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Spring phytoplankton structure and abundance in relation to some environmental factors in Imessouane Bay (Moroccan Atlantic coast)

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Abstract

The main objective of this study is to follow the spring evolution of phytoplankton communities in Imessouane Bay according to the environmental factors, more precisely, we aim to determine the influence of those factors on its spatio-temporal distribution and the structuring of its communities. 18 biological and hydrological samples were taken at three stations during the spring of 2018 (March, April and May). The systematic study of samples in this zone revealed the presence of 74 species with a large dominance of diatoms (69%) followed by (31%) of dinoflagellates. The principal component analysis (PCA) and canonical correspondence analysis (CCA) have identified three groups of phytoplankton, the first one is more abundant in March, the second one in April and the third one in May.

1. Introduction

The bay of Imessouane is an area that presents an important biological and ecological richness and a significant economic value [1]. This richness is related to the phenomenon of upwelling, which provides a supply of nutrients necessary for the development of phytoplankton and, consequently, the production of the entire food web [2]. Phytoplankton occupies a primordial position in the marine ecosystem, and constitutes, therefore, a key element of its functioning and its balance. Nevertheless; its mode of development is governed by environmental factors that influence its spring variability [3].

Many scientific studies have been carried out on space-time dynamics of phytoplankton along the Moroccan Atlantic coast [4-8]. However, no work on phytoplankton has been carried out at Imessouane Bay except that of [9], which was largely devoted to the study of zooplankton.

This work aims to study the spatiotemporal variations and the influence of some physicochemical parameters on phytoplankton in the Bay of Imessouane.

2. Material and Methods

The collection of phytoplankton during the spring of 2018 was carried out at three stations in Imessouane Bay: S1 (30 ° 50'20"N, 9 ° 49'58"W), S2 (30 ° 49'22"N, 9 ° 49'30"W) and S3 (30 ° 49'71"N, 9 ° 49'83"W) (Figure 1). At each station, vertical lines have been made at a depth of 10 m for 10 minutes using a plankton net of 100 µm. The samples were fixed in formaldehyde (5%) and Lugol (Iodine/Potassium iodide solution). Phytoplankton enumeration was made according to the sedimentation technique [10]. The observation was carried out using sedimentation chambers of 10 ml, with an inverted microscope (Olympus ULWCD0.30) after sedimentation of 24 h. The specific identification of phytoplankton has been done by consulting various determination keys collections [11-16].

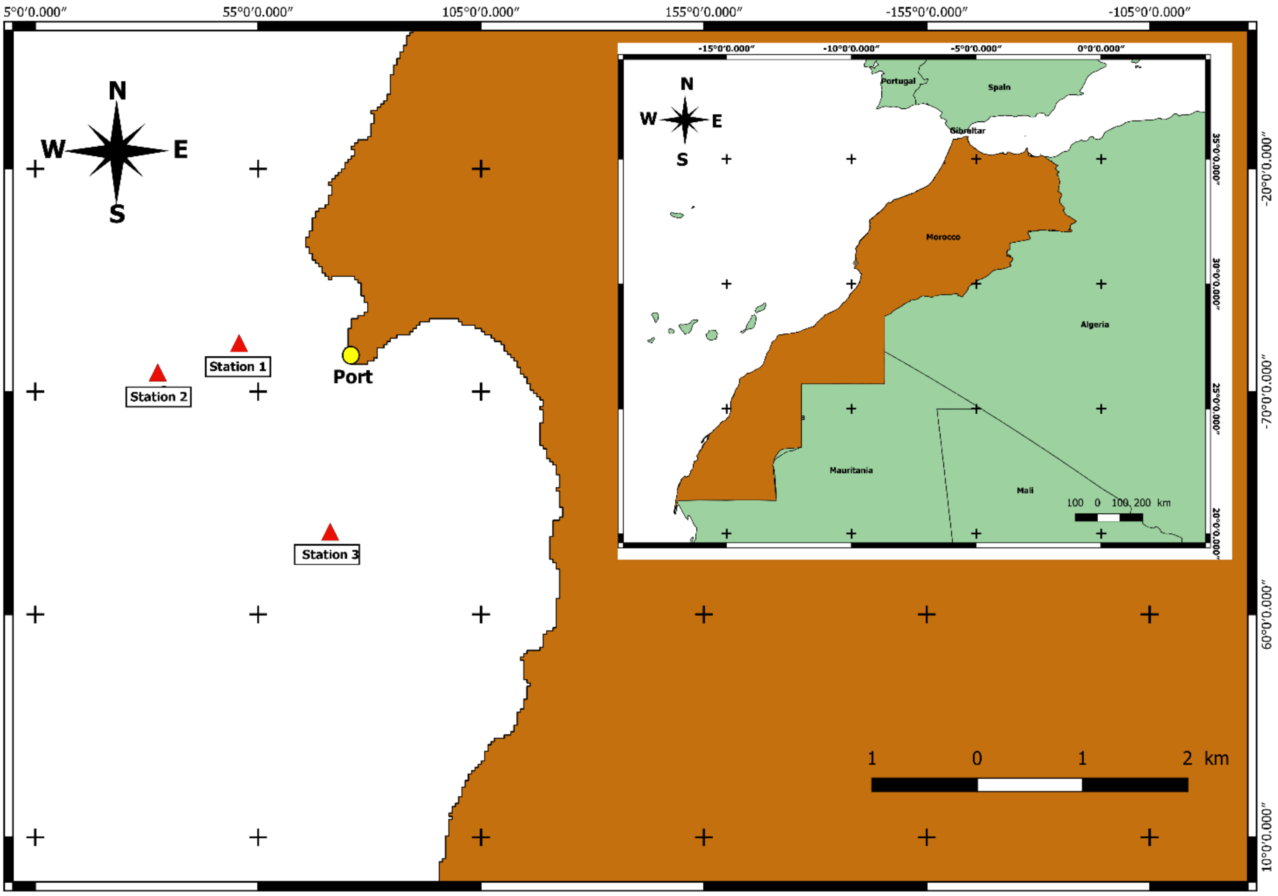

Figure 1 : Map of sampled stations.

The physico-chemical parameters (temperature, pH, salinity, conductivity, turbidity and dissolved oxygen) were measured using a Multi-parameter instrument (Consort C864). The concentrations of chlorophyll-a were estimated monthly for each station using the Worldview NASA software.
Two statistical tests were used for the analysis of our results CAP and CCA, the Component Analysis Principal (CAP) which is a very effective method for the analysis of quantitative data. The Canonical Correspondence Analysis (CCA) connects the abundances of species to environmental variables [17,18].

3. Results and discussion

3.1. Hydrology

3.1.1. Temperature (T)

The analysis of the Figure 2 shows a temperature gradient increasing from March to May. Values fluctuate between a minimum of 15.37 °C in March and a maximum of 17.47 °C during May recorded at stations 1 and 3 respectively, we also note the absence of significant difference between the temperatures recorded at the three stations for each month, this is confirmed by correlation degree values wich reached 98%. These results are similar to those found by Ait-talborjt [9] in the same area.

3.1.2. Hydrogen potential (pH)

The pH of seawater in Imessouane Bay is basic (Figure 3). It is between 8.75 and 8.85. The general profile of monthly changes of the pH of seawater shows a similar pattern in all stations. However, the amplitude of variation is more important in station 3 in April. pH maxima were detected in May in station 2 and in April in station 3 (8.85 and 8.84 respectively). This increase is most likely due to a strong phytoplankton activity during the spring period [4].

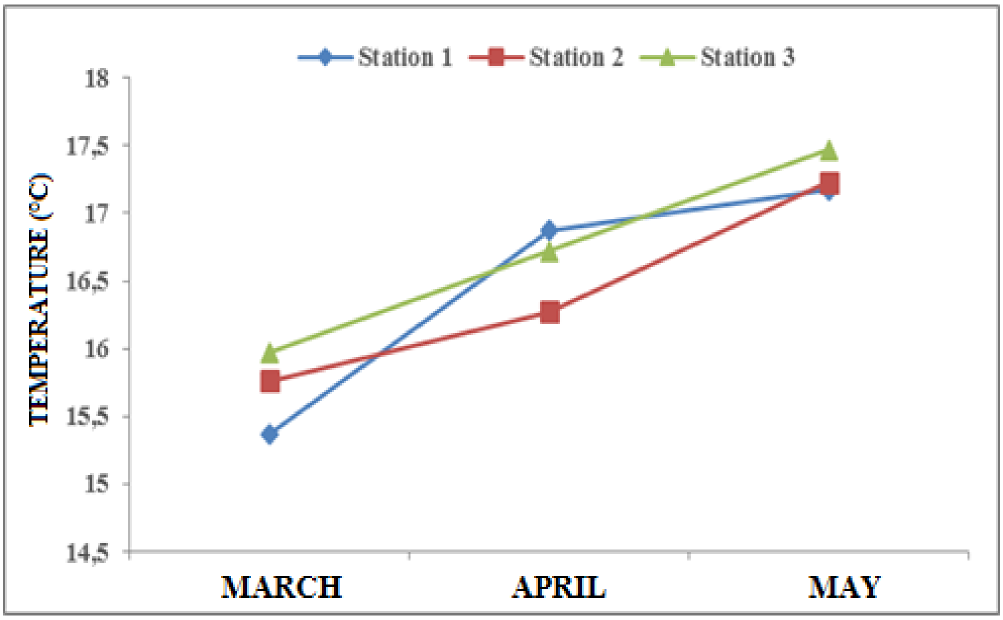

Figure 2 : Spatiotemporal evolution of seawater temperature in Imessouane Bay (2018 Spring).

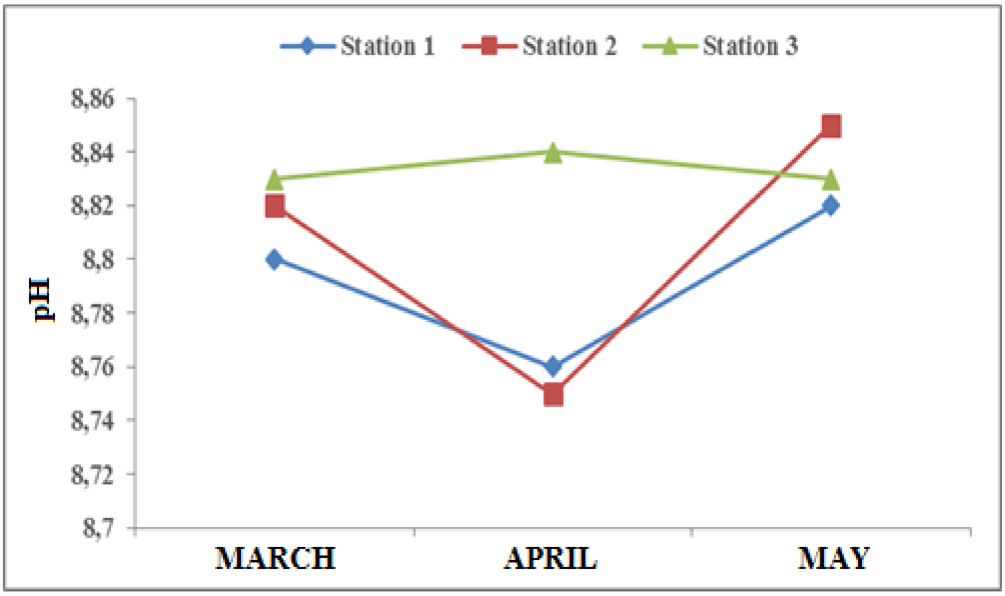

Figure 3 : Spatiotemporal evolution of the pH of seawater in Imessouane Bay (2018 Spring).

3.1.3. Salinity and Conductivity

Salinity and conductivity show almost superimposable monthly profiles in the three studied stations with a correlation coefficient R = 0.91 (Figure 4). It should be noted that the correlation between these two parameters has been demonstrated by several authors such as [19].

The differences between the three stations are more or less negligible. The salinity values in Imessouane Bay fluctuate between 36.1 and 36.8 ‰ (Fig. 4A), similar salinity values were found by Ait-talborjt [9] in the same study area. The conductivity oscillates between 46.2 and 55.6 ms/cm obtained respectively in station 1 during the month of April and in station 3 in Mars (Fig. 4B).

3.1.4. Dissolved oxygen

The levels of dissolved oxygen vary between 7.8 and 8.42 mg / l (Figure 5) which reflects that the seawater in the study area is well oxygenated. The lowest values were recorded in May, followed by average values in March and high values in April up to 8.42 mg/l in station 2. The variation profile of dissolved oxygen can be explained according to [20] by the increase of zooplankton population density, Since the values of O_2 gradually decrease with the increased respiration of these organizations, With the degradation of organic matter by aerobic heterotrophic bacteria and because of the high temperature which increases its evaporation.

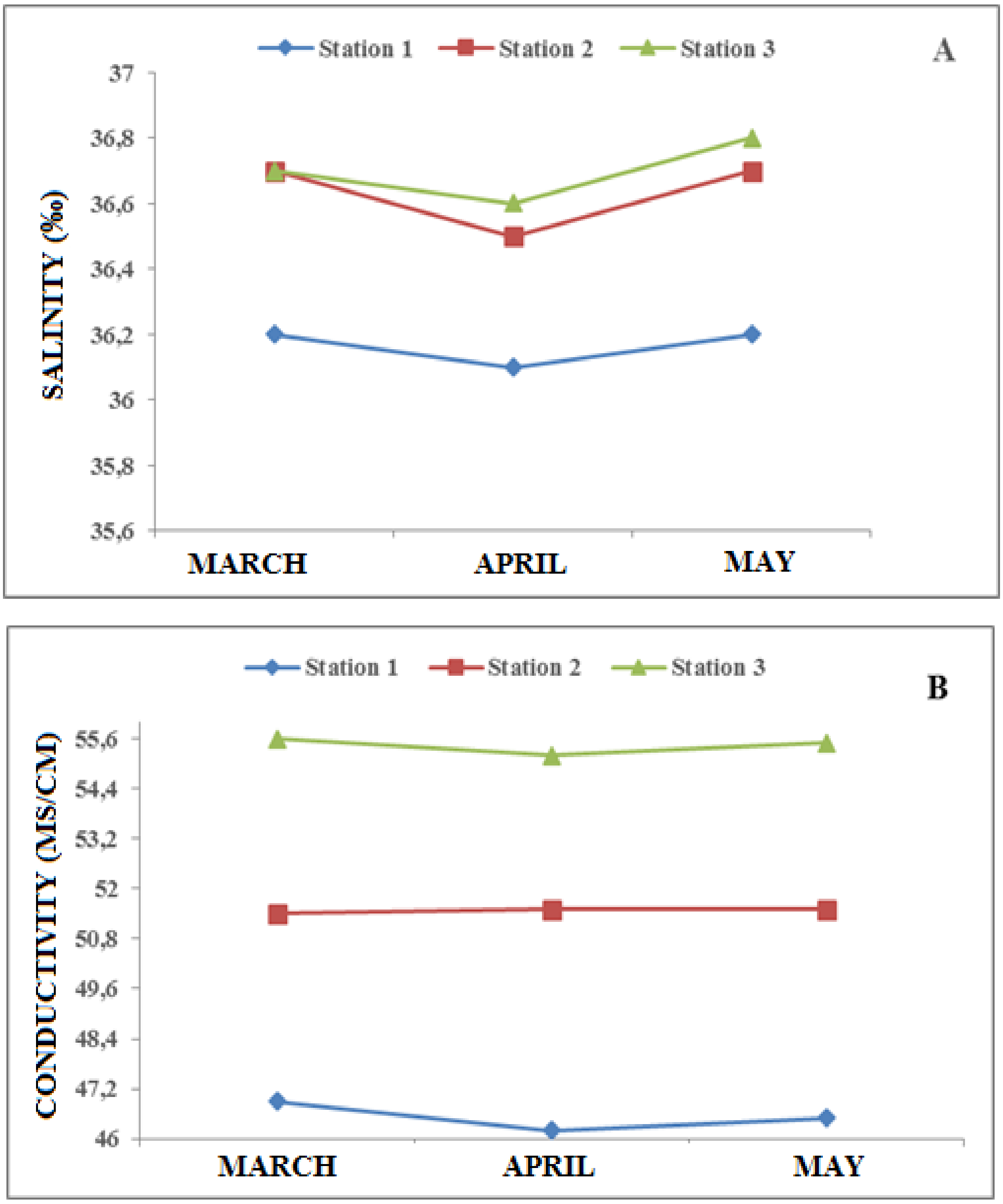

Figure 4 : Spatiotemporal evolution of seawater salinity (A) and conductivity (B) in Imessouane Bay (2018 Spring).

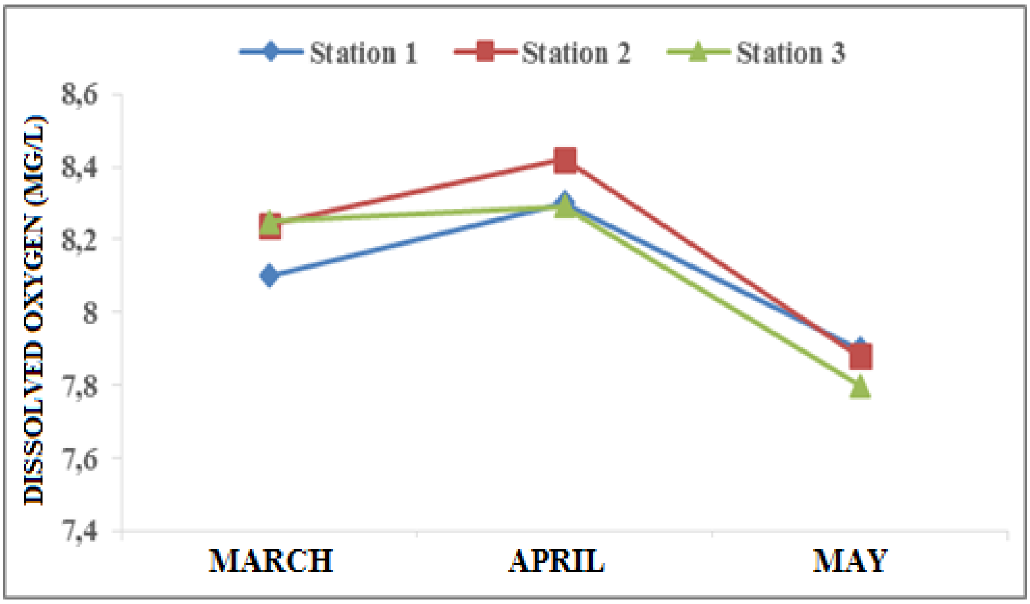

Figure 5 : Spatiotemporal evolution of the dissolved oxygen of the seawater in Imessouane Bay (2018 Spring).

3.1.5. Turbidity

The turbidity profile of seawater in Imessouane Bay shows an increasing gradient during the study period (Figure 6). From the month of May, the turbidity is experiencing an appreciable increase when the maximum reached 2.91 NTU in the station 2 followed by 2.83 and 1.81 NTU successively in the stations 1 and 3. These high turbidity values in May reflect an increase in phytoplankton densities [21].

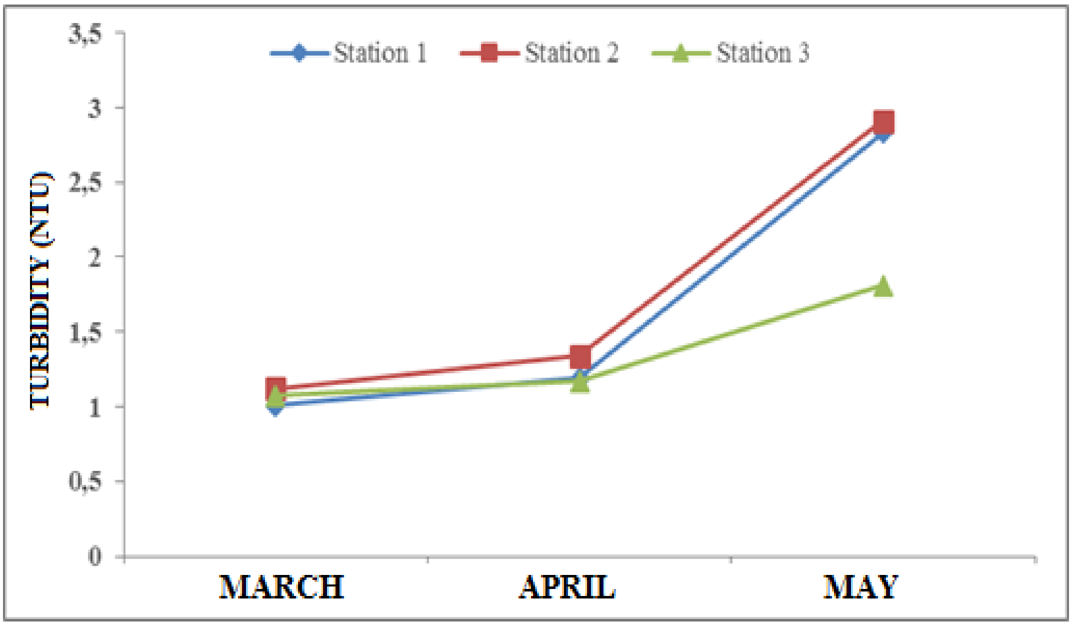

Figure 6 : Spatiotemporal evolution of the turbidity in Imessouane Bay (2018 Spring).

3.1.6. Chlorophyll a

Surface chlorophyll-a concentrations vary from month to month (Figure 7). Indeed, this photosynthetic pigment shows an increasing gradient during the study period ; High concentrations were recorded in May in all stations with concentrations up to 1,891 mg/m² in station 2. Regarding the other two months, the chlorophyll concentration in the three stations is minimal, since the maxima recorded does not exceed

0.97 mg/m² in April in station 3 and 0.841 mg/m² in March in station 1. The minima vary from 0.768 to 0.81 mg/m² corresponding successively to station 3 in March and station 2 in April.

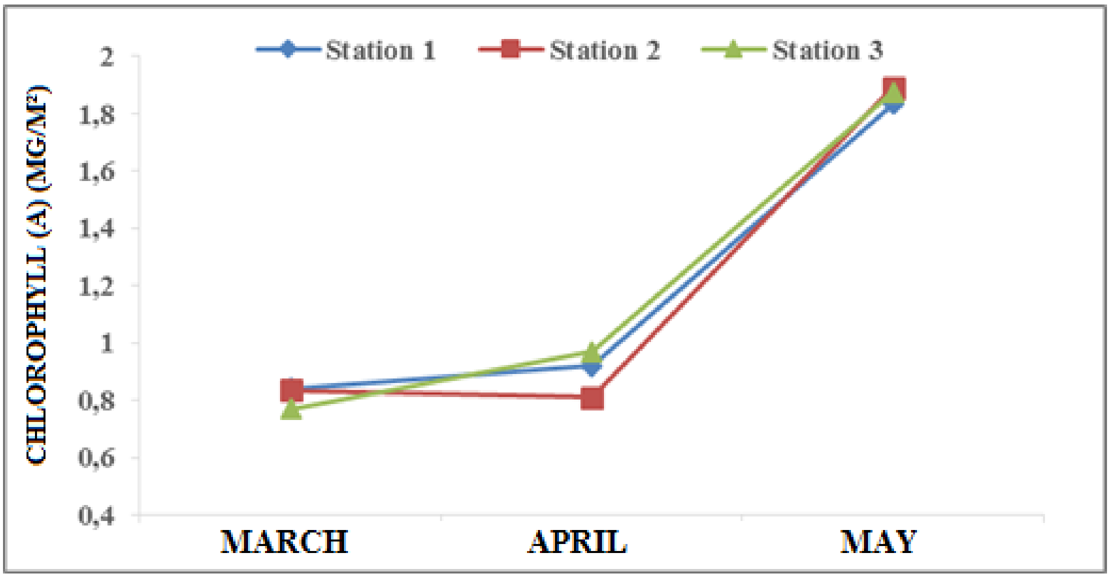

Figure 7 : Spatiotemporal evolution of the « chlorophyll a » of the seawater in Imessouane Bay (2018 Spring).

3.2. Study of the phytoplankton population

3.2.1. Taxonomic composition

The analysis of the Figure 8 shows that diatoms strongly dominate the phytoplankton of Imessouane Bay; they represent more than 69% of the total species richness, with 51 species and 30 genera. The dinoflagellates provide, Also, a large part of this taxonomic richness (31%) with 23 species and 12 genera. We can conclude that diatoms and dinoflagellates are the most important and diverse groups of phytoplankton in Imessouane Bay, this is in agreement with results previously published in the same area [22] and also those found by [4] in Agadir Bay and other coastal marine ecosystems of the Moroccan Atlantic coast.

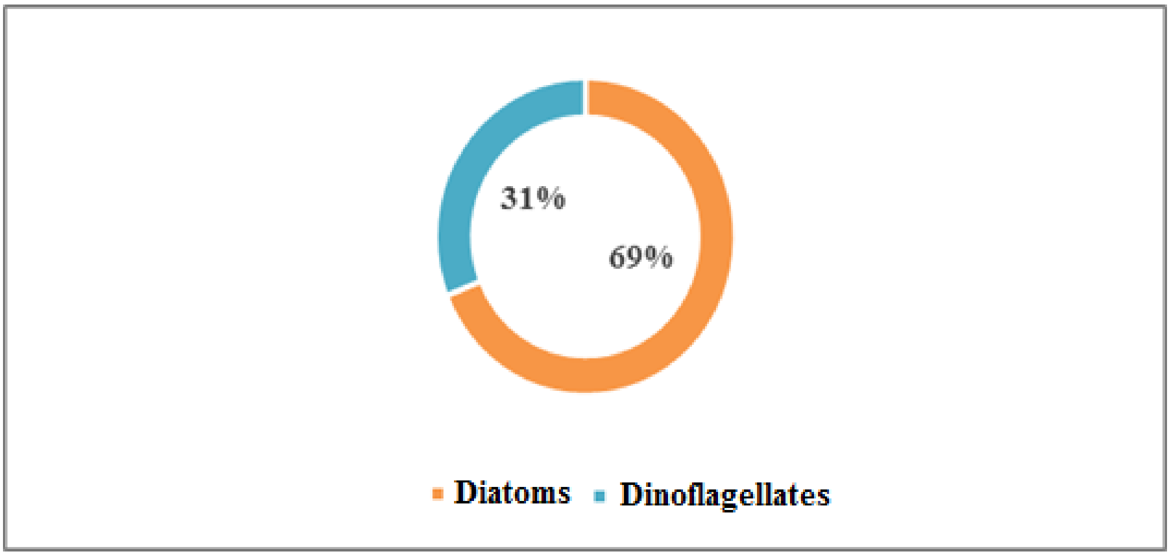

Figure 8 : Proportions of the two phytoplankton groups identified in the spring of 2018 in Imessouane Bay (overall results).

3.2.2. Abundance of phytoplanktonic genera

Figure 9 shows that there are large disparities in the number of individuals observed for each gender as well for diatoms than for dinoflagellates. It is also interesting to note that we obtained two different gradients one increasing and the other decreasing respectively for diatoms and dinoflagellates according to the months. For the class of dinoflagellates, it is the genus *Ceratium* which predominates during the month of March in the three stations, followed by the genus Tripos then *Protoperidinium* and *Dinophysis*. The remaining eight genera represent no more than 16 ind/l. During the month of April, there is a significant drop in terms of the number of individuals of each genus in all stations. In May this decrease is even more pronounced and varies from 10 to 0 ind/l. This reflects unfavorable conditions for the development of dinoflagellates.

Within diatoms, 2 genera namely *Rhizosolenia* and *Pseudo-nitzschia* share the same importance in March in the three stations. The remaining genera include no more than 30 ind/l. In April, the number of individuals of the two previous genera shows a significant decrease, conversely, the genus *Chaetoceros* takes place with 93, 33 and 54 ind/l respectively at stations 1, 2 and 3. In May, it is this genus which strongly dominates the Imessouane Bay with more than 2790 ind/l, the genus *Fragilaria* comes in the second position followed by the genus *Paralia* and *Odontella*.

We can conclude that the phytoplankton community of Imessouane Bay during the spring changes from month to month depending on the temperature gradient, with appearance of new genera *Chaetoceros*, *Fragilaria* and disappearance of others as *Ceratium*, *Protoperidinium*.

3.3. Principal component analysis

We present below the results of the PCA realized from the projection of seven physicochemical parameters measured during the three months study (March, April and May). This projection reveals two factorial axes F1 and F2 which express 100% of the total variance (Figure 10A). In the variable space, the axis F1 accumulated 64.79% of the total variance. It is positively correlated with pH, salinity, chlorophyll-a, turbidity, conductivity and temperature. On the other hand, it is negatively correlated with dissolved oxygen. The axis F2 totaled 35.21% of the total variance. It is defined in its positive part essentially by temperature, turbidity, chlorophyll-a and dissolved oxygen and systematically opposes to salinity, conductivity, and pH.

The F1 axis distinguishes the two months of March and May. In fact, the month of May is characterized by high values of temperature, turbidity and chlorophyll-a which confirm the high biomass recorded at all stations during this month, since phytoplankton increases the intracellular amount of chlorophyll-a to continue to capture enough light in depht (photo-acclimation) [23,24]. The conductivity, salinity and pH tend to go together with the month of March. The F2 axis highlights the effect of dissolved oxygen which is particularly felt in April. In conclusion, the PCA has identified the factors responsible for the difference between the three months, namely temperature, salinity and dissolved oxygen (Figure 10B).

3.4. Relationship environmental parameters community structure

Canonical correspondence analysis was carried out on 17 genera of phytoplankton, the most represented in our study area with total inertia of 100% on the two axes, divided into 91.61% for the F1 axis and 8.39% for the F2 axis (Figure 11).

The CCA has structured phytoplankton communities in three different groups depending on the month. The first group is represented by 6 genera: *Ceratium*, *Tripos*, *Rhizosolenia*, *Licmophora*, *Guinardia* and *Dinophysis*. This grouping is more abundant in March than in April. The second group is present throughout the month of April: *Pleurosigma*, *Protoperidinium*, *Pseudo-nitzschia* and *Cylindrotheca*.

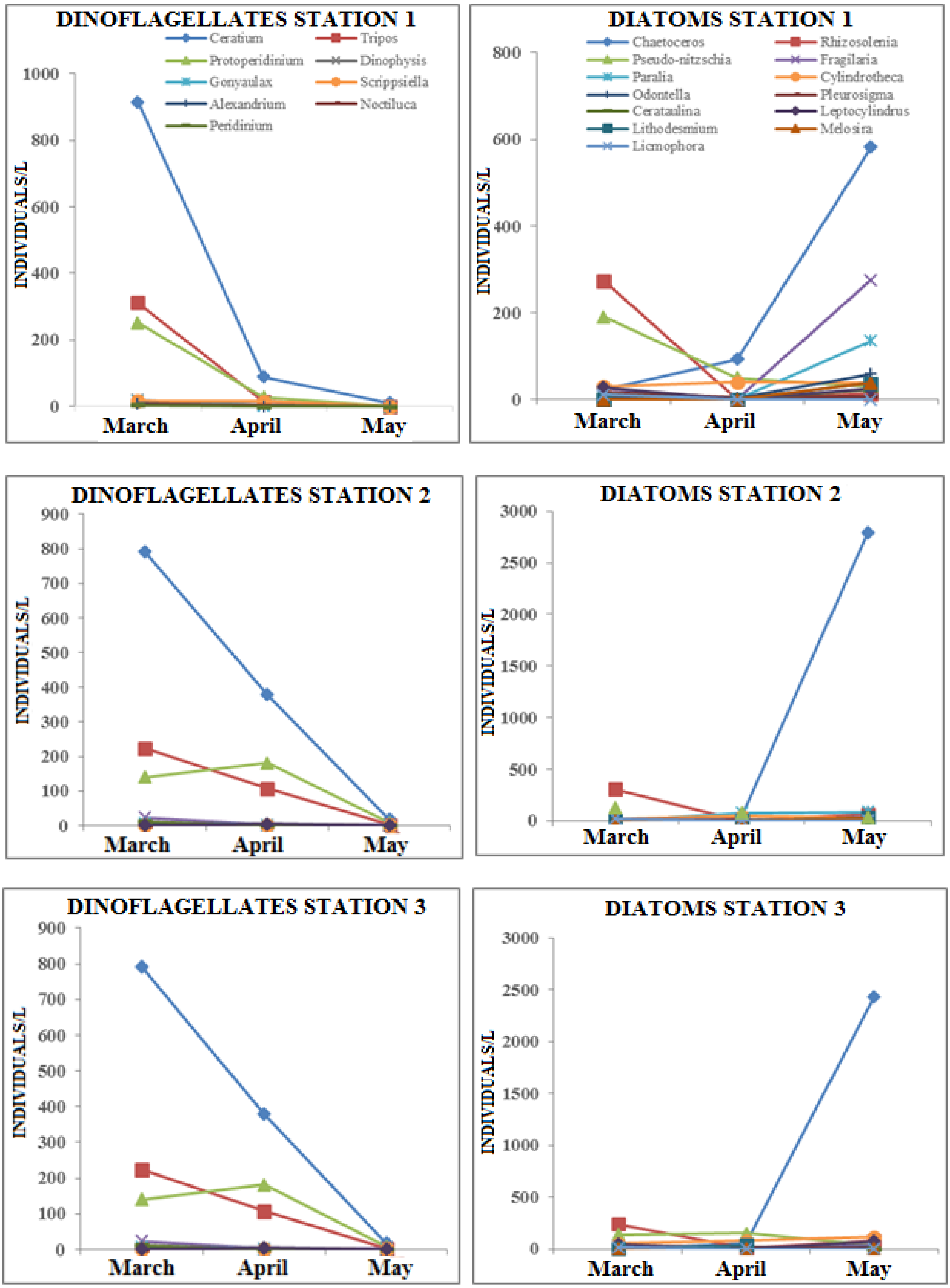

Figure 9 : Spatio-temporal evolution of the most dominant genera of phytoplankton in Imessouane Bay, spring 2018

The third group is that of May: *Chaetoceros*, *Lauderia*, *Lithodesmium*, *Fragilaria*, *Leptocylindrus*, *Odontella* and *Paralia*. We can explain the distinction of these groups over the months by superimposing the physicochemical variables represented in the PCA (Figure 10) with factorial plans of genders (Figure

11). We note the distribution of phytoplankton communities according to the characteristics of the environment. The samples taken in early spring (March) which are dominated by dinoflagellates correspond to populations influenced by the three parameters: pH, salinity and conductivity. Moreover, dissolved oxygen is the variable that governed the distribution of the population for the month of April at the three stations, We can say that this month is considered as a month of transition where we noticed the decrease of the dominant dinoflagellate species in March and the appearance of other species of diatoms which will take place until the end of spring. The temperature, turbidity and chlorophyll-a are the most important physico-chemical variables which allowed to distinguish the population of the end of spring (May).

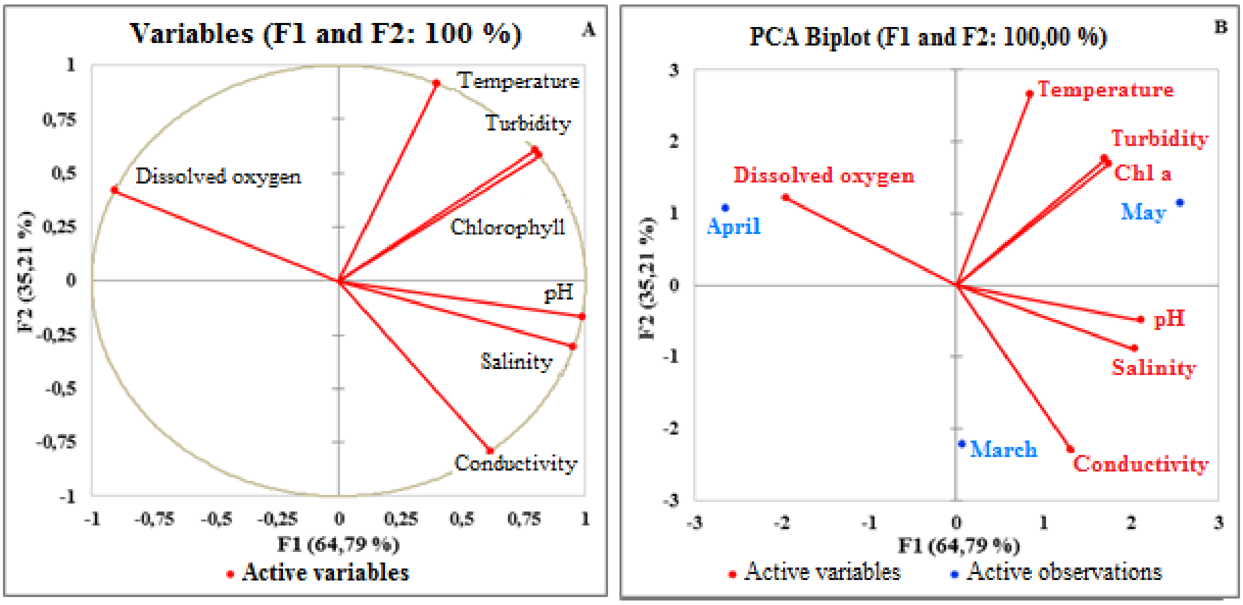

Figure 10 : Principal component analysis: (A) Physico-chemical parameters projection on the factorial plane (1x2); (B) Months projection on the factorial plane (1x2).

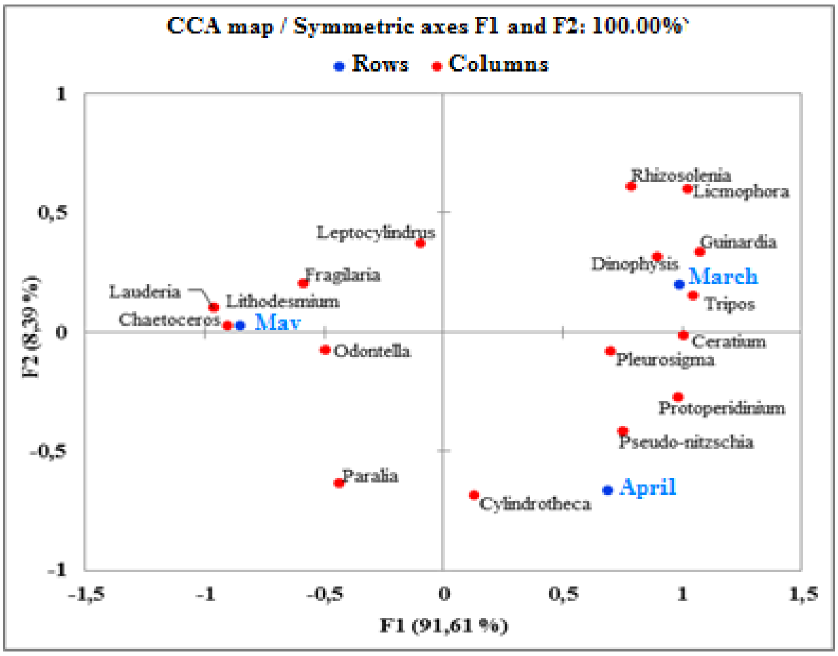

Figure 11 : Canonical correspondence analysis of the most represented genera of phytoplankton in the bay of Imessouane

Conclusion

This study allowed us to identify 74 species of phytoplankton during the spring period 2018 in Imessouane Bay. This number is divided into two major systematic groups: Diatoms which represent the dominant group with more than 69% of the total specific richness, including 51 species and 30 genera, followed by dinoflagellates with 31% with 23 species and 12 genera.

The relationship between environmental parameters and the community structure was demonstrated by the principal component analysis (PCA) and canonical correspondence analysis (CCA). These analyses allowed to identify the factors responsible for the existing difference between the populations of the three months. They structured the phytoplankton communities into three different groups: the first group includes the genera (*Ceratium*, *Tripos*, *Rhizosolenia*, *Licmophora*, *Guinardia* and *Dinophysis*) which are more abundant in March than in April, this group is influenced by conductivity, salinity and pH, the second group is present throughout the month of April and influenced by dissolved oxygen, this group includes (*Pleurosigma*, *Protoperidinium*, *Pseudo-nitzschia* and *Cylindrotheca*). The third group is abundant in May (*Chaetoceros*, *Lauderia*, *Lithodesmium*, *Fragilaria*, *Leptocylindrus*, *Odontella* and *Paralia*). This group seems to be rather affected by variations in temperature, moreover it's the main factor that allowed to discriminate the late spring phytoplankton (May) with that of the previous months. In May, we note the highest temperatures as well as a high phytoplankton density represented mainly by the genus *Chaetoceros*.

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