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Spring phytoplankton variability along a south coast of Sfax at the water-sediment interface (Tunisia, Eastern Mediterranean Sea)

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ABSTRACT

Objective: To compare the composition of the phytoplankton classes during the two spring studies, to study whether the spatial distribution of the phytoplankton is stable or not between spring 2010 and spring 2011 and to estimate the abiotic factor that mostly affects the structure and the richness of phytoplankton.
Methods: Phytoplankton sub-samples were counted under an inverted microscope using the Utermöhl method. Phytoplankton identification was made from morphological criteria after consulting various keys.
Results: Results showed a significant difference from spring 2010 to spring 2011 regarding nitrate/phosphate ratio, with high value in spring 2010 (30.19 ± 25.70). Relatively low nitrate/phosphate ratio (1.13 ± 0.53) during spring 2011 might result from phosphogypsum. Phytoplankton was characterised by the proliferation of Bacillariophyceae (46%–78% of the total microphytoplankton) and by the large number of Euglenophyceae. Thirty two Bacillariophyceae species were identified at every station, represented essentially by *Amphora* sp., *Navicula* sp., *Coscinodiscus* sp. and *Grammatophora* sp. The results advise that Bacillariophyceae are usually adapted to particular ecological environment.
Conclusions: This study shows that hydrological conditions in the south coast of Sfax present a high spatial and seasonal variability. The phytoplankton community distribution showed clear variations along the coastal stations during a spring cruises conducted in May 2010 and May 2011. The phytoplankton community found along the coast was dominated by opportunistic Bacillariophyceae species.

1. Introduction

The city of Sfax is the second largest in Tunisia, located on southeastern Mediterranean Sea[1]. It It is also an important rapidly developing industry centre and one of the main harbour of the Gulf of Gabes. Sfax is characterized by a dry climate and by the hot southerly wind[2]. The south coast of Sfax is marked by salt extraction ponds from solar saltern located over an area of about 1 500 hectare (COTUSAL, a company) and, especially, by an uncontrolled dumpsite of phosphate treatment from the plant for producing phosphoric acid (SIAPE, Tunisian phosphate industry)[3-5]. Its southern coastal area is subject to degradation of water quality[2].

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The coastal area has been subjected to an increase in industrial and human activities; the population development and anthropogenic pollution have resulted in degradation of water quality and marine sediments[6,7], growing eutrophication[3,4], green tides caused by coastal *Ulva rigida* replacing the *Posidonia oceanica* seagrass beds[8], and thus degrading benthic habitats[9].

This coast is endowed with rich aquatic resources and has an important contribution to the Tunisian fish production. However, it suffered a substantial decrease in fish resources over the last two decades. Studies suggest that such a decrease might have resulted from industrial and urban activities, menacing Tunisia's socio-economic resources[10]. For this reason, important measures were used to tackling the pollution threatening the beaches and coastal waters of Sfax. Nevertheless, chronic and uncontrolled pollution already present in this ecosystem, would still pose a danger to marine biodiversity and human health[6].

A first investigation have focused on plankton community using phytoplankton size class such as heterotrophic bacteria, autotrophic picophytoplankton, nanophytoplankton, microphytoplankton and ciliate abundance[2]. However, information on spring distribution of phytoplankton species were missing. It would in consequence be motivating to analysis novel data on phytoplankton community performances under the particular environment in spring 2010 and 2011.

Our specific objectives were to compare the composition of the phytoplankton classes during the two spring studies, to study whether the spatial distribution of the phytoplankton is stable or not between spring 2010 and spring 2011 and to estimate the abiotic factor that mostly affects the structure and the richness of phytoplankton.

2. Materials and methods

2.1. Study site

The study area in the south coast of Sfax (Tunisia) is located at 34°43’ N and 10°46’ E. The city coastline (50 km) stretches from the Sidi Mansour area in the north, to Chaffar in the south. The Sfax south coast (15 km) extends from the fishing port to Gargour. The south coast includes part of the city, the harbour, the solar saltern, the two industrial areas of Madagascar and Sidi Salem, the SIAPE and business area of Thyna[2] (Figure 1).

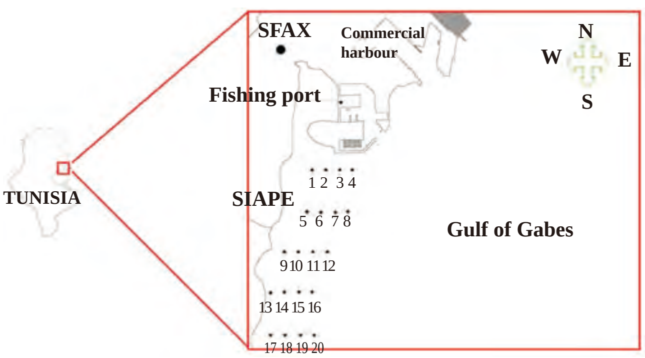

Figure 1. Location of the 20 sampling stations on the south coast of Sfax.

2.2. Field sampling

Samples for nutrients and phytoplankton were collected in May 2010 and May 2011. Water samples were collected on 20 stations, four stations in each transect at different depths (0.5–7.0 m) along the Sfax south coast (Figure 1). Seawater samples were collected at each station, with a Van Dorn-type closing bottle that was deployed horizontally, from the water sediment interface. Nutriment samples (120 mL) were kept immediately upon collection (20 °C, in the dark) and those for phytoplankton enumeration (1 L) were preserved with Lugol iodine solution (4%)[11]. Samples for phytoplankton were preserved at 4 °C in the dark for enumeration. Water samples (1 L) for chlorophyll-*a* analysis were filtered by vacuum filtration onto Whatman GF/F glass fiber filters which were then immediately stored at 20 °C.

2.3. Physico-chemical variables

Physical parameters (temperature, salinity, and pH) were measured using a multi-parameter kit (Multi 340 i/SET) immediately after sampling. Chemical parameters (nitrite, nitrate, ammonium, orthophosphate, silicate, total nitrogen and total phosphate) were analyzed with a Bran and Luebbe type 3 autoanalyzer. Suspended matter concentrations were measured using the dry weight of the residue after filtration of 0.5 L of seawater onto Whatman GF/C membrane filters.

2.4. Phytoplankton enumeration

Sub samples (50 mL) for phytoplankton counting were analysed under an inverted microscope using the Utermöhl method after 24 to 48 h settling[12]. Identification of phytoplankton species was made according to various keys[1,2,13].

2.5. Chlorophyll-a

Chlorophyll-*a* was estimated by spectrometry, after extraction of the pigments in acetone (90%). The concentrations were then estimated using the equations of SCOR-UNESCO[14].

2.6. Statistical analysis

The physicochemical and biological parameters assessed at the 18 observation stations were submitted to a normalised principal component analysis (PCA)[15]. Simple log (x + 1) transformation was applied to data in order to correctly stabilize variance[16]. Means and standard deviations were reported when appropriate. The potential relationships between variables were tested with Pearson’s correlation coefficient. One-way ANOVA using XLSTAT software followed by a *post hoc* comparison using Tukey’s test was applied to identify significant differences between the spring 2010 and spring 2011 at the water sediment interface.

3. Results

3.1. Physico-chemical variables during the cruise periods

The range (Min-Max) and mean values of physico-chemical variables showed that the average temperature ranged between 22.0 and 31.7 °C, with an average value of (27.58 ± 2.91) °C and (26.97 ± 3.24) °C in spring 2010 and 2011 respectively (Table 1). pH ranged from 7.5 to 8.5 (mean = 8.0) with high value recorded in spring 2011, and the lowest and the highest pH were observed in station 4 and 18 respectively. The mean pH value of spring 2010 cruise (7.86 ± 0.11) was significantly different (F = 11.79, df = 18, P < 0.01) from that of spring 2011 cruise (8.08 ± 0.33). In contrast, concentrations of suspended matter were relatively stable (Table 1).

Table 1

Physico-chemical and biological parameters at the water-sediment interface on the south coast of Sfax and results of ANOVA analysis to identify the significant differences between the sampled spring 2010 and spring 2011 seasons.

Variables	Spring 2010	Spring 2011	*F*	*P*
Physical variables				
Temperature (°C)	27.58 ± 2.91	26.97 ± 3.24	0.39	0.54
Salinity (psu)	37.78 ± 0.39	38.78 ± 1.45	5.44	0.03*
pH	7.86 ± 0.11	8.08 ± 0.33	11.79	0.00**
Suspended matter (mg/L)	47.78 ± 6.90	47.62 ± 7.03	0.05	0.82
Chemical variables				
NO_3^- (μmol/L)	3.39 ± 1.96	6.50 ± 2.22	37.24	4.11×10^{-7}***
NO_2^- (μmol/L)	0.23 ± 0.21	0.32 ± 0.13	0.80	0.38
NH_4^+ (μmol/L)	1.46 ± 0.86	3.92 ± 1.54	55.63	5.95×10^{-9}***
Total N (μmol/L)	18.02 ± 1.29	21.13 ± 3.14	23.41	2.20×10^{-5}***
PO_4^{3-} (μmol/L)	0.20 ± 0.04	11.19 ± 4.33	307.86	8.12×10^{-20}***
Total P (μmol/L)	4.00 ± 2.05	30.26 ± 12.38	172.54	1.05×10^{-15}***
$Si(OH)_4$ (μmol/L)	14.63 ± 9.24	30.91 ± 15.10	58.85	3.09×10^{-9}***
Nitrate/phosphate ratio	30.19 ± 25.70	1.13 ± 0.53	24.54	1.53×10^{-5}***
Biological variables				
Chlorophyll-*a* (mg/L)	5.29 ± 5.49	7.20 ± 6.17	1.02	0.32
Phytoplankton ($\times 10^2$ cells/L)	33.95 ± 40.06	86.00 ± 117.34	6.93	0.01*
Cyanobacteriae ($\times 10^2$ cells/L)	0.05 ± 0.22	1.30 ± 2.17	6.66	0.01*
Bacillariophyceae ($\times 10^2$ cells/L)	15.45 ± 34.25	66.00 ± 102.19	7.25	0.01*
Dinophyceae ($\times 10^2$ cells/L)	11.00 ± 80.39	10.40 ± 26.46	0.29	0.60
Euglenophyceae ($\times 10^2$ cells/L)	7.30 ± 9.65	6.45 ± 6.47	1.08	0.30
Dictyochophyceae ($\times 10^2$ cells/L)	0.15 ± 0.48	0.20 ± 0.61	0.08	0.78

Values are presented as mean ± SD. *F*-values were determined by a One-way ANOVA test. *P* values were for differences among seasons within each variable. *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

The chemical variables analysed were neither regularly concentrated (Table 1). All nutrients were significantly different ($P < 0.001$) (Table 1), except for nitrite (NO_2^-), in May 2010 and 2011. The nitrate concentrations (NO_3^-) varied from 1.56 μmol/L to 13.42 μmol/L. The highest concentrations were recorded in spring 2011 at station 7. The NO_2^- concentrations ranged from 0.02 to 0.64 μmol/L, with an average of (0.23 ± 0.21) μmol/L in spring 2010 and (0.32 ± 0.13) μmol/L (spring 2011), the maximum being observed during spring 2010, station 12. The concentration of NH_4^+ was in the range of 0.40–7.92 μmol/L with maximum values observed at station 4 in spring 2011. Total phosphorus concentration varied from 1.93 to 50.37 μmol/L with an average value of (4.00 ± 2.05) μmol/L and (30.26 ± 12.38) μmol/L; this concentration decreased in spring 2010 and increased in spring 2011 (Table 1). The $Si(OH)_4$ concentrations were more available during spring 2011 [(30.91 ± 15.10) μmol/L] than those during spring 2010 [(14.63 ± 9.24) μmol/L] (Table 1). The nitrate/phosphate (N/P): dissolved inorganic nitrogen (NO_2^- + NO_3^- + NH_4^+) to dissolved inoganic phosphate (PO_3^{4-}) ratio, ranged from 0.45 at station 9 (spring 2011) to 94.69 at station 20 (spring 2010). N/P ratios in coastal waters in spring 2010 were about (30.19 ± 25.70), indicating that the coast was supplied with more dissolved inorganic nitrogen. N/P ratio average was less than the Redfield ratio (16) in spring 2011, suggesting a potential N limitation.

3.2. Phytoplankton community structure, abundance and diversity

Two contrasting spatial patterns were recorded for water sediment interface chlorophyll-*a* concentrations during the spring cruises in 2010 and 2011. A clear spring bloom of phytoplankton was observed during the May 2011 cruise in the south coast of Sfax. During this cruise, the chlorophyll-*a* ranged from 1.29 mg/L (station 10) to 27.10 mg/L (station 14), with a mean of (7.20 ± 6.17) mg/L. In contrast, during May 2010, the chlorophyll-*a* concentrations were approximately (5.29 ± 5.49) mg/L (Figure 2).

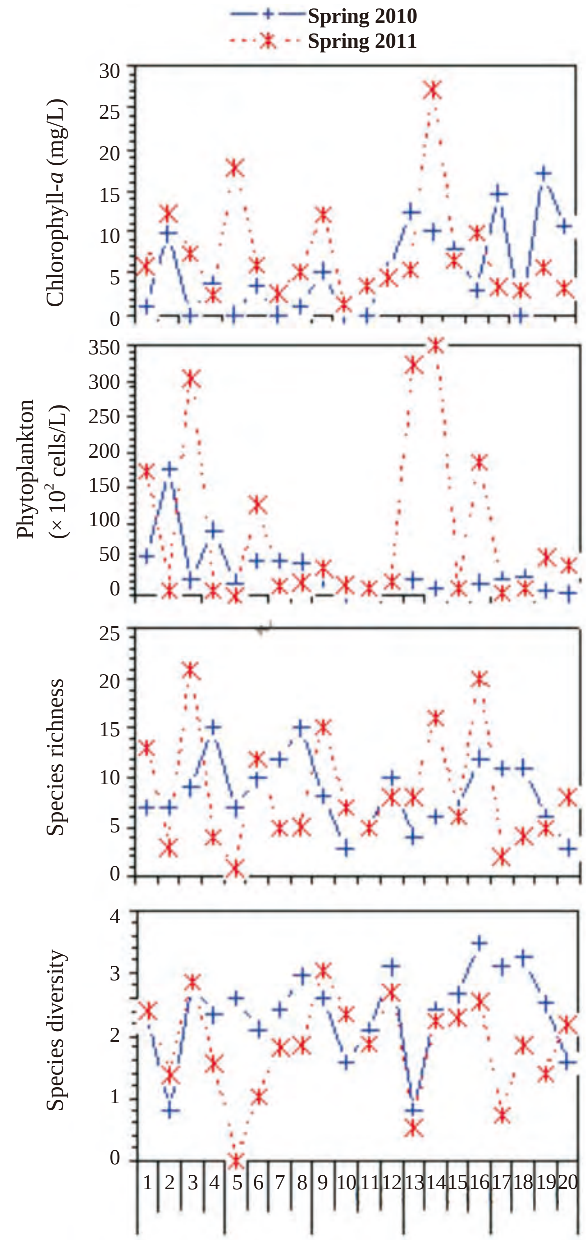

Figure 2. Chlorophyll-*a*, phytoplankton, density, species richness and diversity values in the 20 sampling stations on the south coast of Sfax.

Phytoplankton abundance followed closely the chlorophyll-*a* seasonal trend (Figure 2), with the best important abundance observed in spring 2011. The highest phytoplankton abundance value was observed in spring 2011, with an average of about ($86.00 \times 10^2 \pm 117.34 \times 10^2$) cells/L, lower values were recorded in spring 2010 ($33.95 \times 10^2 \pm 40.06 \times 10^2$ cells/L) (Table 1). The phytoplankton abundance varied from 10^2 cells/L (station 5, spring 2011) to 350×10^2 cells/l (station 14, spring 2011) (Figure 2). The composition of the phytoplankton in May 2010–2011 was characterized by considerable variability. There were significant differences in the phytoplankton community between two groups ($P < 0.05$, ANOVA) in the species richness based on density, taxonomy and diversity (Figure 2).

In terms of species richness, the phytoplankton community consisted of 59 species. They consisted mainly of 37 taxa in spring 2010 and 54 taxa in spring 2011 (Table 2). The Bacillariophyceae were the most abundant group in terms of species richness during this study (varied from 17 to 31 of the total phytoplankton species richness). The Dinophyceae were the second essential classes in terms of species number accounting for 17 taxa of total phytoplankton species richness, in May 2010 and 2011.

The species diversity [Shannon index (H')] of the phytoplankton community was less pronounced in spring 2011 than in spring 2010. This was particularly clear in station 5 where phytoplankton was represented by only one species (*Pleurosigma* sp.) (H' = 0, Figure 2) representing presumably beneficial environmental conditions along the coast during spring 2011. This was also recorded in station 13 where the relative abundance of the diatoms *Navicula* sp., resulted in a low diversity of the assemblage (H' = 0.54, Figure 2). H' reached a maximum (H' = 3.46, 12 species, station 16) during spring 2010.

Five different algal classes were determined, Bacillariophyceae (46%–78%), Dinophyceae (12%–32%), Euglenophyceae (8%–22%), Cyanobacteriae (< 2%) and Dictyochophyceae (< 1%), were identified in spring 2010 and 2011 respectively (Figure 3). The most important group was Bacillariophyceae in terms of abundance with the most dominant taxa being the diatom *Amphora* sp. (> 10^3 cells/L in spring 2010) and *Navicula* sp. (> 4×10^3 cells/L in spring 2011). *Coscinodiscus* sp. and *Grammatophora* sp. were also a bloomer particularly in spring 2011. Phytoplankton composition based on cell counts (spring 2010–2011) showed the importance of Dinophyceae to phytoplankton composition in south coast of Sfax. Results for Dinophyceae showed high spring variability of *Peridinium* sp. and *Protoperidinium* sp., for spring 2010, reaching 2.85×10^2 cells/L and 1.10×10^2 cells/L respectively. Other abundant Dinophyceae, *Prorocentrum lima* and *Alexandrium* sp., also attained high cell counts 7×10^2 cells/L and 1.30×10^2 cells/L respectively during spring 2011. The Euglenophyceae *E. acusformis* was observed in south coast and was particularly abundant in spring 2010 (reaching 7.30×10^2 cells/L). During the 2010 and 2011 spring cruises, Cyanobacteriae and Dictyochophyceae were detected only at a few stations.

3.2. Statistical analysis

The PCA was performed in spring 2010 and spring 2011 by assessing physical (temperature, salinity), chemical (pH, suspended matter, nutrients) and biotic (chlorophyll-*a* concentration, phytoplankton groups abundance) parameters at water sediment interface of the 20 stations (Figure 4). Difference between stations was more important during spring 2010. The PCA (explaining 48.03% in spring 2010 of the total inertia) approved discrimination of four groups around the components of the F1 and F2 axes. The positive relationship between chlorophyll-*a*, salinity, suspended matter and total phosphate in G1. Forms of N-nutrients (NO_3^-, NO_2^-, NH_4^+ and N/P ratio) linked to Cyanobacteriae abundance (G2). Low concentration of orthophosphate was correlated to phytoplankton groups such as Dinophyceae, Bacillariophyceae, Euglenophyceae and Dictyochophyceae (G3). G4 comprised of temperature, pH, TN and $Si(OH)_4$.

In spring 2011, the PCA plots illustrated that, in G1 selected, microorganism's diversity (Bacillariophyceae, Dinophyceae, Cyanobacteriae and Euglenophyceae) was linked to chlorophyll -*a*, salinity, suspended matter and ammonium. G2 and G4 formed by physico-chemical variables [pH, NO_3^-, NO_2^-, total N and N/P ratio (G2) Temperature, total P and $Si(OH)_4$ (G4)]. The presence of Dictyochophyceae in G3 was associated with high orthophosphate concentration (Figure 4).

Table 2

List and abundance of the phytoplankton species observed in spring 2010 and 2011 at the water-sediment interface on the south coast of Sfax.

Phytoplankton species	Spring 2010	Spring 2011
Cyanobacteriae		
Anabeana sperica (Bornet and Flahault, 1888)	-	C
Oscillatoria sp. (Gomont, 1892)	C	C
Spirulina subsalsa (Gomont, 1892)	-	C
Bacillariophyceae		
Achnanthes sp. (Hustedt, 1933)	C	C
Amphiprora paludosa (Smith, 1853)	-	C
Amphora sp. (Kützing, 1844)	A	C
Bacillaria sp. (Gmelin, 1788)	-	C
Bellerochea sp. (Crawford, 1990)	C	C
Biddulphia sp. (Gray, 1821)	C	C
Chaetoceros decipiens (Cleve, 1873)	C	C
Climacosphenia sp. (Ehrenberg, 1843)	C	C
Cocconeis pellucida (Hantzsch, 1863)	C	C
Coscinodiscus sp. (Ehrenberg, 1839)	-	A
Epithemia sp. (Kützing, 1844)	-	C
Fragilaria sp. (Lyngbye, 1819)	-	C
Grammatophora sp. (Ehrenberg, 1840)	C	A
Hemiaulus sp. (Heiberg, 1863)	-	C
Leptocylindrus danicus (Cleve, 1889)	-	C
Licmophora sp. (Agardh, 1831)	-	C
Licmosphenia sp. (Kützing, 1844)	-	C
Lithodesmium undulatum (Ehrenberg, 1839)	-	C
Melosira granulata (Ralfs, 1861)	-	C
Melosira sp. (Kützing, 1844)	C	C
Navicula sp. (Bory de St Vincent, 1822)	A	A
Nitzschia longissima (Ralf, 1861)	C	C
Nitzschia sp. (Ehremberg, 1831)	-	C
Oestrupia sp. (Mann, 1990)	-	C
Pinnularia sp. (Mann, 1990)	C	C
Pleurosigma angulatum (Quekett, 1841)	C	C
Rhizosolenia striata (Ehrenberg, 1841)	-	C
Skeletonema costatum (Cleve, 1873)	-	C
Skeletonema grevillei (Sarno and Zingone, 2005)	-	C
Striatella unipunctata (Kützing, 1844)	C	C
Synedra sp. (Greville, 1833)	C	C
Thalassiosira sp. (Lebour, 1930)	C	C
Dinophyceae		
Alexandrium sp. (Halim, 1960)	-	A
Amphidinium crassum (Lohmann, 1908)	C	C
Ebria sp. (Borgert, 1891)	-	C
Gonyaulax spinifera (Diesing, 1866)	C	C
Gymnodinium sanguineum (Hirasaka, 1922)	C	-
Gymnodinium sp. (Stein, 1878)	C	C
Hermesinum sp. (Zacharias, 1906)	-	C
Noctiluca sp. (Suriray, 1816)	-	C
Peridinium sp. (Ehrenberg, 1830)	A	C
Polykrikos sp. (Bütschli, 1873)	C	C
Prorocentrum compressum (Dodge, 1975)	-	C
Prorocentrum gracile (Schütt, 1895)	C	C
Prorocentrum lima (Stein, 1878)	C	A
Prorocentrum micans (Ehrenberg, 1834)	C	C
Prorocentrum triestinium (Schiller, 1918)	A	C
Protoperidinium conicoides (Balech, 1973)	C	-
Protoperidinium curvipes (Balech 1974)	C	C
Protoperidinium minutum (Loeblich III, 1970)	-	C
Protoperidinium sp. (Balech, 1974)	A	C
Protoperidinium steinii (Jorgensen, 1899)	C	-
Pyrophacus sp. (Stein, 1883)	C	-
Scrippsiella trochoidea (Stein, 1883)	C	-
Euglenophyceae		
E. acusformis (Schiller, 1925)	A	A
Dictyochophyceae		
Dictyocha fibula (Ehernberg, 1839)	C	C

A: Abundant (> 100 cells/L); C: Common (< 100 cells/L); -: Not detected.
E. acusformis: *Euglena acusformis.*

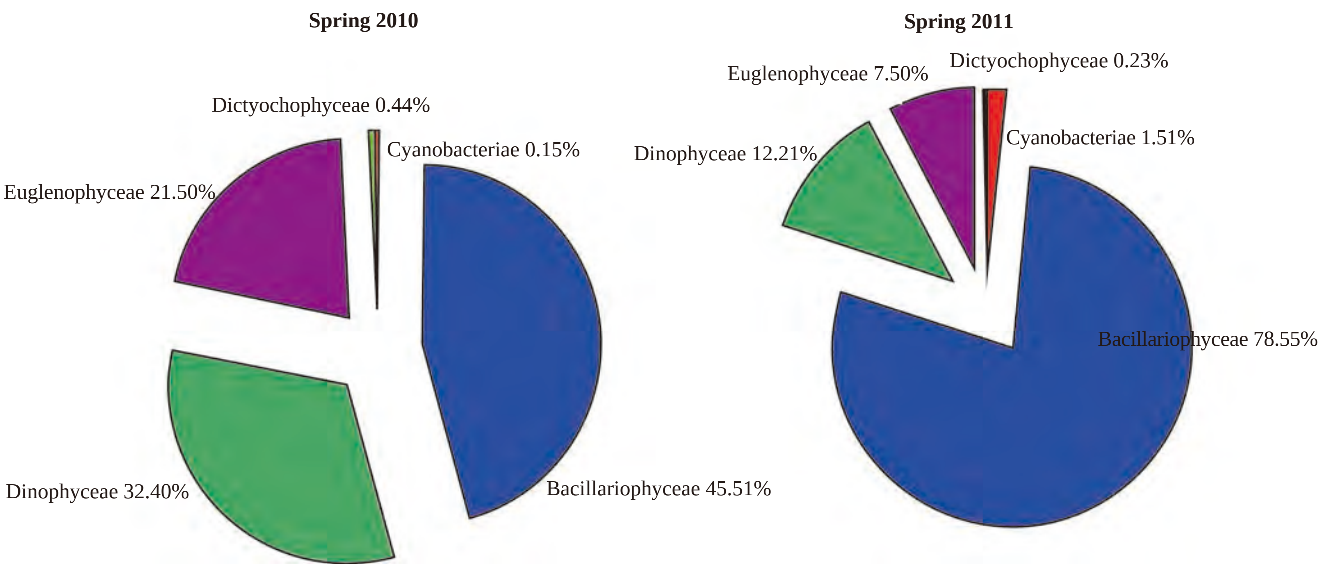

Figure 3. Contribution of different phytoplankton groups to abundance on the south coast of Sfax.

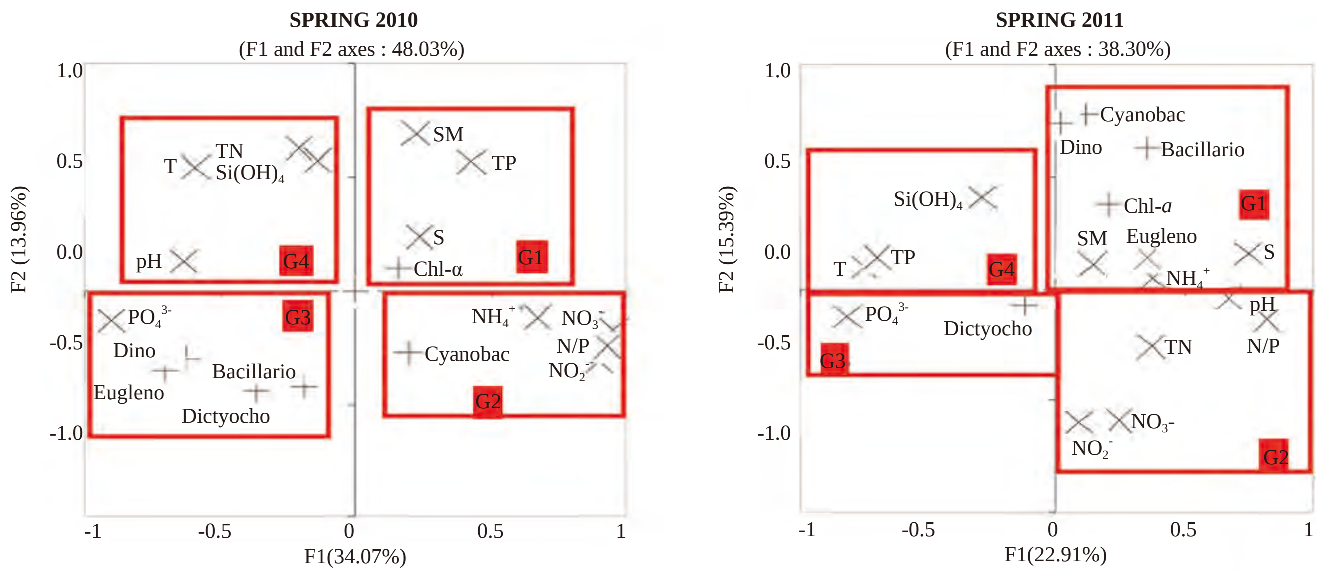

Figure 4. PCA (Axis I and II) of biological parameter abundance and selected environmental variables at sampled stations on the south coasts of Sfax. T: Temperature; S: Salinity; SM: Suspended matter; TN: Total nitrogen; TP: Total phosphate; N/P : N/P ratio; Bacillario: Bacillariophyceae; Dino: Dinophyceae; Cyanobac: Cyanobacteriae; Eugleno: Euglenophyceae; Dictyocho : Dictyochophyceae; Chl a : Chlorophyll-*a*.

4. Discussion

This study is the first attempt to investigate information about spring phytoplankton species composition and their spatial distribution coupled with environmental parameters at water sediment interface in the south Sfax coast.

Temperature variations were characteristic of Mediterranean climate type semi-arid to arid[17].

The station variability, in terms of temperature and physical parameters (salinity, pH and suspended matter), were mainly related to complex bathymetry[1]. The availability of nutrients remains the main factor controlling phytoplankton composition and biomass in coastal ecosystem[18]. N and P ions could have a secondary influence on the phytoplankton distribution and fluctuation[18]. Nutrient concentrations were high during spring 2011. The nutrients might be originated from the bottom mixed water during winter. The nutrient-rich bottom water is a result of nutrient accumulation in the south Sfax coast during the previous summer and autumn. The same results were obtained in the southern Yellow Sea[19]. In addition, in the southern coastal, the high availability of inorganic phosphate is associated with the high release of phosphogypsum[8]. Results showed significant difference between the two years regarding inorganic phosphate, with important value of seawater in the spring 2011, which may be generated by industrial pollution. It also highlights the large inorganic phosphate increase in the south due to industrial activity and that may be alleviated through improved industrial processes and waste control. The inorganic phosphate increase in the south suggests that equilibrium had not yet been reached and that inorganic phosphate restoration had been acutely necessary.

The N/P ratio could therefore be a important structuring factor for phytoplankton[18]. The study periods could be distinguished in the variations of the hydrochemical regime. If the N/P ratio is compared with the Redfield value (N/P = 16), the studied period can be clearly divided into two hydrochemical conditions: the first: N/P > 16, spring 2010 and the second N/P < 16, spring 2011.

The spring 2010, at the water-sediment interface of the south coast of Sfax, presents the most important value of N/P ratio which corroborated the results for the Mediterranean Sea[20]. This was possibly due to phytoplankton's rapid consumption, the average nutrient concentrations were low, particularly the PO_4^{3-} concentrations[21]. The importance of N availability may be caused by atmospheric deposition[19]. Phosphate was also reported to be a limiting element for phytoplankton growth in the western[22] and the eastern Mediterranean Sea[23]. Contrasting with the results we found in spring 2010, the N/P ratio decreased (< 16) in spring 2011. Relatively high phosphate concentration compared with dissolved inorganic nitrogen can be a result of orthophosphate fast regeneration[24]. Nitrogen is the most common element limiting phytoplankton growth in most marine ecosystems[25].

The south coast of Sfax showed low chlorophyll-*a* concentration together with an N/P ratio more important than the Redfield ratio, during spring 2010, indicating that this ecosystem is oligotrophic[26], confirming the observations reported from the eastern Mediterranean basin[27]. Nevertheless, the south coast of Sfax is showing signs of progressive eutrophication (spring 2011) [28]. The nutrient concentration ranges reported as criteria of eutrophication in coastal waters in spring 2011 were: 3–9 μmol/L for NH_4^+, 6–10 μmol/L for NO_3^- [29], 3–11 μmol/L for PO_4^{3-}[29] and > 6 μg/L for chlorophyll-*a*[29]. According to these values, sites in our study could be classified as eutrophic during spring 2011.

Spring phytoplankton assemblages in coastal ecosystem were controlled by environmental factors. An important bloom of Euglenophyceae was recorded in this period, but on the whole, the Bacillariophyceae is more abundant along the coast and particularly in spring 2011. Previous studies suggest that Bacillariophyceae have a more extensive growth range, however, 13–25 °C is an optimal temperature[30]. The temperature (27 °C) was very close to the most suitable range for Bacillariophyceae. The water sediment interface stability during our study may be among the most important factors governing Bacillariophyceae variations in the south Sfax coast. This was able to be confirmed by the prevalence of large Bacillariophyceae (*Coscinodiscus* sp., *Grammatophora* sp., *Navicula* sp. and *Amphora* sp.)[31]. Nutrient molar ratios have been used to infer potential nutrient limitation, as well as changes in the phytoplankton community assemblage[18]. The spring 2011 was marked by the ow value of N/P ratio (0.50–2.43) and it was notable that the important development of Bacillariophyceae was observed in this season. The nutrient ratios are key regulators in the Bacillariophyceae abundance. Field data analysis of all studied seasons between 2010 and 2011 allows the identifications of some regularities in the occurrence of different phytoplankton species and nutrient ratio. It was found that Bacillariophyceae have an advantage in conditions of low nitrogen concentrations, and a low ratio of nitrogen to orthophosphate (less than the Redfield ratio) is an obligate condition for an important dominance of Bacillariophyceae[18,32]. Compared with other phytoplankton species, the growth of Bacillariophyceae is influenced by the change in the silicate concentration. As an indispensable element to form Bacillariophyceae siliceous cell walls, there is a close relationship between the level of the silicate concentration and Bacillariophyceae[30]. The silica concentration was important (> 4 μmol/L in most cases) and could not limit the Bacillariophyceae growth. The observed silica concentrations were much higher than those of the half-saturation constant for the silica uptake[33].

The striking finding was the important proliferation in coastal samples of *E. acusformis*. Generally the stations are polluted such as the transect 2, which is located in front of the plant of producing phosphoric acid (SIAPE), led to the development of saprobiontic Euglenophyceae which assimilate lots of organic matter[34] and become dominant (22% of the total phytoplankton abundance) during 2010.

Phytoplankton can only propagate in proper temperatures, nutrient concentrations, and hydrodynamic force conditions, and changes in any of these factors affect the growth and succession of the community. It is likely, therefore, that the mechanism and processes of the spring bloom are very difficult and probably exceptional in the south coast of Sfax. To improve our basic understanding of the spring bloom in the water sediment interface, it is important to clarify the origin of nutrients and estimate phytoplankton consumption at the same time.

This study addressed the spring spatial distribution of phytoplankton and its links with hydrographic properties based on taxa enumeration techniques. Though phytoplankton abundance was highly variable with seasons along the sampled coastal stations. The phytoplankton community found along the coast was dominated by Bacillariophyceae species that thrived as favoured by the nutrient-rich coast, the temperature and the stability of the water sediment interface. The south coast of Sfax is characterized by anthropogenic pressure and industrial activities which have an impact on phytoplankton assemblage and could be the determining factors of phytoplankton dynamics. On the other hand, trophic interplay between phytoplankton and predators suggests that factors other than hydrographic conditions and nutrients were also involved in the environmental forcing of the spring phytoplankton dynamics in the south coast of Sfax.

Conflict of interest statement

We declare that we have no conflict of interest.

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