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Phytoplankton Diversity and Community Composition along the Salinity Gradient of the Massa Estuary

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The aim of this paper is to determine the seasonal succession, overall structure, diversity spatial and temporal of phytoplankton populations of the Massa-lagoon estuary, situated in the biological reserve of Massa. This reserve is situated in the heart of the National Park of Souss Massa in southern Morocco and indeclared in the area protected by the Ramsar Convention in 2005. The phytoplankton characteristics were studied at four sampling sites on the basis of the data collected monthly intervals, at low and high tides during a 12 months sampling period. Species diversity (Shannon-Weaver, H), Simpson's index and evenness were calculated. A total of 105 species of phytoplankton were recorded during the study period, showing a well-diversified taxonomy. Diatoms (64%) contributed more towards the percentage composition of different groups of phytoplankton at all stations, followed by Dinophyceae (14%), Chlorophycaea (10%), Cyanophyceae (9%) and Euglenophyceae (3%). Diversity index show a large heterogeneity of the phytoplankton composition. High cellular densities essentially represented by the diatoms that show high productivity of Massa estuary.

Keywords: phytoplankton, Massa lagoon-estuary, ecosystem, diversity index, seasonal succession

Introduction

Living resources of polluted water, particularly in the tropics support high levels of stress of all kinds. Lagoons and estuaries are rich and have a great diversity of species higher than in similar environments located in temperate climates. The generally observed decrease of catches, which is due both to the environmental degradation and over exploitation, has prompted studies of dynamic populations.

Indeed, understanding how are productive these ecosystems can help to reduce the constraints imposed on their threatened biological resources. Estuaries form a transitional zone between two aquatic biomes, the freshwater and the marine biomes. Marine organisms are adapted to high salinity and cannot survive in freshwater area. Freshwater organisms are adapted to low salinity and do not survive in seawater. Some marine or freshwater species have evolved a tolerance to intermediate salinities or to salinity fluctuations and can therefore survive in the brackish water of estuaries. Ecologically, wetlands are competitive among the most productive habitats estuarine ecosystems from the land and are a major part of the wetlands of Morocco due to its two seaboards. Estuarine ecosystems are also very favorable for Algae plants and animal life.

Estuarine play an important ecological role because they are natural habitants of water. They are widely used as an indicator of water pollution. Aquatic ecosystem is a habitat to a variety of communities, which constitute characteristics and functioning of the ecosystem in terms of maintaining production and food chain. Phytoplankton is one of the initial biological components from which the energy is transferred to higher organisms through food chain (Rajesh et al., 2002; Ananthan et al., 2004; Tiwari & Chauhan, 2006; Tas & Gonulal, 2007; Saravanakumar et al., 2008). The density and the diversity of phytoplankton are biological indicators for evaluating water quality and the degree of eutrophisation (Adoni et al., 1985; Chaturvedi et al., 1999; Ponmanickam et al., 2007; Shekhar et al.,2008) that were undertaken by several scientists. No previous studies have been recorded in the algal flora and no information was available in the Massa estuary. We report here on the phytoplankton composition and seasonal dynamics. This document discusses the seasonal variation of phytoplankton in the Massa estuary.

Materials and Methods

The study area

The Massa Lagoon is located along the south-east coast of Morocco, about 60 km south of Agadir (Figure 1). The choice of sampling stations 1-4 was conducted according to the gradient of

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salinity, agricultural areas, significant anthropogenic activities and places of wintering birds.
Station 1: located at a downstream of the river near the sea and where birds are abundant when the river was a closed lagoon.
Station 2: is located along the southern boundary. It has particular characteristics, in the sense that it is near farming areas of alfalfa, corn.
Station 3: characterized by the presence of a water pumping station of the river, used for irrigation of adjacent agricultural areas. It is located in an area with intense agricultural activity; it is an area of calm water at low flow.
Station 4: characterized by its great depth, which can reach 6m and it has a particular topography as a lake and aquatic riparian vegetation, which is abundant and diverse

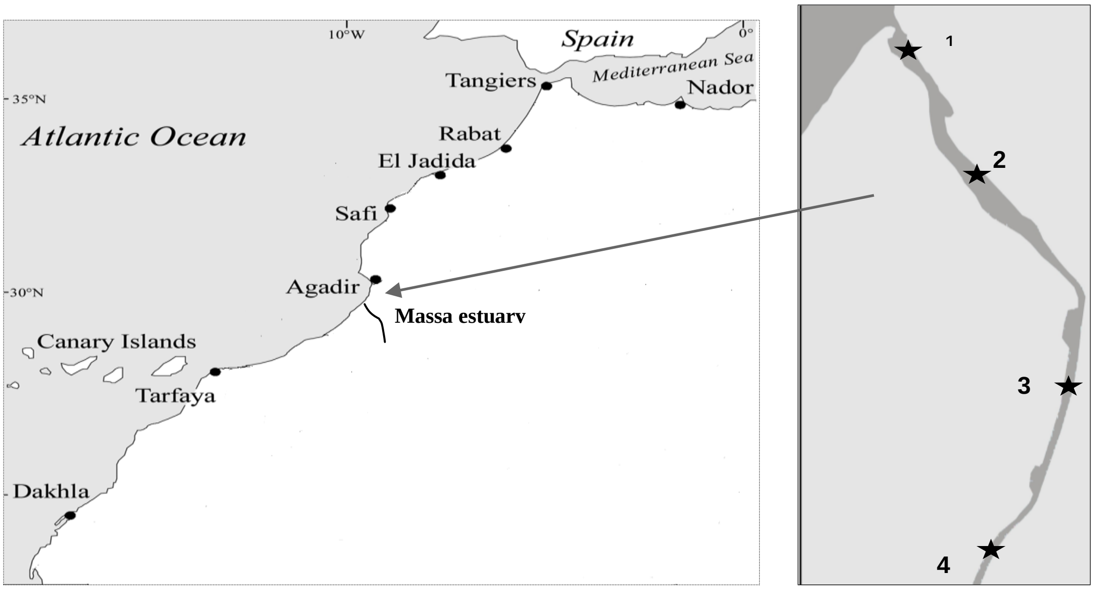

Figure 1. Map showing the location of the study areas in Massa estuary in Agadir, Morocco.

Phytoplankton community

In the present study, the phytoplankton of the Massa River was observed monthly at the four stations from March, 2009, to March, 2010. The collected algal samples were fixed and preserved with Lugol's Iodine solution. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope. Phytoplankton net samples were also taken and used to assist identification. The preserved samples were brought to the laboratory for quantitative and qualitative analysis. In compiling the inventory of various taxa collected, key documents, Bourrelly (1966, 1968, 1970), Tomas (1996) and Nezan (1996). Phytoplankton species diversity index (H') (Shannon and Wiener, 1949; Pielou, 1966), species richness (Gleason, 1922) and evenness index (J') (Pielou, 1966) were worked by using the respective formulae.

Biodiversity: H' = ∑iS =1 (Pi) (log2 Pi); I = 1; richness: D = 1-C; C = SPi^2; Pi= ni/N and evenness: J'= $H'/log_2(S)$. Here H' is the Shannon-Wiener Index of diversity, Pi= proportion of S made up of the i th species of phytoplankton, total number of phytoplankton species. Simpson's Diversity Index [SDI] according to Simpson (1949) equation: SDI = N (n-1) / Σn (n-1).

Where SDI = Simpson's Diversity index N = Total number of individuals of all species, n = Number of individuals per samples; Σ = sum

Hierarchical Cluster Analysis

Groups of similar stations and species that have ecological neighboring affinities were distinguished using Hierarchical Cluster Analysis (HCA) and (FAC) Factorial Correspondence Analysis had been used to give an idea about the whole similarities between the different phytoplankton groups and stations. The distance used is the Chi-2 (Benzecri, 1992). Factorial Analysis of Correspondence (FAC) and hierarchical cluster analysis (HCA) for this work were done through the use of statistical programs.

Results and Discussion

Composition and community structure of phytoplankton

A list of phytoplankton collected from the present study area is presented in Table 1.The total number of species listed in each of the four stations considered, varied considerably. The phytoplankton consisted of 105 taxa belonging to Bacillariophyceae (67) followed by Dinophyceae (14), Chlorophyceae (12), Cyanophyceae (8) and Euglenophyceae (3). The highest number of taxa (77) was recorded at station 1, 73 taxa were observed at stations 2. Stations 3 and 4 had 65 and 55 taxa, respectively. Indeed, the movements of standing water circulation allow good water renewal in the downstream sector which is responsible for its high species richness. In Massa River, Bacillariophyceae (Diatoms) were dominant and constituted 64% (Figure 2) of the total taxon. Moore (1974) and Round (1984) pointed out that diatoms are usually the most common element of epipelic communities. It is well- known that diatoms are sensitive to a wide range of limnological and environmental variables, and that their community structure may quickly respond to changing physical, chemical and biological conditions in the environment (Mooser et al., 1996). Other classes of phytoplankton (Figure 2) were only present in some seasons and with minor percentage like Dinophyceae (14%), Chlorophycaea (10%), Cyanophyceae (9%), and Euglenophyceae (3%). The number of Pennals diatoms is higher than centric diatoms. This is justified by the shallowness of the estuary of Massa and resuspension of sediment and microphytobenthos. Generally, diatoms were found to be dominant in mangrove waters, which could be due to the fact that diatoms can tolerate the widely changing hydrographical conditions (Kannan and Vasantha, 1992; Rajasegar et al., 2002). *Navicula cryptocephala*, *Navicula veneta*, *Gleocapsa turgida* and *Cyclotella ocellata* were the most abundant and common diatoms in the epipelic community. Navicula is abundant in Massa estuary, Nather Khan (1990) explained that this species of were common and abundant in both, organically enriched and non-enriched areas.

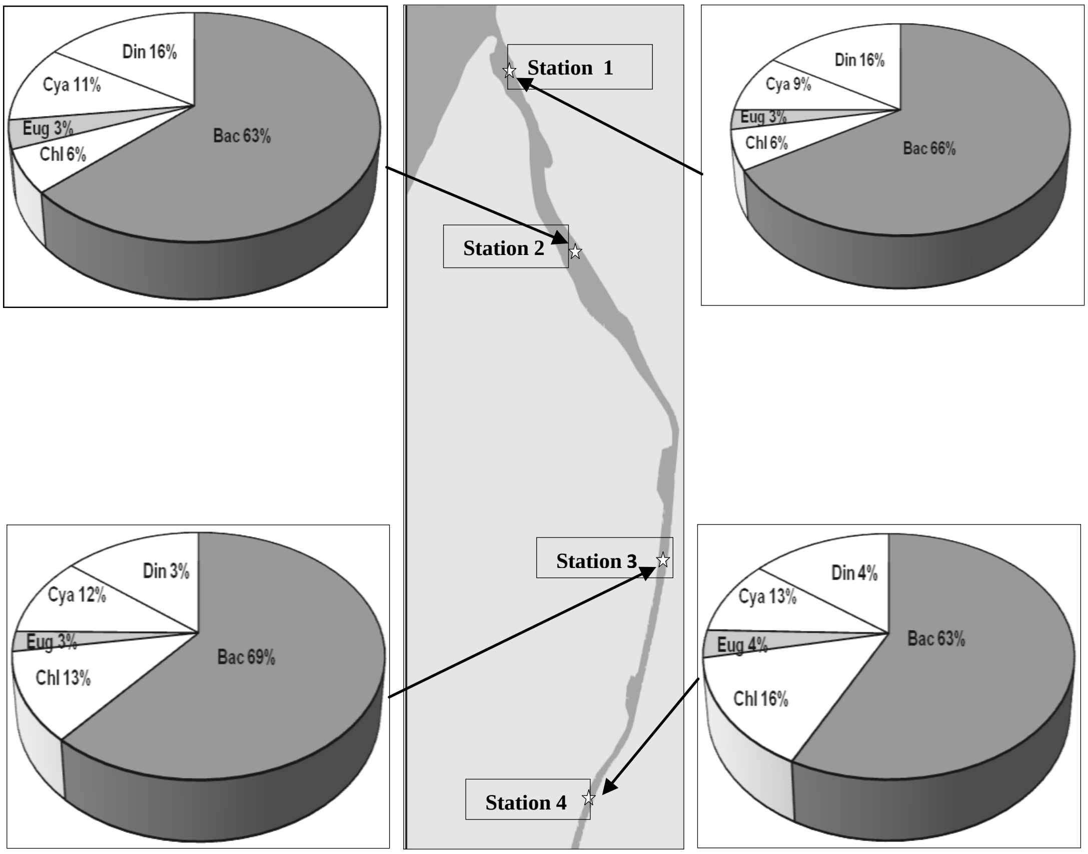

Figure 2**.** Spatial distribution of the qualitative of phytoplankton in the Massa estuary.

High value of Shannon's index (H ') was recorded in station 3 (2, 51) compared to other stations (figure 3) Dash (1996) Reported that the high value of Shannon's index (H ') signifies the planktonic diversity. Low values of Shannon's index were recorded in February in all stations. This may be due to heavy rain in Massa. Bajpai (1997) reported that the low diversity of the species would be due to the disturbance such as flooding. Adesalu and Nwankwo (2008) and Rajagopal (2010) reported thats the low value of Shannon's index of phytoplankton population in rainy season is due to dilution of area. This index of diversity (H ') shows a value below to 3 for all stations during the study period. This indicates a low specific structure of these groups. Indeed, a low diversity characterizes, in principle, young settlments of Species. While a great diversity indicates mature settlements, the low diversity index shows a weak internal structure of populations (Le Bris, 1988; Glémarec & Le Bris, 1995). The Simpson index varies within between 0,014 and 0, 99. Species evenness index varied from 0, 01 and 0, 99. These wide ranges of values coupled with their spatial and temporal variations reflect the heterogeneity of the population. Wide ranges of values coupled with their regular spatial and temporal variations reflect the heterogeneity of the population that would be regularly examined by phytoplankton unbalanced. The number of species and number of individuals show no down-gradient upstream. The low species richness was recorded in the lower-level stations. Entities, that have high species richness, are not the most diverse. This is due to the limited number of species (2-3 species) dominant at these entities. The low depth of the ecosystem accentuated by its enrichment in nutrients coming from the watershed of Massa and sediments (Badsi et al., 2010), favors the maintenance of community relatively immature in this ecosystem (Deaux 1980; Amblard, 1992).

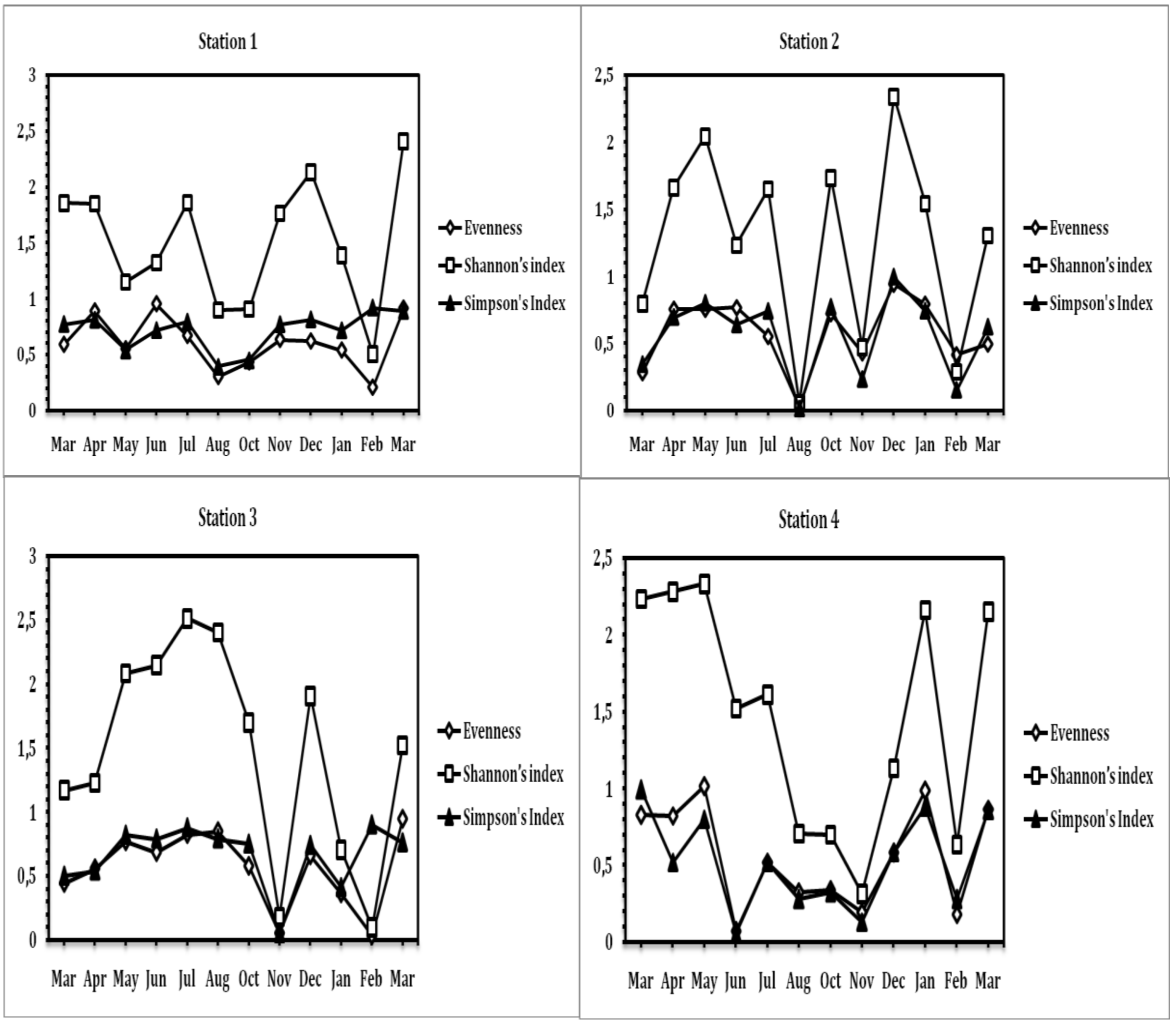

Figure 3. Simpson’s index and evenness at the sampling stations from March 2009 to March 2010.

Hierarchical cluster

The HCA was performed using the coordinates of seven study sites on the 3 axes of Correspondence Analysis. The matrix subject to the FAC is based on the presence or absence of species in the sites. The matrix thus formed has 4 variables (stations) and observations (species). The diagram obtained from the AFC (Figure. 4) allows us to distinguish two groups. The first group is presented by saltwater stations (1 and 2). The second group is presented by the freshwater stations (3 and 4). This distribution could be explained by a salinity gradient, temporal gradient with effect seasonal and the existence of similar conditions in the stations of the same group.

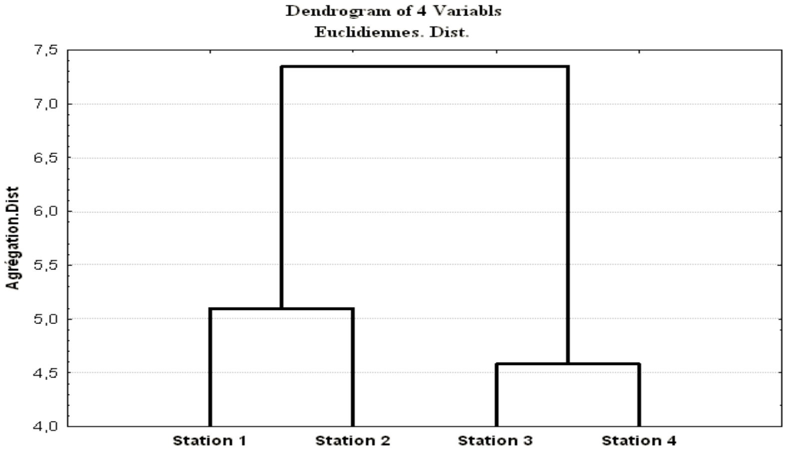

Figure 4. Dendograms hierarchical clustering of the stations samples in the Massa River.

The spatiotemporal distribution (Figure 5) shows that it is the group of Bacillariophyceae which dominates the entire study period at the level of four stations and all the months. It is represented mainly by *Cyclotella ocellata*, *Navicula cryptocephala* and *Gleocapsa turgida*. From a qualitative standpoint, and with percentage terms, only Bacillariophyceae can dominate until 100% the phytoplankton community. Then we have identified Dinophyceae with a percentage not exceeding 40% (Figure 5), Cyanophyceae vary between 0% and 33%. Chlorophyceae show a value of 50% at station 3. Finally, Euglenophyceae (Figure 5) show a near-absence with a percentage not exceeding 19%.

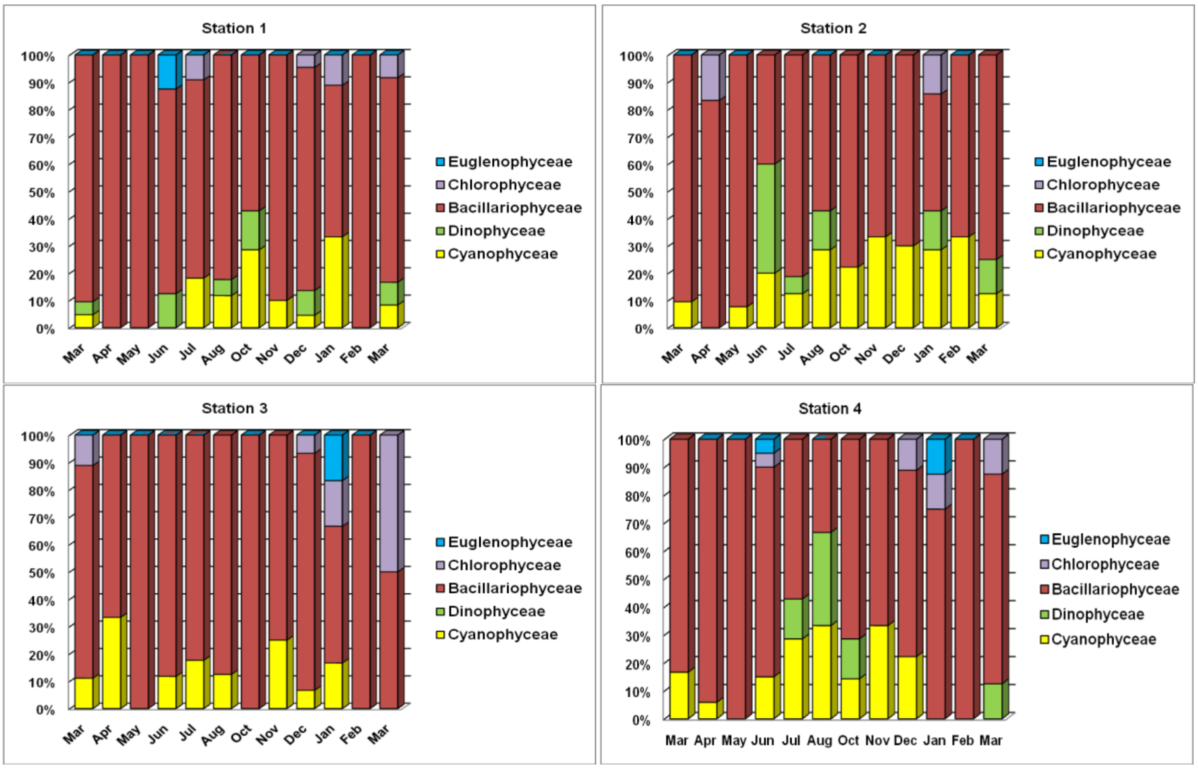

Figure 5. Spatiotemporal variability of species richness in %.

Figure 6 shows the evolution of total cell densities including all classes of algae. Despite a similar algal inventory at Massa River, the total density of phytoplankton at the mouth is high compared to that recorded upstream. The strong accumulation of algae cell is observed in spring (March 2009) peak at four stations. The high phytoplankton densities are caused by the increase in light irradiation, an enrichment of the area with nitrogen compounds due to inputs of water. The increase in the abundance of cells in 2009 derive from human influence and the high density of phytoplankton ,that are also due to the large amounts of organic matter caused by eutrophication (Badsi et al., 2010). The population density in all the 4 sites (figure 6) varied between (300 cells l-1) was recorded during February in station 4 at 2010 and ($16016*10^{10}$ cells l-1) during March 2009 at station 1. Station 1 showed comparatively high population density due to high nutrient concentrations and optimal salinity than at stations 1 and 2(Gouda and Panigrahy, 1996). The increase in cell abundance stems from human influence and large phytoplankton densities are also due to the large amounts of particulate organic matter through phytoplankton autrophie (Benabdellouahad, 2006).

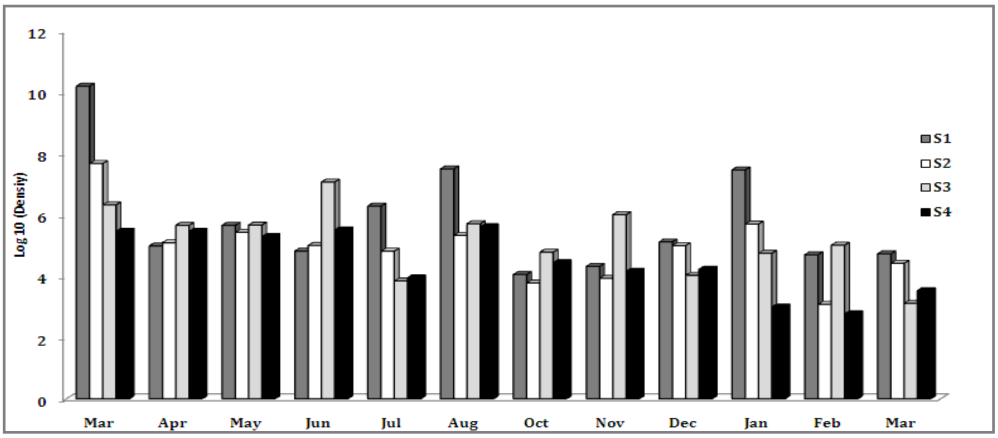

Figure 6. Seasonal variation of population density recorded from Stations 1, 2, 3 and 4.

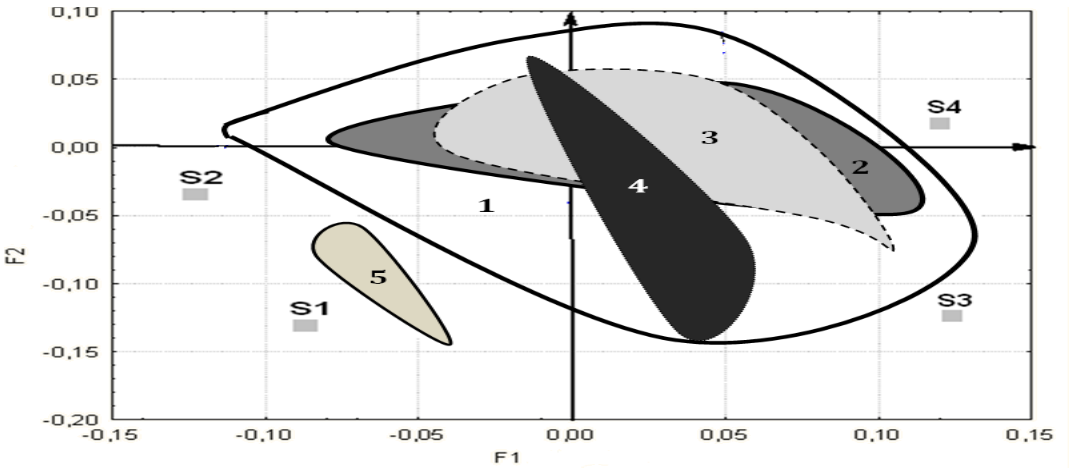

Figure 7. Representation of the result of combination between groups and stations made by factorial correspondence analysis in the Massa River from March 2009 to March 2010; *With: 1: Bacillariophyceae; 2 :Chlorophyceae; 3: Euglenophyceae; 4 : Cyanophyceae; 5 :Diaptomyceae. S1: station 1, S2: station 2, S3: station 3 and S4: station 4.*

In this work, the analysis of the FCA (Figure 7) was performed using the maximum density as a general term of the binary matrix set for each station. The first axis F1 represents 44, 90% and axis F2 represents 29.02% from the total inertia. The organization of the four stations, at the level of both F1 and F2 axes shows that stations 3 and 4 are in the positive side and the other stations 1 and 2 are in the negative side. For F2 axis, station 4 is presented in the positive side, while stations 1, 2 and 3 are in the negative side. The Bacillariophyceae are a group that dominates in all stations and it is the group that is diverse and which occupies a greater space, followed by Diaptomyceae with the majority of species that are recorded only at stations (1 and 2) closer to the sea. Chlorophyceae and Cyanophyceae are largely present at stations 3 and 4. As to the Euglenophyceae which are less diversified in terms of the four stations.

Conclusion

The results showed the influence of the salinity gradient on the compositional of the phytoplankton community. According to the results Massa lagoon-estuary is dominated by Diatoms, mainly of the genera *Navicula*, *Gleocapsa*, *Cyclotella* and *Diploneis*. Cell densities of phytoplankton show a decreasing gradient of the station 1 to station 4 due to the transformation from the state of closed lagoon to the estuary state.

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