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Variability of spatial and temporal distribution of marine zooplankton communities in relation with environmental parameters in Tangier and M'Diq (Gibraltar strait) regions

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Abstract
Spatiotemporal distribution of zooplankton in the Tangier and M'Diq showed variability during the study periods. This variability more related to the environmental parameters studied, mainly in spring and summer compared to autumn in both areas. Temperature and chlorophyll 'a' influence the spatial distribution of zooplankton in Tangier during the warm periods of study (spring and summer). While during the same period, water salinity affects the spatial distribution of zooplankton in M'Diq.

Key words: Zooplankton communities, chlorophyll 'a', Tangier, environmental parameters.

Introduction
The continental Moroccan Atlantic shelf has been the subject of several zooplankton studies since the 1950. The earliest studies were carried out by these authors [1-6]. Actually, these studies were followed up by more recent work [7-11]. However, the plankton community in two sides of the Gibraltar Strait did not benefit from this interest. Similarly, the influence of environmental conditions on the zooplankton community has yet to be assessed in this area. Nevertheless, many physical and chemical studies carried out in this region [12-23]. Knowing also, that the zooplankton community is very sensitive and highly reactive to the environment variations [24]. In many cases, a change of the structure of the zooplankton populations reflects a change in hydrological and climatic conditions. Many authors have suggested using the zooplankton like an indicator of the total change [25-28]. In this context, our objective is to follow the spatiotemporal variation of the zooplankton community and its relationship with environmental parameters in both ecosystems.

Material and Methods
1. Studies areas and sampling
Two radials investigated using a transect methodology: the first transect on the Atlantic coast was in the area of Tangier, and the second on the Mediterranean coast, in the region of M'Diq. On each radial, three stations have sampled. Sampling conducted during the following periods: March, May and December 2006; May, July and November 2007 (Figure 1).
The measurements of physical parameters (temperature and salinity), at each station in both areas, were made at different levels in connection with thermocline. These two parameters were measured using a multisonde CTD. Data have recorded with computer connected to the probe Neil Brown.

The multiprobe was coupled with a rosette for the sampling of waters. The determination of the water content on chlorophyll 'a' carried out according to chemicals methods in the laboratory.
The zooplankton samples collected using a small size Bongo net with 145 µm of mesh size. The net is equipped with a flowmeter for measuring the opening of the volume filtered and determinates at its lower end by a collector. Sampling carried out in a standard way: bottom to the surface, where the net trailed horizontally for 3 minutes (at constant speed) and then hauled up vertically in 1 minute. Then it is towed at the next depth at the same speed (varying between 2 and 3 knots) and again for three minutes. The samples were fixed with seawater formulized at 5%. Identification and counting of zooplankton have carried out under a binocular microscope, after dividing the initial sample into fractions with the Motoda box [29]. Thus, we compiled a specific list for each sample using suitable keys for taxas determination [30-36].

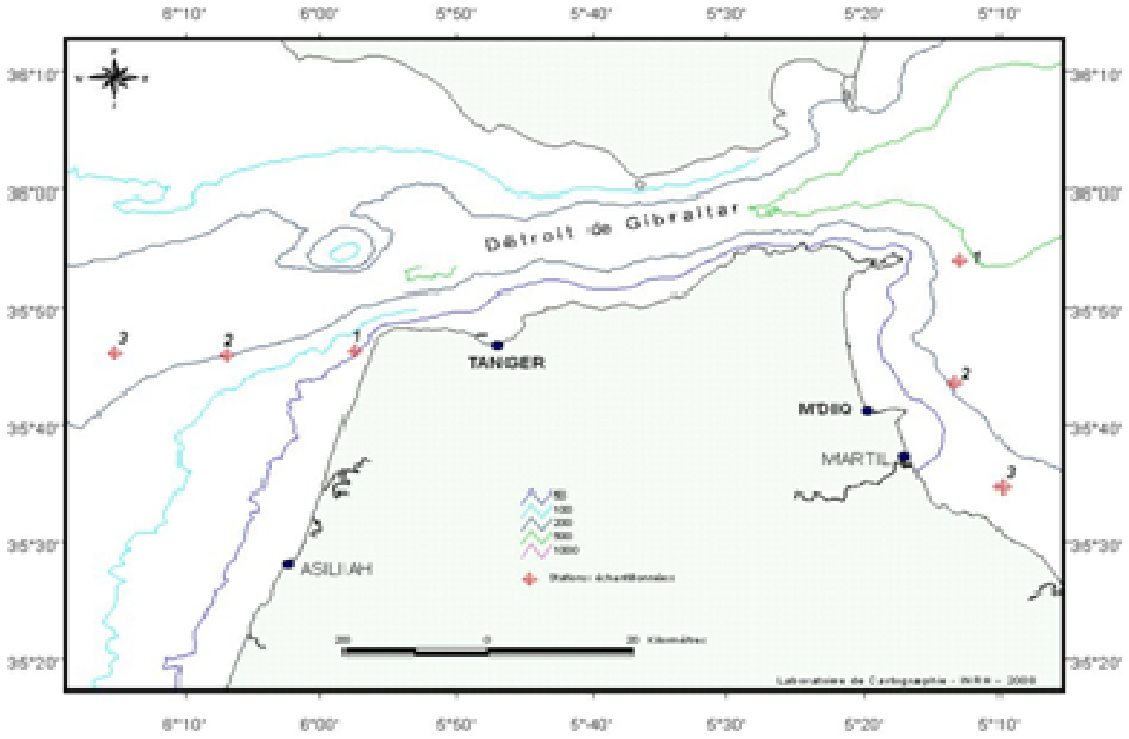

Figure 1: Prospected areas and localisation of the sampled stations

2. Statistical analysis of data

To describe the variability of total zooplankton distribution; in both radials located in both sides of the strait of Gibraltar in conjunction with the environmental parameters; the statistical treatment applied consists to a principal component analysis (PCA) normalized [37] has conducted. Total of two PCA were performed on two data matrices with a reduced focus an array composed of 4 columns representing the set of variables (salinity, temperature, chlorophyll 'a' and total zooplankton) and 9 lines (3 stations sampled in each radial * 3 seasons of exploration during the years 2006 and 2007). The software we used to carry out this statistical analysis is ADE4. In addition, a Pearson correlation test has performed.

Results and discussion

1. Physical and biological characteristics of the two radial

Spatiotemporal variability of water temperatures in Tangier area along two years of studies revealed the presence of a thermal front created in warm periods. In fact, in spring and summer (May 2006 and May, July 2007) an increased thermal gradient between the coastal and offshore stations was noted in this region (Figure 2). This gradient becomes more important in summer, mainly in july 2007, where the cold water located near

the coast (15,8°C) and the warm waters (21,2°C) located on the offshore station. In general, this thermal difference between inshore and offshore stations in this period, due principally to the upwelling characterized waters of the Atlantic Ocean during the warmer periods (spring and summer). Compared to the Tangier area, in M'Diq a thermal gradient is more lower because the thermal difference between stations was relatively less important during all periods of study, with exception in July 2007, where a little variation of temperature waters was recorded between the station located in south and north of M'Diq (Figure 2).
Regarding salinity, no temporal variability observed in both radials. However, spatial variability was noted in both areas of our studies. The most saline waters located in offshore station at Tangier and in the north station at M'Diq (Figure 3).
The highest concentrations of chlorophyll 'a', in both regions, were recorded at the warm seasons (spring and summer) compared to the cold periods (fall). For the spatial variability, the higher concentrations of the chlorophyll 'a' were located at the coastal stations in Tangier and in south of M'Diq regions. This difference in the chlorophyll 'a' concentration between inshore and offshore stations is probably related to increasing of temperature gradient observed during the warm periods (Figure 4).

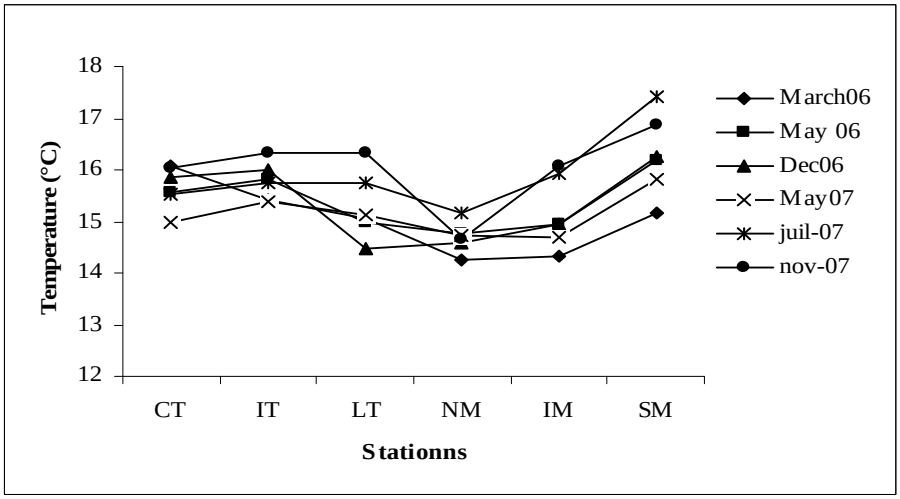

Figure 2: Spatiotemporal variability of temperature in both radials

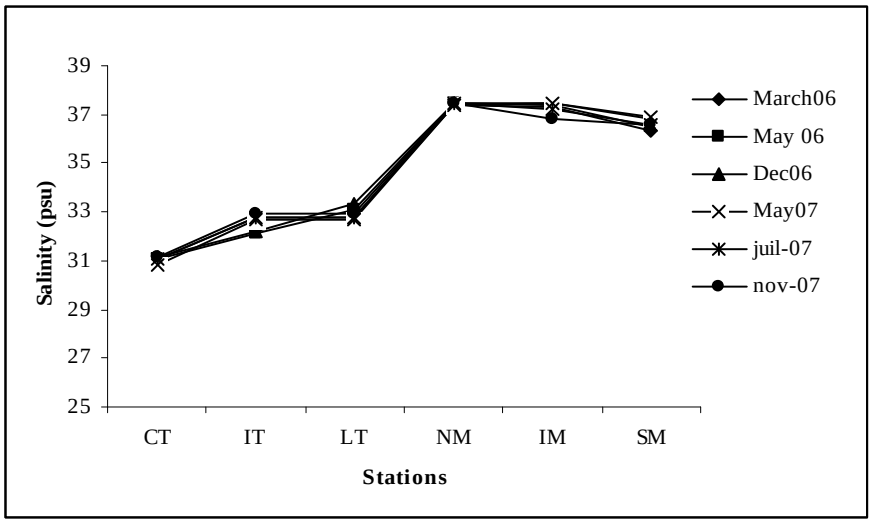

Figure 3: Spatiotemporal variability of salinity in both radials

With CT: Coastal station, IT: middle-station and LT: offshore station in Tangier NM: station located in the north of M'Diq, IM: intermediate station and SM: station located in the south of M'Diq.

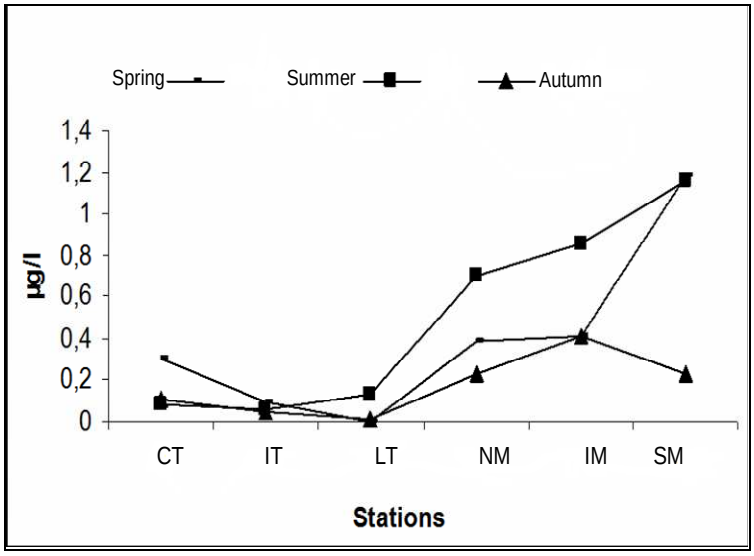

Figure 4: Spatiotemporal variability of chlorophyll 'a' in both radials

2. Structure of zooplankton community

The higher densities of zooplankton communities observed in M'Diq compared to Tangier. In fact, the maximum of the density is reached 900 ind/m^3 in M'Diq, whereas, it not exceed 800 ind/m^3 in Tangier. In general, the high densities of zooplankton were noted in the stations located near of the coast in both areas studies. Specially, at the coastal station (CT) in Tangier, and at the intermediate station in M'Diq. Apart from the spatial viability, we observed a seasonal variability of zooplankton density in both areas. The zooplankton community is more abundant on the warm periods (spring and summer) compared to the cold periods (autumn). In general, the densities of zooplankton starts low in autumn, increases in spring and peaked in summer (Figure 5).

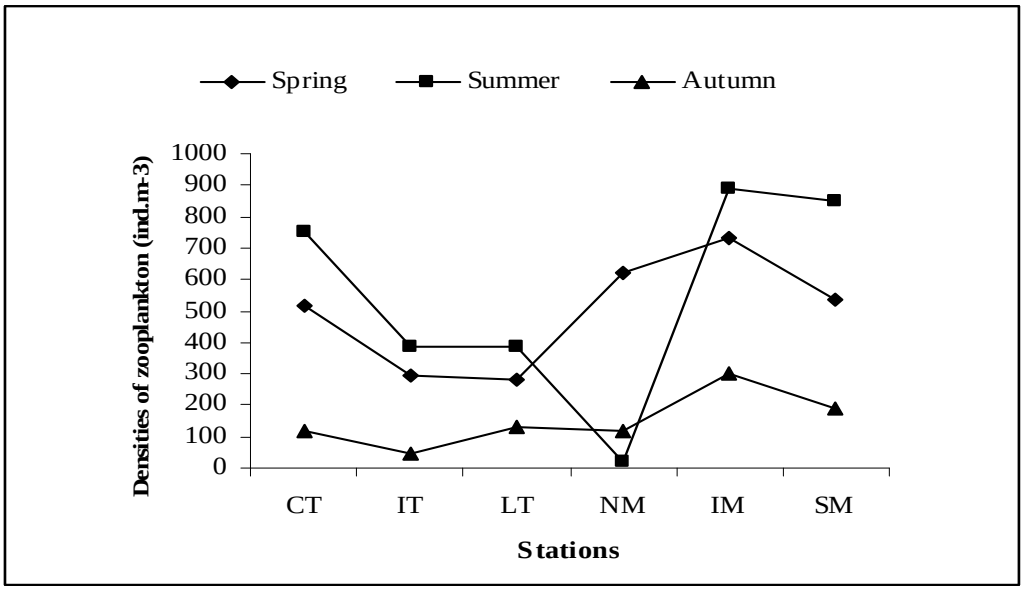

Figure 5: Spatiotemporal variability of zooplankton density in both radials

The principal component analysis (PCA) of total zooplankton in relation with environmental parameters performed on all periods of our studies (spring, summer and autumn). Indeed, F1 * F2 axis explains 73, 60% of the variance. The F1 axis negatively correlated to the salinity parameters. On its positive side, F1 select the

coastal station characterized by the high densities of zooplankton, which correlated significantly with the concentration of chlorophyll 'a', mainly in spring and summer ($r = 0,98$, $p < 0,05$), ($r = 0,98$, $p < 0,05$).
The F2 axis, on its positive side is negatively correlated with the temperature parameters. In this side, F2 selects the total zooplankton collected in spring when the temperature waters decreases and the zooplankton density begins to increase. On the other side, F2 selects the periods when the waters temperature increase and the total zooplankton decrease gradually. Then, this result defines a hydrological separation between offshore and coastal stations characterized by less saline waters during all the periods of our studies. The distribution of zooplankton based on the seasonal variability of the water temperature in this region.
The result performed on the data collected in M'Diq shows that F1 axis explains 64,26% of total variable. The F1 axis of its positive side is positively correlated to salinity parameters. In this side, F1 selects the station located in the north of M'Diq characterized by low concentrations of chlorophyll 'a' and zooplankton density. In the other side, F1 axis positively correlated with chlorophyll 'a' and zooplankton density. F2 selects the station located on the south of this area, characterized by less saline water and important concentration of chlorophyll 'a' and zooplankton densities. It has concluded that this axe defines the effect of salinity waters on the spatial distribution of zooplankton density.
We have noted also, that the F2 axis represents 20,90% of total variables and that this axis positively correlated with temperature. In this side, F2 selected the stations located in the north of M'Diq with low concentrations of chlorophyll 'a' and zooplankton densities. This axis describes a state of opening the M'Diq to transfers of water from the Atlantic Ocean.

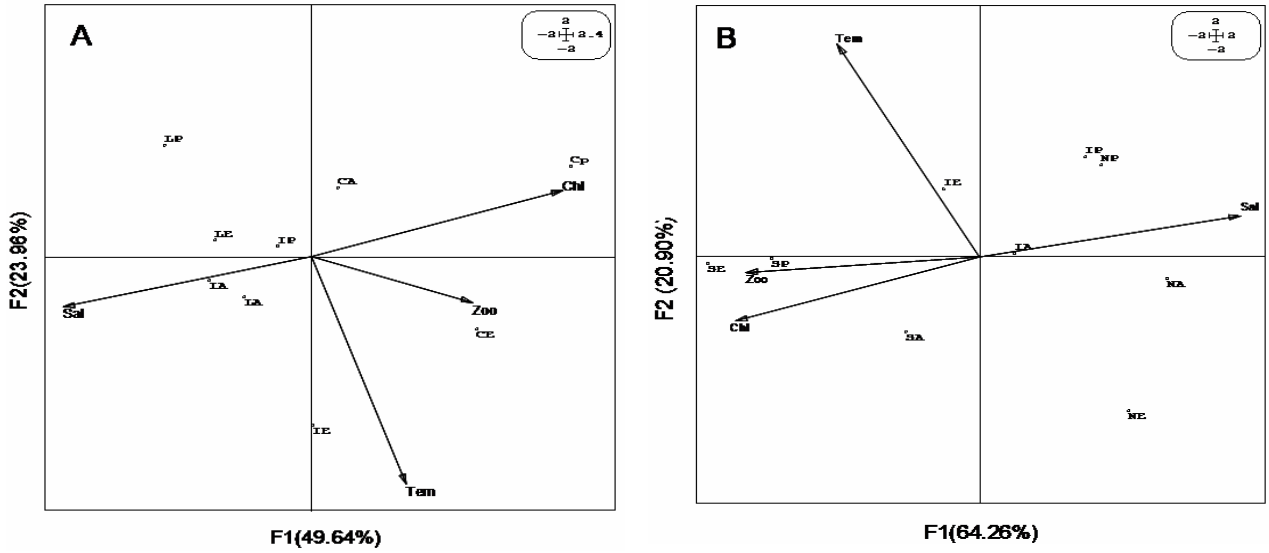

Figure 6: The principal component analysis (PCA) performed based on the total density of zooplankton in relation to abiotic parameters in Tangier (A) and M'Diq (B).

With Zoo: zooplankton total; Tem: temperature, Sal: salinity, Chl 'a':chlorophyll 'a '.
C: coastal station, I: mid-station and L: offshore station (The radial Tangier).
N: station located in the north of M'Diq, I: intermediate station and S: station located in the south of M'Diq. P: spring; E: summer and A: autumn

The study of the relationship between zooplankton community and the abiotic parameters showed a correlation between spatiotemporal variability of zooplankton densities and temperature, salinity and chlorophyll 'a' in both sides of Strait of Gibraltar.
In Tangier area, the zooplankton density decrease from the coastal to offshore station. The higher densities recorded, mainly, in spring and summer with a maximum been located on the coastal station. This seasonal and spatial variability correlated, mainly, to abiotic parameters. In fact, the establishment of thermal font during the warms periods of studies promotes the development of phytoplankton near the coast. The results of the (PCA) analysis explains more that, which shows that the coastal station has positively characterized by

high densities of zooplankton correlated negatively correlated to the waters temperature and significantly with the high concentration of chlorophyll 'a', respectively in spring and summer ($r = 0,98$, $p < 0,05$), ($r = 0,98$, $p < 0,05$). This behaviour follows a seasonal cycle of the zooplankton activities along the Moroccan coast. Indeed, the latter has related to the upwelling cycles, which develops in spring, have reinforced in summer, attenuates in autumn and decreases in winter [38-40]. However, in Tangier, the strong copepod densities have recorded in the coastal stations during the whole seasons, except for autumn. This corroborates the results from [41-42], which underline a coastal localization of high zooplankton densities for the Atlantic.
In the other side of Strait of Gibraltar, increases of zooplankton densities recorded on the M'Diq intermediate and south station. In spite of strong, space variability, the seasonal variability shown that the densities zooplankton was low in autumn compared to the spring and summer. According to The PCA result, the water temperature as a parameter abiotic influences the density of zooplankton in M'Diq, benefiting from the contributions of cold water of Atlantic origin characterized by low salinity. In fact, these nutrient-riche waters contribute to the growth of phytoplankton in the middle station and south of M'Diq due to the increased zooplankton densities in these stations compared to north station. This finding confirmed by other studies that reported the zooplankton activity in M'Diq related to the seasonal cycle of the Mediterranean water mass, which follows change of flow entering and outgoing through the Gibraltar Strait [43, 44]. In addition, the accumulation of sea surface water in both anticyclonic gyres of the Mediterranean basin acts on the distribution of zooplankton in this area. Moreover, [45] showed a seasonal cycle that related to an oscillation of the zooplankton abundance and that the maximum values have recorded during the first six months of the year.

Conclusion

In both areas, the influence of the environmental parameters studied on spatiotemporal distribution of zooplankton was significant. In Tangier, the diminution of coastal waters in spring and summer promotes the development of phytoplankton and increase of zooplankton densities. In M'Diq region, the distribution of zooplankton is influenced by the supply of the Atlantic water more located in the south of this region where high densities of zooplankton recorded.

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