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SPRING STUDY OF PHYTOPLANKTON BIODIVERSITY IN IMESSOUANE BAY (MOROCCAN ATLANTIC COAST)

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ABSTRACT

In order to evaluate the taxonomic composition of phytoplankton, monthly monitoring of the composition and distribution of phytoplankton communities was conducted during the spring period of 2018, at three stations in Imessouane Bay. The systematic study of the samples revealed the presence of 74 phytoplankton species with a dominance of diatoms (69%) over dinoflagellates (31%).
The specific diversity was estimated by calculating the specific richness, Shannon-Weaver Diversity Index (H'), Pielou's evenness index (J), Margalef (Mg) and Simpson (Ds). The use of these indices concomitantly has clearly identified the overall state of the living phytoplankton community in Imessouane Bay. The presence of potentially harmful species was detected during the study period but still in small quantities, these mainly belong to the genera (*Pseudo-nitzschia*, *Dinophysis*, *Prorocentrum*, and *Alexandrium*).

1. Introduction

The Atlantic coast of Morocco is one of the pelagic ecosystems where fishery production is very important [1]. This is related to the permanent updrafts (upwelling) which are at the origin of the enrichment of the area in nutritive elements favoring the development of the algal populations [2]. Indeed, Phytoplankton occupies, in the marine ecosystem, a primordial trophic position and constitutes, therefore, a capital element of its functioning and its balance. Any variation in this basic compartment causes variations in the entire food web [3,4].
The present work aims to evaluate the taxonomic composition and the spatio-temporal variations of phytoplankton in Imessouane bay during the spring period of 2018.

2. Material and Methods

2.1. Sampling and analysis of the samples

Collecting phytoplankton samples 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).

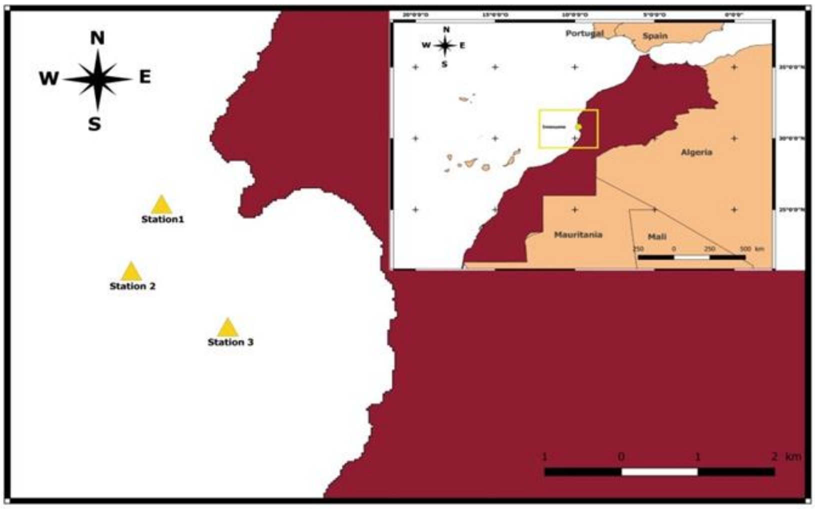


Fig. 1. Map of sampled stations.

Vertical lines of 10 min were made to a depth of 10 m using a plankton net of 100 µm. After their collection, the phytoplankton samples were fixed in a solution of Lugol's iodine and in 5% formalin. In the laboratory, the taxonomic identification was made by consulting numerous documents and specialized determination keys [5-10]. The individuals of each species were counted in a sedimentation chamber of 25 ml, under inverted microscope type (Olympus ULWCD0.30), after decanting the sample for 24 h, according to the method described by [11].

2.2. Statistical treatment

To have a global vision of spatio-temporal organization of the populations in the studied area, the following parameters have been determined:

• Specific richness (S): Represents the number of listed species per station.

• Constancy index (c): This is the index of the species presence in the environment. It is expressed as a percentage and determined by the following formula:

$$C = n / N * 100$$

Where: n = number of records where the species is present; N = total number of samples.

• Sorensen similarity index (Qs): Allows a comparison between the three stations taken two by two [12], according to the following formula:

$$Qs = 2j / a+b$$

Where: a = total number of species at station A; b = total number of species at station B; j = total number of common species between the two stations A and B.

• Specific diversity index: Estimated by the Shannon-Weaver index (H ') expressed in bits.cell-1 [13]. Calculated according to the formula:

$$H' = - \sum Pi \log2 Pi, \; Pi = ni / N \; i=1$$

Where: ni = number of individuals of species i; N = total number of individuals in the sample; S = total number of species.

• Pielou's evenness index (J): Measures the equitability of the species in the stand [14]. It varies from 0 (dominance of a single species) to 1 (even distribution of individuals in stands). It is obtained by the formula:

$$E = H'/\log2 (S)$$

Where : H': Shannon index; S: number of species present.

• Margalef index (Mf): Indicates whether the specific richness of an environment is high or not [15]. It is calculated according to the formula:

$$\mathbf{Mg = (S\text{-}1) / log2(N)}$$

Where: S = specific richness; N = number of individuals of all species in the sample.

• Simpson's diversity index (Ds): Measures the probability that two randomly selected individuals belong to the same species [16]. It varies from 0 (minimum diversity) to 1 (maximum diversity). The index is given by the formula:

$$\mathbf{Ds = 1\text{-}\sum Pi^2}$$

Where: P = Proportion of individuals in the species i.

3. Material and Methods

3.1. Taxonomic composition

The systematic study of phytoplankton, during the spring period 2018, showed an important diversity within the ecosystem studied. In total, 74 phytoplankton species were identified in all the samples taken at the three stations: Diatoms represent 69% of all species with 51 species and 30 genera (Table 1), dinoflagellates (31%) with 23 species and 12 genera (Table 2).

Diatoms and dinoflagellates constitute the largest and most diverse groups of phytoplankton in Imessouane Bay, this is in agreement with the results already published in the same area [17], in the maritime area of Aglou[18] and also in the bay of Agadir [19].

Using the frequency of taxa as an index of their classification, the study revealed the presence of:

- 34 very common species, 21 in diatoms and 13 in dinoflagellates with occurrence percentages range from 55 to 100%.
- 23 common species, 17 in diatoms and 6 in dinoflagellates with occurrence percentages range from 33 to 44%.
- 17 accessory species, 13 in diatoms and 4 in dinoflagellates with occurrence percentages less than 12% (Annex II and III).

We note that the number of accessory species is much less important than the number of common species and very common in contrast to results obtained in the study carried out in the south of Agadir bay [18].

Table 1: Taxonomic list of identified diatoms with their constancy

Diatoms											
Sampling date	March			April			May				
Species/Taxa	st 1	st 2	st 3	st 1	st 2	st 3	st1	st2	st3	Constancy©	Categories
Aulacodiscuskittonii	+	-	+	+	+	+	+	+	+	88,89	Very commonspecies
Bacillariparadoxa	+	+	+	+	-	-	+	+	+	77,78	Very commonspecies
Bacteriastrumhyalinum	-	-	-	-	-	-	+	+	+	33,33	Common species
Cerataulinadentata	+	-	-	-	-	-	+	+	-	33,33	Common species
Chaetocerosatlanticus	-	-	-	-	-	-	+	+	+	33,33	Common species
Chaetocerosconstrictus	-	-	-	-	-	-	+	+	+	33,33	Common species
Chaetoceroscurvisetus	+	-	-	+	+	-	+	+	+	66,67	Very commonspecies

Chaetocerosdanicus	-	-	-	-	-	-	+	+	+	33,33	Common species
Chaetocerosdecipiens	-	-	-	-	-	-	+	+	+	33,33	Common species
Chaetocerosdidymus	-	-	-	+	-	-	+	+	+	44,44	Common species
Chaetoceroslorenzianus	-	-	-	-	-	-	+	+	+	33,33	Common species
Chaetocerosperuvianus	-	-	-	-	-	-	+	+	+	33,33	Common species
Chaetocerosspp	-	-	-	+	+	+	+	+	+	66,67	Very commonspecies
Chaetoceroswighamii	-	-	-	-	-	-	+	+	+	33,33	Common species
Chattonella antiqua	-	-	-	-	-	-	-	+	-	11,11	Accessoryspecies
Climaconeislorenzii	-	+	+	-	-	-	+	+	+	55,56	Very commonspecies
Corethronsp	-	-	-	-	-	-	+	-	-	11,11	Accessoryspecies
Coscinodiscusgranii	-	+	+	+	+	+	-	+	-	66,67	Very commonspecies
Coscinodiscusspp	+	+	+	+	+	+	+	+	+	100	Very commonspecies
Coscinodiscuswailesii	+	-	-	+	+	+	+	+	-	66,67	Very commonspecies
Cylindrothecaclosterium	+	+	+	+	+	+	+	+	+	100	Very commonspecies
Detonulapumila	-	-	-	-	-	-	-	+	-	11,11	Accessoryspecies
Diploneisbombus	-	-	-	-	-	-	+	-	+	22,22	Accessoryspecies
Grammatophora marina	+	-	-	-	-	-	+	-	-	22,22	Accessoryspecies
Guinardiasp	+	+	-	+	-	+	-	-	-	44,44	Common species
Guinardiastriata	+	-	-	-	-	-	-	-	-	11,11	Accessoryspecies
Helicothecasp	-	-	-	+	-	-	-	+	-	22,22	Accessoryspecies
Lauderiaannulata	-	-	-	-	-	-	-	+	-	11,11	Accessoryspecies
Lauderiaborealis	-	-	-	-	-	-	+	+	-	22,22	Accessoryspecies
Leptocylindrusdanicus	+	-	+	-	-	-	+	+	+	55,56	Very commonspecies
Leptocylindrusminimus	+	+	+	-	-	-	-	+	-	44,44	Common species
Licmophoraabbreviata	+	+	+	-	-	-	-	-	+	44,44	Common species
Licmophorasp	+	+	+	-	+	-	-	-	-	44,44	Common species
Lithodesmiumundulatum	-	-	-	-	-	-	+	+	+	33,33	Common species
Melosiramoniliformis	-	-	-	-	-	-	+	+	-	22,22	Accessoryspecies
Navicula distans	+	+	+	+	+	-	+	+	+	88,89	Very commonspecies
Neocalyptrella robusta	-	-	-	-	-	-	+	-	-	11,11	Accessoryspecies
Odontellamobiliensis	+	+	-	+	+	-	+	+	+	77,78	Very commonspecies
Odontellaspp	+	+	+	+	+	+	+	+	+	100	Very commonspecies
Paraliasulcata	+	-	-	-	+	+	+	+	+	66,67	Very commonspecies
Pleurosigmadirectum	+	+	+	+	+	+	+	+	+	100	Very commonspecies
Pleurosigmaspp	+	+	+	+	+	+	+	+	+	100	Very commonspecies
Pseudo-nitzschiasp	+	+	+	+	+	+	+	+	+	100	Very commonspecies
Rhizosoleniaalata	+	+	+	-	-	-	+	+	+	66,67	Very commonspecies

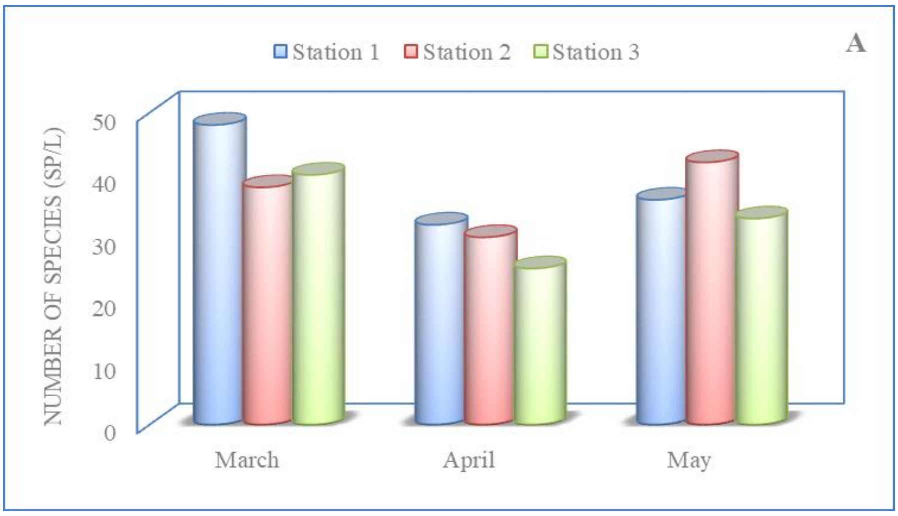
Rhizosoleniabergonii	+	+	+	-	-	-	-	-	+	44,44	Common species
Rhizosoleniaimbricata	+	+	+	-	-	-	+	+	+	66,67	Very commonspecies
Rhizosoleniaspp	+	+	+	-	+	+	+	+	+	88,89	Very commonspecies
Surirellasp	-	-	-	+	-	-	+	+	+	44,44	Common species
T. nitzschioide	+	+	-	-	-	-	-	-	-	22,22	Accessoryspecies
Trachysphenia australis	-	+	-	-	-	-	-	+	-	22,22	Accessoryspecies
Triceratiumspp	+	+	+	-	-	-	+	+	-	55,56	Very commonspecies

Table 2: Taxonomic list of identified dinoflagellates with their constancy

Dinoflagellates											
Sampling date	March			April			May				
Species/Taxa	**st1**	**st2**	**st3**	**st 1**	**st 2**	**st 3**	**st1**	**st2**	**st3**	Constancy ©	Categories
Alexandriumcatenella	+	-	+	-	-	-	-	-	-	22,22	Accessoryspecies
Ceatiumbilon	-	-	+	-	-	-	-	-	-	11,11	Accessoryspecies
Ceratiumcandelabrum	+	+	+	-	-	+	-	-	-	44,44	Common species
Ceratiumfurca	+	+	+	+	+	+	-	+	+	88,89	Very commonspecies
Ceratiumfusus	+	+	+	+	+	+	+	+	+	100	Very commonspecies
Ceratiumgravidum	+	-	-	-	-	-	-	-	-	11,11	Accessoryspecies
Ceratiumlineatum	+	+	+	-	+	-	-	-	-	44,44	Common species
Ceratiummacroceros	+	+	+	+	+	+	-	-	-	66,67	Very commonspecies
Ceratiumpentagonum	+	+	+	+	+	+	-	-	-	66,67	Very commonspecies
Ceratiumtripos	+	+	+	+	+	+	-	+	-	77,78	Very commonspecies
Dinophysis acumunata	+	+	+	+	+	+	-	+	+	88,89	Very commonspecies
Dinophysis caudata	+	+	+	+	-	-	-	-	+	55,56	Very commonspecies
Gonyaulaxbirostris	+	+	+	+	+	+	-	-	-	66,67	Very commonspecies
Gymnodynium	-	-	+	-	-	-	-	-	-	11,11	Accessoryspecies
Noctilucascintillans	+	+	+	+	-	-	-	-	-	44,44	Common species
Peridiniumgrani	+	-	+	-	+	+	-	-	-	44,44	Common species
Prorocentrummicans	+	+	+	+	-	-	-	-	-	44,44	Common species
P.caudatum	+	+	+	+	+	+	-	+	+	88,89	Very commonspecies
P.depressum	+	-	+	-	+	-	-	-	-	33,33	Common species
P.diabolum	+	+	+	+	+	+	-	-	-	66,67	Very commonspecies
P.divergens	+	+	+	+	+	+	-	-	-	66,67	Very commonspecies
Pyrophacussp	+	+	-	+	+	+	-	-	-	55,56	Very commonspecies
Scrippsiellatrochoidea	+	-	-	+	+	+	-	-	+	55,56	Very commonspecies

3.2. Specific diversity

The graph in Figure 2A illustrates the specific diversity of each sampled site. For all stations, the minimum values of the specific richness are recorded during April, this is confirmed by the low values of the Margalef index (2.8 <Mf<3.7) during the same month (Figure 2B). The highest values of specific diversity, although fluctuating, are reached during March and May. Thus, we were able to identify 48 species for a Mf = 4.2 and 45 species for a Mf = 3.8 successively at station 1 in March and at station 2 in May. It turns out that the high numbers of species are obtained in early spring, as they decrease in mid-spring and rise again in late spring, indicating the appearance of new species.



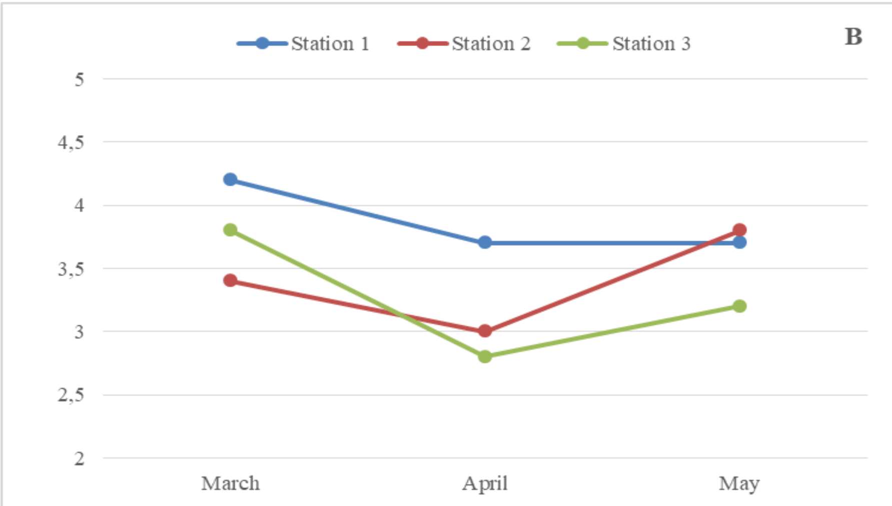


Fig. 2. Spatio-temporal evolution of the specific richness of phytoplankton (A) and the Margalef index (B) in Imessouane bay during spring 2018

3.3. *Similarity index*

The similarity indices calculated are relatively high (Figure 3), with monthly averages of 0.84 between station 2 and 3, 0.81 between station 1 and 2 and 0.80 between station 1 and 3. For the three stations, the highest similarity indices were observed in May (0.8 <Qs <0.83) and the lowest indices in April (0.77 <Qs <0.86). We noted a good similarity between the stations, however with a substantially decreasing order: S2-S3> S1-S2>S1-S3.

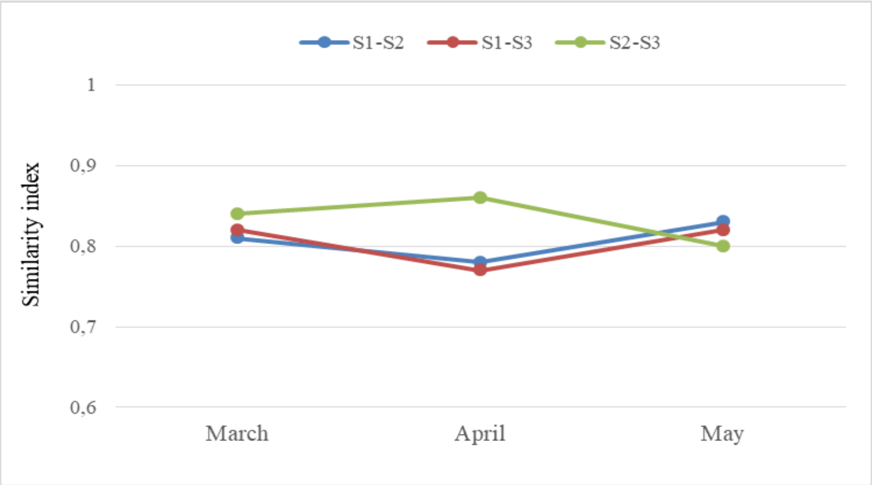
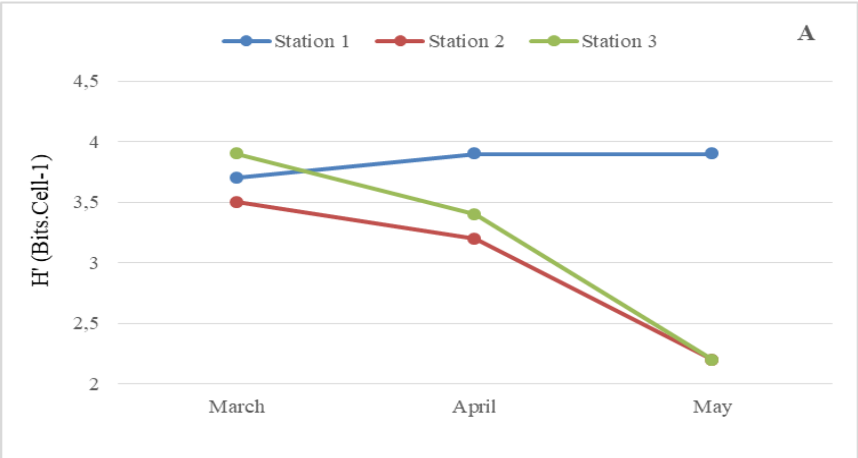


Fig. 3. Variation in the similarity index between the phytoplankton populations of the three stations in Imessouane Bay, spring 2018

3.4. Shannon diversity and Pielou's evenness index

The Shannon diversity index (H') varied in parallel with Pielou's evenness index (J) throughout the study period. The curves in Figure 4 (A and B) show generally high indices except for a few points. The lowest values are observed in May, these reflect the existence of preponderant species. Indeed, the minimum values in May explain the very wide dominance of species of the genus *Chaetoceros* (84%). This is best explained with the evenness index, which highlights the imbalance in the distribution of species [20]. It should be noted that the values of (H') and (J) fall from March to May at stations 1 and 2 with a more pronounced decrease in May while station 1 seems to be less affected by the *Chaetoceros* push.



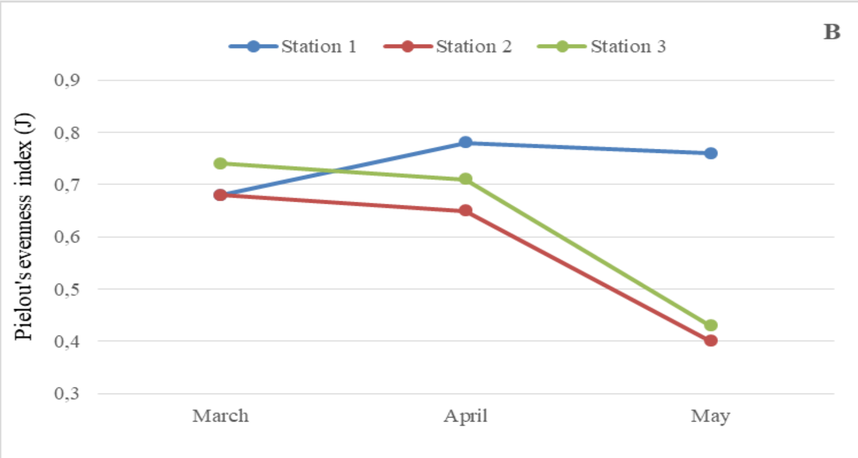


Fig. 4. Spatio-temporal variation of Shannon diversity index (A) and Pielou's evenness index (B), spring 2018

3.5. Simpson's Diversity Index (Ds)

Simpson index expresses generally high degrees of diversity (0.82 <D <0.90) which represents the maximum of diversity (Figure 5). Only stations 2 and 3 in May are the exception, where there are weak indices of 0.50 and 0.53 respectively. In fact, the combination of the lowest value of Shannon Weaver, Pielou's evenness, and Simpson indices for these two stations in May, explains a minimal phytoplanktonic diversity thus illustrating the dominance imposed by *Chaetoceros*. This dominance may be due to the favorable conditions for the development of species of this genus, especially high temperature and salinity values [8]. Indeed, the use of these three indices: Shannon Weaver, Pielou's evenness, and Simpson concomitantly allows a more complete study of the phytoplankton community structure [21].

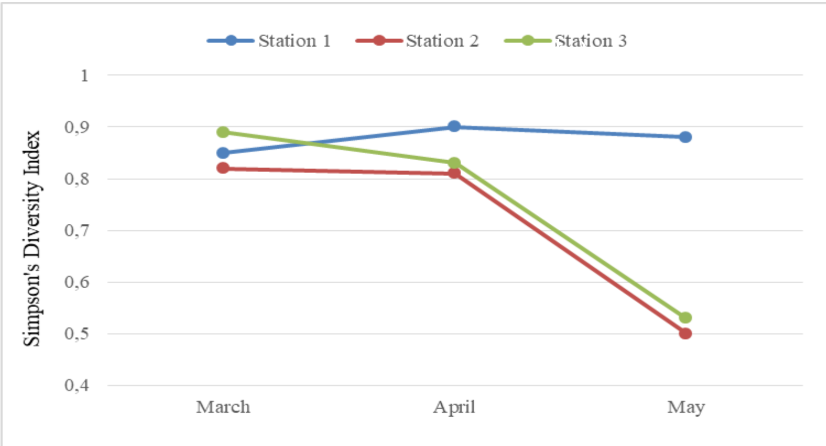


Fig. 5. Spatio-temporal evolution of Simpson's diversity index, spring 2018

3.6. Detection of harmful species

During the spring of 2018, we were able to identify some potentially toxic or harmful species. These species belong to different genera among which: the genus *Pseudo-nitzschia*, *Dinophysis*, *Prorocentrum* and *Alexandrium*. In the three stations, these genera were detected several times during our study but always with low concentrations ranging from 2 to 191 ind/L.

The genus *Prorocentrum*was found only in March and April in the bay of Imessouane. It is mainly represented by *P. micans*. The genus *Dinophysis* persists throughout the three months of study with more or less significant concentrations in March for the species *D. caudata* than for *D. acumunata*, the same for the genus *Pseudo-nitzschia*. While *Alexandriumcatenella* was rarely represented in our samples, it is encountered only in March. The species *Noctilucascintillans* was also observed on several occasions but in low concentrations. In general, the highest concentrations of all these genera were recorded in March.

The species described above are all harmful phytoplankton species responsible for the production of paralyzing phycotoxins (*Alexandrium*), amnesiac (*Pseudo-nitzschia*), diarrheal (*Dinophysis*) and phytoplanktonic efflorescence (colored water or bloom), this phenomenon is produced seasonally because it requires the conjunction of conditions favorable to their proliferation [22].

Conclusion

The specific spring richness of phytoplankton in Imessouane Bay is represented by 74 species. Diatoms and dinoflagellates constitute the two main groups of this algal flora. There is a dominance of diatoms (69%) with 51 species and 30 genera over dinoflagellates (31%) with 23 species and 12 genera.

For each month, the specific diversity was estimated by calculating the specific richness, the Shannon-Weaver Diversity Index (H'), Pielou's evenness (J), Margalef (Mg) and Simpson (Ds). The concomitant use of these indices has clearly defined the overall state of the living phytoplankton community within Imessouane Bay. We note that at the beginning of spring genera of dinoflagellates (*Ceratium, Tripos, Protoperidinium* ...) have recorded maximum abundances, on the other hand at the end of spring, these genera gave way to the diatoms which invaded the bay, more precisely the genus *Chaetoceros*.

During the spring period, we were able to identify at the three stations some potentially toxic or harmful species responsible for colored waters. These species belong to different genera among which: the genus *Pseudo-nitzschia*, *Dinophysis*, *Prorocentrum* and *Alexandrium*, the species of these genera were detected several times during our study but always with low concentrations.

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