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Identification of Planktonic Genera/Species and Determination of the Physicochemical Factors Favoring the Growth of These Species in Cape 7 (Aftissat) Zone, South of Morocco

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Abstract

The diversity of oceanic phytoplankton communities depends in part on environmental, physical, chemical and biological factors where they are. The study that we conducted in cape 7 (Aftissat) zone, south of Morocco, located 232 km south of Laayoune city and 62 km south of Boujdour city, aims at the identification of planktonic genera/species and determination of the physicochemical factors favoring the growth of these species. The study was carried out on 427 samples, distributed, therefore, as follows, 57.2% (n = 245) of the samples during the year 2016 and 42.5% (n = 182) in the year 2017. In addition, 32.8% and 27.6% of the samples were taken, respectively, in winter and autumn, 24.4% of the samples in summer and 15.2% of all samples taken in the spring. We have identified 30 phytoplankton species, of which 70% (n = 21) are diatoms, 26.67% are dinoflagellates and one species is *silicoflagellates*. Moreover, the most abundant species in the diatoms are *Navicula* sp. (69), *Licmophora* (47), *Nitzschia* sp. (35), *Pseudo nitzschia* spp. (31) and in the class *Dinoflagellates*, *Scrippsiella* spp. (24), *Protoperidinium* spp. (11). The physicochemical parameters show very significant associations with density, so they favor a very high abundance species, especially those belonging to the diatom class. Some toxic species have also been identified, but with very low frequencies, below the norm. The cape d'Afissat has a very important role in the economic life of the region, so we must increase efforts to preserve it and if it is possible to improve the quality of water.

Keywords

Phytoplankton, Cape 7 (Aftissat), Physicochemical Parameters,

Diatoms, Density

1. Introduction

98% of the surface waters of the terrestrial globe are marine waters; the remaining 2% is continental waters represented by rivers, lakes and ponds. This vital food provides added economic value to many areas such as agriculture, energy production and industry [1] [2]. Numerous national and international studies have shown that disruption of aquatic ecosystems can lead to various phenomena such as eutrophication [3], proliferation of phytoplankton, anoxia, food poisoning [4] [5] [6]. Phytoplankton is all the unicellular microscopic algae that float in the water. They are able to proliferate intensively thus forming red, brown or green waters; these efflorescences can be sources of nuisance, reducing the transparency of the water and the concentration of dissolved oxygen, resulting in a loss of biodiversity of all trophic levels [7].

There are 84 listed wetlands in Morocco according to the 1997 Protected Areas Study. An ongoing study reports about 300 sites covering an area of 400,000 ha. The region of Laayoune-Boujdour-Sakia el Hamra is rich in wetlands such as cape of Afissat area.

The objective of this study is to determine the phytoplankton community and to assess the physicochemical quality of cape of Afissat.

2. Material and Methods

2.1. Climatological Characteristics of the Study Area

The area cape 7 (Aftissat), with the geographic coordinates 25˚35'31.08"N 14˚41'16.82"O, is located 232 km south of the town of Laayoune and 62 km south of the city Boujdour. The geomorphology of the coastline is characterized by the dominance of the cliffs with a limited narrow range (**Figure 1**).

The climate is characterized during the summer by the dominance of the trade winds, which generate activity of the Upwelling's, which results in the enrichment of water in mineral matter. The surface temperature between 18.4˚C north cape Boujdour and between 18.4˚C and 21.6˚C south cape Boujdour. In the deepest waters, outside the upwelling zone, the temperature reaches 20˚C to 21.6˚C. Surface currents are induced by atmospheric circulation.

2.2. Sampling Methods

2.2.1. Species Identification

Samples are taken at high tide (±2 h) at the surface, using one-liter spill bottle at one meter depth. The samples thus obtained are fixed on site. After vigorous stirring, the samples are decanted for 24 hours and then subjected to observation under optical microscope morpho-anatomic characters (shape, size and color) representing the identification keys retained by Gregoire *et al*., 1978, Bourrelly,

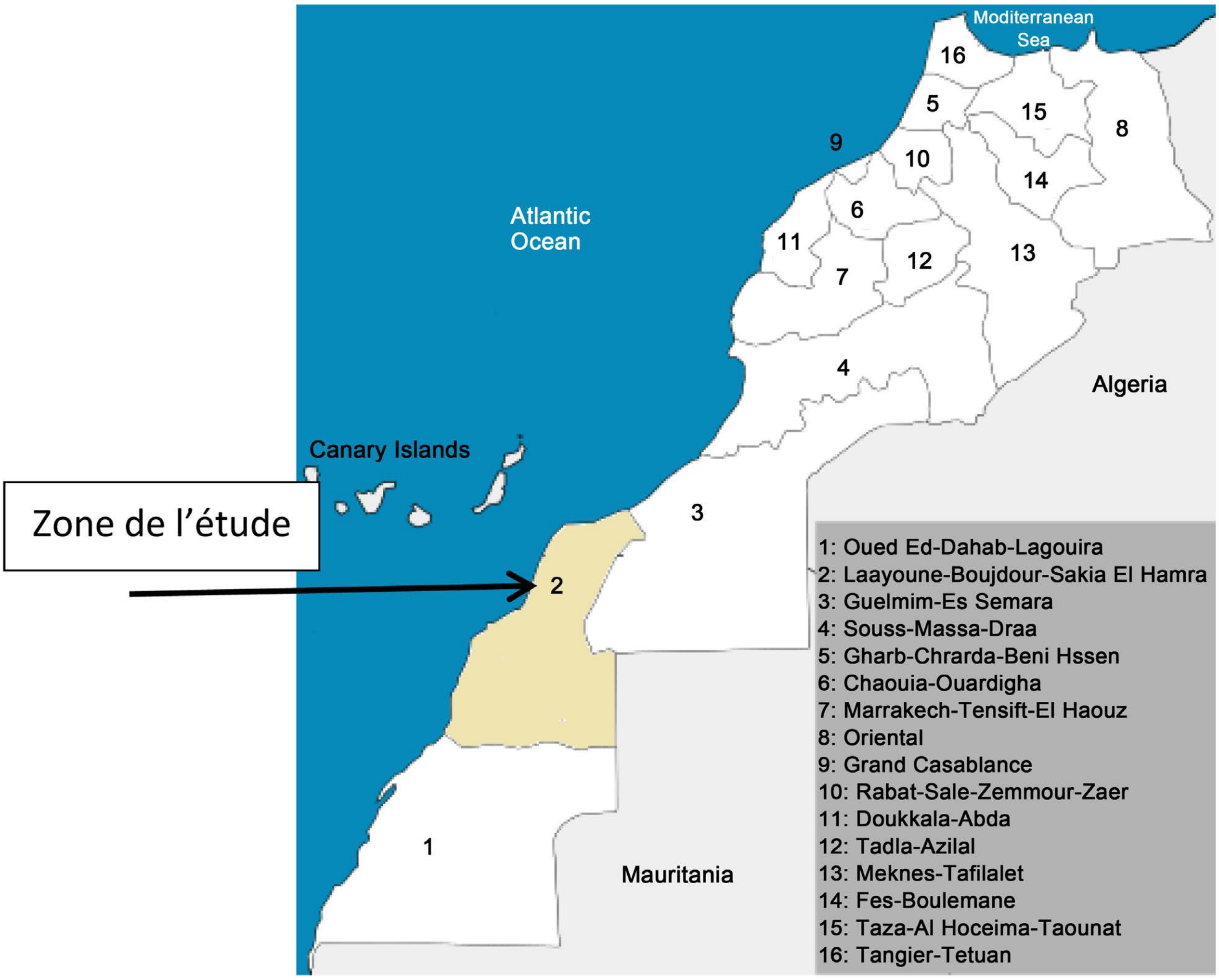

Figure 1. Map of morocco and study area.

1985 [8] [9]. The cells then are counted per liter per vat. With five repetitions and only the average values are taken into consideration.

2.2.2. Measurement of Physicochemical Parameters

The physical parameters (temperature, salinity and pH) were measured in situ using a portable multi-parameter probe of WTW LF 197 brand (accuracy of 0.1 unit).

Dissolved oxygen was determined by Winkler's chemical method, sampling was carried out in special glass vials with ground glass stoppers of known volume. Oxygen is fixed on site by the addition of reagents. The method is designed to isolate the sample from air and fix dissolved oxygen as quickly as possible by reaction with a precipitate of manganese hydroxide formed in the sample. Thanks to a succession of reactions, we finally obtain an iodine solution, easily dosable with precision, of concentration proportional to that of the oxygen initially present. The results are expressed in mg/l [10].

The samples intended for the analysis of the nitrite, nitrate and phosphate were taken in sub-surface to approximately 0.5 m of depth in polyethylene bottles, preserved protected from light at a temperature d'' about 4˚C. They were dosed by colorimetry according to the protocols described by Aminot and Kerouel, 2004 [10].

2.3. Statistical Analyzes

The collected data are entered on an Excel support, the exploitation is carried out on a statistical processing software. The chosen analyzes in this sense are significance tests such as single-point analysis of variance, correlations, principal component analysis. The results are generally expressed as relative frequencies and/or means ± standard deviation.

3. Results

3.1. Description of Phytoplankton Samples from the Study Area

The study we conducted in the area of the area cape 7 (Aftissat), is focused on 427 samples. They are distributed, therefore, as follows, 57.2% (n = 245) of the levies in 2016 and 42.5% (n = 182) in the year 2017. In addition, 32.8% and 27.6% of the samples were taken, respectively, in winter and autumn. 24.4% of the samples in summer. However, 15.2% of all samples were taken in the spring.

Of the total samples, 30 phytoplankton species were identified (**Table 1**), of which 70% (n = 21) were diatoms, 26.67% were dinoflagellates and one species was silicoflagellates. Moreover, the most abundant species in the diatoms are

Table 1. Distribution of phytoplankton species identified in the study area according to the algal classes.

Diatoms	Silicoflagellates.	Dinoflagellates
Amphora (18)		
Asterionella sp. (1)		
Biddulphia spp. (3)		
Chaetoceros (27)		
Coscinodiscus (23)		
Diplonies sp. (12)		
Guinardia sp. (7)		*Alexandrium* spp. (2)
Lauderia spp. (5)		*Ceratium furca* (6)
Leptocylindrus (15)		*Dinophysis* (4)
Licmophora (47)		*Katodinium* spp. (2)
Navicula sp. (69)	*Dictyocha* (4)	*Ostreopsis* sp. (4)
Nitzschia sp. (35)		*Prorocentrum* (9)
Odontella spp. (9)		*Protoperidinium* spp. (11)
Pleurosigma sp. (19)		*Scrippsiella* spp. (24)
Pseudo nitzschia spp. (31)		
Rhizosolenia sp. (14)		
Stolterfothii (1)		
Surirella sp. (1)		
Tabellaria sp. (14)		
Thalassiosira spp. (4)		
Triceratium sp. (3)		

Navicula sp. (69), *Licmophora* (47), *Nitzschia* sp. (35), *Pseudo nitzschia* spp. (31) and in the class Dinoflagellates, *Scrippsiella* spp. (24), *Protoperidinium* spp. (11).

At the same time, three of the 30 species identified are classified as having high toxicity; these unicellular microalgae are Dinophysis (Dinoflagellates); Prorocentrum (Dinoflagellates) and *Pseudo nitzschia* spp. (Diatoms). These microorganisms produce phytotoxins most often causing food poisoning, without the need for the presence of the germ, this occurs during the algal bloom.

3.2. Density of Species Identified in the Aftissat Zone

The monthly and seasonal distribution of phytoplankton density during the two years of study shows that the average density is 366.34 ± 19.22, with a minimum average density of 40 and a maximum average density of 2280. Indeed, the analysis of variance with only one criterion of classification "effect month or season" shows a significant difference ("fisher = 2.62"; $p < 0.003$). **Figure 2** shows the monthly and seasonal trends in average densities. This graph shows that the average maximum densities are recorded during the months of July and September, with respectively 518.182 and 516.4 and low in December (200). The grouping of monthly densities by season shows that the density is much higher in summer that is to say during the warm months and stable during the other seasons.

The distribution of the three algal classes listed in the sampling area shows by analysis of variance (Fisher = 14.61, $p < 0.000$) that diatoms are the most frequent, with an average density of 407.87 ± 21.72 followed by dinoflagellates with an average density of 138.49 ± 17.03 and finally the sicicoflagellate class with a density of 70 ± 10. However, the distribution of species identified according to their density has allowed them to be classified into three groups:

- The first group is composed of species with the highest densities, such as *Pseudo nitzschia* spp. (744), *Asterionella* sp. (660), *Navicula* sp. (544.67) and *Chaetoceros* (500).
- The second group includes the less abundant species with a density below

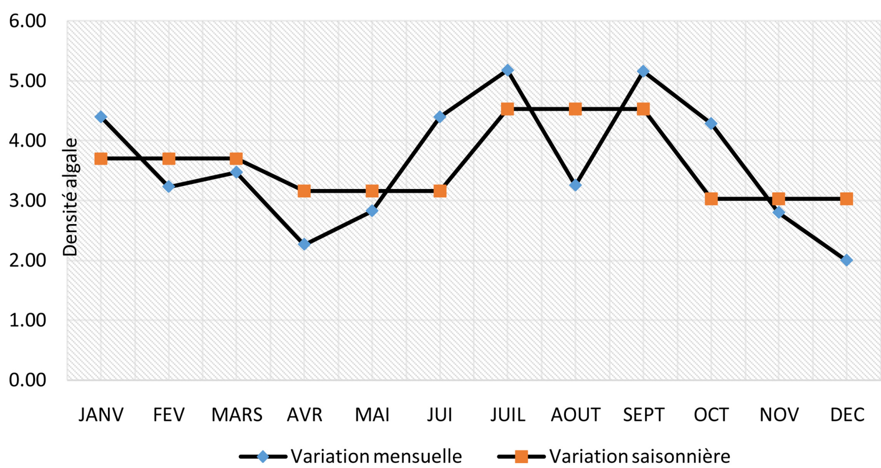

Figure 2. Monthly and seasonal evolution of phytoplankton the Aftissat zone.

200 such as *Biddulphia* spp. (93.33), *Triceratium* sp. (93.33), *Protoperidinium* spp. (84), *Dinophysis* (80), *Surirella* sp. (80), *Dictyocha* (70).

- The third group is composed of other phytoplankton species with a density between 100 and 500. This group is characterized by the presence of toxic species.

3.3. Frequency of Occurrence of Phytoplankton Collected

The distribution of phytoplankton species identified according to the frequency of occurrence shows that:

- The genus Navicula is encountered during the 12 months of the year of study (ubiquitous).
- The *Chaetoceros genera*; *Licmophora*; *Pseudo nitzschia* spp. are constant (encountered 11 months out of 12 and their frequency of appearance is 83.33%).
- The genera, *Amphora* and *Scrippsiella* spp. are regular; they are present 10 months at the time of sampling, with a frequency of appearance of 66.66%.
- Rare types encountered one to two months out of 12 and their frequency of appearance less than 25% which are: *Alexandrium* spp.; *Asterionella* sp.; *Dictyocha*; *Katodinium* spp.; *Stolterfothii* and *Surirella* sp.

3.4. Physicochemical Analyzes in the Study Area

3.4.1. Temperature

The monthly temperature distribution recorded in the surface waters of the Aftissat site during the two years of study shows that the average annual temperature is 19.48˚C, with averages exceeding 20˚C in August (21.60˚C), September (20.90˚C) and October (21.39˚C) and averages less than 18˚C recorded in February (17.62˚C) and March (17.01˚C). In fact, the mean temperature ranges recorded during the samplings carried out are in diatoms and dinoflagellates, respectively, of [19.32 - 19.66] and [19.15 - 20.05], whereas in the sillicoflagellates, it is of [17.46 - 18.16]. However, species identified at mean temperatures exceeding 20˚C at the time of sampling are *Biddulphia* spp., *Diplomas* sp., *Ceratium furca* and *Thalassiosira* spp. On the other hand, the species that are recorded during sampling at temperatures below 19˚C are as follows *Alexandrium* spp., *Katodinium* spp.; *Leptocylindrus*; *Odontella* spp., *Asterionella* sp.; *Lauderia* spp.; *Stolterfothii*; *Dictyocha a*nd *Ostreopsis* sp. While other species have identified themselves at temperatures between 19˚C and 20˚C.

So we can say that the temperature is strongly correlated with plankton abundance in the Aftissat zone.

3.4.2. pH

The average pH distribution over months shows that the average annual pH is 7.74 ± 0.14, with a minimum pH of 7.51 and a maximum pH of 8.10. The Fisher test shows a very highly significant month effect on the pH distribution (Fisher =

94.25, $p < 0.000$). Moreover, the comparison of the average shows that the pH is minimal in March (pH = 7.51) and maximum in September (pH = 7.9), the pH during the other months fluctuates between these two extreme values.

Nevertheless, during the samples taken, the average pH recorded in the three algal classes did not show any significant differences (Fisher = 1.15, $p < 0.32$). However, species identified at mean pHs less than 7.7 at the time of sampling are *Katodinium* spp. (7.585); *Ostreopsis* sp. (7.61); *Lauderia* spp. (7.64); *Biddulphia* sp. (7.67) and *Ceratium furca* (7.70). However, the species recorded, during sampling; under very high pH conditions (pH > 7.8) are *Leptocylindrus* (7.786); *Triceratium* sp. (7.81); *Dictyocha* (7.83) and *Thalassiosira* spp. (7.8725).

A significant correlation was therefore found between plankton density and pH in the Aftissat area (Fisher = 5.19, $p < 0.048$).

3.4.3. Dissolved Oxygen

The average annual rate of dissolved oxygen in sampling sites in the Afissat zone is 5.96 ± 0.57 mg/l, with a minimum of 5.20 mg/l and a maximum of 7.10 mg/l. Fisher's test shows that month variation has a very highly significant effect on the monthly distribution of dissolved O_2. However, the average comparison shows that October has the lowest average dissolved O_2 (5.2 mg/l) and August the highest average (7.1 mg/l), the mean dissolved O_2 levels recorded in the samples corresponding to the three algal classes do not show a significant difference (fisher = 0.36, $p < 0.71$). In addition, the species identified in samples where the dissolved O_2 level is less than 5.8 mg/l are *Ceratium furca* (5.45); *Stolterfothii* (5.53); *Asterionella* sp. (5.63); *Ostreopsis* sp. (5.65); *Lauderia* spp. (5.718); *Alexandrium* spp. (5.75); *Rhizosolenia* sp. (5.75); *Prorocentrum* (5.78); *Pseudo nitzschia* spp. (5.79) and *Tabellaria* sp. (5.80). In contrast, the species listed in samples with high levels of dissolved O_2 (>6.2 mg/l) are *Amphora (*6.20); *Guinardia* sp. (6.20); *Biddulphia* spp. (6.25); *Pleurosigma* sp. (6.41) and *Katodinium* spp. (6.5).

The correlation between density and dissolved oxygen was significant in the Aftissat zone (4.42, $p < 0.05$).

3.4.4. Salinity

It refers to the amount of salts dissolved in the water. The average annual content in the Aftissat zone is 36.37 ± 0.21 mg/l, with a minimum of 36 mg/l and a maximum of 36.7 mg/l. Fisher's test shows that month variation has a very highly significant effect on the monthly distribution of salinity. On the other hand, the month of October has the lowest average rate of dissolved salt (36 mg/l) and the month of March has the highest average rate (36.7 mg/l). Species with the ability to be found in waters rich in dissolved salt are *Surirella* sp. (36.53); *Ostreopsis* sp. (36.5); *Prorocentrum* (36.49); *Alexandrium* spp. (36.48); *Thalassiosira* spp. (36.47); *Lauderia* spp. (36.47); *Triceratium* sp. (36.46).

The correlation between density and salinity is negative, this shows that the abundance of planktonic species is advantageous in low salinity environments, although this correlation is not significant ($r = -0.45$, $p < 0.39$).

3.4.5. Phosphate, Nitrite and Nitrate

The annual average levels of phosphate, nitrite and nitrate in the Aftissat area are as follows: 0.29 ± 0.07; 0.28 ± 0.8 and 0.22 ± 0.13 (µmol/l). For phosphate, the minimum value is 0.10 µmol/l and the maximum level is 0.40 µmol/l, while the average low content is recorded in December (0.18 µmol/l) and the highest content is marked in March (0.40 µmol/l). For nitrite and nitrate, the average monthly high levels are reported in July (0.32 µmol/l) and June (0.23 µmol/l), respectively.

3.5. Joint Analysis

Figure 3 presents the results of the physicochemical parameter projection in the space composed of axes 1 and 2 of the principal components analysis. The two axes alone absorb more than 60% of the total variation. Reading this graph show that the average temperature and salinity in the Afissat zone generally change inversely along axis 1, as doe's pH, and the phosphates move in opposite directions along axis 2. On the other hand, we note that planktonic species abundance is governed by temperature, pH and dissolved oxygen parameters and conversely to salinity.

To draw conclusions about the behavior of planktonic species with respect to these physicochemical parameters studied, we superimposed the projections of parameters and species:

- The projection of the average points of all the species according to the two axes 1 and 2 (Figure 4), in compatibility with the projection of the physicochemical parameters, shows that some species tolerate medium high temperatures, but are sensitive to high levels of salinity like *Pseudo nitzschia* spp. (744), *Navicula* sp. (544.67) and *Chaetoceros* (500) and other amphora species…
- Conversely, some species show great adaptation to high levels of salinity but do not tolerate high temperatures such as *Protoperidinium* spp. (84), *Cosciniducus*, *Odontella*, *Dictyocha* (70), *Biddulphia* spp. (93.33)…

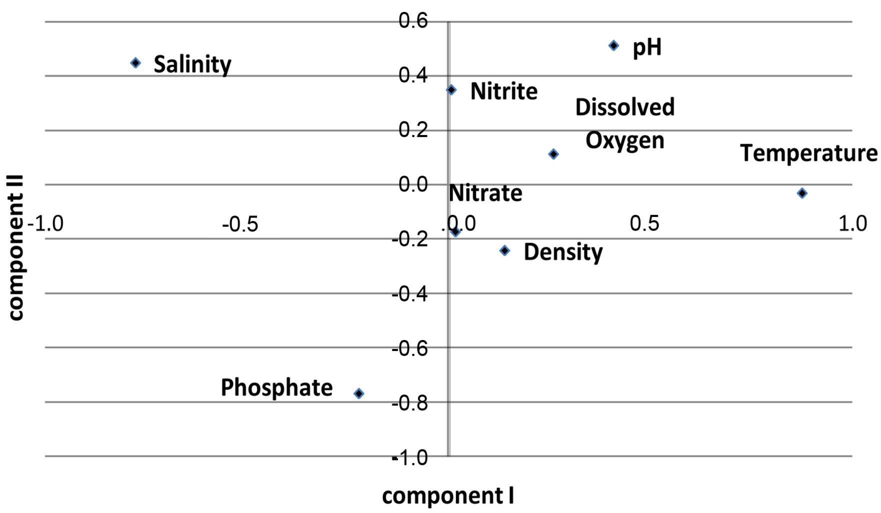

Figure 3. Projection of physicochemical parameters in ACP.

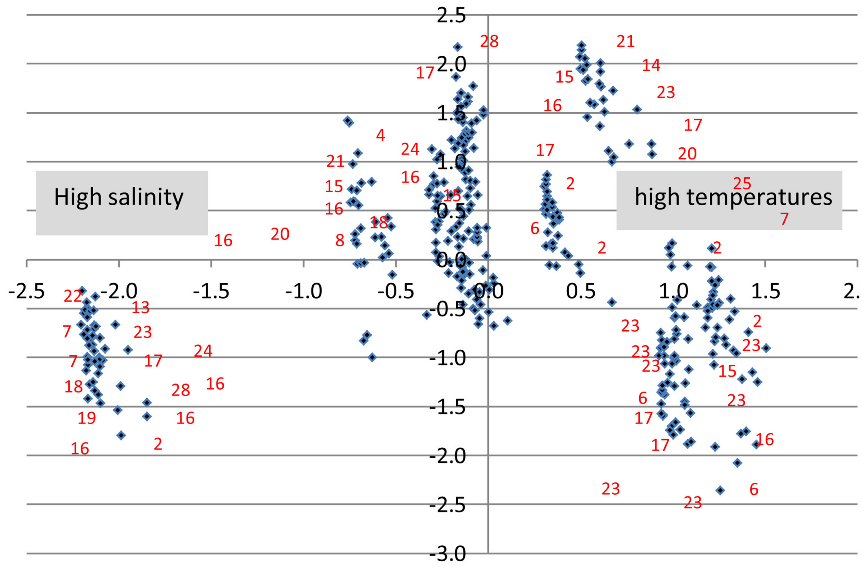

Figure 4. Projection of average points of planktonic species. 1: *Alexandrium* spp.; 2: *Amphora*; 3: *Asterionella* sp.; 4: *Biddulphia* spp.; 5: *Ceratiumfurca*; 6: *Chaetoceros*; 7: *Coscinodiscus*; 8: *Dictyocha*; 9: *Dinophysis*; 10: *Diplonies* sp.; 11: *Guinardia* sp.; 12: *Katodinium* spp.; 13: *Lauderia* spp.; 14: *Leptocylindrus*; 15: *Licmophora*; 16: *Navicula* sp.; 17: *Nitzschia* sp.; 18: *Odontella* spp.; 19: *Ostreopsis* sp.; 20: *Pleurosigma* sp.; 21: *Prorocentrum*; 22: *Protoperidinium* spp.; 23: *Pseudo nitzschia* spp.; 24: *Rhizosolenia* sp.; 25: *Scrippsiella* spp.; 26: *Stolterfothii*; 27: *Surirella* sp.; 28: *Tabellaria* sp.; 29: *Thalassiosira* spp. and *Triceratium* sp.

4. Discussion

The study we conducted in cape Aftissat, known by massive phytoplankton blooms, consists of the determination of the planktonic species community and the physicochemical characteristics of the cape. This geographical area is characterized by eutrophication [3].

The results of the species identification show that 30 phytoplankton species have been recorded, of which 70% (n = 21) are diatoms, 26.67% are dinoflagellates and a single species of the class silicoflagellates. Our results are consistent with those found in the work done in Megagine Lake in Algeria by Taleb and Noui (2011) [11] and Benfiala *et al.* (2013) [12]. In a study conducted by Nadège ROSSI (2008) [13], in the Grande Rade, Bacillariophyceae were also the group best represented with 60 species followed by Dinophyceae (55).

Phytoplankton evolves seasonally both in the lake environment [14] and in the marine environment [15]. The highest densities are recorded during the summer and spring season. Indeed, during the spring and summer seasons, the sun heats the surface water, which makes them less dense. This warm water floats above colder and denser waters, which is normal. This implies that the phytoplankton that develops stays on the surface. It contains abundant light and nutrients, as nutrients are brought up from deep waters during the winter [16]. However, during the fall and winter seasons, the days get shorter and the sun warms less the water. Surface waters cool and their density increases. This makes the amount of nutrients a bit low and this affects plankton abundance. Nevertheless, the most abundant species in the diatoms are *Navicula* sp. (69), *Licmophora* (47), *Nitzschia* sp. (35), *Pseudo nitzschia* spp. (31) and in the class *Dinoflagellates*, *Scrippsiell*a spp. (24), *Protoperidinium* spp. (11).

The physicochemical parameters (temperature, salinity, pH, dissolved oxygen, nitrate and nitrite and phosphate) play an important role in the proliferation of phytoplankton; a significant correlation ($p < 0.05$) was shown between these parameters and the density. Thus, cape Boujdour is a Saharan zone where the dust brought by the wind is too abundant. These dusts provide a significant amount of dissolved inorganic phosphorus, a nutrient essential for development [17].

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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