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# ECOLOGICAL STUDY ON THE ZOOPLANKTON COMMUNITY IN BARDAWIL LAGOON, EGYPT

#### SUMMARY

Distribution, seasonal dynamics, community structure and standing crop of zooplankton were studied in Bardawil lagoon during 2002-2003. A total of 58 zooplankton taxa were recorded from a total of 12 sampling sites. Copepoda were the most abundant, contributing 69.9% of the total zooplankton numbers. Zooplankton reached the highest density during summer at station X (198,500 ind. m<sup>-3</sup>). Protists (23 species), made up 10.3% of total zooplankton. Winter was the season characterized by the highest standing crop. The dominant and common zooplankton species in 1985, *Tintinnopsis lobiancoi* (Ciliophora) and *Acartia clausi* (Copepoda) were replaced by *T. tocantinensis* (Ciliophora) and *Oithona nana* (Copepoda); moreover, 21 zooplankters were newly recorded. Few species occurred all-over the lagoon: *Oithona nana, Centropages ponticus* and *Euterpina acutifrons* (Copepoda), *Tintinnopsis tocantinensis* (Ciliophora) and *Limacina inflata* (Pteropoda), while the others were highly confined to restricted areas.

#### **RIASSUNTO**

La laguna di Bardawil è una depressione costiera naturale ipersalina a causa dell'elevata evaporazione dell'acqua soprattutto nel periodo estivo. È situata ad 1-3 m sotto il livello del mare, lungo le coste del Mediterraneo nella regione del Sinai. Si estende per circa 90 Km in lunghezza ed ha una larghezza massima di 22 Km, una profondità massima di 3,6 m e comunica con il mare attraverso due aperture.

La laguna è considerata la risorsa naturale ecologicamente ed economicamente più importante della regione. Dal 1995 la composizione biologica della laguna è cambiata, perciò lo studio delle comunità zooplanctoniche è importante perché contribuisce alla conoscenza dell'ecologia della laguna e quindi ad una solida base per la sua gestione.

I campioni di zooplancton sono stati raccolti in 12 stazioni (2002-2003) me-

diante trascinamento verticale di un retino a maglie di 55  $\mu$ m e conservati in formalina al 4%. In laboratorio è stata effettuata un'analisi qualitativa e quantitativa mediante un microscopio binoculare.

I risultati sono stati trattati statisticamente. In tutto sono stati rinvenuti 58 taxa zooplanctonici, appartenenti a 9 gruppi principali. Le zone più densamente popolate sono risultate essere la stazione II e X, mentre quelle a più bassa densità la XII e la III. È stata registrata anche una considerevole variazione stagionale: primavera ed estate sono state le stagioni con una maggiore abbondanza di organismi. I copepodi sono la componente principale della comunità zooplanctonica (69,9%) e sono rappresentati da 12 specie. La specie dominante è *Oithona nana*, mentre *Acartia clausi* compare solamente in inverno ed in primavera. *Centropages ponticus* è una specie esclusivamente estiva ed *Euterpina acutifrons* è una specie perenne. La presenza di nauplii e copepoditi durante tutto l'anno in percentuale superiore rispetto agli adulti, indica una continua attività riproduttiva dei copepodi.

Gruppi ben rappresentati sono anche i protozoi, gli pteropodi e il meroplancton.

La Cluster Analysis ha messo in evidenza una forte similarità tra le stazioni IX e X.

È stata utilizzata la CCA (Canonical Corrispondence Analysis) per relazionare le specie zooplanctoniche con le variabili ambientali e ciò ha rivelato che la salinità, la temperatura dell'acqua e l'ammonio sono i fattori più importanti che influenzano la struttura di comunità nella laguna di Baldawil.

In condizione di eutrofizzazione il numero di specie zooplanctoniche decresce gradualmente e generalmente la comunità è semplificata con poche specie che tollerano un'alta variabilità ambientale ed esplodono demograficamente in condizioni di cibo favorevoli.

Le specie dominanti nel 1985, *Tintinnopsis lobiancoi* e *Acartia clausi* sono state rimpiazzate da *Tintinnopsis tocantinensis* e *Oithona nana*; inoltre sono stati trovati 21 taxa nuovi rispetto al passato.

Il cambiamento della struttura della comunità zooplanctonica potrebbe essere una delle cause principali della diminuzione delle specie ittiche economicamente più importanti.

### INTRODUCTION

Lagoons are among the most productive aquatic ecosystems, which for thousands of years have been exploited by man (LASSERRE, 1979). Bardawil lagoon is a shallow natural depression (1-3 m below mean sea level) separated from the Mediterranean Sea by a narrow arc-shaped sedimentary bar of about 90 km length, with a maximum width of 2 km. Bardawil lagoon, particularly at Zaranik area (the eastern region) has been described as a wetland of a major international importance for migrating water birds passing through the eastern Mediterranean region, where wetlands are scarce (MEININGER and ATTA, 1990; VARTY *et al.*, 1990). The lagoon is considered the main ecological and economic natural resource of North Sinai region. A recent estimate of fish and crustaceans production amounts to 2801 ton (GAFRD, 2001), composed of 35.8% mullets, 21.2% shrimps, 18.6% crabs, 8% sea bream, 5.1 sole, 2.4% sea bass and 9.4% miscellaneous.

The characteristics of catch composition in Bardawil lagoon have greatly changed since 1995, when the contribution of the most economic species (sea bream and sea bass) dropped sharply. On the contrary, other species as crabs and shrimps have attained a noticeable contribution in the catch (EL-GANAINY *et al.*, 2002). The study of zooplankton communities seems to be useful for the evaluation of the lagoon ecology and contributes a solid base for its management.

Several studies have been carried out on the abundance, distribution and biomass estimation of zooplankton in the Egyptian Mediterranean Sea (EL-MAGHRABY, 1964; DOWIDAR and EL-MAGHRABY, 1970; 1973; HUSSEIN 1977; 1997; EL-ZAWAWY, 1980; DOWIDAR, 1981; NOUR EL-DIN, 1987; ABOU-ZEID, 1990; ABDEL AZIZ, 1997; HUSSEIN and ABDEL AZIZ, 1997; ABDEL AZIZ and DORGHAM, 2002), despite the importance of zooplankton in lagoon food chain, extremely poor is the knowledge of the distribution and standing crop of zooplankton of Bardawil Lagoon. KIMOR (1975) carried out a preliminary study on the plankton of Bardawil hyper saline lagoon. IBRAHIM et al., (1987) included zooplankton in their studies on fishery and management of the lagoon. FOUDA et al. (1985) listed 87 zooplankton species in Bardawil 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 variety of species, compared to phytoplankton. So, the main objective of the present study is to investigate the biodiversity, species composition, standing crop and seasonal variation of zooplankton community in Bardawil lagoon after the detection of a considerable change in the species composition of fish catch during the last decade.

### MATERIALS AND METHODS

#### Study site

Lake Bardawil is a hyper-saline lagoon located along the Mediterranean shore of the Sinai Region. The lagoon extends for about 90 km length and has a maximal



Fig. 1 - Map of the northern side of Egypt showing the location of Bardawil Lagoon and the selected stations.

width of 22 km. The flooded area is approximately 65,000 hectares between longitudes 32° 40′ to 33° 30′ E and latitude 31° 03′ to 31° 14′ N (Fig 1). Bardawil lagoon is extremely shallow; the water depth ranges between 0.5 and 3,6 m. Three openings (Boughaz) connect the lagoon with 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 whole water supply of the lagoon comes from the Mediterranean Sea which flows constantly through these three openings.

Bardawil lagoon is subjected to excessive water evaporation, particularly in summer that led to a progressive increase in water salinity. Surface water temperature ranged between 19.2 °C at station VIII in winter and 29.8 °C at station VI in summer. Station VIII (Infront to Boughaze I) was the deepest, varied in depth from 3.05 to 3.6 m. The other sites had a depth varied from 0.8 to 1.7 m. The secchi-depth reached the bottom at most sites on most or all occasions, except for site VIII, where it fluctuated from 0.9 m in winter to 3 m in summer. pH was always on the alkaline side and varied from 8 to 8.79. Dissolved Oxygen was lowest, 5.2 mg/l at site XII in spring, while the highest value of 8.8 mg/l occurred at site V in summer (IBRAHIM *et al.*, 1987; ANONYMOUS, 2000; ABDEL-SATAR, 2005). The measured values of salinity fluctuated from a minimum of 41.1 ‰ at station II in autumn to a maximum of 78.8 ‰ at stations VII and XII in summer. Generally the bicarbonate values were high in autumn (≈ 211-267 µg l<sup>-1</sup>), while the lowest values detected in spring (≈106-211 µg l<sup>-1</sup>). The concentrations

of nitrate were fluctuated between 9  $\mu$ g l<sup>-1</sup> at station IV in autumn and 43.8  $\mu$ g l<sup>-1</sup> at station V in summer. The highest value of orthophosphate, 54.2  $\mu$ g l<sup>-1</sup> was recorded at station VI in spring, while the lowest, 3.06  $\mu$ g l<sup>-1</sup> occurred at station VII in summer. Ammonia was generally high in spring and summer in compared with autumn and winter (ABDEL-SATAR, 2005).

### Sample collection

Zooplankton samples for quantitative analysis were collected seasonally during 2002-2003. 12 stations were selected to represent different areas of the lake (Fig. 1, Table I). Integrated samples were collected by vertical towing a 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 (120 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. Zooplankton species were identified according to the literature of TREGOUBOFF and ROSE (1957), NEWELL and NEWELL (1977), NISHIDA (1985) and BRADFORD-GRIEVE (1994; 1999).

Station	Location	Station	Location
I	31° 09' 18 N 33° 19' 25 E 31° 12' 27 N 33° 15' 43 E	VII VIII	31° 05' 35 N 32° 59' 18 E 31° 08' 11 N 32° 55' 75 E
III	31° 11' 78 N 33° 06' 24 E	IX	31° 06' 12 N 32° 53' 30 E
IV V	31° 08' 96 N 33° 07' 92 E 31° 04' 50 N 33° 10' 13 F	X XI	31° 05' 67 N 32° 51' 18 E 31° 04' 20 N 32° 48' 36 F
, VI	31° 05' 81 N 33° 13' 65 E	XII	31° 03' 51 N 32° 46' 75 E

Table I - Location of selected stations (longitude and latitude)

# Statistical treatment of data

We computed Shannon-Winner diversity, Species richness, Evenness and similarity index. The correlation between some environmental variables and zooplankton assemblage was calculated using SPSS program. Canonical Correspondence Analysis (CCA) was performed to assess the influence of environmental factors on the distribution and community assemblage of zooplankton. CCA is a direct gradient analysis technique where the ordination axes are constrained to be linear combinations of environmental factors. The environmental variables included in the analysis were: DO, BOD. COD, NO<sub>2</sub>, NO<sub>3</sub>, NH<sub>3</sub>, Urea, TP, Mg, Ca, SO<sub>4</sub>, K, Na, Cl, pH, CO<sub>3</sub> and HCO<sub>3</sub>.

# **RESULTS AND DISCUSSION**

A total of 58 zooplankton taxa belonging to 9 main groups (Protozoa, Copepoda, Cladocera, Rotifera, Cnidaria, Pteropoda, Chaetognatha, Appendicularia and Meroplankton) were recorded during the present study (Table 2). A mutual increase and decrease in zooplankton density were noticeable from one station to another. Station X and II maintained the highest crops with an average 137,938 and 120,375 ind. m<sup>-3</sup> respectively, while the lowest crops of 71,063 and 75,125 ind. m<sup>-3</sup> occurred at stations XII and III respectively. In contrast to the present study, FOUDA *et al.*, (1985) recorded the highest density of plankton at Raabah station (St XII). Regarding seasonal variation, Spring and summer were the seasons of highest abundance of these organisms, with average of 134,958 and 185,333 ind. m<sup>-3</sup>, respectively, while a severe depletion in zooplankton density were occurred in winter and autumn (Fig. 2).



Fig. 2 - Distribution and seasonal variation of total zooplankton.

### Copepoda

Copepoda attained the highest density, with relative average of 69.9% of the total zooplankton (range, 51.2-74.1%) (Fig. 3). Summer showed the highest density (av. 137,333 ind.  $m^{-3}$ ), with a maximum peak of 198,500 ind.  $m^{-3}$  at station X.

Protozoa         Fotozoa         Fotozoa         Fotozoa         Fotozoa         Fotozoa           Codornella analizatula         -         -         -         R           Codornella analizatula         -         -         R           Educioxia acumunata ( Dadex) Jorcensent#         -         -         R           Envella berracita ( Moluka) Jorcensent#         -         -         R           Envella berracita ( Moluka) Jorcensent#         -         -         R           Metaculas mereschowskii         Kotola & Campbell         -         -         R           Protocoli analizatula         -         -         R         R           Robonella analizatula         -         -         R         R           Robonella conalizatula         -         -         R         R           Robonella conalizatula         -         -		1985	2002	present
Chilophara spor,#         -         R           Codornella acanera Kofold & Campbell         -         R           Codornella acanera Kofold & Campbell         -         MC           Codornella acanera Kofold & Campbell         -         WR           Codornella acanera Kofold & Campbell         -         WR           Dictvocysta minor. Jorgensen #         -         WR           Envisiona Sublido (Campbell & Campbell)         -         -           Favalla elizenberar (Clap & Lach ) Jorgensen #         -         R           Letroctitimus bottnicus (Marciquist) Jorgensen #         -         -         R           Nethocostones and actiona soft #         -         -         R           Nethocostones and file         -         -         R           Nethocostones and on action	Protozoa	1000	2002	status
Codenella acades. Haeckel         -         -         R           Codenella acades. Haeckel         -         R           Codenella mona Ko Lik Carambell         -         -           Chilosculta acades. International (Codenella Carambell)         -         -           Chilosculta academia (Codenella)         -         -           Codenella academiata (Codenella)         -         -           Faulla chilosculta (Codenella)         -         -           Faulta chilosculta (Codenella)         -	Ciliophora spp.#		*	R
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Immitmossis columitica Daday         •         •         MC           Initimoosis lobiancoi Dadav         •         •         •         R           Initimoosis lobiancoi Dadav         •         •         MC         MC           Initimoosis lobiancoi Dadav         •         •         MC         MC           Initimoosis lobiancoi Dadav         •         •         MC         MC           Initimoosis beroidea Stein         •         •         MC         MC           Initimoosis beroidea Stein         •         •         MC         MC           Initimoosis beroidea Stein         •         •         VR         VR           Initimoosis claamines Stein         •         VR         VR         VR           Augiotide Strate         •         •         VR         VR           Naupirus larvae         •         •         C         C         C           Cyclopoid copepodid         -         •         *         MC         C           Luciculta covaits Gesbrecht         •         *         MC         C         C           Luciculta covaits Gesbrecht         •         *         *         C         C           Calanus finmarchisu	<u>Tintinnidium neapolitanum</u> Daday	*	*	P
Tintimonosis lobiancoi. Dadav         -         -         R           Tintimonosis nucula (Fob Brand         -         -         MC           Tintimonosis nucula (Fob Brand         -         -         MC           Tintimonosis locantinensis< Kofold & Campbell #	Tintinnopsis cylindrica Daday	*	*	MC
Initimopsis nuclei (Foh Brandt         -         -         MC           Initimopsis beroides Stein         -         -         MC           Indedia so         Foraminifera         -         -         C           Globiaerina bulloides         Globiaerina bulloides         Origina         -         C           Globiaerina bulloides         Globiaerina bulloides         Origina         -         C           Cyclopoid copepodid         -         -         C         C           Naupilus larvae         -         -         C         C           Calanoid copepodid         -         -         C         C           Harpacticol copepodid         -         -         C         C           Luckulta flavicomis. Class         -         -         MC         C           Luckulta flavicomis. Subsch         -         -         -         C           Araana dissis osa. (Krizz.)#         -         -         -         R           Calanus firmarchisus. Gunnerus         -         -         -         R           Calanus firmarchisus. Gunnerus         -         -         -         C           Cannolicomis Muller         -         -         -         <	Tintinnopsis lobiancoi Daday	*	*	R
Imitimation and the set of the s	<u>Tintinnopsis nucula (Fol) Brandt</u>	*	*	MC
Undella sp.     *     VR       Globiaerina bulloides. d'Orbiany     *     VR       Globiaerina bulloides. d'Orbiany     *     VR       Globiaerina bulloides. d'Orbiany     *     VR       Nauplius larvae     Copepoda     *     VR       Nauplius larvae     *     C     C       Cyclopoid copepodid     *     *     C       Lucicuita dovalis Glesbrecht     *     *     MC       Iuricuita dissetosa (Knicz).#     *     *     MC       Paracadia fulsietosa (Knicz).#     *     *     MC       Calanus finmarchisus Gunnerus     *     *     R       Calanus finmarchisus Barna     *     *     R       Calanus finmarchisus Barna     *     *     R       Calanus finmarchisus Barna     *     *     C       Globoa fumine Dana     *     *     C       Maraontella brevicornis Lubbock     *     *     MC       Paraontella speck     *     *     C	Tintinnopsis tocantinensis Kofoid & Campbell #		*	C
Glabiaerina bulloides d'Orbiany       *       *       VR         Orbilina universa d'Orbiany       Copepoda       *       C         Nauplius larvae       Copepoda       *       C         Cyclopoid copepodid       -       *       C         Calanoid copepodid       -       *       C         Harpaciticoid copepodid       -       *       MC         Harpaciticoid copepodid       -       *       MC         Lucicuiti covalis Glesbrecht       -       *       MC         Zeartia clausii Glesbrecht       -       *       MC         Paracetta latisetosa ( Kricz.) #       -       *       R         Calanus finmarchisus Gunnerus       -       *       R         Eurytemora hirunoloides Nordouist       -       *       R         Calanus fores bonflicus Kara       -       *       R         Calanus fores bonflicus Kara       -       *       R         Paraoontella brevicornis Lubbock       -       *       C         Paraoontella brevicornis Lubbock       -       C       C         Outrona abundra Baird #       -       *       C         Convcaeus claus fores brecht       -       R       R	Undella sp.	*	*	VR
Orbilina universa d'Orbiany         Copepoda         ·         VR           Nauplius larvae         Copepoda         ·         C           Nauplius larvae         ·         C         C           Cyclopoid copepodid         ·         C         C           Harpacticoli copepodid         ·         C         C           Itarpacticoli copepodid         ·         MC         C           Temora loncicomis Müller         ·         MC         R           Acartia clausii Glesbrecht         ·         MC         R           Paracentia latisetosa (Kricz.)#         ·         R         R           Calanus finmarchisus Gunnerus         ·         ·         R           Sapphirina anausta Dana         ·         ·         C           Otifona nana Glesbrecht #         ·         C         C           Microstella norverica Boeck         ·         ·         C           Calibona blumifera Bard #         ·         C         C           Cotiona	Globigerina bulloides d'Orbigny	*		
Nauplius larvae       Copepoda       Image: Copepodid Cop	Orbilina universa d'Orbigny		*	VR
Nadpilot al voe de la composition de la composit	Copepoda	1	*	
Calanoid copepodid       *       C         Harpacticold copepodid       *       MC         Luciculia flavicomis Claus       *       MC         Luciculia flavicomis Claus       *       MC         Luciculia flavicomis Müller       *       MC         Acartia clausii Gisbrecht       *       MC         Paracartia latisetosa (Kricz.) #       *       MC         Calanus financhisus Gunnerus       *       R         Eurofemora hirunoloides Nordavist       *       R         Centropaces ponticus Karavave #       *       C         Sapphirina opalina Dana       *       C         Sapphirina angusta Dana       *       C         Parapontella brevicornis Lubbock       *       C         Parapontella brevicornis Dana       *       C         Olithona nana Giesbrecht #       *       C         Olithona numifera Baird #       *       C         Canuella so #       *       C         Microsetella norvegica Boeck       *       R         Maraottika auropectan Gisbrecht       *       R         Eutemina acutificensis Sars #       *       R         Haraottika sophifra Müller       *       R         Evadne	Cvclopoid copepodid		*	C C
Harpacticoid copepodid * MC Luciculia Ravicomis Claus Luciculia Giesbrecht * MC Luciculia Giesbrecht * MC Acarlie clausi. Giesbrecht * MC Acarlie clausi. Giesbrecht * MC Acarlie clausi. Giesbrecht * MC Calanus finmarchisus Gunnerus Cantopaces ponticus Karavaev # Centropaces ponticus Karavaev # Centropaces ponticus Karavaev # Centropaces ponticus Karavaev # Centropaces for the formation opalina formation opalina for the formation opalina for	Calanoid copepodid		*	C
Luciculia navies         •         •           Luciculia valis Giesbrecht         •         •           Temora lonaicornis Müller         •         •           Acartia classi Giesbrecht         •         •           Paracaria latistosa ( Kricz) #         •         •           Cartia classi         •         •           Paracaria latistosa ( Kricz) #         •         •           Cartia classi         •         •           Carto classi         •         •           Carto classi         •         •           Carto classi         •         •           Carto classi         •         •           Ofthona plumifera         •         •           Corvaeus clausi F. Dahl         •         •           Euternina acutiforms Dana         •         •           Euternina acutiforms Dana         •         •           Euternina acutiforms Dana         •         • <td>Harpacticoid copepodid</td> <td>*</td> <td>*</td> <td>MC</td>	Harpacticoid copepodid	*	*	MC
Temporal lonaticomis Müller     *     MC       Acartia clausii Giesbrecht     *     MC       Paracalausii Giesbrecht     *     R       Calanus filmarchizus Gunnerus     *     R       Eurytemora hirunoloides Nordquist     *     *     R       Eurytemora hirunoloides Nordquist     *     *     R       Calanus filmarchizus Gunnerus     *     *     R       Centropaces ponticus Karavaev #     *     *     R       Centropaces ponticus Karavaev #     *     *     C       Sapphirina angusta Dana     *     *     C       Paraoontella brevicomis Lubbock     *     *     C       Olihona numifiest Blaid     *     *     C       Olihona soutifores Dana     *     *     C       Microsetella norvecica Boeck     *     *     C       Euterina acutiforns Sars #     *     *     R       Matiothix auropecten Giesbrecht     *     *     R       Calauela sp. #     *     *     R       Metiotistiltoralis Sars #     * <td< td=""><td>Lucicutia flavicornis Claus</td><td>*</td><td></td><td></td></td<>	Lucicutia flavicornis Claus	*		
Acartia clausii Giesbrecht     *     *     MC       Paracachi altisetosa ( Kricz) #     *     R       Calanus finmarchisus Gunnerus     *     *     R       Calanus finmarchisus Gunnerus     *     *     VR       Paracachi altisetosa (Kricz) #     *     *     VR       Paracalanus parvus Claus #     *     *     R       Centropages ponticus Karavev #     *     *     C       Sapphirina opalina Dana     *     *     C       Parapontella brevicomis Lubbock     *     *     C       Parapontella brevicomis Lubbock     *     *     C       Parapontella brevicomis Lubbock     *     *     C       Olithona nama Giesbrecht #     *     *     C       Olithona nama Giesbrecht #     *     *     C       Convcaeus claus! F. Dahi     *     *     C       Convcaeus claus! F. Dahi     *     *     C       Convcaeus claus! F. Dahi     *     *     C       Cutoroptica Boeck     *     *     C       Amaltothrik auropecten Giesbrecht     *     *     K       Canuella sp. #     *     *     VR       Hamacticus littoralis Sars #     *     *     VR       Podon polyphemoides Leucka	Temora longicornis Müller	*		
Paracartia latisetosa ( Kricz.) #       *       *       R         Calanus finmarchisus Gunnerus       *       *       VR         Eurytemora hirunoloides Nordqvist       *       *       R         Centropaces ponticus Karavaev #       *       R       R         Centropaces ponticus Karavaev #       *       R       R         Sapphirina anausta Dana       *       *       C         Sapphirina anausta Dana       *       *       C         Parapontella brevicomis Lubbock       *       *       C         Parapontella brevicomis Lubbock       *       C       C         Olthona num Giesbrecht #       *       *       C         Olthona accultions Dana       *       C       C         Istas clavines Boeck       *       *       C         Eutenina accultions Dana       *       *       R         Maticostatella norvegica Boeck       *       *       R         Malathita unovecten Olesbrecht       *       *       R         Editorina span.       *       *       R         Editorialis Sars #       *       *       R         Metis iousseaumei Richard #       *       *       R	Acartia clausii Giesbrecht	*	*	MC
Guinas and should solves         *         *         VR           Paracalans band uss Claus #         *         *         *         R           Centropages ponticus         Claus #         *         *         R           Centropages ponticus         Claus #         *         *         C           Sapphrina anguista Dana         *         *         C           Sapphrina anguista Dana         *         *         C           Parasontella brevicomis         Lubbock         *         C           Parasontella brevicomis         Lubbock         *         C           Olthona nana         Glesbrecht #         *         C         C           Olthona plumifera         Baix         *         C         C           Norcestella norverica         Boeck         *         C         C           Marcostella norverica         Boeck         *         C         C           Marcostella norverica         Boeck         *         C         C           Marcostella norverica         Boeck         *         R         K           Canuella sp. #         *         *         C         C           Amaltothitx auropecter Glesbrecht         *	Paracartia latisetosa (Kricz.) #	*	*	R
Paracalanus parvus Claus #       *       R         Centropaces ponticus Karavaev #       *       C         Sapphirina opalina Dana       *       C         Sapphirina angusta Dana       *       C         Parapontella brevicornis Lubbock       *       C         Parapontella spo       *       C         Oithona nama Giesbrecht #       *       MC         Corvcaeus clausi F. Dahl       *       MC         Lisas clavipes Boeck       *       R         Euterpina acutforms Dana       *       *       R         Microstella norvectica Boeck       *       R       R         Amalothrix auropecten Giesbrecht       *       R       R         Canuella sp. #       *       R       R         Metis iousseaumei Richard #       *       R       R         Evadne spinifera Müller       *       R       R         Evadne spinifera Müller       *       R       R         Evadne spinifera Müller       *       R       R         Svnchaeta calv	Eurytemora hirunoloides Nordqvist	*	*	VR
Centropages ponticus Karavaev #       *       C         Sapphirina opalina Dana       *       C         Sapphirina angusta Dana       *       -         Sapphirina angusta Dana       *       -         Sapphirina angusta Dana       *       -         Parapontella brevicomis Lubbock       *       -         Parapontella brevicomis Lubbock       *       -         Colthona nana Giesbrecht #       *       C         Oithona blumifera Baird #       *       MC         Corvcaeus clausi F. Dahl       *       MC         Isias clavipes Boeck       *       C         Euterpina acutiforms Dana       *       *       C         Microsetella norvecica Boeck       *       *       R         Amallothrix auropecten Giesbrecht       *       *       R         Edinocomptus sop.       *       *       VR         Hamacticus littoralis Sars #       *       *       VR         Hamacticus Bittoralis Sars #       *       *       R         Podon polyphemoides Leuckart #       *       *       R         Synchaeta calva Ruther-Kolosko       *       *       R         Synchaeta sp #       C       *       R	Paracalanus parvus Claus #		*	R
Sapplifinita andustata Dana     *       Parabontella brevicornis Lubbock     *       Parabontella sp     *       Olthona nama Giesbrecht #     *       Covcaeus clausi F. Dahi     *       Euterprina acutiforns Dana     *       Microsetella norvecica Boeck     *       Euterprina acutiforns Dana     *       Microsetella norvecica Boeck     *       Canuella sp. #     *       Hanacitiza littoralis Sars #     *       Metrosetella norvecica Robeck     *       Bosmina maritima Müller     *       Evadne spinifera Müller     *       Rodifera     *       Synchaeta calva Ruttner-Kolosko     *       Synchaeta spi#     *       Paraoticulati Agassiz     *       Coldooria     *       Rhizostoma pulmo Merci.     Cnidaria       Ratios spi#     *       Coldooria spo#     *       Coldooria spo#     * <td>Centropages ponticus Karavaev #</td> <td>*</td> <td>~</td> <td><u> </u></td>	Centropages ponticus Karavaev #	*	~	<u> </u>
Parapontella brevicornis Lubbock*-Parapontella sp*-COithona nana Giesbrecht #*COithona nana Giesbrecht #*MCCorveaeus clausi F. Dahl*MCCorveaeus clausi F. Dahl**Isias clavipes Boeck*CEuterbina acuiforns Dana**Microsetella norveaica Boeck*RAmaliothrix auropecten Giesbrecht*REchinocomptus spp.*RCanuella sp. #*VRHaracaticus littoralis Sars #*VRMetis jousseaume Richard #*VRBosmina maritima Müller**Evadne spinifera Müller*REvadne spinifera Müller*RColoon polyphemoides Leuckat #RColoon polyphemoides Leuckat #*RColon polyphemoides Leuckat #*	Sapphinina opainia Dana	*		
Parabonitelia sp       *       *       C         Oithona nana Giesbrecht #       *       MC         Oithona plumifera Baird #       *       MC         Oithona plumifera Baird #       *       MC         Corveaus clausi F. Dahl       *       *         Isias clavipes Boeck       *       *       C         Euterprina acutiforms Dana       *       *       C         Microsetella norvecica Boeck       *       *       R         Amallothrix auropecten Giesbrecht       *       *       R         Echinocomptus spp.       *       VR       *       VR         Harnacticus littoralis Sars #       *       VR       *       VR         Metis iousseaumei Richard #       *       *       VR         Evadne spinifera Müller       *       *       R         Evadne tercestina Claus #       *       VR       VR         Podon polyphemoides Leuckart #       *       *       NC         Synchaeta sp #       *       *       R         Cotvlorhiza tuberculata Agassiz       *       *       R         Cotvlorhiza tuberculata Agassiz       *       *       R         Cotvlorhiza tuberculata Agassiz	Parapontella brevicornis Lubbock	*		
Online in the construction of	Parapontella sp Oithona nana, Giesbrecht #	~	*	C
Corvcaeus clausi F. Dahl     *     *     *       Isias clavipes Boeck     *     *     C       Euterpina acutiforms Dana     *     *     R       Microsetella norvegica Boeck     *     *     R       Amailothrix auropecten Giesbrecht     *     *     R       Echinocomptus spp.     *     *     R       Canuella sp. #     *     *     VR       Harpacticus littoralis Sars #     *     *     VR       Metis jousseaumei Richard #     *     *     VR       Evadne spinifera Müller     *     *     R       Synchaeta calva Ruttner-Kolosko     *     *     R       Synchaeta sp #	Oithona plumifera Baird #		*	MC
Isias clavipes     Boeck     *     *     C       Microsetella norvegica Boeck     *     *     R       Microsetella norvegica Boeck     *     *     R       Amallothrix auropecten     6iesbrecht     *     R       Echinocomptus spp.     *     *     VR       Canuella sp. #     *     *     VR       Metis jousseaumei     Richard #     *     VR       Metis jousseaumei     Cladocera     *     VR       Bosmina maritima Müller     *     *     R       Evadne spinifera Müller     *     *     R       Evadne spinifera Müller     *     *     R       Evadne tergestina Claus #     *     *     R       Fodon polyphemödes     Leuckart #     *     VR       Synchaeta calva Ruther-Kolosko     *     *     MC       Synchaeta sp #     _     *     R       Colvlorhiza tuberculata Agassiz     Pteropoda     *     R       Limacina inflata d'Orbiany     Cheatognatha     *     R       Sagitta setosa Müller #     Appendiculariae     *     R       Oikopleura longicauda Vogt #     Meroplankton     *     C       Polycheate larvae     *     *     C       Cirripe	Corvcaeus clausi F. Dahl	*		
Microsetella norvegica Boeck     *     *     R       Amallothrik auropecten Giesbrecht     *     *     R       Amallothrik auropecten Giesbrecht     *     *     R       Canuella sp.#     *     *     VR       Canuella sp.#     *     VR       Harpacticus littoralis Sars #     *     VR       Metis iousseaumei Richard #     *     VR       Bosmina maritima Müller     *     VR       Evadne spinifera Müller     *     R       Evadne tergestina Claus #     *     R       Podon polyphemoides Leuckart #     *     VR       Synchaeta calva Ruttner-Kolosko     *     *       Synchaeta sp #	Islas clavipes Boeck	*	*	С
Amailothrix auropecten Giesbrecht     *     *       Cehinocomptus spb.     *     *       Canuella sp.#     *     VR       Harpacticus littoralis Sars #     *     *       Metis jousseaumei Richard #     Cladocera       Bosmina maritima Müller     *     *       Evadne spinifera Müller     *     *       Evadne tergestina Claus #     *     *       Podon polyphemoides Leuckart #     *     R       Podon polyphemoides Leuckart #     *     MC       Synchaeta calva Ruttner-Kolosko     *     R       Synchaeta sp #     Cnidaria     *     R       Rhizostoma pulmo Merci.     *     R       Obeila spp #     *     R       Cotvlorhiza tuberculata Agassiz     *     R       Limacina inflata d'Orbiany     *     R       Sagitta setosa Müller #     Meroplankton     *     R       Polycheate larvae     *     R       Cirripedia larvae     *     C     C       Moliusca larvae     *     *     MC       Chrionofermata larvae     *     K     R       Cotylorhiza tuberculata Agassiz     *     R       Chronofermata setosa Müller #      *     R       Ciriqia astas setosa Müller	Microsetella norvegica Boeck	*	*	R
Echinocomputs spb.     *     VR       Canuella sp. #     *     VR       Harpacticus littoralis Sars #     *     R       Metis jousseaumei Richard #     *     VR       Cladocera     *     VR       Bosmina maritima Müller     *     R       Evadne spinifera Müller     *     R       Evadne spinifera Müller     *     R       Evadne tergestina Claus #     *     R       Podon polvphemoides Leuckart #     *     VR       Synchaeta calva Ruttner-Kolosko     *     *       Synchaeta sp #      *     MC       Synchaeta sp #      *     MC       Synchaeta sp #      *     MC       Synchaeta sp #	Amallothrix auropecten Giesbrecht	*		
Harpacticus littoralis Sars #       *       R         Metis jousseaumei Richard #       Cladocera       *       VR         Bosmina maritima Müller       Cladocera       *       VR         Bosmina maritima Müller       *       R       R         Evadne spinifera Müller       *       R       R         Evadne tergestina Claus #       *       R       R         Evadne tergestina Claus #       *       *       R         Podon polyphempides Leuckart #       *       VR       R         Synchaeta calva Ruttner-Kolosko       *       *       MC         Synchaeta sp #       _       *       MC         Obelia sp #       _       *       R         Cotvlorhiza tuberculata Agassiz       *       *       R         Obelia sp #       _       *       R         Cotvlorhiza tuberculata Agassiz       *       R       R         Obelia sp #       _       *       R       R         Obelia sp #       _       *       R       R         Oblicala tuberculata Agassiz       Pteropoda       *       R       R         Sagitta setosa Müller #       _       _       *       R	Canuella sp. #		*	VR
Metis jousseaumei Richard #     Cladocera       Bosmina maritima Müller     *     K       Evadne spinifera Müller     *     K       Evadne tergestina Claus #     *     R       Podon polyphemoides Leuckart #     *     K       Synchaeta calva Ruttner-Kolosko     *     *       Synchaeta sp #     *     MC       Chidaria     *     K       Rhizostoma pulmo Merci.     *     K       Obelia sp #     *     K       Cotvlorhiza tuberculata Agassiz     *     K       Pteropoda     *     R       Limacina inflata d'Orbiany     *     K       Gikopleura longicauda Vogt #     Meroplankton     *     R       Polycheate larvae     *     *     C       Oikopleura larvae     *     *     C       Ostracoda spp     *     *     C       Ciripedia larvae     *     *     C       Coholondermata larvae     *     *     C       Okopleura larvae     *     *     C       Ciripedia larvae     *     *     C       Chironomus larvae     *     *     C	Harpacticus littoralis Sars #		*	R
Bosmina maritima Müller     *        Evadne spinifera Müller     *     R       Evadne targestina Claus #     *     R       Podon polyphemoides Leuckart #     *     *     R       Podon polyphemoides Leuckart #     *     *     R       Synchaeta calva Ruttner-Kolosko     *     *     MC       Synchaeta calva Ruttner-Kolosko     *     *     MC       Synchaeta sp #      *     R       Obelia sp #      *     R       Cotvlorhiza tuberculata Aqassiz     Chieatognatha        Imacina inflata d'Orbiany     *     *     R       Sagitta setosa Müller #     Appendiculariae	Metis jousseaumei Richard #		*	VR
Evadne spinifera Müller       *       *       R         Evadne tergestina Claus #       *       R         Podon polvphemoides Leuckart #       *       R         Podon polvphemoides Leuckart #       *       R         Synchaeta calva Ruttner-Kolosko       *       *       MC         Synchaeta sp #       *       *       MC         Synchaeta sp #       *       *       R         Obelia sp #        *       R         Obelia sp #        *       R         Cotvlorhiza tuberculata Agassiz       Pteropoda       *       R         Limacina inflata d'Orbiany       *       *       R         Sagitta setosa Müller #       Appendiculariae       *       R         Oikopleura lonaicauda Voat #       Meroplankton       *       R         Polycheate larvae       *       *       C         Cirripedia larvae       *       *       C         Schinodermata larvae       *       *       C         Cirripedia larvae       *       *       C         Cirripedia larvae       *       *       C         Chironomus larvae       *       *       VR	Bosmina maritima Müller	*		
Evadne tergestina Claus #     *     R       Podon polyphemoides Leuckart #     *     VR       Synchaeta calva Ruttner-Kolosko     *     *     MC       Synchaeta calva Ruttner-Kolosko     *     *     MC       Synchaeta sp #     *     *     R       Obelia sp #     *     *     R       Oblia setosa Müller #     *     *     R       Oikopleura longicauda Vogt #     *     *     R       Oikopleura longicauda Vogt #     *     *     C       Oikopleura larvae     *     *     C       Oikopleurat larvae     *     *     C </td <td>Evadne spinifera Müller</td> <td>*</td> <td>*</td> <td>R</td>	Evadne spinifera Müller	*	*	R
Potent polyberinoides Leackart #     Rotifera       Synchaeta calva Ruttner-Kolosko     *     *     MC       Synchaeta sp #	Evadne tergestina Claus #		*	R
Synchaeta calva Ruttner-Kolosko     *     *     MC       Svnchaeta sp #     Cnidaria     R       Rhizostoma pulmo Merci.     *     *     R       Obelia spp #     *     *     R       Cotvlorhiza tuberculata Aqassiz     *     R       Deteropoda     *     *     R       Cotvlorhiza tuberculata Aqassiz     *     R       Cotvlorhiza tuberculata Aqassiz     *     R       Cotvlorhiza tuberculata Aqassiz     *     *     R       Cheatognatha     *     *     R       Sagitta setosa Müller #     Appendiculariae     *     R       Oikopleura longicauda Vogt #     Meroplankton     *     R       Polycheate larvae     *     *     C       Cirripedia larvae     *     *     C       Bollusca larvae     *     *     C       Echinodermata larvae     *     *     R       Ostracoda spp     *     *     R	Rotifera	1		
Synchaeta sp #     Cnidaria       Rhizostoma pulmo Merci.     *     *     VR       Obelia sp #      *     R       Cotvlorhiza tuberculata Aqassiz     *     *     R       Sagitta setosa Müller #      *     *     R       Sagitta setosa Müller #      *     R       Oikopleura lonaicauda Voat #      *     R       Polycheate larvae     *     *     C       Cirripedia larvae     *     *     C       Mollusca larvae     *     *     C       Stracoda spp     *     *     R       Ostracoda spp     *     *     R	Svnchaeta calva Ruttner-Kolosko	*	*	MC
Rhizostoma pulmo     Merci.     *     *     VR       Obelia     Spg #     *     R       Cotvlorhiza tuberculata Agassiz     *     R       Delia     Pteropoda     *     R       Limacina inflata d'Orbigny     *     *     R       Cheatognatha       Sagitta setosa Müller #       Oikopleura longicauda Vogt #       Polycheate larvae     *     *     R       Cirripedia larvae     *     *     C       Chironodermata larvae     *     *     C       Ostracoda spp     *     *     K       Ohronomus larvae     *     *     R	<u>Svnchaeta</u> sp#	_	*	R
Obelia spp #      *     R       Cotvlorhiza tuberculata Aqassiz     Pteropoda         Limacina inflata d'Orbiany     Pteropoda     *     R       Cheatognatha       Sagitta setosa Müller #     R       Appendiculariae       Oikopleura lonaicauda Voqt #     *     R       Olycheate larvae     *     R       Climitation       Polycheate larvae     *     *     MC       Mollusca larvae     *     *     MC       Echinodermata larvae     *     *     VR       Ostracoda spp     *     *     R       Chironomus larvae     *     *     VR	Rhizostoma pulmo Merci.	*	*	VR
Conversion     Pteropoda       Limacina inflata d'Orbiany     *     *       Cheatognatha     *     R       Sagitta setosa Müller #     Appendiculariae     *     C       Oikopleura longicauda Vogt #     Meroplankton     *     R       Polycheate larvae     *     *     C       Cirripedia larvae     *     *     C       Echinodermata larvae     *     *     C       Ostracoda spp     *     *     R       Ohronomus larvae     *     *     R	Obelia spp #		*	R
Limacina inflata d'Orbigny     *     *     R       Sagitta setosa Müller #     Appendiculariae     *     *     R       Oikopleura longicauda Vogt #     Meroplankton     *     R       Polycheate larvae     *     *     R       Cirripedia larvae     *     *     MC       Mollusca larvae     *     *     C       Chrianomus larvae     *     *     VR       Ostracoda spp     *     *     R	Cotviorniza tuberculata Agassiz Pteropoda	-	_	
Cheatognatha       Sagitta setosa Müller #        C       Appendicularia       Oikopleura longicauda Vogt #       R       Polycheate larvae     *     C       Cirripedia larvae     *     *     MC       Mollusca larvae     *     *     MC       Echinodermata larvae     *     *     VR       Ostracoda spp     *     *     R       Chironomus larvae     _     *     VR	Limacina inflata d'Orbigny	*	*	R
Sadiral selosa Muller#     Appendiculariae       Oikopleura longicauda Vogt #      *     R       Polycheate larvae     *     *     C       Cirripedia larvae     *     *     MC       Mollusca larvae     *     *     C       Echinodermata larvae     *     *     C       Ostracoda spp     *     *     R       Chironomus larvae      *     VR	Cheatognatha	1	*	
Oikopleura lonaicauda Voqt #     *     R       Polycheate larvae     *     *     C       Cirripedia larvae     *     *     MC       Mollusca larvae     *     *     C       Echinodermata larvae     *     *     VR       Ostracoda spp     *     *     R       Chironomus larvae     *     *     VR	Appendiculariae			0
Meroplankton       Polycheate larvae     *     C       Cirripedia larvae     *     *     MC       Mollusca larvae     *     *     C       Echinodermata larvae     *     *     VR       Ostracoda spp     *     *     R       Chironomus larvae      *     VR	Oikopleura longicauda Vogt #		*	R
Cirripedia larvae     *     *     MC       Mollusca larvae     *     *     C       Echinodermata larvae     *     *     VR       Ostracoda spp     *     *     R       Chironomus larvae      *     VR	Meroplankton	*	*	6
Mollusca larvae     *     *     C       Echinodermata larvae     *     *     VR       Ostracoda spp     *     *     R       Chironomus larvae    *     *     VR	Cirripedia larvae	*	*	мс
Echinodermata larvae     *     *     VR       Ostracoda spp     *     *     R       Chironomus larvae    *     VR	Mollusca larvae	*	*	С
vstracoda spp         *         *         R           Chironomus larvae         _         *         VR	Echinodermata larvae	*	*	VR
	Ostracoda spp	*	*	
Mysis sp * VR	Mvsis sp		*	VR
Osteichthyes eggs* VR	Osteichthyes eggs		*	VR
Nematoda * * VR	Nematoda	*	*	VR

C: Common Species VR: Very Rare species 1985: After Fouda et al., 1985 2002 Present study

#: new recorded species

**Table 2** - Check list of zooplankton taxa recorded in Lake Bardawil during different time periods (1985-2002).

MC: Moderate Common Species R: Rare Species



Fig. 3 - The percentage frequency of different zooplankton groups.

Winter showed the lowest density (av. 29,083 ind. m<sup>-3</sup>) (Fig. 4). 12 copepod species were identified. FOUDA et al. (1985) previously recorded 16 species, dominated mainly by Acartia clausi. The present study showed that Oithona nana is the most common and dominant copepod. A. clausi occurred only during winter and spring. Nauplii and copepodids proved to be the most common forms, being about 72.7% and 14.9% of total copepod density, while adult stages contributed 12.4% only (Fig. 4). The presence of copepod juveniles (nauplii and copepodids) all year round indicates the continuous reproduction of copepods (RAYMONT, 1983). Nauplii and copepodid stages were the major component of copepod in the whole Egyptian Mediterranean and Red Seas (DOWIDAR and EL-MAGHARBY, 1970; HUSSEIN, 1977; ABDEL RAHMAN, 1997; EL-SHERBINY, 1997). Five broods representing five generation over the year were expected for *Oithona nana*, Euterpina acutifrons and Paracalanus parvus (common species in Bardawil lagoon) in the S-E Mediterranean (DOWIDAR and EL-MAGHRABY, 1970). Oithona nana, the numerically dominant copepod, contributed 59.1% of total adult copepod (range 26.2 - 77.6%). O. nana exhibited a clear peak in summer (avr. 14,583 ind. m<sup>-3</sup>) and persisted with numbers ranging between 1,000 and 7,000 ind. m<sup>-3</sup> during the rest of the year. Station X maintained the highest density (Fig. 4). O. nana is common, not only in the open sea but also in estuaries and enclosed Bays in the tropical and subtropical regions (GRICE, 1960; NISHIDA, 1985). Acartia clausi was recorded only during winter and spring. Station X had



Fig. 4 - Community composition, distribution and seasonal variation of total Copepoda and most common copepod species.

the highest density (5,000 ind. m<sup>-3</sup>) in spring (Fig. 4). *A. clausi* is Atlanto-Mediterranean, anti-lessepian migrant (FOX, 1927), mostly common in the entire Ponto-Mediterranean province (BELMONTE and POTENZA, 2001). NOUR EL-DIN (2001) mentioned that *A. clausi* disappeared at some areas of Bardawil lagoon with salinity above 48‰. During present study, *A. clausi* totally disappeared during summer and autumn.

*Centropages ponticus* is the only summer species, (av. 2,042 ind. m<sup>-3</sup>), with a pronounced peak of 11,000 ind. m<sup>-3</sup> at station VIII (Fig. 4). *C. ponticus* is a neritic species and previously recorded in Suez Canal and Eastern Mediterranean (ABDEL RAHMAN, 1993; SEI *et al.*, 1996). *Euterpina acutifrons* is a perennial species, made up 12.4% (range 4.9 - 31.9%) of total adult copepod. In contrast to the

upper mentioned copepod species, *E. acutifrons* peaked in spring, with a maximum of 11,000 ind. m<sup>-3</sup> at station I (Fig. 3). The species was practically absent in autumn.

#### Protozoa

23 species were recorded, contributing 10.3% (range 4 -36.4%) of total zooplankton density, with average abundance of 11,052 cells m<sup>-3</sup>. The highest density was recorded in winter, with a peak of 77,000 cells m<sup>-3</sup> at station VIII (Fig. 5), while the minimum was in autumn. Tintinnopsis tocantinensis and Favella serrata (both Ciliofora) were the most common protozoan species. FOUDA et al. (1985) recorded 21 protozoan species dominated mainly by Tintinnopsis lobiancoi (Table 2).

*Favella serrata* contributed with about 27.1 % to the total Protozoa density, with an average of 2,995 cells m<sup>-3</sup> (range 250 -60,000 cells m<sup>-3</sup>). Spatially, there is a numerical increase tendency towards station VIII, with showed the peak of 60,000 ind. m<sup>-3</sup> in spring (Fig. 5).

*Tintinnopsis tocantinensis* represented 13.1% of total protozoan population density. Its highest standing crop



Fig. 5 - Distribution and seasonal variation of total Protozoa and most common protozoan species.

(4,083 cells m<sup>-3</sup>; range 1,000 - 16,000 cells m<sup>-3</sup>) occurred in winter (Fig. 5). ABDEL RAHMAN (1997), and EL-SEREHY *et al.* (2000) respectively recorded this species at Suez Gulf of Red Sea and Suez Canal.

## Pteropoda

Pteropoda were represented mainly by *Limacina inflata*, which made up 10.3% of total zooplankton density. It was highly represented in spring with two peaks of 77,000 and 85,000 ind. m<sup>-3</sup> at stations III and IV, respectively (Fig. 6). Lowest density was recorded in winter. HUSSEIN (1977; 1997) recorded a remarkable peak of this species in autumn in Mediterranean waters of Egypt, while NOUR EL-DIN (1987), and DORGHAM and HUSSEIN (1997) recorded the peak during summer in east Mediterranean and Doha harbor.

## Meroplankton

Meroplankton made up 7.6% of total zooplankton density. The maximum standing crop occurred in spring with a peak of 61,000 ind. m<sup>-3</sup> at station II (Fig. 6). Mollusca and Polychaeta larvae were the most common among stations and seasons, while others showed sporadic. The distribution of these larvae is shown in Fig. 6.



Fig. 6 - Distribution and seasonal variation of Pteropoda and meroplankton (Polychaeta and Mollusca larvae).

### Species richness and other diversity indices:

Regarding spatial distribution, the highest species number (40) was found at station II, while station XII had the lowest (20). Stations II and VIII showed the highest evenness (0.67, and 0,67) and diversity (2.47, 0.84 and 2.36, 0.82) (Table 3).

	Ι	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Species	31	40	29	36	27	26	31	33	31	29	30	20
Richness	2.60	3.35	2.44	3.00	2.28	2.22	2.57	2.72	2.59	2.37	2.48	1.70
Evenness	0.55	0.67	0.60	0.56	0.49	0.41	0.47	0.67	0.50	0.57	0.51	0.45
Shannon diversity	1.90	2.47	2.01	2.01	1.60	1.33	1.62	2.36	1.72	1.92	1.72	1.35
Simpson diversity	0.66	0.84	0.78	0.76	0.60	0.49	0.61	0.82	0.64	0.72	0.67	0.55

Table 3 - Diversity measures of the zooplankton (spatial distribution).

Station VI sustained the lowest evenness (0.41), and diversity values (1.33, and 0.49). Cluster analysis of zooplankton measures revealed three groups of stations: II, VIII; V, VI, XII and the others. The highest similarity (80.1) occurred between station IX and station X within the third group (Fig. 7). On a seasonal basis, spring maintained the highest species number (42), while autumn had the lowest (31).



Fig. 7 - Clustering of the Bardawil Lagoon stations according to their zooplankton fauna.

The highest evenness (0.7) and diversity (2.6, and 0.86) were recorded in winter, while the lowest (0.47; 1.73 and 0.69) occurred in summer (Table 4). Canonical correspondence analysis was used to summarized the relationships between the most common zooplankton groups or species (Fig. 8, A and B) and environmental variables. CCA revealed that salinity, water temperature and ammonium were the most important factors affecting zooplankton structure in Bardawil Lagoon. The ordination by dominant groups shows a negative correlation between Rotifera, Protozoa and water temperature, ammonia & salinity. Pteropoda were highly

	Winter	Spring	Summer	Autumn
Species	41	42	37	31
Richness	3.65	3.47	3.30	2.78
Evenness	0.70	0.47	0.47	0.55
Shannon diversity index	2.60	1.74	1.73	1.89
Simpson diversity index	0.86	0.62	0.69	0.73

 Table 4 - Diversity measures of the zooplankton (seasonal).



Fig. 8 - CCA ordination plot of axis I and axis II relating variations in the distribution of zooplankton groups or species to environmental variables. The joint plot of groups A (quadrate) and species B (circle), and the environmental arrows is a biplot that approximate the weighted average of each group or species with respect to each of the environmental variables. The abbreviations used for Physical &chemical variables are: WT = Water temperature, NH3 = Ammonium, HCO3 = Bicarbonate, CO3 = Carbonate, Secch = Secchi-depth, NO3 = Nitrate, NO2 = Nitrite, DO = Dissolved Oxygen, BOD = Biological Oxygen Deman, PO4= Orthophosphate and TP = Total phosphorus.

associated with total phosphorus and dissolves oxygen, while Copepoda can withstand all of a biotic variables. The ordination by dominant species was more informative. *Tintinnopsis tocantinensis*, *Synchaeta calva*, *Acartia clausi* and *Favella serrata* were negatively correlated with most of abiotic factors (salinity, water temperature, ammonia and biological oxygen demand, in particular). *Oithona nana* and *Centropages ponticus* were highly associated with salinity and dissolved oxygen, respectively.

In conditions of increasing eutrophication, the number of zooplankton species gradually decreased and generally the faunistic assemblage is simplified (SIOKOU-FRANGOU et al., 1998). The low species richness under eutrophication conditions and the abundance of few species in a particular biotope result from their tolerance of the environmental variability and their capability for optimum exploitation of food resources. This variable tolerance results from special physiological adaptations of the organisms (GAUDY, 1984). There is an obvious increase in nitrate and soluble phosphate from 0.04 - 0.16 mg/l and 0.009 - 0.42mg/l in 1988 (SILIEM, 1989) to 1.1 - 5.8 mg/l and 0.02 - 0.89 mg/l in 1999 (ANONYMOUS, 2000). Progressive increase in nutrient salts proved to be inversely correlated with zooplankton diversity and may led to changes within zooplankton community structure. The dominant species in 1985 (Tintinnopsis lobiancoi and Acartia clausi were replaced by Tintinnopsis tocantinensis and Oithona nana. The first two species are quit bigger than the second this may indicate stressed situation and /or confined water. Moreover, 21 zooplankton species were found for the first time in the lagoon. Few zooplankters occurred all over the whole area of the lagoon, such as Oithona nana, Centropages ponticus and Euterpina acutifrons (Copepoda) and Tintinnopsis tocantinensis (Protozoa) as well as *Limacina inflata* (Pteropdoda), while others were highly confined to restricted areas.

The total mullet catchs showed general negative trends in spite of general increase in fishing effort. The total mullet catchs reached 1,011 tons in 1994 contributing 67.3% of total lagoon production. The percentage gradually decreased to 43.9% in 1995 and 32.9% in 1999. The production of the most economic important fish species (*Sparus aurata*) sharply decreased from 1,105 ton in 1962-1966 to 252 and 223 tons during 2000 and 2001, respectively (EL-GANAINY and YASSIEN, 2002). The changes in zooplankton community structure may be one of main reasons.

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