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Full Length Research Paper

Zooplankton abundance in the Massa Lagoon, Southern Morocco: Impact of environmental variables

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The biological reserve of Massa, situated in the National Park of Souss Massa, certified Ramsar has a global interest in birdlife. The functioning of the lagoon is affected by the problems of eutrophication, declining water levels, lack of communication with the sea. This work represents a first contribution to the study of the plankton community living in the lagoon of this reserve in connection with the physical chemistry of water. The analysis of the physico-chemical and biological state shows a very advanced eutrophic water of the lagoon, characterized by high levels of orthophosphate and chlorophyll a. The structure of zooplankton populations is characterized by the dominance of species of eutrophic environments and tolerates changes in salinity.

Key words: Reserve of Massa, eutrophication, zooplankton, lagoon, physico-chemical.

INTRODUCTION

Aquatic ecosystems are closed or semi-closed as our site appears as a finite and vulnerable resource threatened by catches in the environment (Aspe et al., 1999) and are considered a siege of several biological, chemical and physical phenomena. Evaluation of factors controlling the distribution of zooplankton species is, by its central position and its dual control by resources and predation, a central point in the biological and ecological functioning of aquatic ecosystems must be taken into account in the context of the management of these environments through the manipulation of the food web (Pinnel-Alloul et al., 1996). It is difficult to identify the main causes that explain the variation in zooplankton abundance (Velho et al., 2001), while abiotic factors such as salinity Ayad (2002), precipitations, or turbidity, have been identified as critical factors in the development of zooplankton (Dejen et al., 2004). Other authors (Wetzel, 2001; Fernández-Rosado et al., 2001) have also mentioned the influence of environmental and biotic interactions on the composition, abundance and dynamics of zooplankton. There has been no hydrobiological study of the Massa lagoon I. Its development and its conservation require the completion of such study.

The lagoon of the biological reserve of Massa is situated in the heart of the National Park of Souss Massa in the South of Morocco. It included in 2005 on the list of Ramsar sites and also as a natural environment that has international significance and one of the most important migration routes and stopover site of wintering birds. This area is also the last refuge for the last wild population of bald ibis (*Geronticus eremita*) in the world, which is a rare and endangered species.

The environment of the Massa lagoon was indeed more severely affected by pollution and in particular with the silting of the mouth, forming a barrier beach sand to prevent any communication with the sea, the installation of the dam Youssef Ben Tachfine upstream, recurrent droughts experienced by the region in recent decades, and agricultural pollution is ever increasing.

These hydrological and environmental issues have accentuated and accelerated the eutrophication of the downstream part of Massa lagoon (lack of oxygen, temperature increasingly, high algal development and mortality of fish). These threats to the area, declared the

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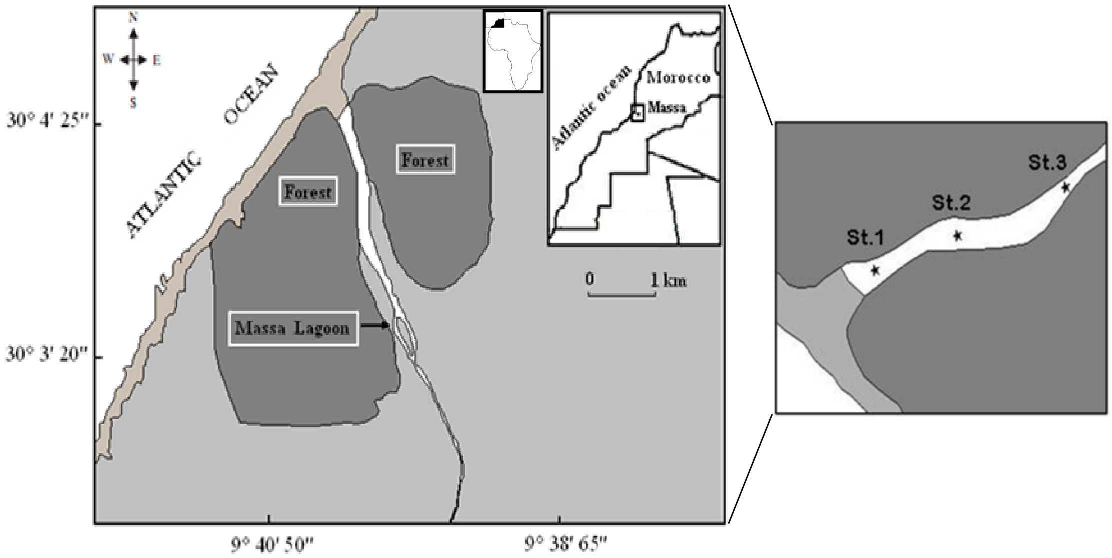

Figure 1. Location of the region of Souss Massa and the three study sites.

Table 1. Average values of physico-chemical of lagoon from February to July 2008.

Parameter	**pH**			**Temperature (°C)**			**Salinity (mg/l)**		
Sites	1	2	3	1	2	3	1	2	3
February	8.1	8.9	7.58	16.1	16.9	17	14	13.05	11.33
March	8.2	8.11	7.93	16.3	17.4	17.3	14.5	14	12.2
April	8.28	8.23	8.03	16.5	17.3	17	16	15	13.5
May	8.21	8.10	8.19	23.2	23.1	23.5	20	17	12.11
June	7.26	7.90	7.32	24.8	25.3	24.9	21.8	20.12	13
July	7.11	7.06	7.60	25.4	26.95	25.5	24.6	21.2	15.7

area protected by the Ramsar Convention in 2005, which include wetlands of Morocco, have consequences for the loss of biodiversity, thus leading to impairment of the biological equilibrium of the lagoon and even destruction of the ecosystem and serious disturbances in the intercontinental migration routes of birds.

Given this situation, we conducted an ecological analysis; through an initial study by the hydrobiological study of the physical chemistry of water and the study of zooplankton which is its key position in the trophic chain, gives a fundamental role in zooplankton and its study seem essential to better understand the functioning of aquatic systems. So its development for its conservation requires the realization of this kind of study.

MATERIAL AND METHODS

Study sites

The Massa lagoon is located along South-East coast of Morocco, about 60 km South of Agadir (Figure 1). The choice of sampling stations was conducted according to the gradient of salinity, agricultural areas, significant anthropogenic activities and places of wintering birds.

Station 1: (Lat. 30°04'20, 29'' N: long.9°40'03, 23''O), downstream of the lagoon near the sea and where shorebirds are abundant and sedentary.

Station 2: located at 2 Km of the station 1, which is located (Lat. 30°03'53, 25''N: long. 9°39'51, 09'' O). It is approximately in an intermediate zone, deeper, near the position of forest and is influenced by human activities.

Station 3: (Lat. 30°3'23, 04'' N: long. 9°39'25, 91''O) and along the southern boundary. It has special features since and localized near farming areas of alfalfa and corn.

Sampling

At each site, qualitative samples have been realized over a period of 6 months (from February to July, 2008 Table 1a, b and c). The horizontal sampling, conducted in each site was created using are empty mesh 80 µm plankton net. At each site, we apply two vertical lines upward. The fauna recovered in the first line is filtered through a nylon sieve of 40 µm mesh vacuum and then placed in a pillbox and preserved in 5% formalin immediately after collection. The

Table 1(b). Average values of physico-chemical of lagoon from February to July 2008.

Parameter	Chlophyll a (mg/m^3)			Ammonium (mg/l)			Orthophosphates (mg/l)		
Sites	1	2	3	1	2	3	1	2	3
February	20	25	45	0.4	0.23	0.2	0. 09	0.12	0 .18
March	42	62	76.33	2.01	0.95	0.35	0.15	0.15	0.20
April	25	50	56.87	1.97	0.50	0.75	0.10	0.13	0.20
May	71.5	72	72	0.5	0.31	0.48	0.17	0.31	0.65
June	40	30	59	1.1	0.6	0.25	0.082	0.118	0.328
July	30	28	48	2.05	0.25	0.12	0.253	0.23	0.40

Table 1(c). Average values of physico-chemical of lagoon from February to July 2008.

Parameter	Dissolved oxygen (mg/l)			Chemical Oxygen Demand (mg/l)			Nitrate (mg/l)		
Sites	1	2	3	1	2	3	1	2	3
February	3.75	4.33	4.58	410	420	455	6.33	5.15	6.8
March	5.5	4.85	5.2	450	500	520	4.98	4.89	5.62
April	4.2	4.18	4.89	400	486	450	9.86	7.3	9.92
May	5.98	5.76	5.6	210	100	110	6.44	4.7	6.68
June	5.45	5.13	5.1	466	476	389	8.39	6.56	7.61
July	5.33	3	6.35	300	350	320	7.1	5.5	5.55

second feature is kept alive for the determination of some species difficult to identify after fixation (protozoans and rotifers) and also for observation after the return to the laboratory. The vertical sampling was done using a closing bottle with a capacity of two liters of type WILDCO valves and two samples filtered through a filter of 40 µm were fixed in 5% formalin and this type of sampling was also used for water samples for the physical chemistry study.

Abiotic variables

In situ measurements

Measurement *in situ* field measurements were for temperature, dissolved oxygen, salinity, pH and water transparency. Water temperature and dissolved oxygen using a thermo-oximeter, salinity using a salinometer, pH using a pH meter and transparency using a Secchi disk.

Laboratory analysis

Suspended solids (mg/l) (filtration filter fiber glass diameter equal to 45 µm). The chemical parameters, nutrients (mg/l) nitrates, nitrites, ammonium and orthophosphate conventional two methods (gravimetric, titrimetric, etc..) were used (Rodier, 1996).

Measures of chlorophyll a

Measuring the concentration of chlorophyll-a was achieved by filtration on a filter Whathman GF / C (0.45 mm), storage and extraction in 90% acetone for 24 h and kept at 4°C in protection from light. Chlorophyll was calculated using a spectrophotometer with a formula Lorenzen (1967).

Biotic variables

After homogenization of the sample, the counting of the number of specimens of each species was done in a Dollfus cuve under a stereoscopic microscope after staining with Rose Bengal (Ait salah, 1997). To facilitate the enumeration of species, we have added to the contents of tanks few milliliters of solution of alcohol 10% glycerol. After evaporation of the alcohol and water species are immobilized in glycerine which can count easily.Species identification was made with reference to the key determination (Pourriot et al., 1986) for Rotifers, (Dussart, 1967, 1969) for Copepods and Amoros (1984) for Cladocera.

Statistical analysis

To study the variations of zooplankton, a PCA was conducted. The principal component analysis (PCA) was one of the most used by Giraudel (2000). It is a factorial method of statistical analysis, linear and multidimensional part of descriptive statistics. It can synthesize, describe and classify data from one table to provide a summary.

RESULTS AND DISCUSSION

Physico-chemical environment

The physico-chemical results during the study period are presented in Table 1, while the inventories of zooplankton in the three sampling stations are summarized in Table 2. Temperature is a key factor regulating the growth of zooplankton populations Ban (1994). During the study period, water temperature ranged from 16, 1 to 26, 95°C with the minimum value in spring and the maximum in summer. It showed significant positive correlation with salinity (r = 0.65) and significant negative correlation with pH (r = -0. 65). The pH values indicate the nature of the water slightly alkaline. It showed significant positive correlation with suspended solids (r = 0.19) and negative correlation with water temperature (r = -0.65). The same values are recorded by (Chaouti 2005) at the Smir lagoon. The dissolved oxygen values ranged from 3 to 6.356 mg l^{-1}, showed significant positive correlation with chlorophyll a (r = 0.57) and negative correlation with chemical oxygen demand (r = -0.39).

The comparison of results shows a variability of these parameters. At site 2, the high value of the water temperature in summer (26, 95℃), due to arid climate, has caused a sharp decrease in dissolved oxygen (3 mg / l) and decreased pH. The interaction between these parameters at this station can be explained by microbial activity that was high in sludge sediment, resulting in a decrease in the concentration of dissolved oxygen and an increase of nitrate and phosphate, Kagalou et al. (2006) demonstrated that the decomposition of organic matter occurs at the sediment-water interface.

During the study period, the salinity of the lagoon ranged from 12, 01 to 24, 6 mg l^{-1}. A gradient of increasing salinity is observed from site 3 to 1. The high evaporation caused by the highest values was recorded in summer .The values the COD vary between 100 to 520 mg l^{-1}. It showed negative correlation with water temperature (r =-0. 48).The high values of COD were due probably to the addition of waste (Mishra and Saksena, 1993; Pandey et al., 1989). Nitrates are nitrogen form preferentially absorbed when the algae have the same time of NH_4^+ and NO_3^-Ait Salah (1997).The values ranged from 4. 08 to 8.64 mgl^{-1}.

The transparency (0.44 to 1.76 cm) showed significant positive correlation with water temperature (r = 0.41) and significant negative correlation with ammonium nitrogen(r = 0.62).The concentration of orthophosphate in the water of the lagoon varies from 0.09 to 0.65 mg l^{-1}. It increases upstream because of the prevailing agricultural effluents to the environment of the lagoon and the livestock are the main socio-economic activities. Indeed, in the irrigated valley Massa, 700 ha are devoted to vegetables and banana. The lagoon is eutrophic and shallow Ruggiero et al. (2004) note that in this type of ecosystem, the availability of phosphorus is mainly determined by the internal load of this element in the sediment and its mobility in the sediment depends on oxygen and redox potential. Suspended solids are crucial in the biogeochemical cycle of many pollutants in aquatic systems by limiting the chemical exchanges between the dissolved and particulate (Maldiney and Mouchel, 1995). The values fluctuated between 272.97 to 50 mg l^{-1}. Indeed, the ammonium ion content of the lagoon shows a decreasing gradient of the site 1 to 3 fluctuated between 0.1 to 2.05 mg l^{-1}. That is the excretions of shorebirds that are very abundant in the site1. Concentrations of chlorophyll a vary from 20 to 76.33 mg/m^3 which are due to significant development of algae. Comparison with other similar ecosystems indicates that the lagoon Massa levels of chlorophyll a were similar to that found in the Nador lagoon by Lefebvre et al. (1993). The evaluation of the trophic level of the Massa lagoon by model O. C D. E, class lagoon in a hyper-eutrophic state.

Zooplankton community

Zooplankton community: data represented in Table 2 reveals that greatest number of zooplankton were noted 54 species at Site 3, followed by Site 4 (45), Site 2 (37).

In the three stations, the rotifers form the bulk of the zooplankton population and they represent respectively 62, 59 and 50% of the total abundance (Figure 2). The Copepods forming the second group of zooplankton a qualitative point of view with a large diversity at the third station (26%), to the detriment of Protozoa and Ostracods are poorly represented. This high species richness downstream, indicating a favorable environment for the successive development of several species.

Figure 4 has shown comparatively high values of temperature; nitrate, salinity and low values of pH and DO are responsible for relatively higher abundance of species of zooplankton at Site I and II. In Site III zooplankton population is less as compare to Site I and II may be less nutrient are available there. The relative contributions of abiotic factors have been determined in the spatiotemporal distribution of zooplankton species collected at three sites.

Abundance of zooplankton

The abundance of zooplankton is largely dominated during this study by Rotifers and Copepods. The average relative importance of the major taxonomic groups in the three sampling sites is presented in Figure 3 In general, the zooplankton population was very low. Densities of zooplankton ranged between 551 and 4217 organism l^{-1} (Figure 3). Rotifers ranged between 503and 4198 organism l^{-1} and were dominant always during the study. The densities of Copepods are low and fluctued between 18 and 76 organism l^{-1}(Figure 3).

Distribution of rotifers

Rotifers are the most important animal group belonging to the ecological niche of small filters (Margalef et al., 1983). Rotifers are able to ingest small particles such as bacteria and organic detritus often abundant in eutrophic environments. According to Margalef (1983) and Pace (1984), a strong representation of rotifers in aquatic freshwater can be considered as an indicator of high biological trophic level. Brachionides is the most dominant presence of the genus *Brachionus* which is common in tropical waters. Gannon and Stemberger

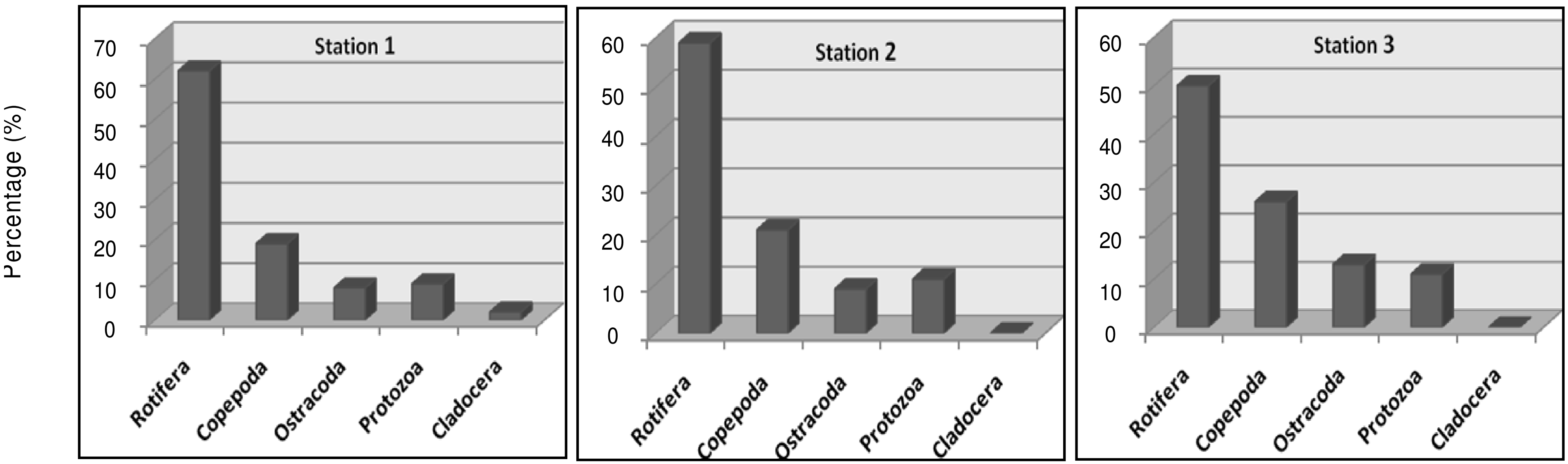

Figure 2. Relative importance of the abundance of the different zooplankton groups observed during the study in the Massa lagoon woks.

(1978), Sladecek (1983) and Maemets (1983), have established a relationship between a high number of species of the genus *Brachionus* and a high trophic level. In this study, *Brachionus plicatilis* (4198 org/l) was among the rotifers, the most common and quantitatively dominant species. These species are essentially herbivore which appears to corroborate the status assigned to hypereutrophic lagoon. Analysis of the stands at three stations to describe the composition and distribution of rotifers that are present in spring and are small numbers in summer and winter.

Overall, the rotifer appears to be continuing into the surface and, as pointed out, this is due to the wealth available algal surface, where chlorophyll a is important. Indeed one of the characteristics of the population of rotifers living in the lagoon is low fertility. There are one or two eggs, which may be a characteristic of eutrophic environments as already noted by several authors Lair et al. (1996); his feature would reflect the importance of using the detrital food despite a good use of algae food. The predominance of one Rotifer species was attributed to the fact that these organizations have a strategy (Amblard et al., 1998) they are opportunistic, small size, with short life cycles and high tolerance to a variety of environmental factors.

Distribution of copepods

In the Massa lagoon, the Copepods are poorly represented (Figure 3). *Halicyclops neglectus* which is a typical species of brackish coastal ponds and salt waters and supports a salinity of 34% according to Loffler (1961) in (Dussart, 1969) is always present during the study period with densities that exceed 38 org l^{-1}. The carnivore species copepod *Acanthocyclops robustus* (Geraldes and Boavida 2004) is dominant in spring with the high densities (57 org l^{-1}).

The Harpacticoida, with *Epactophanes richardi* species are present only at Site 3. It is, therefore, clear that there is a preference of these species to "low salinity" water. The literature calls them as species with wide ecological valence. The scarcity of Copepods is certainly not due to lack of food resources, but it could be attributed to the phenomenon of predation and competition with rotifers colonizing the environment throughout the study period with high densities (4200 org l^{-1}) and biomasses (178.36 µg. l^{-1}) which is calculated by the equations of length-weight regressions (Ruttner-Kolisko 1977).

The absence of oval females was noted. This is due to predation by larvae of the dipteran Chaoborus

Table 2. Occurrence of zooplankton sampling at three sites.+: Present - Absent

Nbr Species	1	2	3
Rotifera (35)	**33**	**26**	**20**
Ascomorpha sp	-	+	-
Asplanchna priodonta	+	+	+
Brachionus angularis	+	+	-
Brachionus calyciflorus	+	+	+
Brachionus caudatus	+	+	-
Brachionus leydigi	+	+	+
Brachionus plicatilis	+	+	+
Brachionus quadridentatatus	+	+	+
Brachionus rotundiformis	+	+	+
Brachionus rubens	+	+	+
Brachionus strita	+	+	-
Brachionus urceolaris	+	+	+
Cluniobicularis	-	+	+
Collotheca sp	+	+	+
Colurella sp	+	+	-
Eosophora	+	-	-
Epiphanes clavulata	+	-	-
Euchlanis sp	+	-	-
Gastropus sp	+	-	-
Hexarthra fennica	+	+	+
Hexarthra mira	+	+	+
Lecane inermis	+	-	+
Lecane luna	+	-	+
Lepadella patina	+	-	-
Notholca squamula	+	+	-
Philodina	+	+	+
Pompholyx complanata	+	+	+
Pompholyx solcata	+	-	-
Rotaria	+	+	+
Synchaeta lokowitziana	+	+	-
Synchaeta oblonga	+	+	+
Synchaeta pectinata.	+	+	+
Synchaeta stylata	+	-	+
Synchaeta tremula	+	+	-
Trichocerca rosea	+	+	-
Crustacea	**1**	**0**	**0**
Cladocera			
Daphnia longispina	+	-	-
Copepoda (13)	**10**	**9**	**7**
Acanthocyclops robustus	+	+	+
Calanus helgolandicus	+	+	-
Centropages typicus	+	+	-
Cryptocyclops bicolor	+	+	-
Epactophanes richardis	-	-	+
Eurytemora affinis	-	-	+
Halicyclops magniceps	+	+	+

Table 2. Contd.

Halicyclops neglectus	+	+	+
Macrocyclops albidus	+	+	+
Moraria sp	-	-	+
Oithona nana	+	+	-
Paracalanus typicus	+	-	-
Paracyclops fimbriatus	+	+	+
	1	**1**	**1**
Larvae (1)			
Nauplii	+	+	+
	4	**4**	**5**
Ostracoda (6)			
Cyprideis littoralis	+	+	+
Cypridopsis aculeata.	+	+	+
Cypridopsis vidua	+	+	+
Eucypris stagnalis	+	+	-
Hemicythere villosa	-	-	+
Herpetocypris chevreuxi	-	-	+
Protosoa (5)	**5**	**5**	**4**
Euplotes sp	+	+	+
Didinium sp	+	+	+
Zoothamnium sp	+	+	+
Vorticella sp	+	+	-
Codonella cratera	+	+	+

gender met at Station 3, which is a major predator of oval females, larger and more visible (Rabette and Lair, 1998).

Distribution of cladocera

The only species of Cladocera recorded at the site I was *Daphnia longispina*, which is very common in small collections of eutrophic water (Amoros, 1972) and very scarce in the media of high degree of eutrophication (Amengal, 1987).The scarcity of Cladocera is explained by the Planktivore predatory fish action inhabiting the lagoon as it has been demonstrated in several similar environments (Persson, 1988; Francisco, 1999) besides, increasing concentrations of suspended solids can block the filtering apparatus and impede their nutrition (Kirk et al., 1990).

Distribution of ostracoda

Ostracoda were recorded at all sites indicating that they are tolerant to the extreme environmental conditions prevailed in this region.

Statistical treatment of data

After logarithmic transformation of variables. The first and second axis of PCA accounted for 25, 35 and 19.7% of the total variance. The first factorial axis (PC1) stronglyassociated with chlorophyll a while the second factorial axis (PC2) closely related with nitrate nitrogen (Figure 4).

Total zooplankton density showed highly significant positive correlation with salinity ($r = 0.68$) so, the dynamics of zooplankton populations present in the Massa lagoon is controlled by this parameter. The selective effect of this parameter binding significantly reduces the richness and species diversity. Thus, the overall results of this study leads us to conclude that the salinity is, in conjunction with the resources, a factor in determining control and selectivity for the diversity and dynamics of plankton populations in Massa lagoon. A factorial axis 1 accounts for 34.02% of the total inertia and the factorial axis 2 accounts for 25.78% of the total inertia. The factorial axis 1 opposes spring in its positive side; in negative side opposes summer and winter.

The factorial axis 2 opposes spring and summer in its negative side (figure 5) and winter in positive side. The projection of both months and species in the factorial axes (Amengal, 1987; Amoros, 1972) shows that a

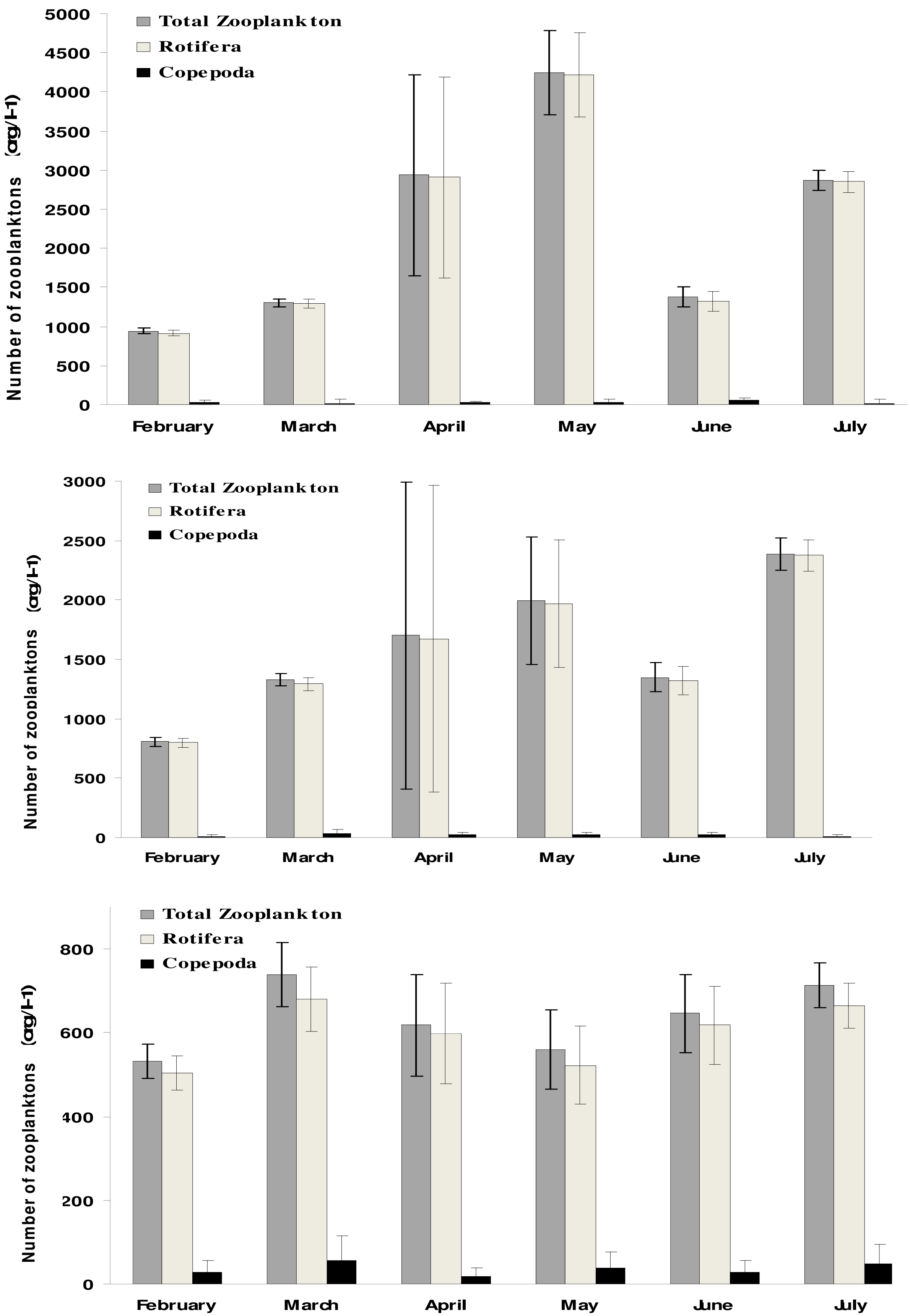

Figure 3. Average density of zooplankton groups (org/l^{-1}) determined in Massa lagoon during the study.

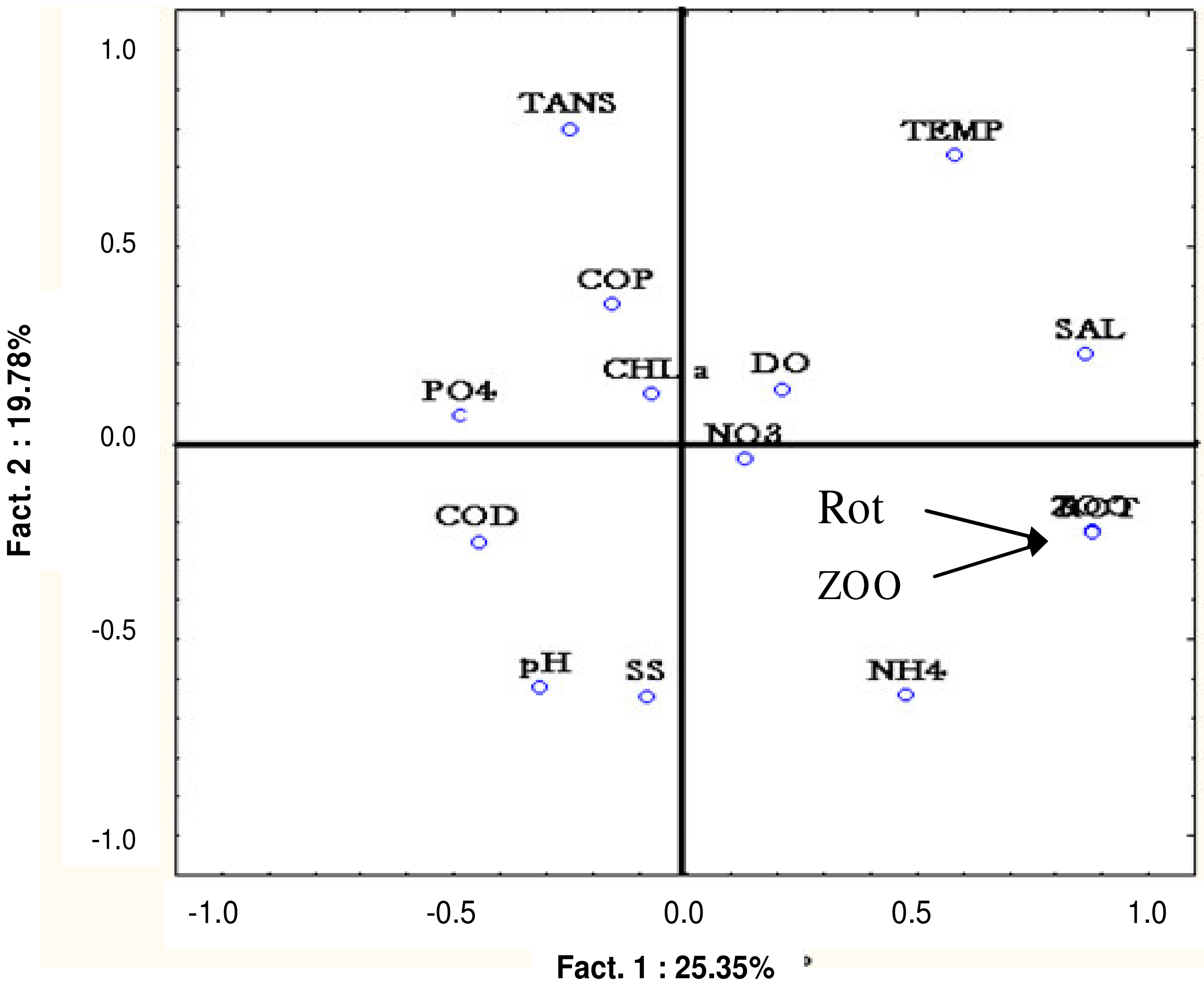

Figure 4. Principal Component Analysis (PCA) of physico-chemical variables and main total zooplankton. Abbreviations: CHL a; chlorophyll a, DO; dissolved oxygen, NH4; ammonium nitrogen, PO4; orthophosphates, COD; chemical oxygen demand, SS; Suspended solids,NO3; nitrate nitrogen, TRNS; nitrate nitrogen, TEMP; temperature, ZOO; total zooplankton. , Rot: Rotifer; COP: Copepod.

factorial axis opposes tree types of species: Spring represented by the following species Mv, Ns, R, Ar ,Pc and Li; summer with Ap , Sp and Er ; winter presented by Er, Ma, Ar and Bu. All other species namely: Bp, Hn, Ma, Er, and Bu are always present during the study period (Figure 5).

Conclusion

The analysis of physicochemical parameters indicates that certain environmental factors are essential to the operation and evolution of the closed lagoon of the biological reserve of Massa. These parameters include nutrients (nitrate, orthophosphates), dissolved oxygen, pH, and temperature.

Rotifers were the dominant zooplankton group most of the study period in Massa lagoon. The studies of the distribution of zooplankton population in the three stations are characterized by the importance of rotifers that are better represented. The zooplankton is represented by a majority of smaller species of rotifers dominated in abundance and they contribute to a large share in the total zooplankton biomass. This illustrates their role and their importance in energy transfer. This rich zooplankton may be a source of important food for wading birds and sedentary abundant downstream. A better understanding of the structure, evolution and functioning of the aquatic and natural ecosystem is certainly a better preservation of biodiversity. The interactions between the components of biodiversity are fundamental to the understanding of how this ecosystem functions. Our study is still to be continued to better understand the structure,

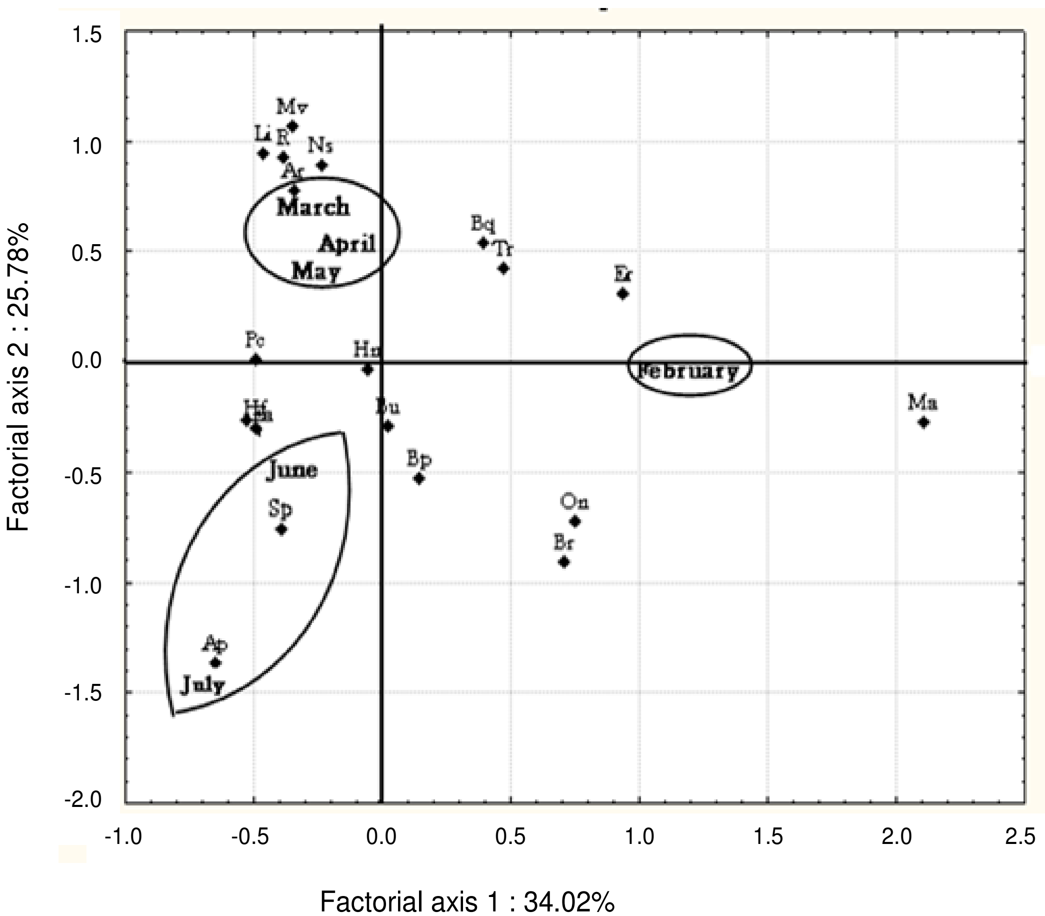

Figure 5. Plan [1-2] species and months of the correspondence analysis performed on the matrix composed of 48 species (rotifers and copepods) and 6 records (months).

functioning and ecology of zooplankton community of the biological reserve of Massa.

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