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# PHYSICAL, CHEMICAL, AND BIOTIC INFLUENCES ON ZOOPLANKTON COMPOSITION IN ZARANIK LAGOON, EGYPT

## SUMMARY

Zaranik Protected Area encompasses the eastern end of Lake Bardawil: the Zaranik Lagoon. The lagoon is shallow, with numerous small islets scattered throughout it, most of which are covered with dense saltmarsh vegetation. Nitrogenous and phosphorus forms (ammonia, nitrite, nitrate, orthophosphate and total phosphorus) were studied as a basic nutrient salts affected different flora and fauna of the studied area. Nitrite was depleted completely during the study period except for winter. The nitrate values were fluctuated in a relatively narrow range (23.5 – 60 $\mu$g/l). Ammonia was detected in a normal range varied between 89-172 $\mu$g/l. Both orthophosphate and total phosphorus exhibit similar distribution dynamics. A total of 45 zooplankton species belonging to 9 main groups (Protista, Copepoda, Rotifera, Cladocera, Pteropoda, Cheatognatha, Cnidaria, Appendiculariae, and meroplankton) were recorded. Copepoda were the most abundant and ubiquitous zooplankton organisms in Zaranik protectorate, forming the 63 % of total zooplankton density. Salinity showed a negative correlation with total Protista (r = - 0.77) while $NH_3$ showed a positive correlation with total zooplankton (r = 0.68).

## INTRODUCTION

Coastal lagoons are naturally stressed systems with frequent environmental disturbances and fluctuations (Barnes, 1980; Kjerfve, 1994) and they are usually considered as physically controlled ecosystems (Sanders, 1968). As transition media between land and sea, they play a filter role with respect to materials coming from their catchment's area, which makes these ecosystems particularly sensitive to upstream dysfunctions (Plus *et a*l., 2006). They are considered as extremely important to human society and very attractive for transport purposes and human settlement (De Jonge *et al.*, 2002). Coastal lagoons support fisheries, aquaculture, tourism and recreation activities, as well as intense agriculture on their watersheds (Gilabert, 2001). Coastal lagoons are characterized by shallow depths and they are partially isolated from the open sea by coastal barriers that maintain some communication channels or inlets. Due to shallowness, light penetration at the sediment-water interface is usually high. Hydrodynamics is conditioned by bottom topography and wind affects the entire water column promoting the resuspension of materials, nutrients and small organisms from the sediment surface layer. Overall, coastal lagoons are composed by a high number of physical and ecological boundaries and gradients – between water and sediment, pelagic and benthic assemblages (Perez-Ruzafa *et al.*, 2005).

Hyper-saline coastal lagoons are confined systems with a negative water balance when evaporation exceeds freshwater input, and the water balance is compensated by marine water supply. Under these conditions, and with moderate or low nutrient input, pelagic primary production tends to be low meanwhile benthic production supports the whole trophic webs (Souza *et al.*, 2003) and usually important fisheries (Perez-Ruzafa *et al.*, 2007). In recent years, nutrient supply to coastal areas has increased as a consequence of human activities, particularly affecting enclosed bays and lagoons (Kormas *et al.*, 2001; Muslim and Jones, 2003; Zaldivar *et al.*, 2003).

Various environmental (physico–chemical) gradients have been identified as determinants of the structure of aquatic invertebrate communities, including temperature and dissolved oxygen (Armengol *et al.*, 1998), pH (Schartau *et al.*, 2001), salinity (Drake et al., 2002; Vieira *et al.*, 2003), trophic state (Duggan *et al.*, 2002), or altitude (Jersabek *et al.*, 2001). The zooplankton communities, very sensitive to environmental modifications, are important indicators for evaluating the ecological status of these ecosystems (Magadza, 1994). The presence and the relative predominance of various copepod species have been used to characterize the eutrophication level of aquatic ecosystems (Park and Marshall, 2000; Bonecker *et al.*, 2001).

Although the great importance of Bardawil Lagoon (including Zaranik area), monitoring studies are still scarce. These few studies dealt with different environmental aspects of the lagoon including geological aspects, hydrological regime, physico-chemical properties, bacterial indices, phytoplankton composition, benthic invertebrates and fishery status (Levy, 1971; Ben-Tuvia, 1975 & 1979; Krumgalz *et al.*, 1980; Fouda and Wanas, 1987; Siliem 1988; Shehata, 1989; Lotfy, 2003; Ameran, 2004; Sabae, 2006; Farahat, 2006). The present study is the first one dedicated to the zooplankton community in Zaranik lagoon. On the other hand, little is known about the distribution and standing crop of zooplankton in Bardawil Lagoon as whole. Kimor (1975) conducted preliminary studies on the plankton, while Fouda *et al.* (1985) listed 87 zooplankton species and mentioned that some species were widely distributed, while the others had been confined to certain localities. Ibrahim *et al*. (1987) included zooplankton in their studies on fishery and management of the lagoon. Recently, El-Shabrawy (2002, 2006) recorded 58 zooplankton species in Bardawil, winter was the season characterized by the highest standing crop. The dominant and common zooplankton species of Fouda et al. (1985), *Tintinnopsis labiancoi* (Ciliophora), and *Acartia clausii* (Copepoda) were replaced by *T. tocantinensis* (Ciliophora), and *Oithona nana* (Copepoda) in 2006. Mageed (2006) reported that zooplankton abundance peaked during August and October while severe depletion occurred in spring.

In this paper, temporal changes in climatic, major ions and nutrients, in the Zaranik protectorate are analyzed in relation to zooplankton assemblages. The main aim is to detect the relationships between hydrological, climatic and biological factors.

## MATERIALS AND METHODS

### Study site

Zaranik is the second oldest protected area in Egypt, established by the Egyptian Government in 1983 and was designated a wetland nature reserve under the International Ramsar convention in 1988. It represents the bottleneck for migratory and resident birds on Mediterranean coast (Salama and Grieve, 1996). As part of Lake Bardawil, the site encompasses a relatively large number of unique aquatic and terrestrial habitat types, which are almost entirely pristine. It is located at the E end of Lake Bardawil on the Mediterranean coast of Sinai. The Protected Area is bordered from the N by the Mediterranean, from the S by the main Qantara - El Arish road, from the E by tourist development areas, and from the W by Lake Bardawil. Its area covers about 250 $Km^2$ (68% water surface and 32% sand dunes). Its altitude ranges from 0 to 30 m above the sea level. The watery part of Zaranik area has three natural openings with the Mediterranean Sea called *Boughazes*. These three inlets are mostly closed around the year due to sand dunes movements. Bardawil Lake including Zaranik area is the cleanest marine oligotrophic water body in the Country, and the largest hypersaline mud flat (known as sabkhat El-Bardawil). These habitat types are home for a wide variety of rare and endemic species of fauna and flora.

Lake Bardawil (including Zaranik area) climate is arid; the Emberger's degree of aridity is about 13.6 (Shaheen, 1998). Annual precipitation averages 82 mm with high variability, and usually extends from October to May (Zahran and Willis, 1992). The monthly average relative humidity varies between 68 and 74% with an annual mean of 72% (El-Bana, *et el.*, 2002). The main soil types are: (i) loose sand which provides little support for the root system of a few small herbaceous plants (e.g. *Lotus halophilus, Moltkiopsis ciliata, Silene villosa*), (ii) compact calcareous sand supporting a few bushy species (e.g. *Retama raetam*, *Calligonum polygonoides, Tamatix amplexicaulis, Phragmites australis*), and (iii) hypersaline mud with a characteristic vegetation of halophilic plants (e.g. *Zygophyllum aegyptium, Zygophyllum album, Suaeda vera*). The bottom sediment of the open water area in the Protectorate is predominantly sandy with areas of mud and supports the three species of see grasses *Cymodocea nodosa, Halodule uninervis* and *Ruppia cirrhosa* (Kassas *et al*., 2002).

**Sampling procedure**

The sampling program was based on four seasonal cruises conducted from February 2005 (winter) to November 2005 (Autumn). Three stations were selected in Zaranik protectorate area. The first station was located near the concentration ponds of El-Nasr Salt Company, the second was located in front of the natural *boughaz* in the E side, while the third was located at the W part (Fig. 1).

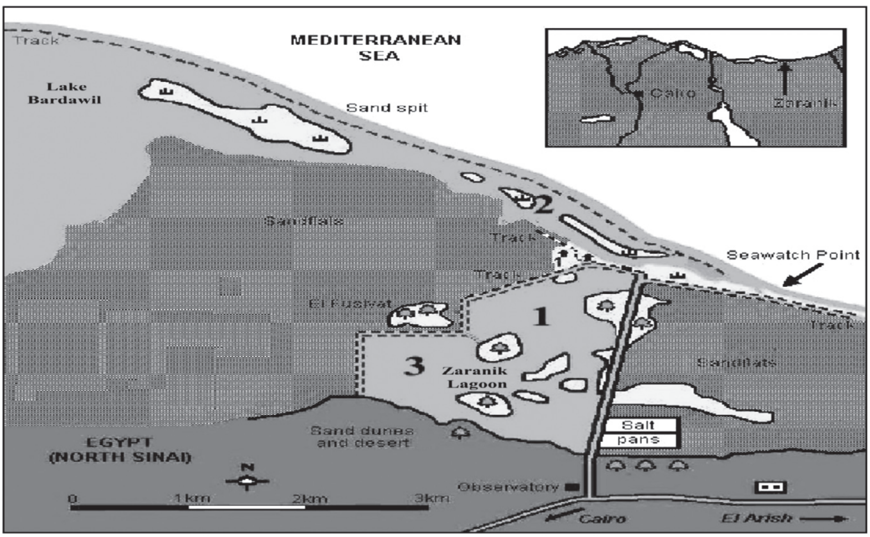



Fig. 1 - Map for Zaranik lagoon showing the selected stations.

Integrated Zooplankton samples were collected, towing vertically a net with 32 cm of diameter and 55 $\mu$m mesh size net. The net was lowered to the bottom and hauled vertically to the surface at a uniform speed. In addition, qualitative samples were taken from each station. Samples were preserved immediately after collection in 4 % formalin solution. In the laboratory, samples were made up to a standard volume (100 ml). Sub-samples (1-3 ml) were used for enumeration by aid of binocular microscope. The major groups of zooplankton (Protozoa, Copepoda, Cladocera, Meroplankton) were submitted to detailed analysis.

### Physical and Chemical Analyses

The methods indicated in the American Public Health Association (APHA, 1992) were used for the determination of the abiotic parameters. Total dissolved solids, electrical conductivity, salinity, and pH were measured *in situ* by using an automatic probe (Hydrolab Multi Set 430i WTW) after previous calibration. COD was carried out using potassium permanganate method. Water alkalinity was determined immediately after sampling collection using phenolphthalein and methyl orange indicators. Chlorosity was measured using Mohr's method. Ca and Mg were determined by direct titration using EDTA solution, while Na and K were determined using flame photometry (Jenway Felsted Gi Dunmow Essex). Ammonia was determined by phenate method. Nitrite was determined using colorimetric method. Nitrate was determined by reduction method as described by MULLIN and RILEY (1956). Orthophosphate and total P were determined by using stannous chloride and acid molybdate method as described in (APHA, 1992).

### Statistical analysis

Regression analysis between some environmental variables and the zooplankton species were calculated using STAT_5 program version 5.1.

## RESULTS

### Physical Parameters

During the study period, water temperature ranged from 12.5°C (Winter, station 1) to 32.2 °C (Summer, station 3) with an overall average of 21.2 °C (Table I, Fig. 2). The shallowness of the basin did not allow any thermal stratification of the water column.

Water salinity varied in a narrow range, fluctuating between 44.5 ‰ (Winter, station 3) and 48.7 ‰ (Summer, station 1) (Fig. 2). In any case salinity was higher than that of the Mediterranean Sea due the continue obstruction of natural opening (*Boughazes*).

Total dissolved solids showed a distribution pattern similar to salinity. The TDS values varied between 45.9 at (Autumn, station 2) and 52.1 (Summer, station 3) with a total average of 49.5 ± 2.2 g/l (Fig. 2). Conductivity varied slightly between 61.7 - 71.2 with a total average of 67.9 ± 2.7 mS/cm (Table I).

### Chemical Parameters

Water of Zaranik protectorate area lies in the alkaline side (8.1 - 8.4). Station 1 showed the lowest pH value in Summer, while station 3 showed the maximum value in Spring (Fig. 2).

Chemical Oxygen demand is an indicator of organic pollution. The recorded values were low and showed narrow fluctuation range. The maximum value (7.6 mg/l) was recorded at station 3 (Autumn), while the minimum value (4.4 mg/l) occurred at station 2 (Autumn) (Fig. 2).

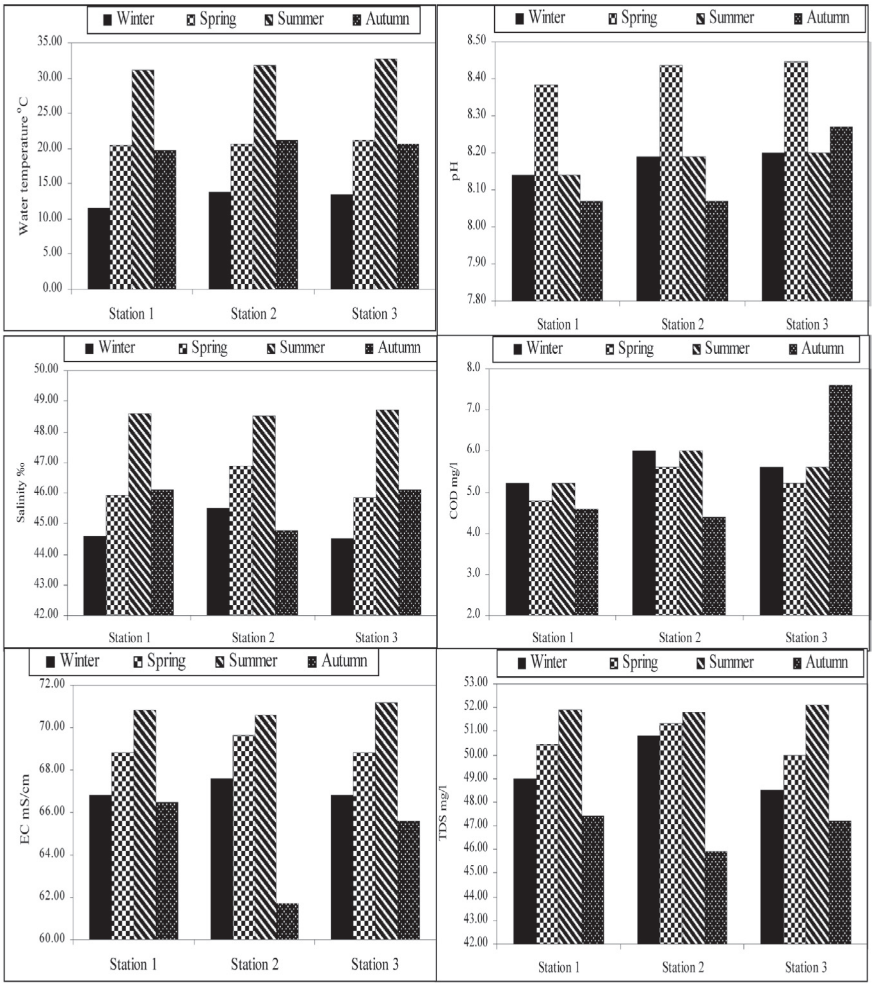



Fig. 2 - Seasonal variations of some physical and chemical parameters in Zaranik lagoon.

## Major ions

Carbonates were recorded only during Autumn. Bicarbonates peaked (187 mg/l) at station 1 (Spring) while the lowest value (112 mg/l) was recorded at station 2 (Autumn). Both sulphate and chloride concentrations exhibit a similar trend, showing their highest values (4.9 and 28.2 g/l) at station 3 (Summer), while their minimum values were recorded at station 1 (4.3 and 25.1 g/l) (Autumn) (Fig. 3).

The highest Ca value (850 mg/l) was recorded at station 2 during summer while the minimum one (625 mg/l) took place during autumn in the same station (Table 2). Mg, Na, and K ions showed their highest values (2.18 g/l, 16.65 g/l and

Table 1 - Range, annual mean ± stamdard deviation of some physical and chemical variables in Bardawil and Zaranik Lagoons

| | Bardawil lagoon (After Ali, 2006) | | | | Zaranik lagoon (Present study) | | | |
|---|---|---|---|---|---|---|---|---|
| | Range | Mean | ± | SD | Range | Mean | ± | SD |
| W. Temp. (0C) | 11. 6 – 32.8 | 21.5 | ± | 6.5 | 12.5 - 32.2 | 21.2 | ± | 6.6 |
| TDS (g/l) | 38.9 – 75.3 | 53.3 | ± | 2.7 | 45.9 – 52.1 | 49.7 | ± | 2.1 |
| EC mS/cm | 50.8 – 110.2 | 70.7 | ± | 3.1 | 61.7 – 71.2 | 67.9 | ± | 2.7 |
| Sal. (‰) | 38.5 – 74.5 | 50.9 | ± | 2.9 | 44.5 – 48.7 | 46.3 | ± | 1.5 |
| pH values | 7.94 – 8.80 | 8.4 | ± | 0.2 | 8.1 – 8.4 | 8.2 | ± | 0.1 |
| Dissolved oxygen (mg/l) | 4.8 – 10.2 | 7.3 | ± | 0.9 | 5.7 - 9.0 | 7.5 | ± | 1.2 |
| Biological oxygen demand (mg/l) | 1.2 – 6.5 | 2.9 | ± | 1 | 1.6 - 4.6 | 2.9 | ± | 1.1 |
| Chemical oxygen demand (mg/l) | 2.1 – 9.2 | 5.2 | ± | 0.4 | 4.4 – 7.6 | 5.5 | ± | 0.8 |
| Carbonate (mg/l) | 0.0 - 40 | 8.1 | ± | 6.4 | 0 – 18 | 3.8 | ± | 3 |
| Bicarbonate (mg/l) | 120 - 220 | 169 | ± | 18.7 | 112 – 187.2 | 163.7 | ± | 23.2 |
| Chloride (g/l) | 22 – 46 | 28.2 | ± | 1.9 | 25.1 – 28.2 | 26.6 | ± | 1 |
| Sulphate (g/l) | 2.9 – 6.6 | 4.9 | ± | 0.5 | 4.3 – 4.9 | 4.6 | ± | 0.2 |
| Calcium (mg/l) | 441 - 1202 | 754 | ± | 38 | 625 – 850 | 732.5 | ± | 73.4 |
| Magnesium (g/l) | 1.53 – 3.11 | 2.11 | ± | 0.17 | 1.9 – 2.18 | 2 | ± | 0.1 |
| Sodium (g/l) | 12.1 – 25.3 | 15.9 | ± | 0.9 | 14.9 – 16.6 | 15.8 | ± | 0.5 |
| Potassium (mg/l) | 381 - 1032 | 603 | ± | 39 | 545 – 666.3 | 619.8 | ± | 33.2 |
| Nitrite (μg/l) | 0.0 – 19.2 | 4.5 | ± | 3.3 | 0 – 18.9 | 4.4 | ± | 1.8 |
| Nitrate (μg/l) | 13 - 89 | 42 | ± | 15 | 23.5 – 60 | 43.5 | ± | 11.5 |
| Ammonia (μg/l) | 9 - 138 | 48 | ± | 11 | 89 – 172.5 | 118.1 | ± | 27.4 |
| Ortho-phosphate (μg/l) | 10-90 | 35 | ± | 12 | 19 – 34 | 27.9 | ± | 5.7 |
| Total phosphorus (μg/l) | 64 –382 | 110 | ± | 63.5 | 70–99 | 84.8 | ± | 11.2 |
| Reactive silicate (mg/l) | 0.3 – 3.08 | 1.01 | ± | 0.5 | 1.1 – 1.9 | 1.5 | ± | 0.2 |

666 mg/l respectively) in spring at station 2 while their minimum values (1.9 g/l, 14.9 g/l and 545 mg/l) occurred during autumn at the same station as a result of intrusion of the sea water from the natural *Boughaz* at this station (Fig. 3).

## Basic nutrient salts

Nitrite was detected only during Winter (Fig. 4). The nitrate values showed a normal distribution pattern during the investigated period and fluctuated in a relatively narrow range (23.5 – 60 $\mu$g/l) with an overall mean of 43.5 ± 11.5 $\mu$g/l. Summer showed the highest values of nitrate at all investigated stations (Fig. 4). Ammonia was detected in a normal range varying slightly between minimum value (89 $\mu$g/l) recorded at station 1 (Summer) and maximum (172 $\mu$g/l) recorded at the same station in Autumn (Fig. 4). Both orthophosphate and total P exhibit similar distribution dynamics. However, their minima (19 and 70 $\mu$g/l) were found at station 1 (Winter), while their maxima (34 and 99 $\mu$g/l) were found during Summer at station 3 (Fig. 4). Reactive silicate fluctuated between 1.1 to 1.9 mg/l, the minimum value was recorded at station 2 during Autumn, while the maximum one was recorded at station 1 during Spring (Fig. 4).

## Zooplankton

A total of 45 zooplankton *taxa* belonging to 9 main groups (Protozoa, Copepoda, Rotifera, Cladocera, Pteropods, Chaetognatha, Cnidaria, Appendiculariae, and

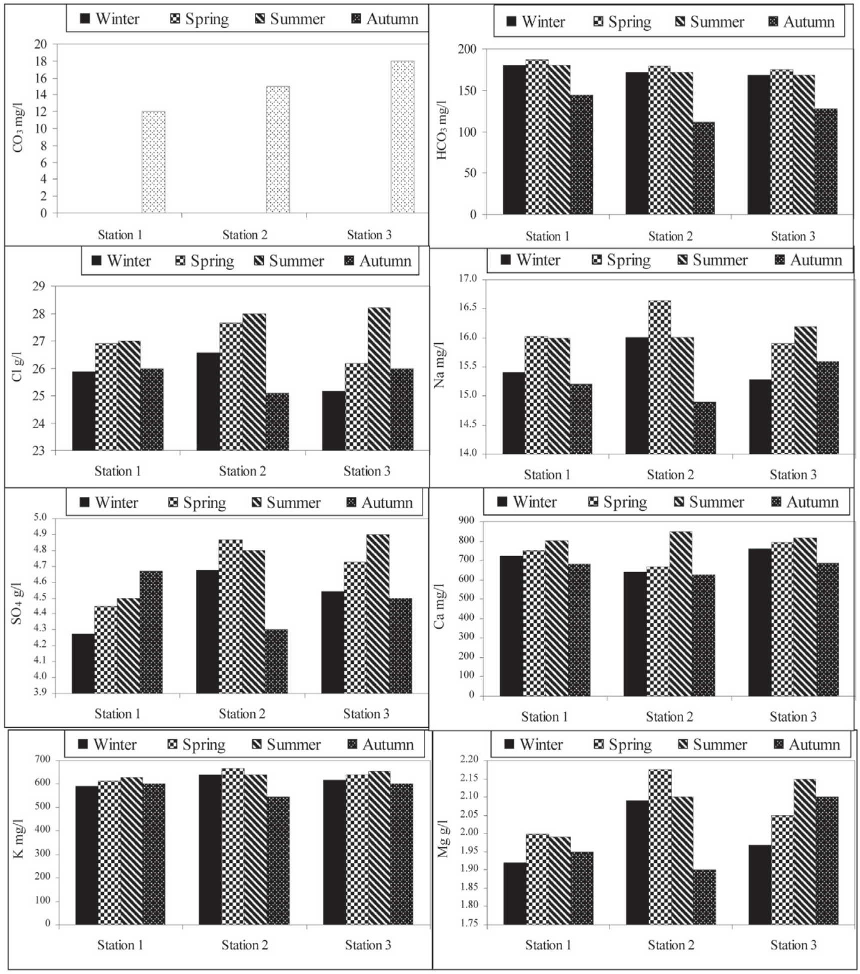



Fig. 3 - Seasonal variations of major anions and cations in Zaranik lagoon.

meroplankton) were recorded (Table II). Regarding seasonal variation, a gradual increase in zooplankton standing crop was measured from 27,333 ind. $m^{-3}$ in Winter to 72,750 ind. $m^{-3}$ in Autumn, with a total average of 48,354 ind. $m^{-3}$ (Fig. 5).

Copepoda represented the most abundant and ubiquitous zooplankton group in Zaranik protectorate, forming 63 % of total zooplankton abundance. Autumn was the season of the highest abundance (52,750 ind. $m^{-3}$), while Winter showed the lowest density, with 9,167 ind. $m^{-3}$ (Fig. 5).

Copepoda nauplii dominated over copepodid and adult stages, contributing the 53 % of total copepod abundance (Fig. 6). *Oithona nana* dominated the adult

Table 2 - A list of zooplankton taxa recorded in Bardawil and Zaranik lagoons
* Present – Absent

| | Bardawil Lagoon | Zaranik Lagoon | | Bardawil Lagoon | Zaranik Lagoon |
|---|---|---|---|---|---|
| **Protozoa** | | | *Centropages ponticus* Karavaev | * | * |
| Ciliophora spp | * | – | *Oithona nana* Giesbrecht | * | * |
| *Codonella agalea* Haeckel | * | * | *Oithona plumifera* Baird | * | – |
| *Codonella amphorella* Biedermann | * | * | *Euterpina acutifrons* Dana | * | * |
| *Codonella aspera* Kofoid & Campbell | * | – | *Microsetella norvegica* Boeck | * | * |
| *Cyttarocylis plagiostoma* Kofoid & Campbell | * | – | *Canuella* sp. | * | – |
| *Dictyocysta obtusa* Jörgensen | * | * | *Harpacticus littoralis* Sars | * | * |
| *Epiplocylis acuminata (*Daday) Jörgensen | * | – | *Metis jousseaumei* Richard | * | – |
| *Favella ehrenbergi (*Clap & Lach.) Jörgensen | * | * | **Cladocera** | | |
| *Favella serrata (*Möbius) Jörgensen | * | * | *Evadne spinifera* Müller | * | * |
| *Helicostomella subulata* (Ehr.) | * | * | *Evadne tergestina* Claus | * | * |
| *Leprotintinnus bottnicus Narolgvist)* Jörgensen | * | * | *Podon polyphemoides* Leuckart | * | * |
| *Petalotricha major* Jörgensen | * | – | **Rotifera** | | |
| *Ptychocylis minor* Jörgensen | * | – | *Synchaeta calva* Ruttner-Kolosko | * | * |
| *Rhobdonella elegans* Jörgensen | * | * | *Synchaeta* sp | * | – |
| *Stenosemella nivalis (*Meunier*)* Kofoid & Campbell | * | * | **Coelentrates** | | |
| *Tintinnopsis campanula (*Ehr.) Daday | * | | *Rhizostoma pulmo Merci.* | * | * |
| *Tintinnopsis cylindrica* Daday | * | * | *Obelia* spp | * | * |
| *Tintinnopsis lobiancoi* Daday | * | * | **Pteropods** | | |
| *Tintinnopsis nucula (*Fol) Brandt | * | * | *Limacina inflata* D'orbigng | * | * |
| *Tintinnopsis beroidea* Stein | * | * | **Cheatognatha** | | |
| *Tintinnopsis tocantinensis* Kofoid & Campbell | * | * | *Sagitta setosa* Müller | * | * |
| *Undella* sp. | * | * | **Appendicularians** | | |
| **Foraminifera** | | | *Oikopleura longicauda* Vogt | * | * |
| *Orbilina universa* d'Orbigny | * | * | **Meroplankton** | | |
| **Copepoda** | | | Polycheate larvae | * | * |
| Nauplius larvae | * | * | Cirripedie larvae | * | * |
| Cyclopoid copepodid | * | * | Mollusca larvae | * | * |
| Calanoid copepodid | * | * | Echinodermats larvae | * | * |
| Harpacticoid copepodid | * | * | Ostracod spp | * | * |
| *Acartia clausii* Giesbrecht | * | * | *Chironomus* larvae | * | * |
| *Paracartia latisetosa* Krica. | * | * | *Mysis* sp | * | – |
| *Eurytemora hirunoloides* Nordqvist | * | – | Osteichthyes egg & Embryos | * | * |
| *Paracalanus parvus* Claus | * | * | Nematoda free living | * | * |

Copepoda with a maximum density of 6,000 ind. m$^{-3}$ in Spring, while it was weakly represented in Winter. *Acartia clausi*, *Paracalanus parvus*, *Euterpina acutiforns* were commonly recorded in Autumn (Fig. 6).

In the present study Protista were the second abundant and common group, forming 21 % of total zooplankton abundance. 15 protozoan species were identified. As shown in Fig. 7, the standing crop of these organisms reached a maximum in Winter (16,000 ind. m$^{-3}$) while the lowest standing crop occurred in Summer (1,333 ind. m$^{-3}$). *Tintinnopsis beroidea, T. bitschlii* and *Favella serrata* were the most abundant species.

Meroplankton, composed by larvae of benthic organisms, represented 9 % of total zooplankton abundance. Autumn was the season of the highest production

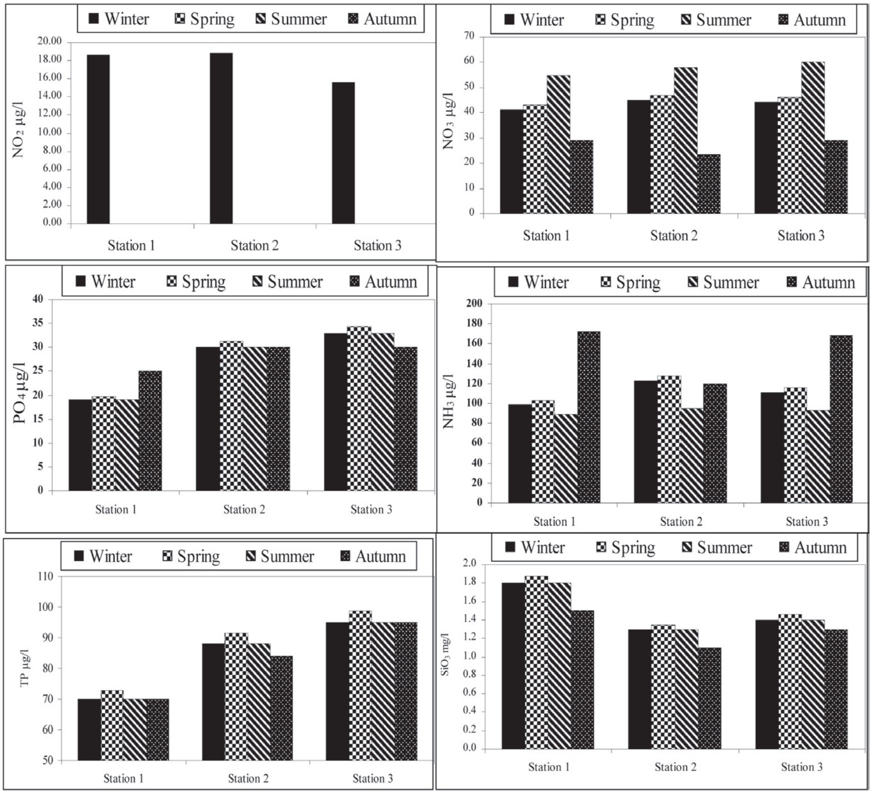



Fig. 4 - Seasonal variations in nutrient concentrations in Zaranik lagoon.

(Avr. 5,750 ind. $m^{-3}$), with Mollusca veliger dominating on the others. The lowest crop occurred in winter with a mean of 1,667 ind. $m^{-3}$ (Fig. 8), when Cirripedia larvae dominated. Summer meroplankton was dominated by Chironomidae larvae.

Regression analysis showed a negative correlation between salinity, electric conductivity, sulphate and calcium and total protozoa (r = -0.77, -0.57, -0.55 and -0.59, respectively), while nitrite was positively correlated with protozoa (r = 0.72). Carbonate and ammonia shows a positive relation with total zooplankton and copepoda (r = 0.68) and vice versa for nitrite (r = -0.54 and -0.6, repectively) (Fig. 9).

## DISCUSSION

Coastal lagoons represent a tiny part (less than 1%) of the world oceans, but they are nonetheless characterized by intense primary production, from 200 to 400 $gC.m^{-2}.y^{-1}$ according to Nixon (1982), that lead to both ecological and economical considerable importance. The prominent role of zooplankton in marine pelagic systems due to their trophic and biogeochemical position justifies the historical interest to study their distribution and community structure as a major issue in Oceanography. The feeding activity of zooplankton has crucial biogeochemical implications in the recycling of nutrient and the export of particulate matter (BANSE, 1995; TURNER, 2002); in addition, as a major food source for larval and juvenile

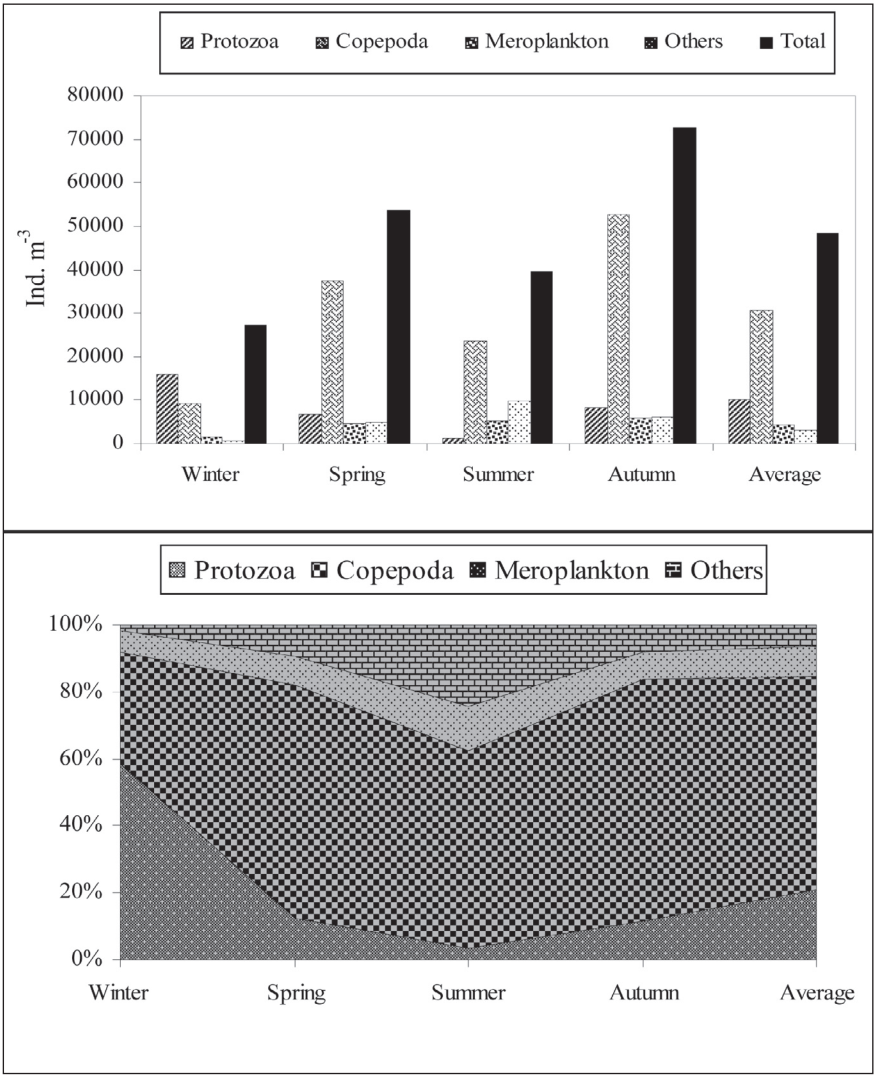
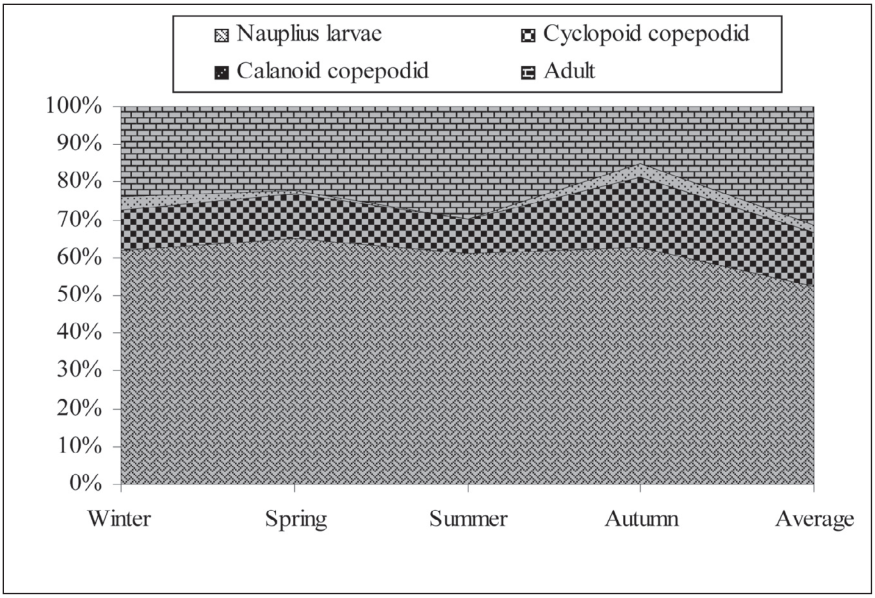



Fig. 5 - Seasonal variation and Community composition of total zooplankton.



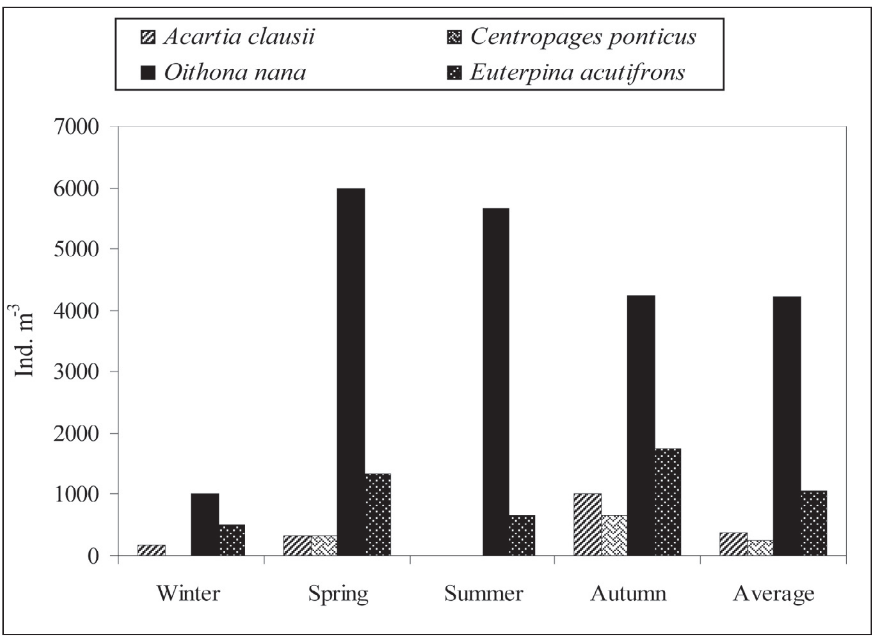




Fig. 6 - Community composition of Copepoda and their dominant species.

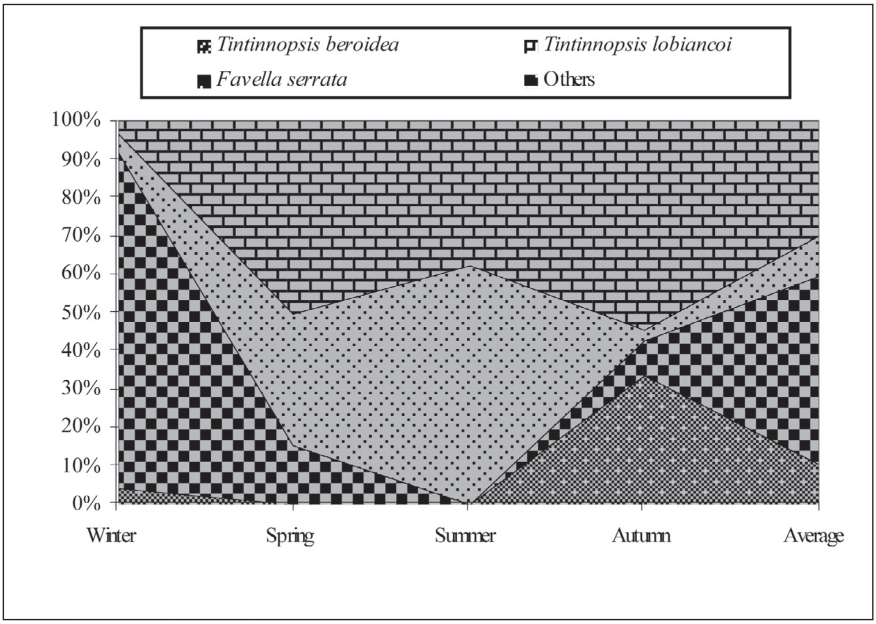



Fig. 7 - Percentage frequency of protozoa.

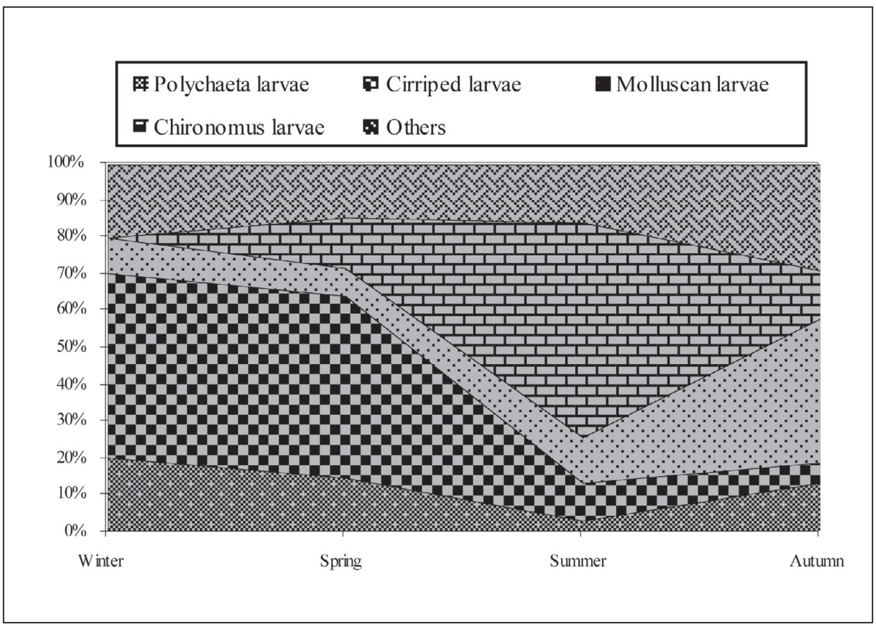



Fig. 8 - Percentage frequency of Meroplankton.

fish, the zooplankton grazing establishes the fraction of primary production able to reach upper consumer levels (Cushing, 1989). The seasonal variation in species composition and abundance of zooplankton is a result of the combined effects of physical and chemical properties of the lagoon water.

Physical gradients within the lagoon environment derived from such exchange rates have also been related to biological gradients in species richness, abundance and productivity. In the early 1980's, Guelorget and Perthuisot (1983) and Guelorget *et al*. (1983) rejected salinity as an essential parameter for explaining the observed gradients in density, biomass, species richness or diversity and proposed that zonation patterns and species distribution inside the lagoons be determined by confinement, a parameter which represents the turnover time for marine waters and impoverishment in some oligo-elements of a marine origin. Later, Perez-Ruzafa and Marcos (1992) suggested that, instead of the recycling of vitamins and oligo-elements, the main factor explaining the lagoon assemblage structure in a confinement gradient would be that of colonization rates by species of marine affinity. The species composition at each lagoon site would be the result of equilibrium in the context of site-specific competition between marine and lagoon species, taking into account that low competition coefficients for alloctonous species may be compensated by high immigration rates from outer habitats (Gascon *et al*., 2008).

Salinity (and its relationship to temperature) has been considered to be the main environmental structuring factor in lagoon habitats (Barnes 1980; Coull 1985; Santos *et al*., 1996). This is supported here as the distributional pattern of the zooplankton community, in the four seasons over the sampling period. Distance from the sea appears in all seasons to be a prominent factor in explaining the gradients of the zooplankton community. The theory of 'confinement', which is related to the rate of exchanges with the open sea and the hydrodynamic pattern of the basin (Guelorget and Perthuisot 1983), has been successfully applied to lagoonal ecosystems for the explanation of the structure of zooplankton. In Zaranik Lagoon, salinity shows a negative correlation with total protozoa (r = -0.77) (Fig. 9).

Food, both in its raw nutrient forms (ammonia, nitrate, phosphate) and as organic material and phytoplankton, was found to play an important role in zooplankton distribution in Zaranik lagoon throughout the year. Research has shown that nutrient limitation in lagoons is a complex matter; in particular nitrogen limitation is important (Nixon 1982; Taylor *et a*l., 1995). During the spring and autumn, raw nutrients are more important in Zaranik, reflecting the growth stage of zooplankton food (bacteria, microphytoplankton) and perhaps limiting distribution and density. $NH_3$ showed a positive correlation with total zooplankton (r = 0.68), while Protista were positively correlated with $NO_2$ (r = 0.72). Contrarily, $NO_2$ was negatively correlated with total zooplankton, Copepoda and *Oithona nana* (r = -0.54, -0.60, and -0.60) (Fig. 9).

Abundance, production, size and nature of phytoplankton cells available for feeding are also known to strongly affect the dynamics of zooplankton communities

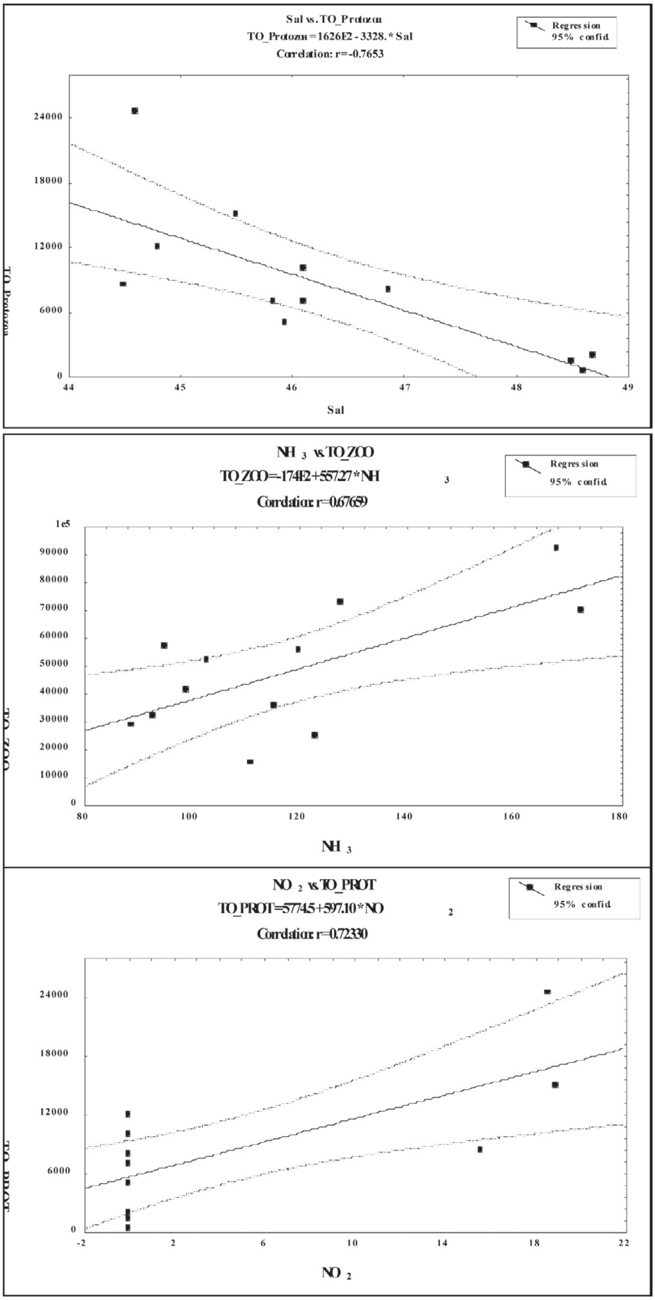



Fig. 9 - Regression analysis between some physico-chemical variable and zooplankton.

(Mauchline, 1998). In Bardawil Lagoon, 241 phytoplankton species were recorded (159 diatoms, 53 dinoflagellates. 15 cyanophytes, 8 chlorophytes, and 4 chrysophytes) (Touliabah *et al.*, 2002). During the period from 1969 till 2002, diatoms were the most important group in Bardawil Lagoon. They constituted more than 60% of the total phytoplankton species and 30% of its abundance (Taha 1990; Touliabah *et al.*, 2002 ). Recently, *Campylostylus striatus* became a perennial and abundant species (Saad, 2006). This species prefers unpolluted water and has been used as an indicator of oligotrophic or beta-mesotrophic conditions (Kolwitz and Marsson, 1950). Moreover, the species *Fragilaria crotonensis*, *Licmophora flabellata*, *Cocconeis bardawilensis* and *Synedra* sp. became abundant species (Saad, 2006). On the other side, the *Nitzschiaceae* species decreased in number and density (Saad, *op. cit.*).

Predation by planktivorous fishes plays a key role in structuring the zooplankton community, especially with respect to size structure, since prey selection is typically size dependent (Brooks and Dodson, 1965). Thus when fish predation pressure increases, the largest zooplankton species are removed from the community allowing the smallest ones to dominate (Brooks and Dodson, 1965; Vanni 1986). In shallow waters, fish predation usually exerts a strong influence on the size structure but also on the taxonomic composition of zooplankton (Jeppesen et al., 1997). Macroinvertebrate predation may also significantly affected zooplankton species composition and size distribution, especially when planktivorous fishes are reduced or removed (Hampton and Gilbert, 2001). Sixty species of fishes were collected from Bardawil lagoon during 1970s, but recently (Khalil and Mehanna, 2006), 44 species only were listed. The Red Sea origin fishes in Bardawil constitute about 25% of the total recorded species. The common commercial fishes of the Bardawil Lagoon are the gilthead bream (*Sparus aurata*), grey mullets (Mugilidae), the sea bass (*Dicentrarchus labrax*), the common sole (*Solea solea*), and crustaceans (shrimps and crabs) (Khalil and Mehanna, op cit). The common commercial fishes of the Bardawil Lagoon are the gilthead bream (*Sparus aurata*), grey mullets (Mugilidae), the sea bass (*Dicentrarchus labrax*) and the common sole (*Solea solea*). Zooplankton shared with 11, 16, 28, and 35% of the food content of *Metapenaeus stebbingi*, *Chelon labrosus*, *Mugil cephalus* and *Liza saliens* in Bardawil Lagoon (El-shabrawy, not published information).

Generally, the concentrations of major anion, cation and nutrient (calcium, potassium & total phosphorus in particularly) were obviously higher in Zaranik lagoon (range 441-1020, 381-1032 & 64-382) than Bardawil (range 625-850, 545-666 & 70-99), the presence of three natural opening Boughaze in this small area may be the main reason. On the other hand ammonia shows a reverse trends. The abundance and diversity of zooplankton in Bardawil lagoon (58 species with 107000 ind. $m^{-3}$) were noticeably higher than the corresponding values (44 species with 44000 ind. $m^{-3}$) in Zaranik. High concentrations of nutrient, major cation and anon may be the main reason.

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