oualidia lagoon (south of the Moroccan Atlantic) are meagre. In view of the importance and scarcity of reports from this area, an investigation was carried out on a bimonthly interval during June 2011 to May 2012 in the coastal waters of Oualidia lagoon to elucidate the i) qualitative and quantitative abundance of phytoplankton, ii) seasonal variations in phytoplankton community organization and iii) the influence of environmental variables on phytoplankton species composition and their abundance in coastal waters of Oualidia lagoon.

Materials and Methods

Study site

Oualidia lagoon (32°40’42’’N-32°47’07’’N and 8°52’30’’W-9°02’50’’W) is located on the Atlantic Ocean (**Fig.1**). This lagoon is 7 km long, on average 0.5 km wide, and exchanges water with the ocean through a major inlet about 150 m wide. During spring tides there is also a secondary, shallower inlet about 50 m wide. The lagoon morphology is characterized by side channels, connected to a meandering main channel, in which the mean depth is 2 m and the maximum depth during flood tides does not exceed 5 m (Carruesco, 1989). Flood tides cover more than 75% (2.25 km^2) of the lagoon surface, bringing salt water up to the upstream reaches of the lagoon and into a saline marsh beyond the second dam.

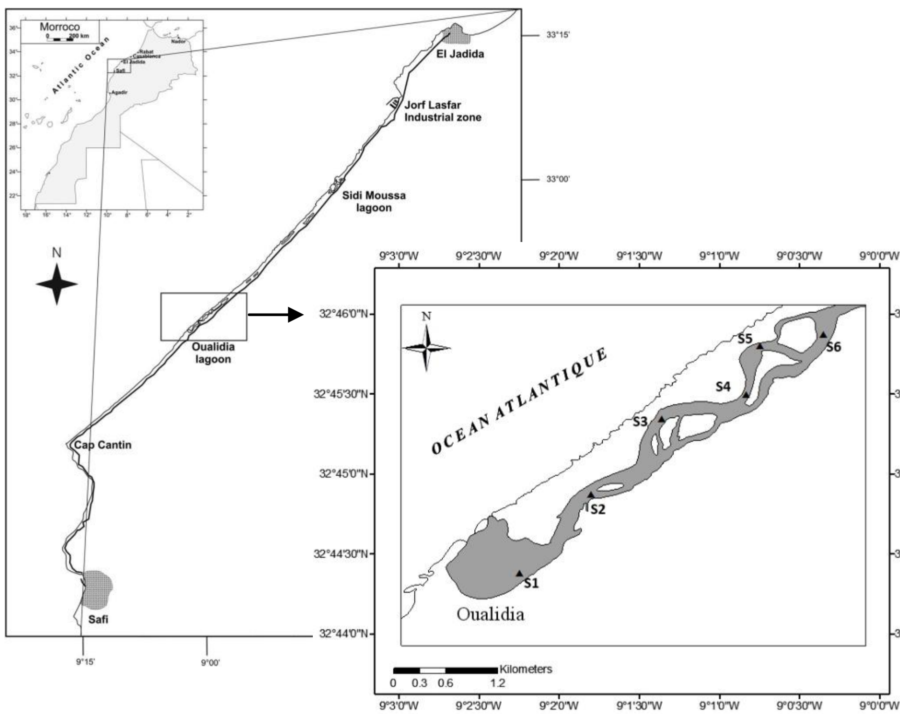

Fig.1. The study area and location of the sampling sites.

Phytoplankton sampling and analysis

This phytoplankton study was conducted during June 2011 to May 2012 in three distinct areas including: (A) areas in upstream zone, near the sea, with anthropogenic activity (i.e. fishing, tourism (Stations 1 and 2); (B) areas in the middle zone with oyster activity, agriculture and fresh water input (Stations 3 and 4); and (C) areas in the downstream zone with agriculture activity and fresh water input (Stations 5 and 6). Physicochemical water quality parameters such as seawater temperature (°C), salinity (mg/l) and dissolved oxygen (mg/l) were recorded at each station with a multiparametric sounding (Multi340i (wtw82362 Weilheim). Nutrients [nitrite, ammonium and orthophosphorus (µmol/L)] were also measured spectrophotometrically during the study (Strickland, 1972; Rodier, 1984). For phytoplankton studies, samples were collected in 1 liter labeled plastic containers by filtering 50 L of water, using a phytoplankton net (20 µm) and immediately preserved with 4% formalin and fixed with Lugol’s iodine for quantitative and qualitative analysis. The samples were left to settle for 24 hours according to the Utermöhl method (Utermöhl, 1958). After sample sedimentation, excess water in the upper part was removed and concentrated to 100 ml (Sukhanova, 1978). Enumerations were carried out using an Olympus CH–2 light microscope (10×, 20× or 40×). Species identification were also carried out using a Epson inverted microscope.

Statistical analysis

Phytoplankton abundances, number of species (S), and Shannon index of diversity (H’, bits) were used as univariate descriptors. The relationship among total phytoplankton, dinoflagellate and diatom abundances, number of species, Shannon index of diversity and environmental parameters were analyzed by the Spearman rank correlation. Wilcoxon and Kruskal-Wallis tests were used to see any significant variation among seasons and stations on each descriptor.

Results

1. Physicochemical parameters and nutrients

Variations in temperature, salinity, dissolved oxygen and nutrients among stations and sampling dates are shown in **figure 2**.

Temperature variation in Oualidia lagoon was recorded in the range of 15,3-24,2 °C. The high temperature (24,2 °C) was noted during September 2011 in station 3. The increased water temperature from the upstream zone (St.1) to downstream zone (St.6) leads to the formation of a horizontal repartition from St.1 to St.6.

Salinity ranged from 26,6 to 40,8 mg/l and it was highest during October at station 5. The distribution of salinity follows a decreasing gradient from downstream (St.1) to upstream of the lagoon (St.6).

Dissolved oxygen varied from 6,1 mg/l-11,1mg/l. Maximum values (11,1 mg/l) were recorded during December 2011 at station 1, minimum during January at stations 2, 3, 5 and during February at stations 1, 2, 3. Dissolved oxygen concentrations follows an increasing gradient from downstream (St.1) to upstream (St.6).

Data revealed that the highest PO_4 levels of (104,37µmol/l and 103,7 µmol/l) were observed at station 1 in November and February respectively. The lowest value (4,37 µmol/l) was recorded during May at station 6.

Nitrite exhibited very low concentrations in the study area. Average nitrite values in surface water ranged from 0,33 to 16,21 µmol/l. The higher nitrite value was recorded in February at station 1, while the low value was noted during October at station 2.

Ammonia concentrations fluctuated between 5,47 and 73,44 µmol/l. Maximum value was observed in May at station 6 and the minimum one was recorded during October at station 2. The variation in ammonia followed a similar pattern to NO_2 and PO_4. An increasing gradient from downstream to upstream of the lagoon was recorded for these three nutrients.

2. Phytoplankton

Species composition

Phytoplankton identified at all stations comprised a total of 127 species (81 Diatoms, 46 Dinoflagellates) **(Table-1)**. Diatoms formed the most dominant taxa and contributed to the total population at almost all the stations, they represent over 70% of total species. The diatom flora comprised of 54 Centrales and 27 Pennales. Among the Centrales, 14 families such as Chaetoceraceae, Coscinodiscaceae and Rhizosolanaceae were found to be floristically riche, while in case of Pennales, 9 families was found i.e Fragilariaceae, Thalassionemataceae and Naviculaceae **(Table- 1)**.

Population density and distribution

The overall mean phytoplankton abundance was higher at station 1 compared to other stations in the study area **(Fig. 3)**. Minimum densities were recorded at station 6. Monthly and station wise variations of phytoplankton densities are clearly depicted in **table-2**. Well marked monthly variations were observed in population densities of phytoplankton. The lowest densities (9100 and 12400 cells/l) were observed in the month of January at Stations 5 and 6, whereas the highest population density (69420 cells/l) was observed during March at station 1. Population density was quite low at station 6 during the study period.

Species diversity

The number of species (S) and range of diversity indices in the study area are shown in **table-3.A. B**. Marked seasonal variation was noticed in species diversity in the present investigation. The maximum number of species (121) was observed at station 1, with a greater exchange of water between the lagoon and the open sea. The maximum number of species was also detected exceptionally in station 6, followed by 118 at station 2 in May while minimum numbers were observed at stations 2 (18) and station 1 (20) during December **(Table-3.A)**.

Shannon index of diversity (H') values generally increased in parallel to the number of species (S) and evenness (J) throughout the study period. The highest diversity (H'= 4.41 bits) was observed at station 1 in May and the lowest value (H'=1.41 bits) was detected at station 4 in December **(Table-3.B)**.

The lowest evenness (J=0.46 to 0.59) values were observed during Dec at station 3, station 4 and station 5 **(Table-3. B)**.

3. Phytoplankton and environmental parameters

Correlation analysis

Diversity and abundance of phytoplankton are related to the physico-chemical parameters (Temperature, dissolved oxygen, salinity and nutrient availability). The statistical relationships between the composition of phytoplankton and the physicochemical environment variables at the different sites were analyzed **(Table-4)**. As a matter of fact, positive correlationship was observed between dissolved oxygen, total phytoplanktons, dinoflagellates and diatoms. Dinoflagellates have shown a significant negative correlation with salinity value ($p<0.01$). Number of species displayed also a negative correlation with salinity ($p<0.05$). A significant positive correlation was founded between temperature and dinoflagellate. Number of species and shannon index showed also a moderately positive correlation with temperature. We found that total phytoplanktons, dinoflagellates, diatoms, number of species and species diversity show a negative correlation with nitrite. Diatom yielded a negative correlation with orthophosphate.

Wilcoxon and Kruskal-Wallis tests

Wilcoxon and Kruskal-Wallis tests revealed significant monthly variation in dissolved oxygen ($r= 0,010$; $p< 0.05$), dinoflagellate ($r= 0,027$; $p< 0.05$), diatom ($r= 0,008$; $p< 0.01$) and shannon index ($r= 0,024$; $p< 0.05$). Significant station variation was observed only in salinity ($r= 0,003$; $p< 0.01$) **(Table-5)**.

Table 1. Check list of phytoplankton species encountered during the present investigation (June 2011-May 2012) in Oualidia lagoon. (A: Bacillariophyta; B: Dinoflagellates).

-A-	
Bacillariophyta	Chaetoceros danicus Cleve
Division: Chromophyta	Chaetoceros decipiens Cleve
Class-Bacillariophyceae	Chaetoceros radicans Schutt
Centrics	Chaetoceros sp.
Order-Biddulphiales	**Family-Eupodiscaceae**
Sub-order-Coscinodiscineae	Biddulphia alternans (Bailey) Van Heurck
Family- Coscinodiscineae	Biddulphia aurita (Lyngbye) de Brébisson
Coscinodiscus granii Gough	Biddulphia pulchella S.F Gray
Coscinodiscus jonesianus (Grunow) Hustedt	Biddulphia regia (Schultze) Ostenfeld
Coscinodiscus radiatus Ehrenberg	Biddulphia sp.
Coscinodiscus sp.	**Family-Naviculaceae**
Family-Hemidiscaceae	Navicula praetexta Ehrenberg
Hemidiscus sp.	Navicula sp.
Family-Leptocylindraceae	Plagiotropis sp.
Leptocylindrus danicus Cleve	Pleurosigma sp.
Family- Melosiraceae	Gyrosigma sp.
Melosira nummuloides Agardh	Diploneis bombus Ehrenberg ex Cleve
Melosira sp.	Diploneis sp.
Family- Thalassiosiraceae	**Family-Cymbellaceae**
Detonula sp.	Cymbella sp.
Lauderia annulata Cleve	Amphora eggregia Ehrenberg
Lauderia borealis Gran	Amphora sp.
Lauderia sp.	**Family-Bacillariaceae**
Thalassiosira mendiolana Hasle & Heimdal	Bacillaria paradoxa Gmelin
Thalassiosira polychorda (Gran) E.Jorgensen	Cylindrotheca fusiformis Reimann & J.C.Lewin
Thalassiossira rotula Meunier	**Family- Amphipleuraceae**
Thalassiosira sp.	Amphipleura pellucida Friedrich Kützing
Family-Heliopeltaceae	Frustulia sp.
Actinoptychus sp.	**Order-Striatellales**
Sub-order-Rhizosoleniineae	**Family-Striatellaceae**
Family-Rhizosoleniaceae	Grammatophora marina (Lyngbye) Kützing
Rhizosolenia crassispina J.L.B.Schröder	Grammatophora undulata Ehrenberg
Rhizosolenia hebetate var. semispina (Hensen) Gran	**Family-Thalassionemataceae**
Rhizosolenia setigera Brightwell	Liolema sp.
Rhizosolenia sp	Thalassionema nitzschioides (Grunow)

Rhizosolenia stolterforthii H.Peragallo
Guinardia flaccida (Castracane) H.Peragallo
Guinardia delicatula (Cleve) Hasle
Guinardia sp.
Sub-order-Biddulphiineae
Family- Chaetocerotaceae
Chaetoceros affinis Lauder
Chaetoceros curvisetus Cleve

Mereschkowsky
Thalassionema sp.
Sub-order-Bacillariineae
Family-Achnanthaceae
Achnantes longipes C.Agardh
Achnantes sp.
Cocconeis pellucida Hantzsch
Cocconeis sp.

-B-

Dinoflagellates
Division: Chromophyta
Class: Dinophyceae
Order: Peridiniales
Family-Ceratiaceae
Neoceratium arietinum (Cleve) F. Gómez, D. Moreira & P. López-García
N. belone (Cleve) F. Gómez, D. Moreira & P. López-García
N. breve (Ostenfeld & Schmidt) F.Gómez, D.Moreira & P.López-Garcia
N. candelabrum (Ehrenb.) F. Gómez, D. Moreira & P. López-García
N. furca (Ehrenberg) F. Gómez, D. Moreira & P. López-García
N. fusus (Ehrenberg) F. Gómez, D. Moreira & P. López-García
N. horridum (Gran) F. Gómez, D. Moreira & P. López-García
N. karstenii (Pavillard) F.Gomez, D.Moreira & P.Lopez-Garcia
N/ macroceros (Ehrenb.) F. Gómez, D. Moreira & P. López-García
N. massiliens (Gourret) F. Gómez, D. Moreira & P. López-García
N. minutum (Jørgensen) F. Gómez, D. Moreira & P. López-García
Neoceratium sp.
N. symmetricum (Pavill.) F. Gómez, D. Moreira & P. López-García
N. trichoceros (Ehrenb.) F. Gómez, D. Moreira & P. López-García
N. tripos (O.F.Müller) F. Gómez, D. Moreira & P. López-García
Family-Peridiniaceae
Heterocapsa sp.
Peridinium quinquecorne Abé
Family-Protoperidiniaceae
Protoperidinium bipes (Paulsen) Balech
Protoperidinium cerasus (Paulsen) Balech
Protoperidinium depressum (Bailey) Balech
Protoperidinium diabolus (Cleve) Balech
Protoperidinium sp.
Protoperidinium steinii (Jorgensen) Balech
Family-Calciodinellaceae

Prorocentrum gracile Schütt
Prorocentrum micans Ehrenberg
Prorocentrum scutellum Schröder
Prorocentrum sp.
Prorocentrum treistinium Schiller
Order-Gymnodiniales
Family-Gymnodiniaceae
Gymnodinium sp.
Order-Gyrodiniales
Family-Gymnodiniaceae
Gymnodinium sp.
Order-Gyrodiniales
Family-Gyrodiniaceae
Gyrodinium spirale (Bergh) Kofoid & Swezy
Order- Dinophysiales
Family-Amphisoleniaceae
Amphisolenia sp.
Family-Dinophysiaceae
Dinophysis acuminata Claparède & Lachmann
Dinophysis acuta Ehrenberg
Dinophysis caudate Saville-Kent
Dinophysis fortii Pavillard
Dinophysis hastate Stein Dinophysis rapa (Stein) Balech
Dinophysis rotundata Claparède & Lachman
Dinophysis saccula Stein
Family-Gonyaulacaceae
Gonyaulax verior Sournia
Gonyaulax polyedra F.Stein
Gonyaulax polygramma Stein
Lingulodinium polyedrum (Stein) Dodge
Family-Ostreopsidaceae

Scrippsiella sp.	Ostreopsis sp.
Family- Kolkwitziellaceae	
Diplopsalis sp.	
Order-Prorocentrales	
Family-Prorocentraceae	

Table 2. Variations in population density during June 2011 to May 2012 in Oualidia lagoon

Month Intervals	Phytoplankton density (cells.l^{-1})					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Jun'11	53800	37000	23000	43000	44000	28000
Jul	56200	39400	38800	32800	29300	17300
Aug	54800	39800	35800	28000	30300	20100
Sep	53300	49400	42700	64600	59800	50200
Oct	65300	47200	37000	52200	37000	27440
Nov	25800	29800	27900	26100	22100	23800
Dec	26300	13900	27900	51600	30800	23400
Jan'12	15200	14900	15900	12600	9100	12400
Feb	19400	31000	34600	22900	19600	23200
Mar	69420	51000	55500	51200	50900	43400
Apr	55600	60700	65500	43000	53300	43900
May	60900	55100	55400	44900	39500	44100

Table 3. A: Number of phytoplankton species (S), B: Diversity indices (H') and equitability (J) during June 2011 to May 2012 in Oualidia lagoon.

-A-

Month intervals	No. of. Species					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Jun'11	51	58	**59**	55	50	42
Jul	50	51	**58**	54	49	38
Aug	50	52	**57**	50	50	40
Sep	80	**81**	78	73	77	69
Oct	**84**	77	76	79	82	71
Nov	28	**31**	30	28	28	28
Dec	20	18	22	21	**23**	22
Jan'12	**25**	22	24	22	**25**	20
Feb	23	**35**	29	23	24	29
Mar	104	108	102	**111**	100	104
Apr	**107**	102	104	99	102	103
May	**121**	118	117	117	114	**121**

-B-

Month Intervals	Species diversity H'						Evenness J					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Jun'11	3,81	4,08	3,77	3,72	3,60	3,50	0,91	0,91	0,92	0,93	0,92	0,94
Jul	3,63	3,58	3,64	3,63	3,52	3,35	0,93	0,91	0,90	0,91	0,90	0,92
Aug	3,63	3,64	3,67	3,64	3,63	3,44	0,93	0,92	0,91	0,93	0,93	0,93
Sep	3,42	3,62	3,74	3,43	3,38	3,32	0,78	0,82	0,86	0,80	0,78	0,79
Oct	3,45	3,72	3,94	3,33	3,88	3,90	0,78	0,86	0,91	0,76	0,88	0,91
Nov	2,96	2,44	2,12	2,67	2,80	2,65	0,89	0,71	0,63	0,80	0,84	0,80
Dec	2,33	2,26	1,83	1,41	1,67	1,91	0,78	0,78	0,59	0,46	0,53	0,62

Jan'12	2,77	2,65	2,60	2,55	2,89	2,45	0,86	0,86	0,82	0,83	0,90	0,82
Feb	2,37	2,79	2,59	2,60	2,77	2,75	0,76	0,78	0,77	0,83	0,87	0,82
Mar	3,85	4,15	4,04	4,11	4,01	4,16	0,83	0,89	0,87	0,87	0,87	0,90
Apr	4,14	3,79	3,78	4,15	3,82	4,09	0,89	0,82	0,81	0,90	0,83	0,88
May	4,41	4,30	4,28	4,40	4,39	4,38	0,92	0,90	0,90	0,92	0,93	0,91

Table 4. Spearman rank correlation coefficients (rho) between environmental parameters and total microphytoplankton, dinoflagellate and diatom abundances; number of species (S), Shannon index of diversity (H').

	Rho					
	Temperature	**Salinity**	**DO**	**PO_4**	**NO_2**	**NH_4**
Total phytoplankton	0,115	-0,205	0,326**	-0,199	-0,438**	-0,113
Dinoflagellate	0,378**	-0,328**	0,360**	0,112	-0,299*	0,96
Diatom	-0,019	-0,126	0,236*	-0,289*	-0,372**	-0,165
Number of species	0,262*	-0,270*	0,231	-0,111	-0,523**	0,24
Shanon index	0,258*	-0,222	0,214	-0,051	-0,484**	0,011

$^*p<0.05$; $^{**}p<0.01$ (p= significance level)

Table 5. Wilcoxon test (season effect) and Kruskal-Wallis test (station effect) on each descriptors. Significantly differences are shown in bold (p < 0.05). DO: dissolved oxygen.

Descriptor	**Season effect**		**Station effect**	
	Wilcoxon	**p**	**χ^2**	**p**
Temperature	313	0,542	8,153	0,148
Salinity	295	0,239	17,696	**0,003**
DO	252,5	**0,010**	0,592	0,988
NO_2	308	0,443	0,872	0,972
NH_4	333	1,000	0,233	0,999
PO_4	291	0,192	0,858	0,973
Total phytoplankton	306	0,406	6,736	0,241
Dinoflagellate	263,5	**0,027**	6,963	0,223
Diatom	250,5	**0,008**	2,509	0,775
Number of species	279	0,091	0,471	0,993
Shanon index	262,5	**0,024**	0,230	0,999

Table 6. The total numbers of phytoplankton species observed in the different coastal waters of Morocco and other countries.

	Sites	**Number of species**	**Periods**	**References**
Morocco	Oualidia lagoon	127	June 2011-May2012	This study
	Bou Regreg estuary	307	Mar 1999-Mar 2001	Benabdellouahad, 2006
	Moulay bousselham lagoon	35	Oct 2003-Sep 2004	Loumrhari et al., 2009
	Massa estuary	105	Mar 2009-Mar 2010	Badsi et al., 2012
	Bay of Agadir	210	Sept 2002-Sept 2003	Fraikech et al., 2005
	Nador lagoon	311	Nov 2007-Aug 2008	El Madani et al., 2011

Tunisia	Boughrara lagoon	66	Aug 1999-Dec 1999-Feb 2000- May 2000	Benrejeb et al., 2002
	Ghar El Melh Lagoon	61	Jan 2011- Jan 2012	Dhib et al., 2013
Turkey	Datça and Bozburun Peninsulas	132	May 2002-Apr 2004	S. TAŞ., 2013

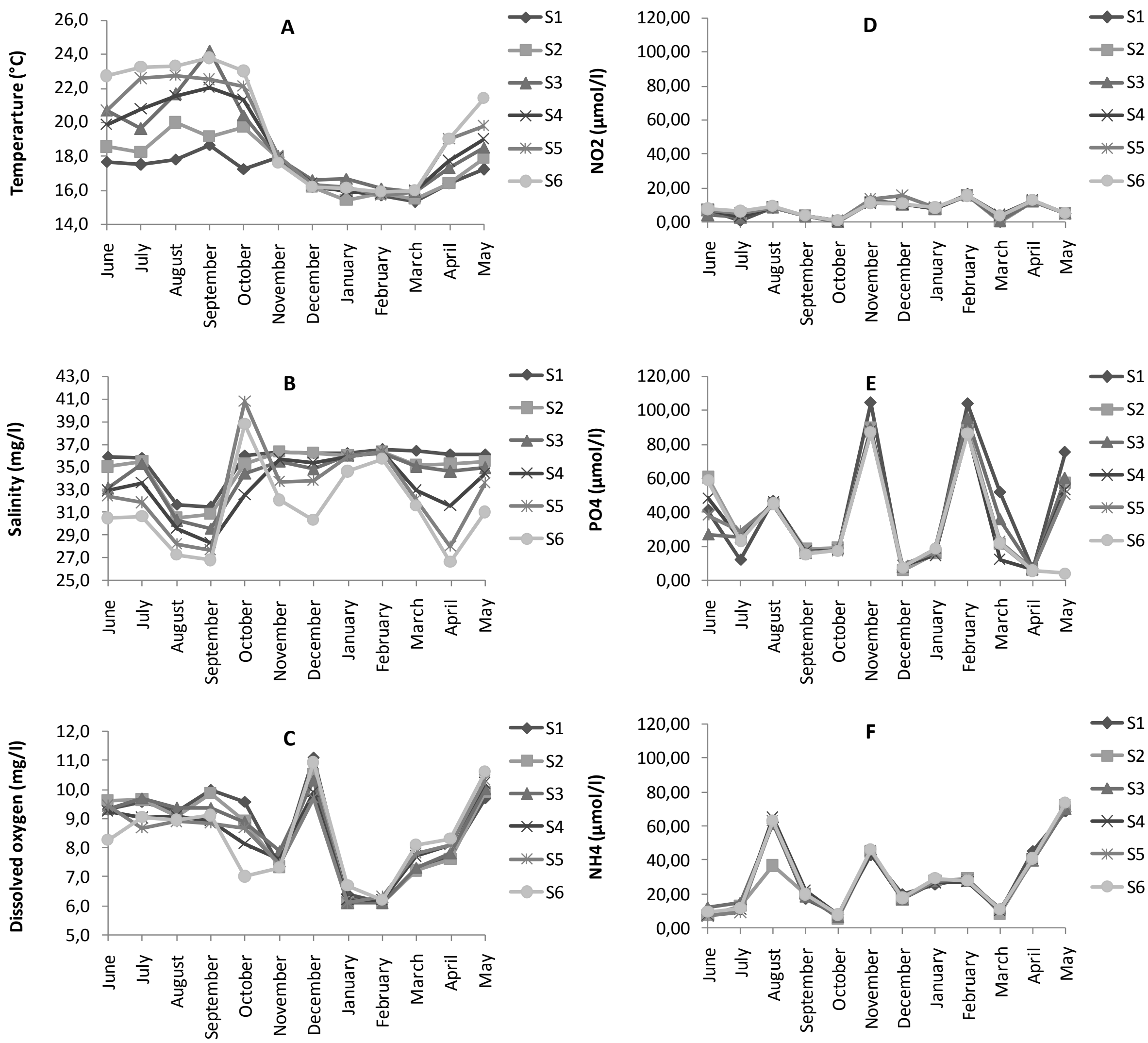

Fig.2. Variations in physicochemical water quality parameters and nutrient concentration during June 2011 to May 2012 in Oualidia lagoon. A: Temperature (°C), B: Salinity (PSU), C: Dissolved oxygen (mg/l), D: Nitrite (µmol/l), E: Orthophosphorus (µmol/l), F: Ammonium (µmol/l).

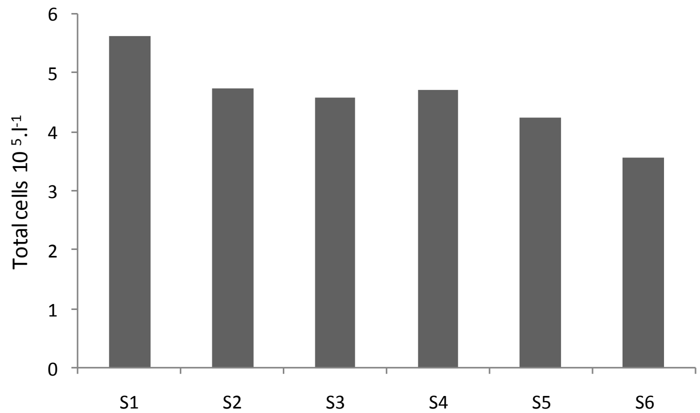

Fig.3. Mean abundance of phytoplankton during June 2011 to May 2012 in Oualidia lagoon.

Discussion

In the present study, diatoms were generally dominant at almost all the stations. Bennouna et al. (1999) also observed the predominance of diatoms followed by dinoflagellates during their study on phytoplankton community in Oualidia lagoon which was in relevance with our present study. The algal flora from Oualidia lagoon can be considered as rich in the number of taxa. The maximum number of taxa (121) was observed at station 1, situated near the major inlet. This richness may be related to a great exchange of water between the lagoon and the open sea. The minimum number of taxa (18) was found at station 6. Gilabert, (2001) explains the low diversity in a lagoon by strong physical perturbations. A comparison in total numbers of phytoplankton species between Oualidia lagoon and different coastal waters of Morocco and other countries is given in **table-6**.

In Oualidia lagoon we recorded a high phytoplankton density (69420 cells/l) in March at station 1. This value is low compared to that recorded by Bennouna et al. (2002) ($0,375.10^6$ cells/l in June 1999) in the same area. Dinoflagellate community appeared relatively less in abundance in Oualidia lagoon throughout the study period as compared to the diatoms. This might be due to the preferential oligotrophic nature of dinoflagellate and their competition with diatoms (Cushing, 1989).

In ecology, a diversity index is a statistics, which is applied to measure the species biodiversity in an ecosystem. A stressed environment typically has a lower number of species with one or two species (those adapted to the stress) having many more individuals than the other species (Gao and Song, 2005). As our study area was identified as a high productive zone (Rharbi, 2000), the diversity index remained between 1.41 and 4.41 throughout the study period. According to Margallef, (1978), the diversity index H' varies between 1 and 2.5 bits.cell^{-1} in coastal waters and between 3.5 and 4.5 bits.cell^{-1} in ocean waters. Thus our results clearly show the influence of ocean waters on the diversity of phytoplankton in Oualidia lagoon in spring season when this influence is less pronounced in winter season where H 'do not exceed 2.5 bits.cell^{-1}. Adesalu and Nwankwo, (2008) and Rajagopal, (2010) reported that the low value of Shannon's index of phytoplankton population in rainy season is due to dilution of area.

Phytoplankton composition and diversity is known to change seasonally in response to changes in physical, chemical and biological conditions of the lagoon (Lucas et al., 1999; Ferreira et al., 2005).

Seasonal changes of temperature as observed in this study shows a gradual rise from winter season to summer. These increases in temperature could be one of the factors that have promoted blooms of dinoflagellates identified between March and September. This is in accordance to our findings where temperature was correlated positively with dinoflagellates. The same phenomenon was mentioned by Kamel, (1997) in Tetouan (Moroccan Mediterranean Sea). The recorded higher values could be attributed to the low amount of rainfall and also due to neritic water dominance (Asha and Diwakar, 2007; Rajasegar, 2003). The lowest salinity can be attributed to rainfall coupled with the local freshwater inflow. In Moulay Bousselham lagoon (Moroccan Atlantic Ocean), similar salinity values were found by Lamrini et al. (2007). Salinity showed a significant negative correlation with dinoflagellates. Studies conducted by Schumann et al. (2006) and Cremer et al. (2007) shows similarity with our results where salinity affects the phytoplankton community.

Higher dissolved oxygen concentration registered in December might be due to the freshwater influence in these areas and to the maximum occurrence of the phytoplankton density. This is in accordance with correlation results, where dissolved oxygen was correlated positively with total phytoplankton, densities of diatom and dinoflagellates.

Low dissolved oxygen concentration recorded during spring season indicates a high biological activity and a microbial decomposition of organic matter. From the results obtained, Oualidia lagoon is well oxygenated compared to other lagoons such as Moulay bousselham lagoon and Mehdia site, they recorded respectively a maximum of 7.93 mg/l and 7.89 mg/l in spring and in summer (Loumrhari, 2009).
Phytoplankton needs a wide variety of chemical elements but the two critical ones are nitrogen and phosphorous (Dawes, 1981).
In the present study it was registered that orthophosphate concentrations are higher than those recorded for nitrite and ammonia. This finding can confirm the influence of sea water which serves as the main source of phosphate in coastal waters. The highest orthophosphate value reported at November and February could be related to reduced uptake rates by phytoplankton (Berges et al., 2004). This can be confirmed by the negative correlation registered between Orthophosphate and diatoms. The higher value can indicates that coastal waters of Oualidia lagoon receives wastes from agro field rich with phosphate-phosphorous fertilizers and pesticides as well as freshwater contaminated with domestic wastes containing detergents. The same conclusion was done by Gabche and Smith (2002) where they deduced that the increased concentration of phosphate was the result of agricultural run-off along with city drainage. By comparing our concentrations of orthophosphate with those found by Loumrhari et al. (2009) in both Mehdia and Moulay Bousselham lagoons (Moroccan Atlantic Ocean) our results remain very important.
The recorded higher nitrite values could be due to the increased phytoplankton excretion. This can be confirmed by the significant negative correlation between total phytoplankton, diatom and nitrite. The highest values can be related also to oxidation of ammonia, reduction of nitrate and the recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007; Govindasamy et al., 2000). Our nitrite values still important comparing to those recorded in Nador lagoon (Moroccan Mediterranean Sea) where the maximum value was 0,4 µmol/l (Ruiz et al., 2006).
Recorded higher concentration of ammonia could be partially due to the death and subsequent decomposition of phytoplankton and secondly to the excretion of ammonia by planktonic organisms (Segar et al., 1989). Our results remain close to those registered in Nador lagoon (Daoudi et al., 2012).
The results of nutrient analyses highlighted the richness of Oualidia lagoon in nutrients, partly due to anthropogenic influence all over the lagoon.
According to Wilcoxon and Kruskal-Wallis, significant monthly variation was recorded in dissolved oxygen, dinoflagellates, diatom and species richness. This result highlights the dynamics of water, which acts as a mixing of different water masses, preventing establishment of a vertical stratification and decreasing the upstream-downstream gradient.
A significant station variation was observed only in salinity. This finding reveals that the waters of Oualidia lagoon define two ecological entities:
Zone 1 represented by stations 1, 2 and 3, marked by oceanic influence.
Zone 2 represented by stations 4, 5 and 6, influenced by the presence of fresh water resurgence.

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