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SPATIO-TEMPORAL VARIATIONS OF ZOOPLANKTON COMMUNITY IN THE HYPERSALINE LAGOON OF BARDAWIL, NORTH SINAI – EGYPT

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ABSTRACT

Bardawil Lagoon is a shallow oligotrophic hypersaline lake, located at the northern periphery of Sinai peninsula-Egypt, connected to SE Mediterranean Sea through two main openings known as Boughazes. Distribution of zooplankton in Bardawil Lagoon during 2004 was studied, not only in space and time but also with reference to species assemblages and environmental factors. Copepoda, Protozoa, and Mollusca were dominating the lagoon zooplankton community during the period of study with 58 identified forma. Zooplankton stock peaked during August and October with severe depletion in spring. Spatially, the maximum density occurred near the sea opening I. The lowest density and species richness were noticed at stations with high salinity. The community composition was highly changed with time series. Twenty new taxa were recorded during the study, whereas thirty three taxa disappeared from the lagoon along twenty years

1. INTRODUCTION

Bardawil Lagoon is a large hypersaline coastal lagoon on the Mediterranean coast of Sinai, Egypt. Although it is shallow and oligotrophic (Touliabah *et al*., 2002), it is one of the most important lakes in Egypt as a source of good quality fish and a habitat for wildlife.

The significance of Bardawil Lagoon fisheries lies not only in the supply of fish for regional domestic consumption (3,300 tons in 2003), but especially in regional employment and in export earnings. The lagoon represents a spawning area for fish and supports the following commercially important populations; *Sparus aurata*, *Mugil cephalus*, *Dicentrarchus labrax*, *Argyrosomus regium*, *Solea solea* and *Epinephelus aeneus*.

The lagoon is known to suffer from many problems which might lead to substantial changes in its ecosystem. The closure of boughaz connecting the lagoon with the sea rises creating the danger of drying up of the lagoon and subsequent loss of its biological and economic value. An extensive salt production system, constructed in the eastern part of the lagoon, leads to considerable ecological changes. There is an increasing pressure to establish tourism developments along the lakeshores. There is a large-scale agriculture reclamation project in North Sinai near the lake, the inflow of freshwater from these lands will change the lake from a saline to brackish lagoon, leading to the deterioration of water quality.

Zooplankton is among the most important components of the aquatic ecosystem, playing a major role in energy transfer between the phytoplankton and the various economically important fish populations. The abundance of zooplankton in Bardawil Lagoon depends on a great variety of abiotic and biotic factors, which collectively affect individual species of the zooplankton community.

Despite the importance of zooplankton in lagoon food chain, that are utilized by early life stages of many species of fishes, little is known about the distribution and standing crop of zooplankton in Bardawil Lagoon. Kimor (1975) conducted preliminary studies on the plankton of Bardawil Lagoon, while Fouda *et al.* (1985) listed 87 zooplankton species in the lagoon and mentioned that some species occur over a relatively wide range of habitats, while others were confined to certain localities. They added that zooplankton populations were poor in a variety of species, compared to phytoplankton. They were dominated by copepods and tintinnids, while the other groups were infrequently recorded. Ibrahim *et al.* (1987) included zooplankton in their studies on fishery and management of the lagoon. Recently, Shabrawy (2002) recorded 57 zooplankton species, where copepods were the most abundant group (70% to total zooplankton).

Many environmental factors can affect zooplankton assemblages, including water temperature, nutrient concentrations, and salinity. Increased nutrient concentrations typically correspond with increased phytoplankton abundance, which can have an effect on zooplankton. Therefore, changes in primary production lead to changes in the distribution and abundance of zooplankton species (Francis *et al.*, 1998). Thus, the objectives of this study were to describe the dynamic of the community composition and structure of the lagoon zooplankton and to describe environmental parameters that may best correlate with patterns in species distribution.

2. MATERIALS AND MATHODS

Bardawil Lagoon is the largest lagoon in Egypt with an area of about 650 km^2 (Por, 1972). In the present time, the area has recently decreased, reaching to 595 km^2, with 95km long and 25 km wide. It is extremely shallow; the water depth ranges between 0.5 and 2m. It is separated from the Mediterranean Sea along most of its length by a long, narrow sand bar. Bardawil Lagoon is about 35 km to the west of El Arish city, north of Sinai Peninsula - Egypt, between longitudes 32^0 $40^\backslash$ to 33^0 $30^\backslash$ E and latitude 31^0 $03^\backslash$ to 31^0 $14^\backslash$ N. Three openings (Boughazes) connect the lagoon to the sea. Two of these are man-made (the western Boughaz I and the Middle Eastern Boughaz II), while the third one is natural (eastern Boughaz III at Zaranik Protectorate). The main water supply of the lagoon comes from the Mediterranean Sea which flows constantly mainly through the first two openings. Bardawil is a hypersaline coastal lagoon, the highest salinities are reached along the southern shore. It is the least polluted wetland in Egypt and the entire Mediterranean region.

Twelve sites were selected for sampling, to represent different microhabitats of the lagoon (Fig. 1), five at the eastern arm (I, II, III, IV, and V), two in the middle (VI and VII), and five at the western one (VIII, IX, X, XI, and XII). Sites IV and X were in-front of the opening of the lagoon to the Mediterranean Sea directly, representing Boughaz II (BII) and Boughaz I (BI), respectively. Samples were monthly collected through twelve cruises during Jan. – Dec. 2004.

A number of physico-chemical and zooplankton density variables were investigated in Bardawil Lagoon during the sampling program. One liter of subsurface water sample was collected from each location, for which seven water variables were measured. In the field, water temperature, pH value, and dissolved oxygen (DO) were measured during daytime, while in the laboratory, water samples were analyzed using standard methods (APHA, 1985) for measuring salinity, nitrate (NO_3-N), total phosphorus (TP), and orthophosphate (PO_4-P).

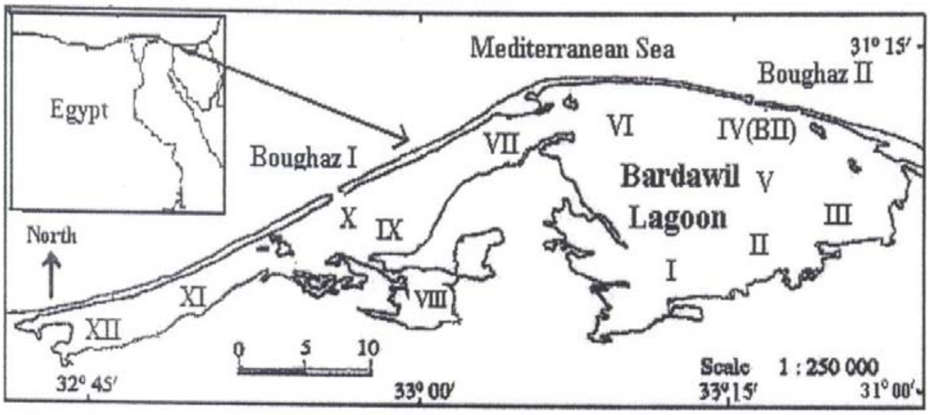


Fig. 1: Map showing stations of sampling collection in Bardawil Lagoon, North Sinai, Egypt

Zooplankton quantitative analysis was carried out by filtration of 50 liters through 30 cm diameter plankton net with 20µm mesh size. Horizontal hauls for qualitative analysis were taken from each station. Samples were preserved immediately after collection in 4% neutral formalin solution. Eight main groups of zooplankton (Protozoa, Rotifera, Cladocera, Copepoda, Coelenterata, Pteropods, Chaetognatha, and Appendicularia) were examined in details in addition to the meroplankton.

The density of organisms were expressed as organisms/m^3. Correlation, regression, and cluster analyses for data were carried out by Minitab 12, under Windows 2003.

3. RESULTS

3.1. PHYSICO-CHEMICAL FACTORS:

The average monthly water temperature fluctuated between 15.6°C in January and 32.7°C in August. The highest average dissolved oxygen value of 7.93mg/L was recorded in January, while the lowest (avg. 6.87mg/L) occurred in July. The pH values always, fluctuated within alkaline side at a narrow range of 7.94 to 8.79. The water salinity reached its maximum in July-September (avg. 53psu), while the lowest average value of 46 psu was recorded in January - March. The highest salinity was measured at sites VIII and XI (avg. 58psu) reaching the maximum at site XII (avg. 63psu), whereas the lowest values were measured near the Boughazes (avg. 40psu). The nitrate average values varied from 36µg/l at site V to 48µg/l at site II, while the range of orthophosphate and total phosphorus average values were 26-42 and 93-130µg/L with maximum values at the Boughazes (Ali and Ebdellah, personal communication).

3.2. POPULATION DYNAMICS AND COMMUNITY STRUCTURE OF ZOOPLANKTON:

A total of 58 zooplankton species and taxa belonging to 17 groups were recorded. Three groups were dominant (Copepoda, Protozoa, and Mollusca) and three were rare (Polychaeta, Rotifera, and Planocera), whereas the others were very rare which occasionally occurred in the plankton hauls (Table 1). The holoplankton groups (The crustaceans Copepoda & Cladocera, Protozoa, Rotifera, Coelenterata, Chaetognatha and Pteropoda) contributed about 81% to the total zooplankton density; while meroplankton represented about 19% to total zooplankton. The latter were composed of the larvae of Mollusca, Polychaeta, Planocera, Cirripedia, Mysidacea, Echinodermata and other groups as Ostracoda, Nematoda and Chordata.

The standing crop of zooplankton in Bardawil Lagoon was subjected to significant temporal and regional variations (Fig. 2). It was more abundant in August and October, with a mean of 316,871 and 331,083 org./m^3 respectively. There was a severe decline in zooplankton density during spring with a mean of 92,926 org./m^3. Spatially, the number increased nearly gradually from site I (119,869 org./m^3) reaching to the maximum number at sites VII, IX, and X (380,314, 348,013, and 372,986org./m^3 respectively). A noticeable decrease was noticed at site VIII and the far west (92,386 and 91,655org./m^3 respectively).

From all the adult zooplankton recorded species, only 8 species were dominant, of which the tintinnids *Salpingella glakentoegri* & *Codonella galea* and the copepod *Oithona nana* were the most dominant species (20%, 13%, and 9% of the adults respectively), whereas nauplius larvae of copepods were the most dominant larvae at all, representing 69.26% of the total recorded larvae (Table 2).

3.2.1. Holoplankton:

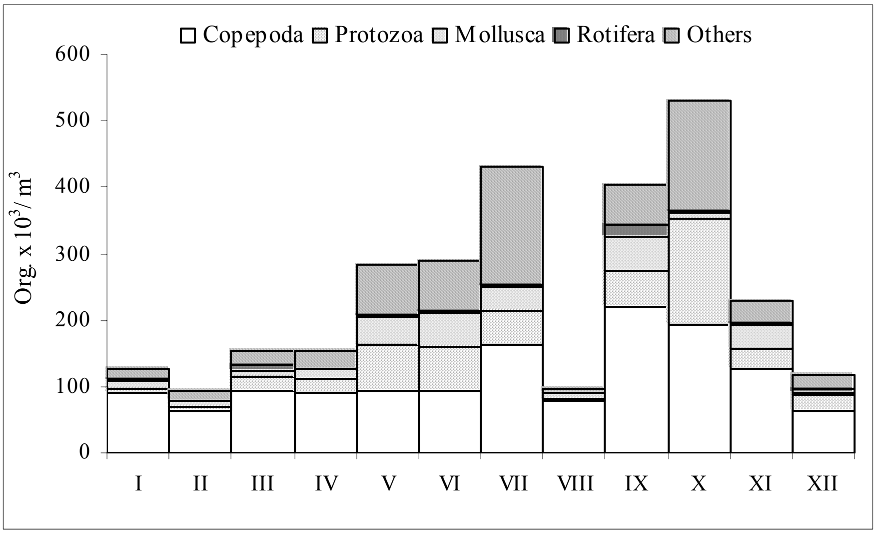
Copepoda comprised the most abundant and ubiquitous zooplankton organisms in Bardawil Lagoon, forming about 57% to the total zooplankton density (70% to the total holoplankton). August and October were the months of highest production of these crustaceans (avg. 263,124 and 213,950org./m^3 respectively) with prominent peaks of 220,456 and 194,097org./m^3 at stations IX and X, respectively. The period of December-May sustained the lowest densities, with a mean of 60,491org./m^3 (Fig. 3). Nauplii and copepodid stages proved to be the most common forming 79% and 11% to the total copepod density, while adult stages of copepods contributed only 10%. Nauplii peaked in August, followed by October (avg. 196,881 and 178,350 org./m^3, respectively). The lowest population density of these larvae occurred in December-May (avg. 45,777 org./m^3). Spatially, sites IX and X harbored the highest density of these larvae (avg. 180,044 and 144,589 org./m^3) followed by sites VII and XI. The nauplii numbers were low, with more or less similar density to the other sites (avg. 70,597 org./m^3). Copepodid stages of Cyclopoida, Calanoida, and Harpacticoida were recorded. Cyclopodites contributed 81% to total copepodites density. Their highest occurrence was recorded in August (avg. 39,953 org./m^3), while they persisted around 8,022 org./m^3 during the rest of the year. Site VII showed the highest standing crop of these larvae (avg. 19,400 org./m^3), while the lowest crop was noticed at sites II and XII (avg. 3,079 and 2,826org./m^3 respectively). Calanopodites contributed 15% to total copepodites density. Their maximum number was in March, August and October, while the lowest number was recorded in February and July, with an overall average of 1,933org./m^3. The spatial distribution of these larvae showed a high density at sites VII and X (in front of Boughaz I), whereas harpactopodites appeared scattered as rare forms (4% of copepodites number). For adult copepods, twelve species were identified during the study of which *Oithona nana* was the most dominant (5% to the total copepods and 48% to the adult copepods), and recorded a high density during the whole period of investigation. It was flourished during July and August with the maximum counts at Stations IX and X. *Lucicutia flavicornis* ranked the second order of adult copepods (28%) although it appeared only during February (40,021 org./m^3) and few specimens during May (55 org.m^{-3}) with maximum numbers at the west of the lagoon (sites IX and X). Other copepods including *Centropages calaninus*, *Clausocalanus furcatus*, *Parvocalanus crassirostris*, *Paracalanus parvus*, *Acartia clausii*, *Euterpina acutifrons*, *Oncaea conifera*, *Microsetella* norvegica, *Canuella* sp., and *Harpacticus littoralis* appeared as rare types contributing 2.41% to the total copepods and 23.45% to total adult copepod forms.

Table (1): The abundance of the recorded groups in Bardawil Lagoon by total zooplankton abundance.

Group	Org. /m^3	%
Dominant groups (> 10 %):		
Copepoda	114,410	57.18
Protozoa	42,382	21.18
Mollusca	20,562	10.28
Rare groups (10 % - 1 %):		
Annelida (Polychaeta)	11,716	05.86
Rotifera	4,938	02.47
Planocera	2,888	01.44
Very rare groups (< 1 %):		
Echinodermata	0,742	00.37
Coelenterata	0,608	00.30
Nematoda	0,443	00.22
Decapoda	0,436	00.22
Cirripedia	0,395	00.20
Appendicularia	0,198	00.10
Chordata	0,187	00.09
Pteropoda	0,074	00.04
Ostracoda	0,059	00.03
Cheatognatha	0,027	00.01
Cladocera	0,017	00.01

Table (2): The most abundant adult zooplankton species and larvae in Bardawil Lagoon by total abundance

Taxa	Group	Org. /m^3	%
Adults:			
Salpingella glackentoegeri	Protozoa	12,328	20.09
Codonella galea	~	7,806	12.72
Oithona nana	Copepoda	5,717	9.32
Tintinnopsis tocatinensis	Protozoa	4,640	7.56
Undella dohrni	~	4,180	6.81
Synchaeta calva	Rotifera	3,876	6.32
Codonella amphorella	Protozoa	3,867	6.30
Lucicutia flavicornis	Copepoda	3,340	5.44
Larvae:			
Copepod Nauplius larvae	Copepoda	90,197	69.26
Gastropod Veliger larvae	Mollusca	18,716	14.37
Copepodid stages	Copepoda	12,873	9.89
Bivalve Veliger larvae	Mollusca	4,614	3.54



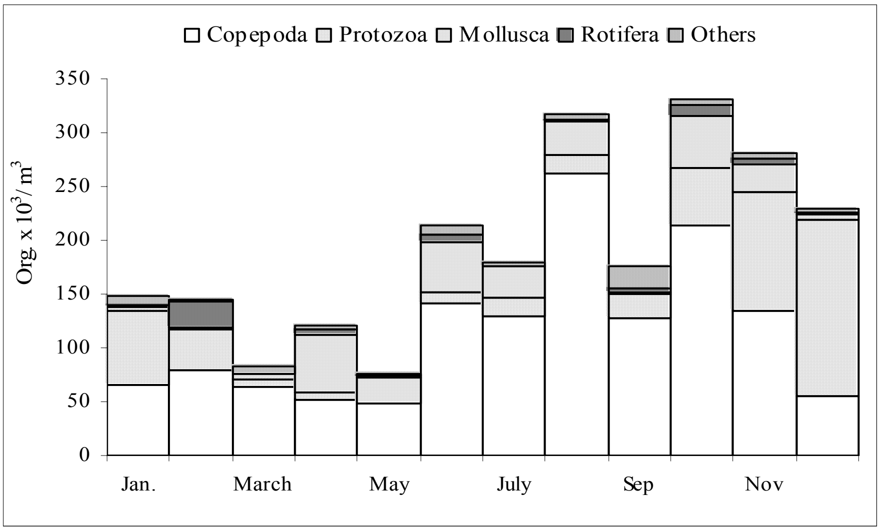
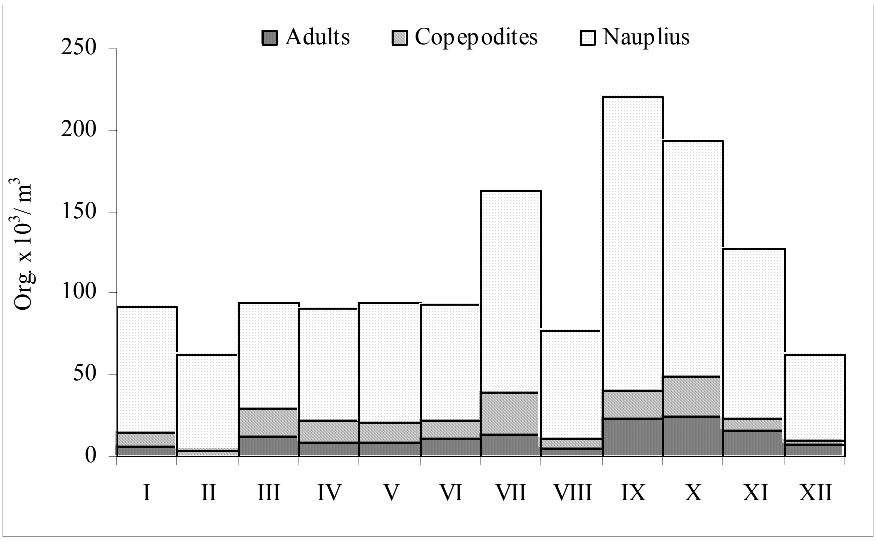


Fig. (2): Spatial and temporal variations of the main dominant zooplankton groups in Bardawil Lagoon during 2004.



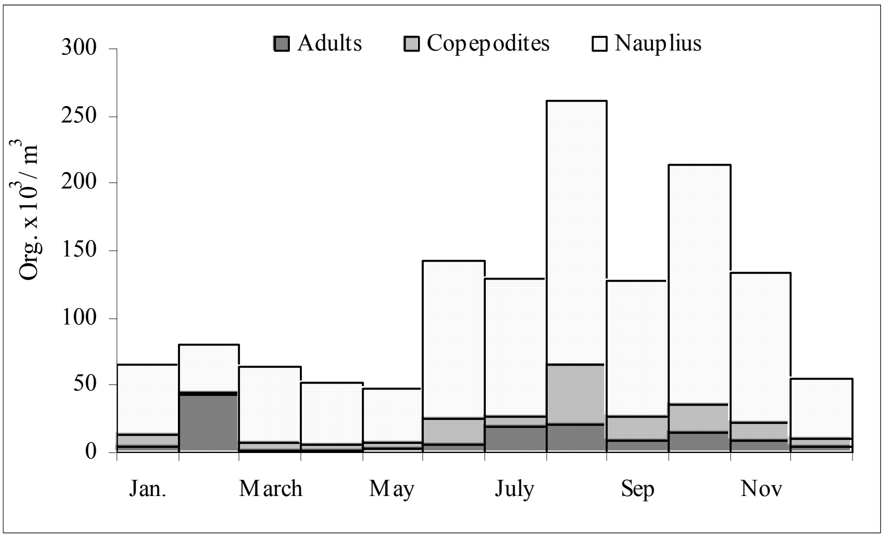


Fig. (3): Spatial and temporal variations of the different life forms of Copepoda group in Bardawil Lagoon during 2004.

Protozoa (tintinnids and foraminiferans) was of the most common and diverse zooplankton groups in Bardawil Lagoon (21% to the total zooplankton, 26% to the total holoplankton). 23 protozoan species were identified during the present study. *Salpingella glackentoegeri* was the most dominant protozoan in the lagoon (29% to the total protozoans), though it was recorded only during November, December and January with maximum number at site X (BI). *Codonella* spp. ranked the second position (27% to protozoans). They were represented by *C. galea* and *C. amphorella*, which were flourished during November and December especially at sites V, VI, and VII. *Tintinnopsis* spp. (19% to total protozoans) were represented by six species with the dominance of *T. tocanensis* (11% to the genus). Regarding seasonal variations, winter maintained the highest standing crop of these organisms. Spatially, the highest flourishing of these protests occurred at site V (Fig. 4).

Rotifera was a rare group from the holoplankton (3%). They showed a high peak of 184,000 org./m^{-3} at site IX, during February. Rotifera was represented by 7 species with the dominance of *Synchaeta calva* (78% to the total rotifers). The population density of this species showed an obvious peak of 184,000 org./m^3 at site IX during February. Summer and spring sustained the lowest numbers of this species.

Coelenterata, Appendicularia, Pteropoda, Chaetognatha, and Cladocera were very rare (totally <1% of holoplankton). Coelenterata was represented by *Rhizostoma pulmo* and *Obelia* sp. which peaked during September. The other groups were represented only by one species; Appendicularia was represented by *Oikopleura longicauda* with the maximum peak during summer at site X. Pteropoda was represented by *Limacina inflata*, which was recorded only during January with maximum number at site X. Chaetognatha was represented by *Sagitta setosa*. It was noticed only in May and June at sites IV and X. Cladocera was represented by *Evadne spinifera* which was recorded once at site X during autumn.

3.2.2. Meroplankton:

Mollusc larvae were the most dominant meroplankton in the lagoon (55% to the total meroplankton, with avg. 20,562 org./m^3). They were represented by veligers of gastropods and bivalve (80% and 20% to veligers, respectively). The maximum population density of these larvae reported in April and October, with major peaks at sites VI and IX. The lowest occurrence has been recorded in winter. Larvae of Terbellidae and Serpulidae (Polychaeta) ranked the second order in meroplankton (totally 31%). March and June were the months of highest production of these larvae, with high numbers at sites VI and VII. On the other hand, there was a severe drop in standing crop at sites VII, XI, and XII which were characterized with higher salinity. Larvae of Planocera (8% of meroplankton) were recorded only during early summer and early autumn (avg. 100 and 2,933 org./m^3, respectively) with maximum number at the eastern arm of the lagoon. Echinodermata (2% of meroplankton) was represented by larvae of Ophiotrichidae and Asteroidae. They appeared with maximum numbers at sites V, VI, and VII during the period of April–November, with two peaks in June and October. The other meroplankton groups appeared as sporadic, without definitive trend, representing totally 4% of meroplankton.

4. DISCUSSION

The temporal and spatial distribution of zooplankton differ according to the controlling factors. The lagoon is hot and dry in summer leading to increase of salinity due to high evaporation, especially in the isolated areas, at sites VIII and XII. There is a seasonal fluctuation of salinities with water temperature, with a range of about 10 psu. The lowest salinity (48 psu) in February was due to occasional rains, while the maximum

(54 psu) in July was due to high evaporation rate of nearly 3 m/year (Ibrahim *et al.*, 1987). The salinity in the lagoon is in equilibrium between the evaporation and the sea water exchange; the stronger the exchange, the lower salinity. It showed a great effect on zooplankton density and species richness in Bardawil Lagoon (Table 3), that was negatively affected by salinity (R^2 = 60%). The number of species decreased from 43 species at salinity 40psu to only 24 species at 63 psu. Por (1972) stated that, in lagoons, the truly marine biota tends to disappear at 60 to 80psu salinity. At salinity values higher than this, the lagoon is inhabited by a small number of euryhaline organisms of marine origin. These species are independent of population supply from the open sea, but unable to withstand desiccation (Bayly, 1967).

Table (3): Horizontal mean values of salinity, zooplankton density (org. x $10^3/m^3$), and species number in the study area.

Variable		***Sites***					
		East	#BII	Middle	#VIII	#BI	Far west
Salinity (psu)		51	40	49	58	40	63
Protozoa	Density	25	21	59	5	157	26
	Species no.	17	14	17	10	17	10
Copepoda	Density	86	90	128	77	194	62
	Species no.	11	9	11	4	8	3
Total zooplankton	Density	124	128	214	93	373	92
	Species no.	34	42	45	24	43	24

Note: East= average value at sites I, II, III, & V; Middle, sites VI & VII; Far west= value at site XII. B= Boughaz (the opening with the Mediterranean Sea).

Table (4): Check list of zooplankton species recorded in Lake Bardawil during the Period 1985 - 2004

Taxa	**85**	**02**	**04**	**Taxa**	**85**	**02**	**04**
Protozoa				*Parapontanum parvus* Dana	*	-	-
Codonellopsis lusitanica Jorg.	-	-	*	*Oithona nana* Giesbrecht	-	*	*
Codonella amphorella Biedermann	*	*	*	*O. plumifera* Baird	-	*	-
C. agalea Haecxel	*	*	*	*Oncaea conifera* Giesbrecht	-	-	*
C. aspera Kof & Camp.	*	*	-	*Corycaeus clausi* F. Dhal	*	-	-
Tintinnopsis beroidea Stein	*	*	*	*Isias clavipes* Boeck	*	-	-
T. tocantinensis Kofoid & Campbell	-	*	*	*Euterpina acutiforns* Dana	*	*	*
T. kofoidi Hada	-	-	*	*Microsetella norvegica* Boeck	*	*	*
T. labiancoi Daday	*	*	-	*Amallothrix auropecten* Dana	*	-	-
T. nucula Fol	*	*	-	*Echinocomptus* spp.	*	-	-
T. cylindrical Daday	*	*	*	*Canuella* sp.	-	*	*
T. campanula Ehr.	*	*	*	*Harpacticus littoralis* Sars	-	*	*
T. buetschlii Daday	-	-	*	*Metis Jousseaumei* Richard	-	*	-
Tintinnidium neapolitanum Ehr.	*	-	-	**Cladocera**			
Eutintinnus medius (Kofoid & Camp.)	-	-	*	*Bosmina coregoni maritima* Müller	*	-	-
Leprotintinnus bottnicus Nordqvist	-	*	*	*Evadne spinifera* Müller	*	*	*
Undella dohrni (Jorg.)	*	*	*	*E. tergestina* Claus	-	*	-
Favella serrata Mömus	-	*	*	*Podon polyphemoides* Leuckart	-	*	-

Dictyocysta obtuse *(Jorg.)*	*	-	-	***Ostracoda***				
D. muvileri	*	*	-	Ostracod sp.		*	*	*
Rhobdonella elegans Jorgensen	*	*	-	**Mysidacea**				
Ptychocytis minor Jorgensen	-	*	-	*Mysis* sp		-	*	*
F. ehrenbergi Clap & Lach.	*	*	*	**Rotifera**				
Helicostomella subulata (Ehr.)	*	*	*	*Brachionus plicatilis* (Muller)		-	-	*
H. strigosa Eher.	*	*	*	*Keratella tropica* (Apestin)		-	-	*
Stenosemella nivalis (Meunier)	*	-	*	*K. quadrata* (Muller)		-	-	*
Metacylis meraschkowskii (Laackmaan)	*	*	*	*K. cochlearis* (Gosse)		-	-	*
Petalotricha major Jorgensen	-	*	*	*Synchaeta calva* Ruttner-Kolosko		*	*	*
Salpingella glackentoegeri (Brandt)	-	-	*	*S.* sp		-	*	-
Amphorellopsis acuta (Schmidt)	-	-	*	*Trichocerca stylata* Gosse		-	-	*
Cyttorocylis plagiostoma Kof. & Camp.	*	*	-	*Lepadella cristata* Rousselet		-	-	*
Epiplocylis acuminata Daday	-	*	-	**Coelenterates**				
Ciliophore spp.	-	*	-	*Rhizostoma pulmo*		*	*	*
Quinqinquilina sp.	-	-	*	*Obelia* sp.		-	*	*
Globegrina bulloides d'Orbigny	*	*	*	*Cotylorhiza tuberculata* (Macri)		*	-	-
Orbulina universa d'Orbigny	*	-	-	**Pteropods**				
Copepoda				*Limacina inflata* D'orbigng		*	*	-
Lucicuta flavicornis Claus	*	-	*	**Chaetognatha**				
L. ovales Wolfenden	*	-	-	*Sagitta setosa* Müller		-	*	*
Temora longicornis Hill	*	-	-	**Appendicularia**				
Acartia clausii Giesbrecht	*	*	*	*Oikopleura longicauda* Vogt		-	*	-
Paracartia latisetosa Kriczaguin	-	*	-	**Meroplankton**				
Clausocalanus furcatus Brady	-	-	*	Polycheate larvae	Terbellidae	*	*	*
Parvocalanus crassirostris Dahi	-	-	*		Serpulidae			*
Paracalanus parvus Claus	-	*	*	Echinodermate larvae	Ophiotrichidae	*	*	*
Calanus finmarchisus Gunnerus	*	-	-		Asteroidae			*
Eurytemora hiruridoides Hill	*	*	-	Mollusca larvae	Gastropoda	*	*	*
Centropages calaninus (Dana)	-	-	*		Bivalvia			*
C. potincus Karawiew	-	*	-	Cirriped larvae		*	*	*
Sapphirina opalina Dana	*	-	-	Planocera larvae		-	-	*
S. angusta Dana	*	-	-	Chirnomus larvae		-	*	-
Parapontella brevicornis Lub.	*	-	-	Free living nematodes		*	*	*
				Fish egg & Embryo		-	*	*

Note: 85, after Fouda *et al*. (1985); 02, after El Shabrawy (2002); and 04, Present study (2004); *, was recorded; and -, not recorded.

Regarding the similarity of zooplankton community between different sites, the cluster analysis (Fig. 5) indicated a relatively high degree of similarity in the zooplankton density between sites II, III, and X. Such similarity was less clear at sites VIII, XI, and XII, which may be attributed to high salinity at these sites.

The population density of the most dominant taxa; *Salpingella glakentoegri*, *Codonella galea, Tintinnopsis tocatininensis, Oithona nana*, and mollusc veliger larvae were negatively correlated with salinity (r=-0.50, r=-0.63, r=-0.59, r=-0.62, and r=-0.70 respectively at $p<0.05$). The density of these species, except *O. nana*, decreased during summer, when salinity reached its maximum value with high evaporation. The count at site VIII and far west was the lowest with maximum salinity. El-Shabrawy (2002) confirmed this result. *O. nana* is euryhaline and eurythermal species. Its maximum number was noticed in summer. In accordance with the present study, the highest standing crop of this species occurred in summer at Egyptian Mediterranean water, Lake Timsah, and Suez Bay (Dowidar & El-Maghraby, 1970; Abou Zeid, 1990; Abdel Rahman, 1993; and Hussien & Abdel Aziz, 1997). *O. nana* was the most important species in Doha Harbor (Arabian Gulf), comprising 34% to the total copepods, with highest density in summer (Dorgham & Hussien, 1997). It is distributed in the tropical and subtropical waters of the pacific and Indian oceans, with high density in the tropical water (Nishida, 1985). It has frequently been recorded from tropical and subtropical Atlantic (Grice, 1960; Gonzalez & Bowman, 1965). Simmons (1957) found polychaete worms withstanding at salinities of 75 psu.

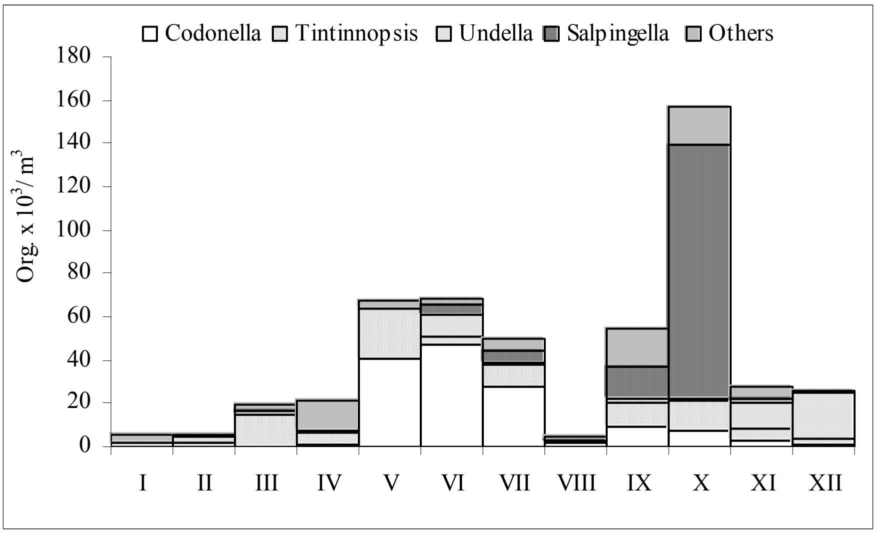
Nutrient salts represent the natural fertility of water, on which primary productivity and ultimately fish production depend. Nutrient-cycles are probably driven by the winter influx of seawater from the Mediterranean and the growth cycle of the sea grass, *Ruppia* and *Cymodocea*. Range of average nitrate and orthophosphate during the study was 36.15-47.66 µg/L and 26.05-42.13µg/l, respectively. The maximum zooplankton density and copepods were found in-front of the Mediterranean Sea (station X), where the highest orthophosphate value was measured. Standing stock of mollusc veliger larvae and polychaete larvae increased at sites V, VI and VII, when maximum phytoplankton appeared, due to the increase of total phosphorus. White and Roman (1992) found mollusc larvae feeding on diatoms and dinoflagellates. In accordance with the present study, Abdel Aziz and Dorgham (2002) found a positive correlation between nutrients and standing crop of Copepoda in western harbor of Alexandria (East-South of the Mediterranean Sea).

Copepoda was the most dominant group due to richness of their larvae. The presence of copepod larval stages all the year round indicates the continuous production of copepods all the year (Raymont, 1983). Juvenile stages were the major component of copepod populations in the whole Egyptian Mediterranean and Red Sea coast (Abdel Rahman, 1997). Most of the copepod species were recorded by Dowidar & El-Maghraby (1970) and El-Sherbiny (1997) in the Mediterranean Sea, which may be originating from the Sea and entered the lagoon via the Boughazes. Fox (1927) found *Acartia clausii* as Atlanto-Mediterranean, anti-lessepsian migrant. It is the most common acartiid species in the entire Ponto-Mediterranean province (Belmonte and Potenza, 2001).

Predation also affects the abundance of zooplankton as they constitute significant food source for fish larvae (Damodara, 1983). Predation of tintinnids by macrozooplankton as copepods (Turner and Anderson, 1983) and mollusc larvae (Damodara, 1983) was accompanied by decrease of their density with richness of these groups. This may explain the reduced counts of tintinnids observed during August, coinciding with high counts of copepods and mollusc larvae, while the opposite trend was observed during December. These results agreed with those of Aboul-Ezz *et al.* (1995) in Suez Bay (Egypt).

A total of 58 zooplankton taxa representing 17 groups were recorded in the lagoon water during the present study, while Fouda *et al.* (1985) and El-Shabrawy (2002) recorded 49 and 55taxa, respectively in the lagoon. The variation in the species number is not considerable, but the community composition was highly changed with time. Twenty new taxa were recorded during the study, whereas thirty three taxa disappeared from the lagoon (Table 4). The difference between the taxa composition from one study to the other may be deceptive, due to differences in methodology, number of samples, and inclusion or exclusion of littoral species, although the species spectrum gives a good indicator of the dynamic balances of the community (Mc Lachlan, 1974).

Furthermore, changes in zooplankton diversity are known to be significant indicators of environmental disturbance (Attayde and Bozelli, 1998). In fact, changes in species composition of zooplankton assemblages are considered to be among the earliest responses of the aquatic ecosystem to environmental stress (Schindler, 1987). Early identification of perturbations in the marine environment may facilitate recovery or allow for better-informed management decisions, which are particularly important to commercial fisheries.



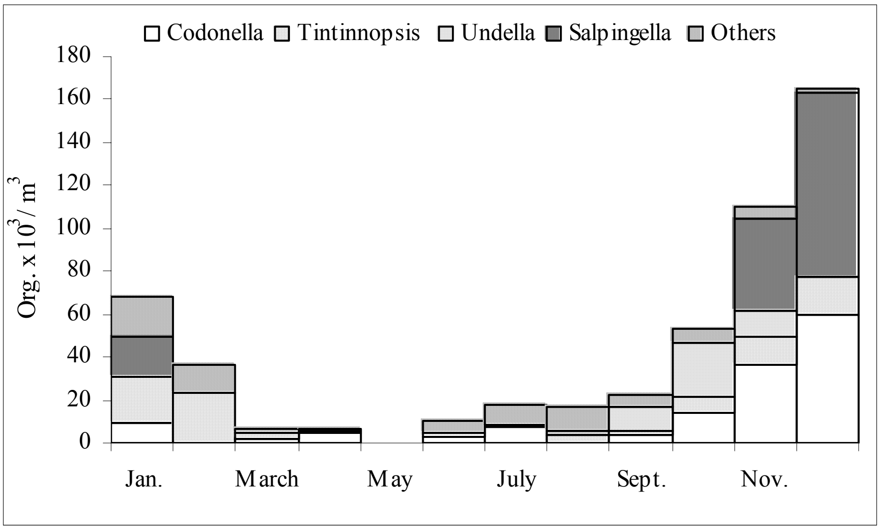


Fig. (4): Spatial and temporal variations of the main dominant protozoan groups in Bardawil Lagoon during 2004.

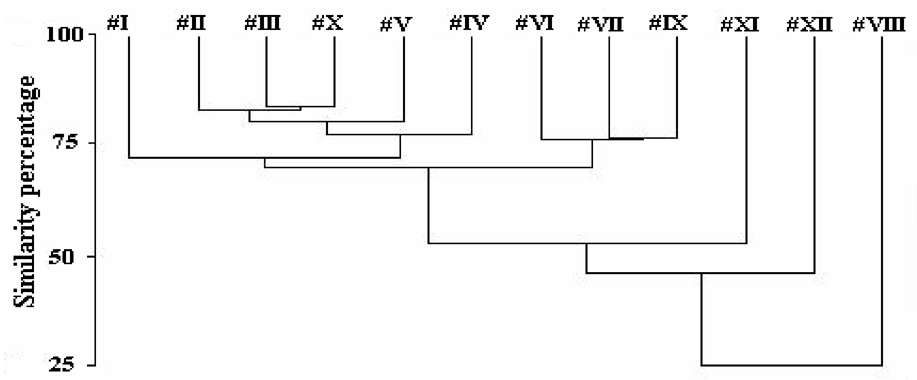


Fig. (5): Cluster analysis showing site similarity of zooplankton composition in Bardawil Lagoon during 2004.

4. CONCLUSIONS

Three main zooplankton groups were identified in the study (Copepoda, Protozoa, and Mollusca) with 58 identified forma. The maximum zooplankton stock peaked in August and October with severe depletion during spring. Spatially, the highest levels occurred near the sea opening I. Salinity was the most important factor influencing zooplankton assemblages. A noticeable decrease in density and species richness of zooplankton was noticed at stations with high salinity. The community composition was highly changed with time series. Twenty new taxa were recorded during the study, whereas thirty three taxa disappeared from the lagoon along twenty years

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