Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(5):117-130**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Phytoplankton Population Study of the Occidental Mediterranean Coast of Morocco

Ferdaous Sitel[1]*, Asmaa Fakih Lajri[2], Benlahcen Rijal Leblad[3], Hassan Er-Raioui[1]

[1]Laboratoire de Géosciences et environnement, Faculté des Sciences et Techniques de Tanger, Université Abdelmalek Essaâdi Tanger-Tétouan.
[2]Laboratoire de Génie Chimique et Valorisation des Ressources (LGVCR), Faculté des Sciences et Techniques de Tanger, Université Abdelmalek Essaâdi Tanger-Tétouan.
[3]Laboratoire de Phytoplancton, Institut National de Recherche Halieutique, 90000 Tanger, Morocco

Abstract This study, based on qualitative and quantitative analysis of the phytoplankton population, aims to compare the environmental conditions between four different ecosystems: M'diq Bay; Corniche Martil; Foum l'Oued and Targha (western Moroccan Mediterranean coasts) during the one-year cycle (June 2013 - May 2014). The results obtained show a spatiotemporal variation in species composition. This variation highlights the importance of hydrodynamic factors on the geographic structure of phytoplankton communities at the four study sites. Throughout the period, the dominance of diatoms followed by dinoflagellates is well marked. The species of dinoflagellates (*Gymnodinium* sp. *Gymmodinium catenatum* sp., *Pentapharsodium* sp., *Gyrodinium* sp., *Heterocapsa* sp. *Scriptiella*sp., *Prorocentrum* sp.) and diatomic species (*Chaetoceros* sp. *Thalassiosira* sp. *Leptocylindrus* sp. *Pseudonitzshia* sp. *Nitzschia* sp. *Asterionella* sp. *Skeletonema* sp. *Guinardia* sp.and *Pleurosegma* sp), dominate the algal population. These species differ according to the month and the sites. Discriminant analysis (SFM) of the data (nutrients and dominant species) makes it possible to identify perfect seasonal discrimination. At all study sites, the seasonal pattern is observed. Winter and fall are characterized by high nutrient inputs, but despite this nutrient richness, algal biomass is low. On the contrary, spring and summer are characterized by a depletion of the environment in nutritive elements following the assimilation by phytoplankton of the gold of the summer and spring flushes.

Keywords Phytoplankton populations, M'diq, Corniche martil, Foum l'oued, Targha, Environmental conditions

1. Introduction

For a few decades, the Moroccan coasts have seen an intensification of the appearance of harmful algal blooms. Indeed, coastal areas are small in size but are characterized by high biological production [1]. They contribute 14 to 30% to primary ocean production [2]. However, some filter-feeding marine organisms bioaccumulate phycotoxins produced by toxic phytoplankton species, causing food poisoning following their consumption [3-4] and consequently altering their potential in fishery resources and as healthy sites for aquaculture and posing a real threat to public health. Such phenomena, as well as massive fish mortality, have already been observed at various points along the Mediterranean or Atlantic coasts of Morocco [5-7]. In 1978 in Al-Hoceima, the first poisoning was recorded following the ingestion of "Mytilus galloprovincialis" mussels. The symptoms recorded in patients (amnesia), indicate that contamination is most likely caused by amnesiac phycotoxins (Domoic Acid). In 1994, on the Moroccan coast, 64 cases of poisoning were reported, 23 of which were hospitalized and 4 died following ingestion of bivalves poisoned by the paralytic toxin PSP [8]. From 1998 to 2007, this type of phycotoxin was detected with varying concentrations in several bivalve species at the Moroccan coastal level [9-12].

The phytoplankton community's response to environmental factors is often reflected in direct responses in composition, abundance and distribution [13]. Indeed, the ecophysiological diversity associated with the specific richness of phytoplankton populations suggests the existence of an environmental preference for each species. Thus, knowledge of the factors that control the dynamics of phytoplankton communities as a whole would be necessary to understand the mechanisms that promote the development of toxic or harmful phytoplankton populations.

2. Material & Methods

Site d'étude

Quatre sites sur la côte méditerranéenne marocaine ont été retenus: M'diq Bay (S1), Cornichee Martil (S2), Oued laou estuary (S3) and Targha (TARGHA) (Fig.1). This region corresponds to the littoral fringe of the western Moroccan Mediterranean Sea. This region is located in northern Morocco in the northern rif of the region of Tetouan and Chefchaouen. It is privileged by a geographical and strategic position thanks to its opening on the Mediterranean. It is subject to several pressures and risks of pollution. It has an interesting number of seaside resorts and harbors with fishing and pleasure activities. It is exposed to domestic and industrial discharges from agglomerations and industrial units located on the coast. It is also the site of significant maritime traffic.

The choice of sampling sites was conditioned by the public health protection vocation of the INRH network, *i.e.* close to shellfish production areas in coastal areas.

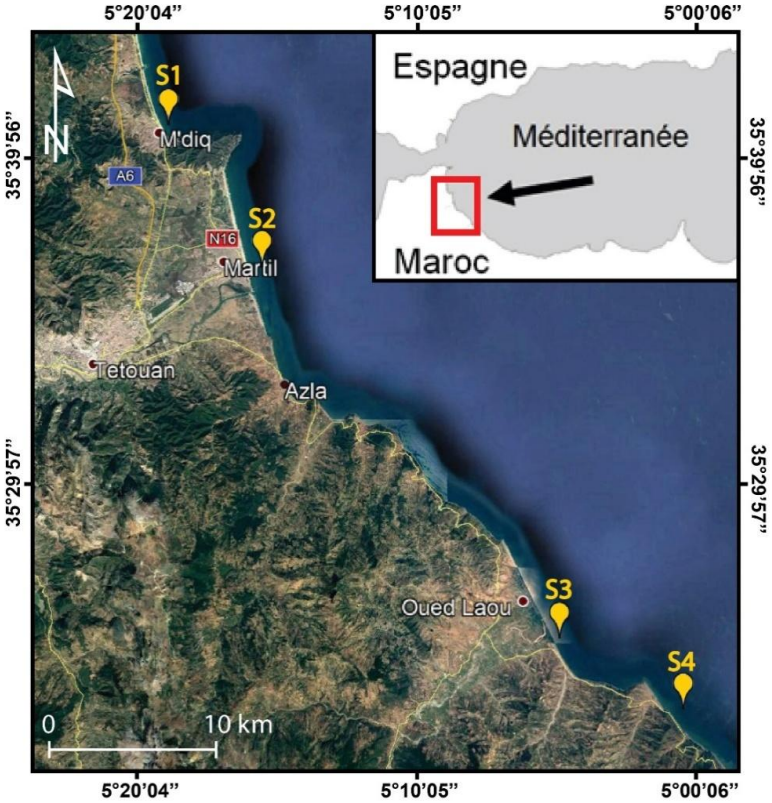


Figure 1: Geographical location of sampling sites S1(M'diq), S2 (Cornich martil), S3 (Foum l'oued) and S4 (Targha)

Sampling and Analysis

Sampling was done in a quinzodomadar way over an 12-month period "from June 2013 to May 2014". It is made by means of a Nansen spill bottle. The samples taken are unconcentrated samples. The "Lugol" fixative is used to preserve the phytoplankton. These samples already attached to Lugol are agitated and then poured into sedimentation tanks of 25 ml. The analysis of the tanks is carried out only after a settling time which lasts from 6 hours to one night for most of the analyzes. Observations are made using a LEICA-type inverted microscopy

at 10, 20, and 40x magnifications. The tanks are read by the HASLE method. The concentration of the phytoplankton species observed is expressed in (cell.L^{-1}).

In order to carry out a study of the systematics of taxa present, taxonomic identification of phytoplankton is carried out by referring to several textbooks and photographic descriptions. For the determination of nutrients, we used the method of Mullin and Riley [14] adapted by Strickland and Parsons [15] to A. Aminot and Chaussepied [16].

3. Results

Taxonomic Composition

Monitoring of the phytoplankton community in the 4 sites during the study period to show the presence of four phytoplankton classes: Diatoms, Dinoflagellates, Dictyochophyceae and Flagellates. The two classes of Diatoms and Dinoflagellates are the majority classes. These last two groups are considered the main components of phytoplankton in the Mediterranean [17]. Throughout the study period, the dominance of diatoms followed by dinoflagellates was noted. This result is also attested by Rijal Leblad's study [18]. In a study conducted by Daoudi [19] in M'diq Bay and the Ouedlaou estuary, diatoms and dinoflagellates were dominant.

At the M'diq level, Diatoms dominate during spring, summer and winter with a maximum of 19 taxa recorded during summer compared to 15 in Dinoflagellates. Dinoflagellate taxa dominate during summer, autumn and spring with a maximum of taxa recorded during the whole autumn period in September, 2013 with 19 taxa against 15 of Diatoms.

The phytoplankton population at Cornich Martil is characterized by the dominance of Diatom taxa during most of the study period with a maximum recorded during the summer in August 2013 with 20 taxa as maximum against 17 dinoflagellate taxa. Dinoflagellate taxa dominate during spring, in May 2014 with 18 taxa against 11 of diatoms and during autumn, in September, 2013 with 9 taxa against 4 for diatoms.

At the Oued laou and Targha levels, there was great fluctuation in the dominance of diatom and dinoflagellate taxa during the study period. The maximum of Diatoms taxa is recorded during spring in April 2014 at S3 level with 17 taxa against 16 in dinoflagellates and during summer in August 2013 with 20 taxa against 14 in dinoflagellates. Dinoflagellates present a maximum of taxa during summer with 17 taxa against 10 in Diatoms and during spring at Targha level with 21 taxa against 18 in Diatoms (Tab.1).

Table 1: Range and Average (Mean ± SDev) of taxons Diatoms and Dinoflagellates in stady stations: S1=M'diq, S2=Corniche Martil, S3=Foum l'Oued, et TARGHA=Targha

Station	M'diq	Cornich martil	Foum l'oued	Targha
Diatomées (Taxons)	(6-9) (10.95±3.75)	(1-20) (10.89±5.11)	(3-17) (11.29±4.43)	(2-21) (10.94±5.58)
Dinoflagellés (Taxons)	(6-9) (11.16±3.35)	(4-18) (9.95±4.35)	(6-17) (10.18±3.49)	(5-20) (10.82±4.71)

Specific Diversity

The specific diversity curves show indices generally low and below 1 bit except for a few points. The shannon index H' is indeed often lower than 1 bit.cells-1 and reach, according to the stations, maximums from 0.96 to 1.09 bit.$cells^{-1}$. The average values of H' vary between 0.73 bit recorded at Cornich Martil and 0.84 bit recorded at Foum l'oued. The lowest values were detected during winter at M'diq, summer at Cornich Martil and Foum l'oued, and autumn at Targha (Fig.2).

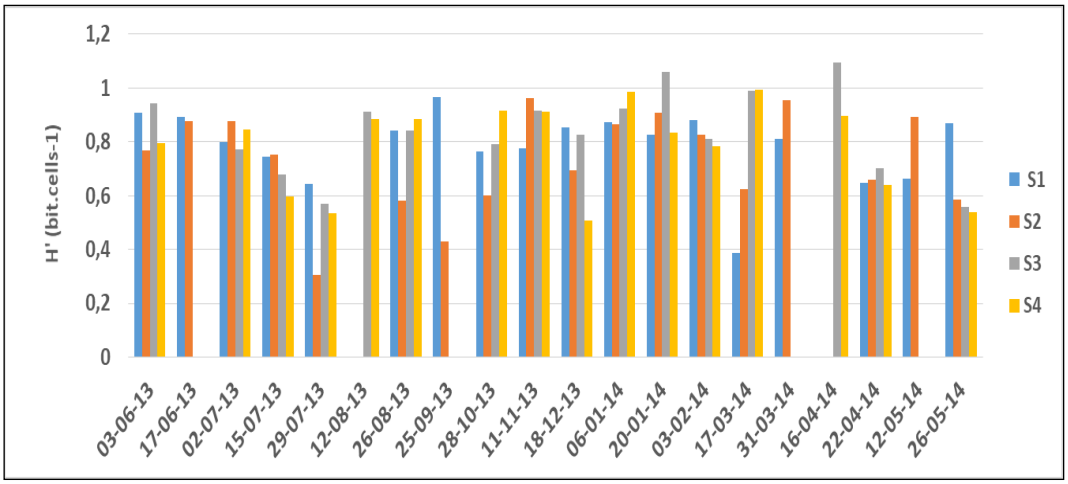


Figure 2: Evolution of specific diversity at the level of the four study sites

Spatio-temporal Distribution of Phytoplankton Populations

The mean annual phytoplankton abundance in the study area is 86.7×10^3cells l^{-1}. It varied between 85.6×10^3 cells l^{-1} recorded at Targha and 101.38×10^3 cells l^{-1} recorded at M'diq with a maximum abundance of 326×10^3 cells l^{-1} detected during summer and a minimum abundance of 1.4×10^3 cells l^{-1} detected during autumn at Targha (Fig. 3).

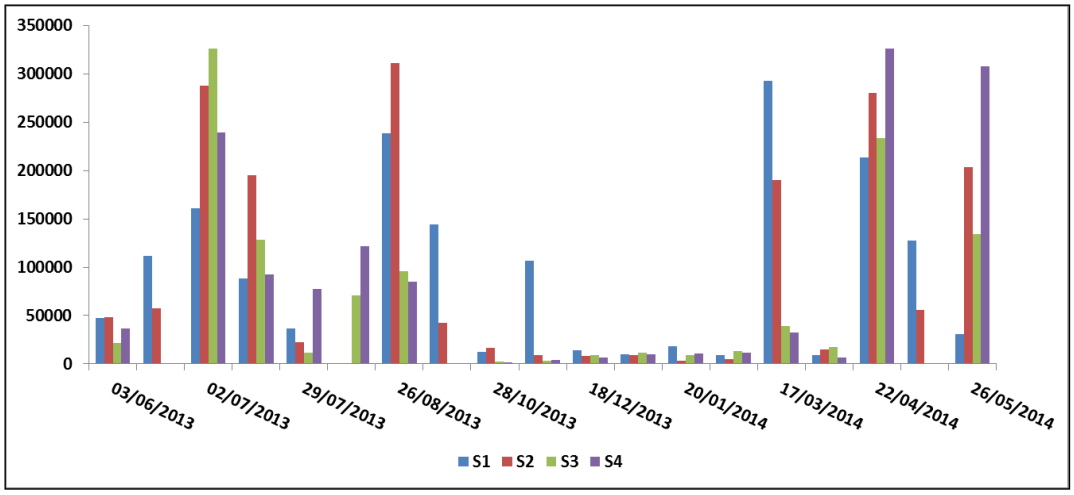


Figure 3 : Evolution of cellular concentrations in the waters of S1=M'diq, S2=Corniche Martil, S3=Foum l'Oued, and TARGHA=Targha

Diatoms constitute, on average, 67.39% of the total phytoplankton abundance in the study area. The varied abundance from 60.14% recorded at the M'Diq level to 71.98% recorded at the Foum l'Oued level. The maximum abundance of diatoms is 323×10^3cells l^{-1} recorded at Foum l'oued level during the summer in July 2013, thus constituting 98.89% of total phytoplankton abundance. The minimum abundance is recorded at Corniche Martil during the autumn in October 2013 with a value of 0.32×10^3cells l^{-1}, or 1.95% phytoplankton abundance. The concentration of Diatoms is still high compared to that of Dinoflagellates.

The annual average of dinoflagellates varies between 26.21% recorded at Foum l'Oued and 35.56% recorded at M'diq and constitutes 30.45% of the total abundance of phytoplankton in the study area. The maximum abundance of dinoflagellates is 87.8×10^3cells.l^{-1} recorded at the Targha level during the summer in August 2013. The minimum abundance is recorded at Foum l'Oued during the autumn in October 2013 with a value of 0.68×10^3cells.l^{-1}, or 32.08% phytoplankton abundance. (Fig.4)

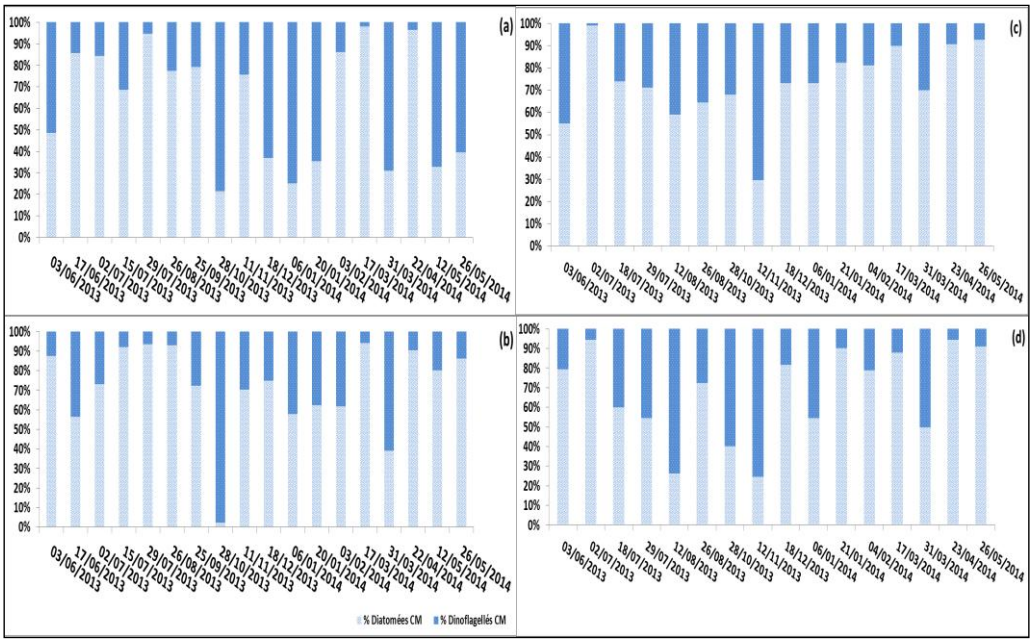


Figure 4: Evolution of the percentages of diatoms and dinoflagellates in the waters of (a) M'diq, (b) Corniche Martil, (c) Foum the Oued, and (d) Targha.

The Seasonal Abundance of Dominant Species

Of the 91 taxa identified during our study period, only 16, or only 17.58% of the total species richness, dominate the phytoplankton stand. These taxa contribute at least 10% of the total cell density and belong to the Diatoms and Dinoflagellates class. These are the species: *Gymnodinium* sp. *Gymmodinium catenatum*, *Pentapharsodium*sp., *Gyrodinium* sp., *Heterocapsa* sp., *Scriptiella* sp., *Prorocentrum* sp., for dinoflagellates and: *Chaetoceros* sp. *Thalassiosira* sp. *Leptocylindrus* sp. *Pseudonitzshia* sp. *Nitzschia* sp. *Pleurosegma* sp.,*Asterionella* sp. *Skeletonema* sp. *Guinardia* sp. for diatoms species. (Tab.2)

Table 2: Range and Average (Mean ± SDev) of total cell abundance (cells-l) of dominante species : Gym=*Gymmodinium* sp, Gym cat=*Gymmodinium catenatum* sp, Penta=*Pentapharsodium* sp ., Gur=*Gyrodinium* sp., Proro=*Prorocentrum* sp, Hetp=*Hétérocapsa* sp, Scrp=*Scriptiella* sp, Pz=*Pseudonitzschia* sp, Nitz=*Nitzschia* sp., Pleug=*Pleurosegma* sp., Astr=*Asterionella* sp, Chaet=*Chaetoceros* sp, Lept=*Leptocylindrus* sp, Skel=*Skeletonema* sp, Thalr=*Thalassiossira* sp, Gui=*Guinardia* sp.

Dominante specie	Classe	M'diq	Cornich martl	Foum l'oued	Targha
Gym	**Dinoflagellate 10^3 cells l^{-1}**	**(0,68-75,1) (9,45±17,2)**	**(0,8-32,1) (7,75±8,42)**	**(0,2-30,8) (6,68±9,41)**	**(0,36-40,4) (10,2±13,3)**
Gym cat		**(0,08-2) (0,61±0,48)**	**(0,12-1,44) (0,46±0,47)**	**(0,12-1,76) (0,59± 0,5)**	**(0,04-5,08) (1,2±1,41)**
Penta		-	-	**(0,16-2,8) (1,64±1,35)**	-
Gyr		-	-	-	**(0,04-3,16) (0,69±0,86)**
Proro		**(0,04-17) (2,57±4,66)**	-	**(0,04-10,8) (1,5±3,18)**	**(0,08-32,6) (3,51±8,96)**
Hetp		**(0,04-17,4) (4,57±4,36)**	-	-	-
Scrp		-		-	-
Pz	**Pennale Diatom**	**(1,12-101) (19,4±25,1)**	**(0,28-151) (22,9±38,7)**	-	**(0,12-190) (18,2±47,1)**

Nitz	**10^3 cells l^{-1}**	-	**(0,04-21,2) (3,5±7,21)**	-	-
Pleug		-	-	-	**(0,04-0,44) (0,097±0,12)**
Astr		-	-	**(0,04-35,8) (5,49±13,4)**	-
Chaet	**Centric Diatom 10^3 cells l^{-1}**	**(0,04-229) (29±59)**	**(0,04-223) (46,2±70,9)**	**(0,12-93,7) (20,2±31,8)**	**(0,04-218) (29,9±56)**
Lept		**(0,04-74,2) (15,3±22)**	**(0,02-84,4) (21,4±27,1)**	**(0,32-98,3) (19,7±30,4)**	**(0,2-64) (17,1±23,4)**
Skel		**(0,16-21,9) (5,19±7,29)**	**(0,16-14,7) (4,76±5,91)**	**(0,32-15,4) (4,08±6,03)**	**(0,8-32) (12,8±12,6)**
Thalr		**(0,12-11,6) (3,21±3,77)**	-	**(0,08-10,6) (1,53±2,63)**	-
Gui		-	**(0,04-11) (2,09±3,22)**	-	-

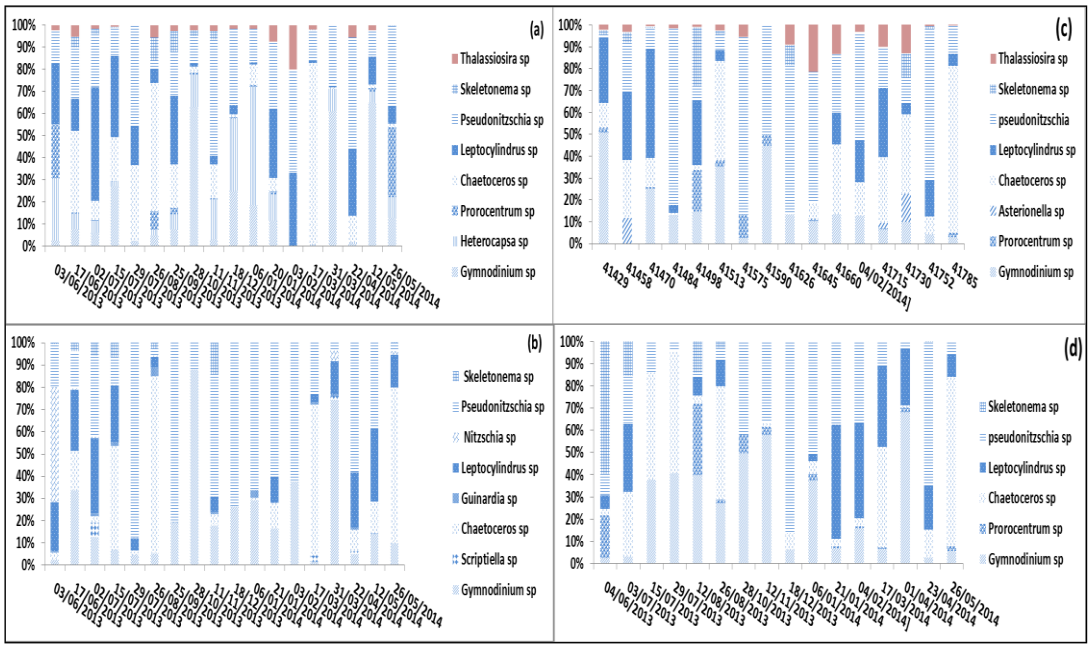


Figure 5: Percentage changes of dominant species in relation to total phytoplankton in the waters of (a) M'diq, (b) Corniche Martil, (c) Foum l'Oued, and (d) Targha

The Seasonal Abundance of Nutritive Salts

The average mineral phosphorus content varies between 3.65 µM /l recorded at M'diq and 4.71 µM/l recorded at Targha. This last site presents the highest values with three peaks, during spring, summer and winter with values 9.52 µM /l, 5.65 µM /l and 5. 59 µM /l respectively. (Fig. 6)

The average nitrate content is low. It varies between 1.05 µM /l recorded at Cornich Martil and 1.56 µM /l recorded at Foum l'oued. The M'diq site has the highest values with 3 remarkable peaks: the first was detected during spring (3.58 µM /l), the second in late autumn (2.65 µM /l), and the third in early winter (2.63 µM /l). (Fig. 6)

Nitrites have relatively close annual averages: 1.48 µM /l (at M'diq and Foum l'oued), 1.62 µM /l (at Cornich martil) and 1.44 µM /l (at Targha). At M'diq and Cornich martil, the values being highest during winter and spring. (Fig. 6)

Average ammonium concentrations predominate over other forms of nitrogen throughout the study period. The average ammonium content varies between 3.21 µM /l and 4.02 µM /l. The highest concentrations are recorded at the M'diq level (17.98 µM/l) during the spring period. (Fig. 6)

The average silicon concentration varies from 5.7 µM /l to 7.71 µM /l. the highest values were recorded at M'diq (30.49 µM/l) during the autumn period, while at the other sites the silicon content did not exceed 8.93 µM/l. (Fig. 6)

The N/P ratios of the concentrations of these elements can be compared to the ratio of REDFIELD (N/P at / at = 16 for vigorous phytoplankton). If the N / P ratio is greater than 30, phosphorus could be depleted first; while a ratio of less than 10 would indicate a potential limitation by nitrogen. During the study period; the mean annual N / P ratio of all sites was in the range of 0.4 to 6, suggesting potential nitrogen limitation during the study year.

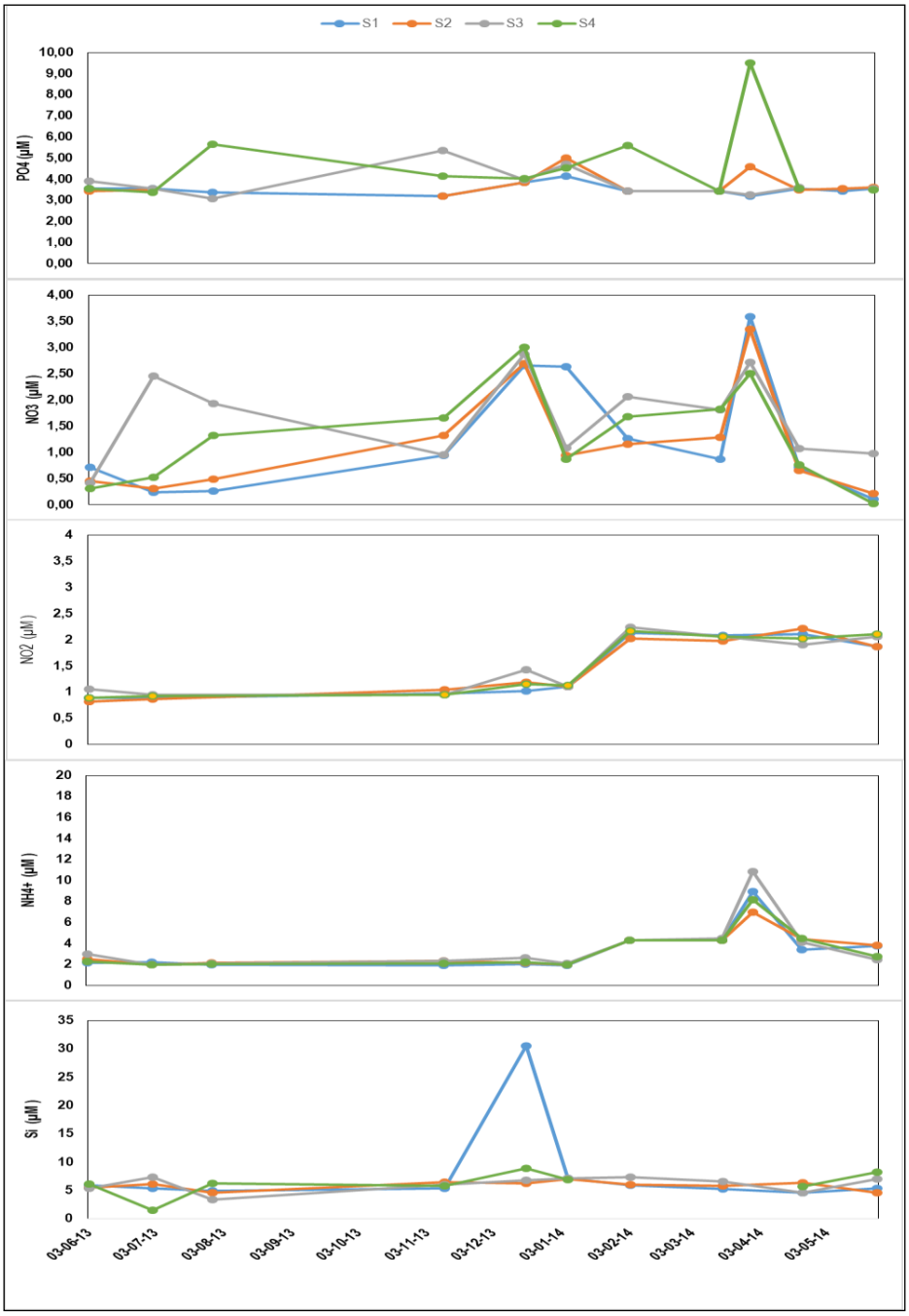


Figure 6: The evolution of nutrients (PO4, NO3, NO2, NH4+ and Si (µM /l)) in S1=M'diq, S2=Cornich Martil, S3=Foum l'oued and S4=Targha

4. Discussion

The species inventory lists 91 phytoplankton species belonging to the 4 classes: Dichtyophycea, Flagellates, Dinoflafellates and Diatoms. The last two groups are considered the main components of Mediterranean phytoplankton [17]. The phytoplankton population study revealed the classical pattern of phytoplankton community succession described by Margalef, 1958 [20]: the majority of diatoms are observed in winter and spring, while dinoflagellates predominate in summer. According to Smayda (1984) [21], this pattern of seasonal succession of phytoplankton is characteristic of temperate zones. This pattern is mainly related to the alternating mixing and stratification periods of the water column induced by the establishment of a thermocline, which Targhaétend from May to October [22] promoting the development of dinoflagellates, and a cool period when there is a mixing of the water column [23], which Targhaétend during the winter and promotes the development of Diatoms. In our study dinoflagellates predominate in the summer period (with 15485 cells.l^{-1} as an average abundance of the four sites with 87840 cells.l^{-1} as a maximum abundance recorded at Targha and 39 species recorded. While diatoms dominate in winter and spring at M'diq Bay and Corniche martil and in spring and summer at Foum l'Oued and Targha with 70025 cells.l^{-1} as an average abundance of the four sites and 322560 cells.l^{-1} as a maximum abundance recorded at Foum l'Oued). 47 species divided into 35 genera have been inventoried (29 species of order centred and 18 of order pennales). Our results are consistent with those obtained by Daoudi [19] and Rijall lebled [24] who found that the phytoplankton community in M'diq Bay and Oued Laou Estuary is dominated by Diatoms in winter and spring and Dinoflagellates in summer. On the other hand, Aubert et al. 1985 [25], de Marasovic et al. 1995 [26] found that dinoflagellate outbreaks in several Mediterranean coastal bays start when temperatures rise above 20°C even if nutrients are in low concentrations. Moreover, the almost permanent dominance of diatoms during periods when the waters are strongly agitated by the effect of the wind can be explained by the fact that the latter, unlike dinoflagellates, are considered less sensitive to the turbulence of water tides and can even be stimulated by this agitation which induces their cellular division [27-28].

In terms of structure, the phytoplanktonic community of M'diq Bay is characterized by maximum abundance during summer and late winter. At Corniche Martil, maximum abundance is recorded during summer and spring. The periods of maximum proliferation at Foum l'Oued and Targha are summer and spring. The maximum proliferation periods recorded at the M'diq level are not consistent with the results of Margalef [30] and Rijal Lebled [25]. Both authors found that maximum phytoplankton abundance in M'diq Bay was recorded during late spring and early summer.

Generally, phytoplankton concentrations during fall and winter are low. Note that a *Gymnodinium catenatum* bloom was detected at Targha with a density of 2160 cells.l^{-1}, but this value remains very low compared to the concentration of other species. In addition, phytoplankton concentrations during summer and spring are very high, where phytoplankton growth is optimal, and during which blooms of *Pseudonitzschia* sp were detected throughout the study area with values of 10.10^4, 15.10^4, 14.10^4 and 19.10^4 cells.l^{-1} to M'diq, Cornich Martil, Foum l'oued, and Targha respectively, and a *Gymnodinium catenatum* bloom at Targha with a concentration of 5080 cells.l^{-1}. These booms occurred following the enrichment of medium in nutritive elements.

The difference in phytoplankton population abundance observed at the four study sites would be related to the geographic configuration of the four ecosystems. M'diq Bay and Cornichee Martil are relatively closed areas and are then a favourable place for the development and accumulation of phytoplankton populations. M'diq Bay receives water from outfalls without prior treatment and subsequent nutrient enrichment. Foum l'Oued and Targha are relatively open areas and also offer a favourable environment for phytoplankton development because of the presence of fluvial inputs which constitute an important source of nutrients, but exposed and under oceanic influence, phytoplankton would be dispersed after its development, which would explain the low average abundances observed in this area.

Note that there is a slight variation in diversity across the four sites. A total of 91 taxa (species and genus) were recorded. Some species are identified only in the bay M'diq namely: *Catenula*sp., *Cocconies* sp., *Diplonies* sp., *Fragilariopsis kergulensis, Polyedra* sp., *Pronoctiluca* sp., *Raphonies surirella*. Others are identified only at the level of the Cornichee Martil namely: *Bacillaria panadona, Ceratium ranipes, Fragilaria striatula, Guinardia striata, Guinardia flaccida, Plagiogramma brockmanni*, and *Proocentrum lima.* The species identified at Foum

l'Oued are: *Cylindrotheca glacialis, helicotheca tamesis, lithodesmium undulatum, ornithocercus* sp, *Pronoctiluca* sp, *Protoceratium* sp, *Protopéridium depressum*, and *Protopéridium divergens*. Those identified at Targha level are: *Bactériastrum hyalinum*, *Biddulphia* sp, *Chrysochromulina* sp, Ebria borgert, *Lingulodinium polyedra, Prorocentrum mexicamum, Protoceratium reticulatum,* and *Rhizosolenia indica.*

The lowest values of the specific diversity index H' indicating that we have Blooms. These values are recorded at M'diq level following an intense proliferation of Chaetoceros sp which constitutes 78% of the phthoplanktonic composition in March 2014, and at Cornich Martil, Foum l oued and Targha level following a proliferation of Pseudonitzschia sp which constitutes 85.4%, 65.4%, and 72.3% of the phytoplanktonic composition in July 2013 (for Cornich Martil and Foum l'oued) and December 2013 (for Targha).

The Discriminant Factorial analysis, carried out using data from the taxonomic units of dominant species, aims to highlight the seasonal evolution of these species, and to identify the groups of species characteristic of each period of the year.

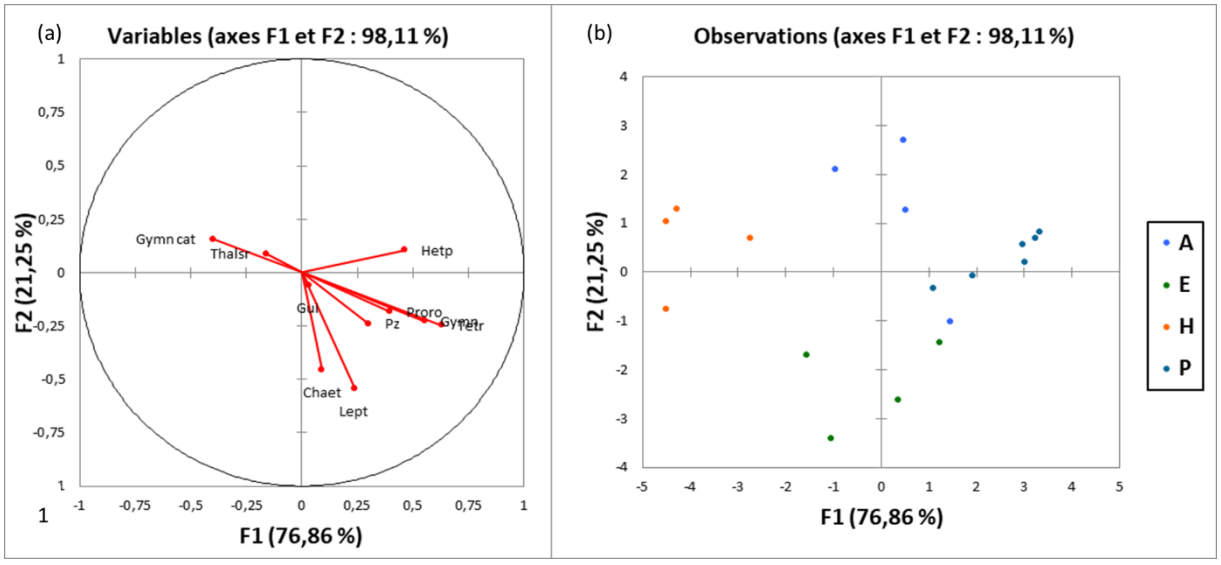
The representations of individuals (sampling dates) and variables (dominant species) in the first principal plane of the centred-reduced SFM of the M matrix of geographic averages are shown in Figure 7. Contributions to the total variation of the first two axes total between 98% and 99.88% for the 4 study sites ; this is explained by a good representation on the first planes represented by axes F1 and F2. From Figure 7, four seasonal groups can be distinguished at each study site :

The first group is characterized by an intense proliferation of certain species during the spring period. This period is marked by the proliferation of *Tetracelmis* sp, *Prorocentrum* sp, *Gymnodinium* and *Heterocapsa* sp, at the M'diq level, of *Gymnodinium* sp., *Heterocapsa* sp., *Prorocentrum* sp., *Chaetoceros* sp., *Leptocylindrus* sp., *Pseudonitzschia* sp., and *Thallassiosira* sp. at Corniche Martil, de *Chaetoceros* sp. *Tetracelmis* sp., *Pentapharsodium* sp. And *Pseudonitzschia* sp. at Foum l'oued, and *Chaetoceros* sp., *Pseudonitzschia* sp., *Leptocylindrus* sp at Targha.

The second group corresponds to species with a high concentration during the summer period. This period is characterized by the proliferation of *Chaetoceros* sp. And *Leptocylindrus* sp. at M'diq, *Thallassiosira* sp. And *Chaetoceros* sp. at Corniche martil, *Prorocentrum* sp., *Scriptiella* sp., *Skeletonema* sp., *Gymnodinium* sp., *Asterionella* sp., and *Leptocylindrus* sp. at Foum l'Oued and *Nitsdchia* sp., *Skeletonema* sp., *Heterocapsa* sp., *Gymnodinium* sp., *Gymnodinium catenatum* and *Guinardia* sp. at Targha's level.

The third group is observed during the fall period. This period is characterized by a low concentration of *Pseudonitzschia* sp and *Heterocapsa* sp. but marked by the proliferation of *Heterocapsa* sp. at M'diq and Corniche Martil.

The fourth group consists of species with high concentrations during the winter period. This period is characterized by the proliferation of *Guinardia*sp., and *Thalassiosira* sp. at M'diq, *Pleurosegma* sp at Targha and *Gymnodinium catenatum* at all sites except Tagha.



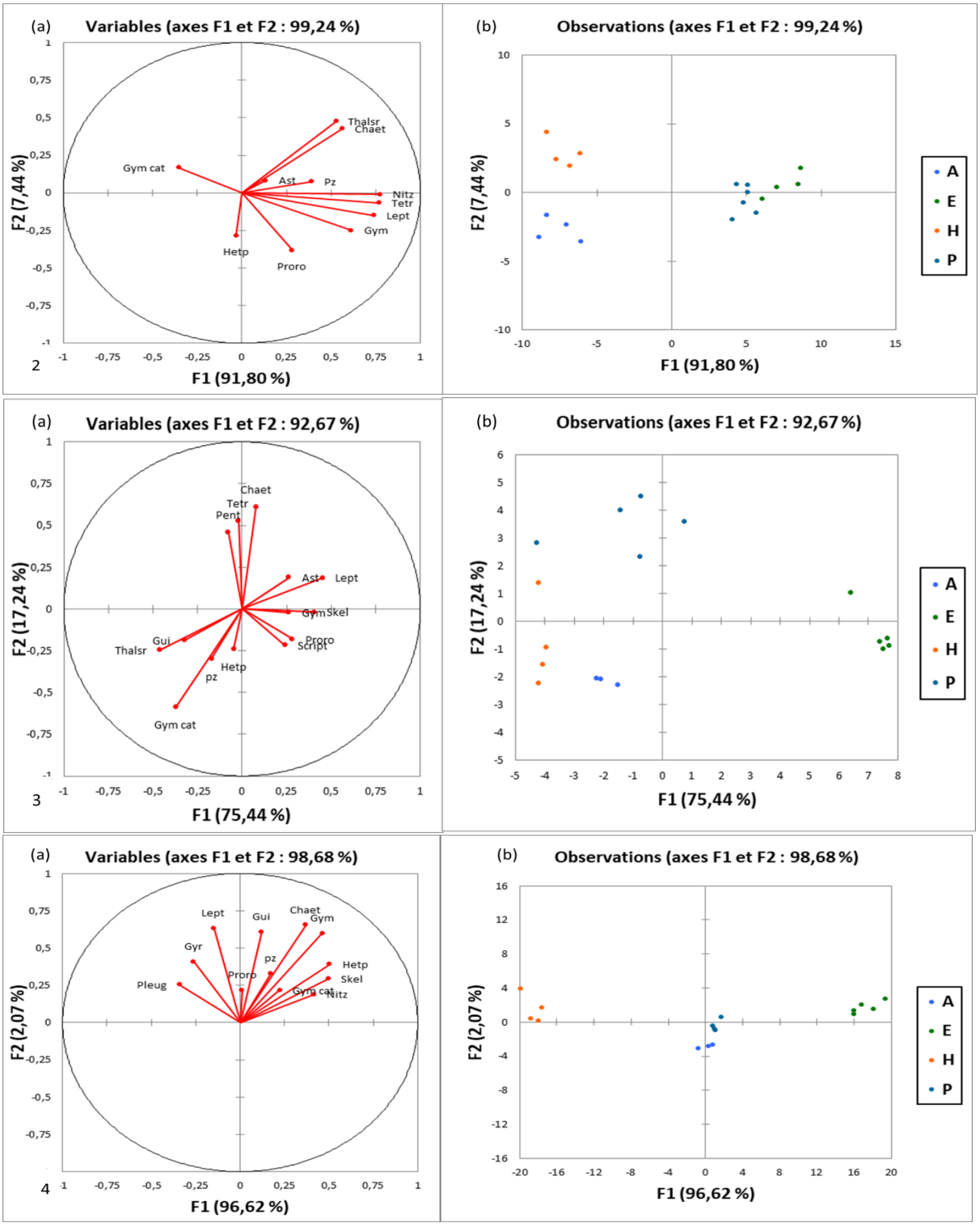


Figure 7: (a) Projection of variables (dominant species) in factorial plane F1 and F2), (b) Projection of individuals (sampling dates) in factorial planes F1 and F2. (A : Autumn, E : Summer, H : Winter, P : Spring)(1 :la baie de M'diq, 2 : Corniche Martil, 3 : Foum l'Oued, 4 : Targh.) (Gym.Cat=Gymnodinium catenatum, Gym=Gymnodinium sp., Hetp=Heterocapsa sp., Gui=Guinardia sp., Proro=Prorocentrum sp., Chaet=chaetoceros sp, Lept= Leptocylindrus sp., Pz=Pseudonitzschia sp., Thalr=Thallassiosira sp., Tetr=Tetracelmis, Ast=Asterionella sp., Nitz=Nitsdchia sp., Penta=Pentapharsodium sp., Skel=Skeletonema sp, Gyr=Gyrodinium sp., Pleug=Pleurosegma sp.

The increase in the ammonium, nitrate and nitrite content can be explained by the input of the rinsing water. In contrast, a fraction of nitrates and nitrites appear to be produced by the natural nitrification process by bacteria. Indeed, Boutaib [30] showed the presence of an increase in bacterial activity during the rainfall period in M'diq Bay and the Oued Laou estuary. However, the low concentrations of these elements can be explained by the use of these elements during phytoplankton blooms or by the sedimentation process whereby nutrients are recycled between sediments, seaweed and the water column [31]. They are normally trapped by sediment and then released, depending on the surrounding conditions in the water column and possibly assimilated by phytoplankton.

During the study period, the average annual N / P ratio at the four sites was in the range of 0 to 6, suggesting potential nitrogen limitation during the study year. Revelante and Gilmartin [32], Berland et al [33], generally consider that phosphorus is the main limiting factor in the Mediterranean, whereas Becacos-Kontos [34], [37] considers that phosphorus and nitrogen are both limiting in an alternative way. Other authors suggest that production in transition zones (sea-land inputs) may be limited by factors other than phosphate and nitrogen that are related to the amount of input received [35]. Balkis [36] notes, in a bay in the Marmara Sea, values of this ratio lower than the value of 16 with nitrogen as a limiting factor. Variations in the N:P ratio are particularly large as a result of irregular and diverse coastal inputs (riverine inputs, domestic and industrial effluents, precipitation and torrents).

The evolution of seasonal variation shows that, of the four ecosystems studied, the temporal variability of environmental parameters is subject to a seasonal cycle. The treatment of all the data by discriminant factor analysis (AFD) shows a good diagonalisation of the data on each axis. The contributions to the total variation of the first two axes total 94.95%, 89.24%, 95.75% and 97.73% at M'diq, Corniche Martil, Foum l'oued and Targha respectively.

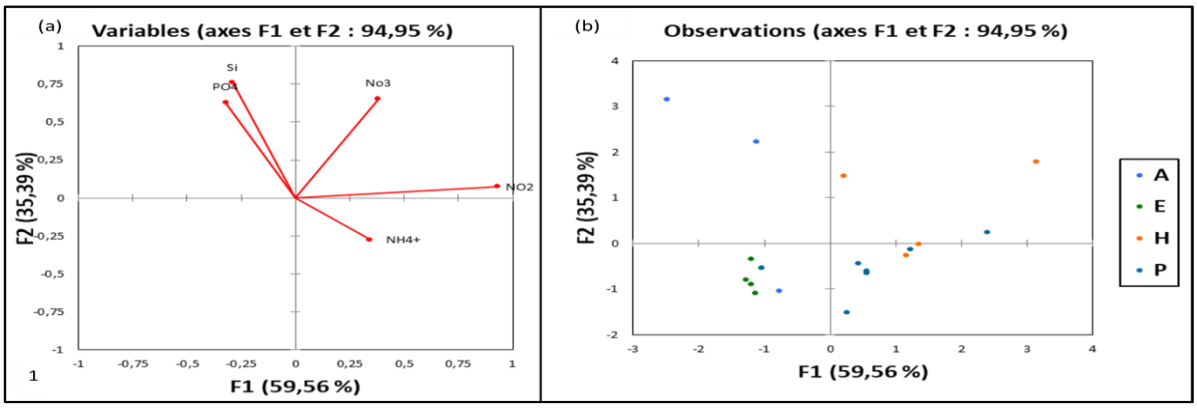
The seasonal progression of nutrients throughout the study area makes it possible to distinguish four groupings (Fig. 8):

The first grouping characterizes the spring period. It is characterized by high levels of NH4 and NO2 at the four study sites. A strong correlation between these two elements is only observed at Cornichee Martil. This period is also characterized by high concentrations of NO_3 and Si in Foum l'oued where they correlate strongly. B concentrations are also high at targha.

The second grouping characterizes the summer period when there are significant concentrations of PO_4 in Foum l'oued. Si concentrations are low at all four study sites. This period is also characterized by low levels of NO_2 and NH_4 at Corniche Martil and NO_3 at M'diq. These low Targha levels explain by the use of these elements by phytoplankton gold summer flushes.

The third grouping corresponds to the autumn period. This period is characterized by high PO_4 concentrations at all sites except M'diq, and high NO_3 concentrations at Targha. The M'diq site shows high concentrations of B. Let us note thus, an important correlation between PO_4 and Si at the M'diq level.

The fourth grouping corresponds to the winter period, during which high NO_2 levels are observed at all sites, in Si and NH_4 at Corniche Martil and Targha, from PO_4 to Corniche Martil and Foum l'oued, and in NO_3 at all sites except Foum l'oued.



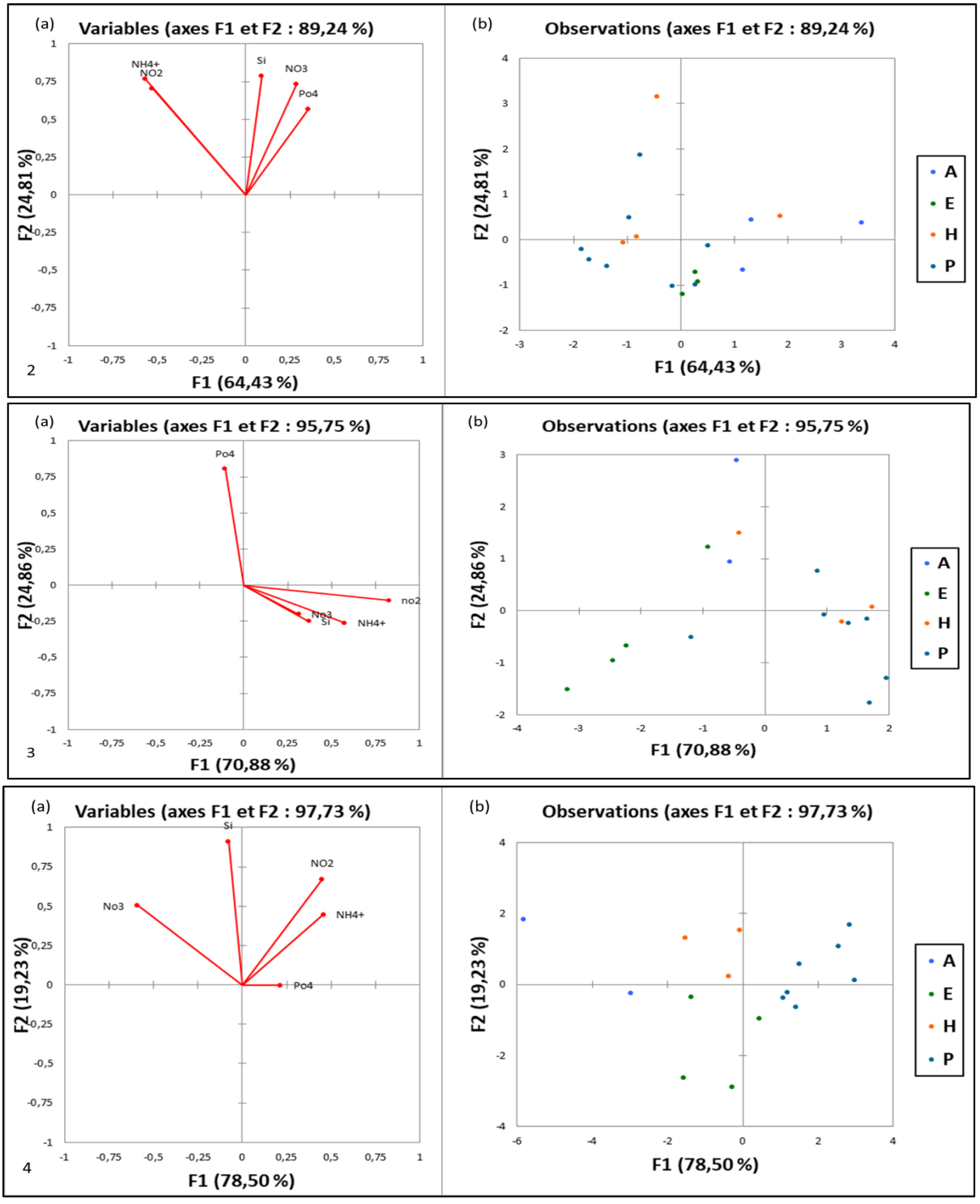


Figure 8: (a) Projection of variables (Nutrients) in factorial plane F1 and F2), (b) Projection of individuals (sampling dates) in factorial planes F1 and F2. (A: Autumn, E: Summer, H: Winter, P: Spring). (1: la baie de M'diq , 2: Corniche Martil , 3: Foum l'Oued , 4: Targh.)

5. Conclusion

Qualitative and quantitative analysis of the phytoplankton population during the study period revealed the dominance of diatoms followed by dinoflagellates. The species *Gymnodinium* sp. *Gymmodinium catenatum*, *Pentapharsodium* sp., *Gyrodinium* sp., *Heterocapsa* sp. *Scriptiella* sp., *Prorocentrum* sp. among diatoms and *Chaetoceros* sp. *Thalassiosira* sp. *Leptocylindrus* sp. *Pseudonitzshia* sp. *Nitzschia* sp. *Asterionella* sp.

Skeletonema sp. *Guinardia* sp. and *Pleurosegma* sp among dinoflagellates dominate the phytoplankton stand. In general, the evolution of seasonal variation shows that, for the four ecosystems studied, the proliferation of phytoplankton species is significant in summer and spring with optimal growth. During autumn and winter, algual biomass is low, despite high nutrient inputs.

The regulation of the cycles of different phytoplankton populations in an ecosystem is influenced by several biological, chemical, physical and geological processes. The biotope's interaction with its environment acts directly on the phytoplankton stand. Moreover, the chemical composition of seawater results from the interaction of geological (mineralogy) and biological (assimilation...) processes.

References

[1]. Zeitzschel, B., (1978). Oceanographic factors influencing the distribution of plankton in space and time. Micpalyontology, vol. 24, no. 1, p. 139-59.

[2]. Mantora et al., (1991). Etude de la dynamique des communautés phytoplanctoniques par microscopie et cytométrie en flux, en eaux côtières de la Manche orientale. 15, 18, 23 pp.

[3]. Hallegraeff, G.M., (1993). A review of harmful algae blooms and their apparent global increase. Phycologia, 32: 79-99.

[4]. Pruss A., (1998). Review of epidemiological studies on health effects from exposure to recreational waters. Int. J. Epidemiol. 27:1-9.

[5]. Beaubrun PC., (1979). Les phénomènes d'eaux rouges au Maroc. Rev. Attabea, 32: 31-35.

[6]. Tahri Joutei L., Idrissi, H., Shafée, MS., Berday, N., (1996). Etude du phytoplancton toxique sur le littoral méditerranéen de Restinga à Kaasras. Trav. Doc. INRH, 895, 82 pp.

[7]. Tahri Joutei L., (1998). Gymnodinium catenatum blooms in Moroccan waters. In: Harmful algae. Reguera B., Blanco J., Fernandez M. L. & Wyatt T. Harmful Algae, Xunta de Galicia and IOC. UNESCO 1998, 66-67 pp.

[8]. Tagmouti F., (2001). Etude des phycotoxines marines PSP, DSP chez les mollusques bivalves des côtes marocaines. Mémoire de thèse. Université Hassan II, Faculté des sciences Aïn chock, Casablanca, Maroc. 170p.

[9]. Taleb, H., Vale, P., Jaime, E. & Blaghen, M., (2001). Study of paralytic shellfish poisoning toxin profile in shellfish from the Mediterranean shore of Morocco. Toxicon 39 (12): 1855– 1861.

[10]. Taleb, H., Vale, P., et Blaghen, M., (2003). Spatial and temporal evolution of PSP toxins along the Atlantic shore of Morocco. Toxicon 41(2): 199–205.

[11]. Sagou R, Amanhir R, Taleb H, Vale P, Blaghen M. & Loutfi M, (2005). Comparative study on differential accumulation of PSP toxins between cockle (*Acanthocardia tuberculatum*) and sweet clam (Callista chione). Toxicon, 46 (6) 612-8.

[12]. R., Taleb H., Bennouna A., Erler K., Chafik A & Moukrim A., (2008). Paralytic shellfish poisoning toxin profile of mussels Perna perna from southern Atlantic coasts of Morocco. Toxicon, 51: 780-786.

[13]. Goodman, D., Eppley, RW., Reid, F.M.H., (1984). Summer phytoplankton assemblages and their environmental correlates in the Southern California Bight. Journal of Marine Research.42 (4): 1019-1049.

[14]. Mullin and Riley (1955). The colorimetric determination of silicate with reference to sea and natural waters. Anal. Chim. Acta, 12, 162–176.

[15]. Strickland, J. D. H. and Parsons, T. R., (1972). A practical handbook of sea water analysis. Bull. Fish. Res. Bd. Can. 167. 311p.

[16]. Aminot A., and Chaussepied M., (1983). Manuel des analyses chimiques en milieu marin.Brest, CNEXO, 395p.

[17]. Trégouboff, G., ct Rrose, M., (1957). Manuel de planctonologie méditerranéenne. 1 (texte), 587 p. II (illustrations), 207 pl. -- Paris, C.N.R.S.

[18]. Rijal Leblad B., (2006). Variation spatio-temporelle des espèces phytoplanctoniques réputées toxiques au niveau de la côte Méditerranéenne Occidentale Marocaine. Mémoire de troisième cycle, Diplôme d'Etude Superieure Approfondie (DESA). Université abdelmalek Assaadi, Tétouan. 90 pp

[19]. Daoudi, (2004). Etude du peuplement phytoplanctoniques de la baie de M'diq et l'estuaire de Oued Laou: variabilité spatio-temporelle.
[20]. Margalef, R., (1958). Temporal succession and spatial heterogeneity in phytoplankton. In: Perspectives in Marine biology, Buzzati-Traverso (ed.), Univ. Calif. Press, Berkeley, pp. 323-347.
[21]. Smayda, T. J., (1984). Variations and long-term changes in Narragansett Bay, a phytoplankton-based coastal marine ecosystem: relevance to field monitoring for pollution assessment. In Concept in marine pollution, pp. 663–679. Ed. By H. H. White. Maryland Seagrant College, University of Maryland. 743 pp.
[22]. Duarte, C. M., Agust´ı S., Cole, J. J., and del Giorgio, P. A. (1999). Is the oligotrophic ocean heterotrophic, Science, 284, 1735,.
[23]. Vaulot,D., et frisoni, G.F., (1986). Phytoplanktonic productivity and nutrients in five Mediterranean lagoons. Oceanolo~ica Acta, 9 : 57-63
[24]. Rijall lebled, B., (2012). Variabilité de la contamination des bivalves (callista chione et acanthocardia tuberculata) par les phycotoxines paralysantes (PSP) et amnésiantes (ASP) dans la frange littorale méditerranéenne marocaine : cas de la baie de M'diq et de l'estuaire de OuedLaou.
[25]. Aubert M., P. Revillon, J. Aubert, (1985) . Sels organiques, eutrophie et dystrophie en milieu marin. Revue int. Océanogr. méd., 77-78 : 3-45.
[26]. Marasovic I., Z. Nincevic, N. Odzak, (1995). The effect of temperature on blooms of Lingulodium polyedra and Alexandrium minutum in Kastela bay. In: Harm- fuI marine algal blooms. P. Lassus, G. Arzul, E. Erard- Le Denn, P. Gentien, C. Marcaillou - Le Baut (eds), Technique et Documentation, Lavoisier, Paris, France, pp : 187-192.
[27]. Thomas W.H., C.H. Gibson, (1990). Quantified smallscale turbulence inhibits a red tide dinoflagellate Gonyaulax polyedra Stein. Deep-Sea Res., 37: 1583-1593.
[28]. Berdalet E., M. Estrada, (1993). Effects of turbulence on several dinoflagellate species. In: Toxic phytoplankton blooms in the sea. T.J. Smayda, Y. Shimizu, (eds), Elsevier, Amsterdam, Netherlands, pp : 737- 740
[29]. Margalef, R., & CASTELL VI, J. (1967). Filoplancton y production primera de la costa catalane, de Julio 1966 à Julio 1967. Inv. Pesq, 31: 491-502.
[30]. Boutaib R.., (2010). Qualité microbiologique des gisements coquilliers de la frange littorale méditerrannéenne : F'nideq – Kaa Srass, Période 20032008. Mémoire d'Ingénieur en chef, INRH. 119p.
[31]. Lacaze J.C., (1996). L'eutrophisation des eaux marines et continentales. Book
[32]. Revelante, N., Gilmartin,, M. (1976). The effect of Po river discharge on phytoplankton dynamic in the northern Adriatic Sea. Mar. Biol., 34: 259-271.
[33]. Berland, B.R., Bonin, D. J. & Maestrini, S. Y. (1980). Azote ou phosphore. Considérations sur le« paradoxe nutritionnel » de la mer Meditérranée. Oceanologica Acta, 3(1):135142.
[34]. Becacos-Kontos, T. (1977). Primary production and environmental factors in an oligotrophic biome in the Aegean Sea. Mar. Biol., 42: 93-98.
[35]. VOLLENWEIDER R. A., RINALDI A. et MONTANARI G., (1992). Eutrophication, structure and dynamics of a marine coastal system: results of ten year monitoring along the Emilia 130 omagna coast (Northwest Adriatic Sea); in: Marine Coastal Eutrophication. Eds. Vollendweioder R. A., Marchetti R. et Viviani R.: 63 – 106.
[36]. Balkis, N. (2003). Seasonal variations in the phytoplankton and nutrient dynamics in the neritic water of Büyükçekmece Bay, Sea of Marmara. J. Plank. Res., 25(7): 703-717.
[37]. Becacos-Kontos, T. (1969). Saranicos Gulf. In Mediterranean Productivity Project, Technical Report 47, NATO Subcommittee on oceanographic research edited by E. SteemannNielsen, B. Battaglia, H.J. Minas, Copenhagen: 64-78.