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Zooplankton Dynamics and Ecology of an Eutrophic Area, Egypt

Abstract: The qualitative and quantitative dynamics of a zooplankton community were studied monthly over a year in relation to the variable environmental conditions in Dekhaila Harbour, a coastal eutrophic area.

The temporal changes of water temperature were similar to those previously known along the southeastern Mediterranean coast (15-29^{O}C). Dissolved oxygen varied between a low level of 1.7 ml/L and well oxygenated conditions (8.3 ml/L). Surface salinity suffered from marked seasonal and regional variations, falling between 17.34%^{O} and 39.18%^{O} over the year. The low transparency was one of the characteristic features of the harbour water, where Secchi depth maintained low values (45 - 270 cm). The phytoplankton chlorophyll a showed an abnormally wide range of variations from a significantly low value of 1.63 mg/m^3 to an abnormally high one (1323 mg/m^3).

The species composition and density of zooplankton were clearly affected by the ecological variations. The annual average count (22,640 organisms/m^3) demonstrated a relatively low standing crop, fluctuating all the year round between 781 and 236,644 organisms/m^3.

The zooplankton community showed a group structure more or less different from those usually known in the coastal Egyptian Mediterranean waters. The protozoans appeared as the major constituent, forming 66.1% of the total catch, and copepods came in second (26.5%). The bulk of zooplankton density was attributed to a few species, including the tintinnids *Favella serrata, Tintinnopsis nana, T. lata, T. compressa* and *Eutintinnus lusus-undae* and the copepod *Oithona nana*, which all together formed 62% of total count. Several freshwater holoplanktonic forms were recorded in the area, contributing 2.7 % to the total crop, and reflecting the impact of the discharged waste water.

The temporary planktonic assemblages played a small role in the study area, averaging annually 5.2%, with the dominance of the larval stages of polychaetes and cirripedes.

The index of biotal dispersity, diversity index and species richness exhibited pronounced temporal and spatial variations as a reflection of environmental changes.

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ديناميكية الهائمات الحيوانية وبيئتها فى منطقة تلوث عضوى في مصر

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المستخلص: يهتم هذا البحث بدراسة التركيب النوعى والكثافة العددية للهائمات الحيوانية وعلاقة ذلك بالعوامل البيئية فى ميناء الدخيلة الذى يقع داخل خليج المكس على ساحل البحر المتوسط غرب الاسكندرية. ويعتبر ميناء الدخيلة من المناطق الملوثة عضويا، كما أنه يتأثر بمخلفات زراعية وصناعية وآدمية تصب فى خليج المكس من خلال مصرف العموم.

أجريت الدراسة على عينات شهرية جمعت من خمسة مواقع لمدة عام، وشملت بعض العوامل البيئية مثل درجة حرارة الماء، الملوحة، شفافية الماء والأكسجين الذائب، وكذلك كثافة الهائمات النباتية معبرا عنها بكمية يخضورأ. كما تضمنت الدراسة تعريف أنواع الهائمات الحيوانية الدائمة منها والمؤقتة المتواجدة فى الشهور المتتالية وكثافتها العددية.

وقد أشارت النتائج إلى ما يلى:

لم يحدث تغير جوهرى فى درجة حرارة الماء عما هو مألوف فى السواحل المصرية، حيث تراوحت طوال العام ما بين 15^{o} مئوية كحد أدنى فى الشتاء و 29^{o} درجة مئوية حد أقصى فى الصيف. وتميزت المنطقة بانخفاض واضح فى شفافية الماء ليصل عمق قرص سيكى إلى 45-105 سم معظم أوقات السنة، ويرتفع فى الربيع إلى 130-270 سم. الأكسجين الذائب دلت قيمه على تباين واضح فى الأوقات المختلفة وعند مواقع جمع العينات، وتأرجح التركيز بين 1.7 -8.3 مللتر/لتر، الأمر الذى يعكس تغيرا واسعا فى العوامل البيئية فى منطقة الدراسة. وقد ارتبطت تركيزات الأكسجين الذائب بقيم اليخضور أ (1,63-1323 ملجرام/م3) التى دلت على أن ميناء الدخيلة يتميز بوجود كميات كبيرة من التلوث العضوى.

ومن أهم ما تميزت به منطقة الدراسة التغير المستمر فى ملوحة المياه كنتيجة للتدفقات الأرضية الهائلة مما أدى إلى تباين قيم الملوحة طوال فترة البحث بين 17.34 جزء فى الألف إلى 39.18 جزء فى الألف.

من ناحية أخرى فإن مجتمع الهائمات الحيوانية تعرض لتغيرات كبيرة سواء فى عدد الأنواع المتواجدة فى الشهور المتتالية أم فى الكثافة العددية لها. وأهم ما بينته الدراسة فى هذا الشأن هو أن ميناء الدخيلة تدنى فيه عدد أنواع هذه الهائمات (102 نوعا) مقارنة بمناطق أخرى على السواحل المصرية، كما أن المتوسط السنوى لكثافتها العددية (22640/م3) أقل بكثير من نظرائه فى تلك المناطق.

الحيوانات الأولية (التنتنيدات) أظهرت تفوقا عدديا واضحا فى فترات محدودة، كان سببا فى ازدهار الهائمات الحيوانية فى شهرى سبتمبر ومارس واحتلت بذلك المركز الأول (66,1%) بالنسبة للمتوسط السنوى لهذه الهائمات، إلا أن الكوبيبودا كانت الأكثر سيادة غالبية الوقت بالرغم من وجودها فى المركز الثانى (26,5 %) بالنسبة للمتوسط الكلى.

عدد قليل من الأنواع هو الذى ساد على مجتمع الهائمات الحيوانية، كان من

أهمها التنتنيدات مثل تنتنوبسز نانا، فافيلا سيراتا، تنتنوبسز لاتا، تنتنوبسز كومبرسا، يوتنتنس ليوسس-أوندى، وكذلك بعض الكوبيبودا مثل أويثونا نانا، يوتربينا أكيوتفرونز، أكانثوسيكلوبس أميريكانس وغيرها. بالإضافة إلى ذلك فإن بعض الأنواع التى تعيش عادة فى البحر المفتوح بعيدا عن الشاطئ وجدت فى منطقة الدراسة مما يشير إلى انتقال هذه الأنواع إلى المياه الساحلية عن طريق التيارات، ومن جهة أخرى رصد 21 نوعا من تلك القاطنة فى المياه العذبة والتى انجرفت إلى الميناء عن طريق مياه الصرف. وقد بينت النتائج تواجد بعض الأنواع الأخيرة بكثرة عددية ملحوظة الأمر الذى يدل على أنها تأقلمت على الملوحة العالية فى الميناء، ومن أمثلتها نوع أكانثوسيكلوبس أميريكانس.

وتعتبر الملوحة من أهم العوامل التى أثرت على توزيع الأنواع فى ميناء الدخيلة وعلى كثافتها العددية حيث ظهر ذلك فى التباين الواضح بين قيم المحصول القائم للهائمات الحيوانية عند المواقع المختلفة وكذلك قيم كل من دليل التنوع البيولوجى، ودليل الانتشار الحيوى، أضف إلى ذلك الانخفاض الملحوظ فى كثافة يرقات الحيوانات القاعية مما يدل على عدم موائمة ميناء الدخيلة لنمو كثير من هذه الحيوانات. ولا يمكن إغفال تأثير التلوث العضوى الناتج عن النمو المكثف للهائمات النباتية وكذلك الملوثات المتنوعة القادمة مع مياه الصرف على مجتمع الهائمات الحيوانية فى هذه المنطقة.

ومن الدراسة أمكن استنتاج أن التغير المستمر فى العوامل البيئية فى ميناء الدخيلة والناتج عن تدفق المخلفات بأنوعها المختلفة أدى إلى تدهور التنوع البيولوجى للهائمات الحيوانية وانخفاض كثافتها العددية بالمقارنة بمناطق أخرى فى المياه المصرية.

Introduction

Dekhaila Harbour (4-20m depth) is a part of Mex Bay, which lies on the western side of the Alexandria sea coast. It has been used for maritime-goods traffic since October 1986. The main basin of the harbour is subdivided by ship quays into 3 parts, directly opened to the Bay water. The harbour receives different types of minerals, ores, fertilizers, salts and grains. Some of these goods, such as wrought iron, pellet iron and coke, are stored in great heaps in open areas. Meanwhile, grains are packed in the harbour, a process through which flying flour precipitates on the sea surface, causing nutrient enrichment of the Harbour water. On the other hand, the harbour is exposed to several sources of pollution from urbanization processes and shipping activities, in addition to great volumes of waste water (6.6x10^6 m^3/day) discharged to Mex Bay and loaded with agricultural, industrial and domestic pollutants (Aboul-Dahab *et al.*, 1984; El-Rayis *et al.*, 1984 and Dorgham *et al.*, 1987).

In addition to the above mentioned authors, water quality and the phytoplankton community of Mex Bay and Dekhaila Harbour, have attracted the attention of many investigators (El-Sherif, 1989; Zaghloul and Nessim, 1991 Emara *et al.*, 1992; Nessim, 1994; Zaghloul *et al.*, 1995; Zaghloul 1996; Labib, 1997; Fahmy *et al.*, 1997). However, very little is known about zooplankton of this area (Hussein, 1997a, 1997b; Soliman and Gharib, 1998). The urbanization, maritime activities and land-based effluents cause negative stress on the ecosystem of Dekhaila Harbour, and were reflected in the structure and abundance of the zooplankton community.

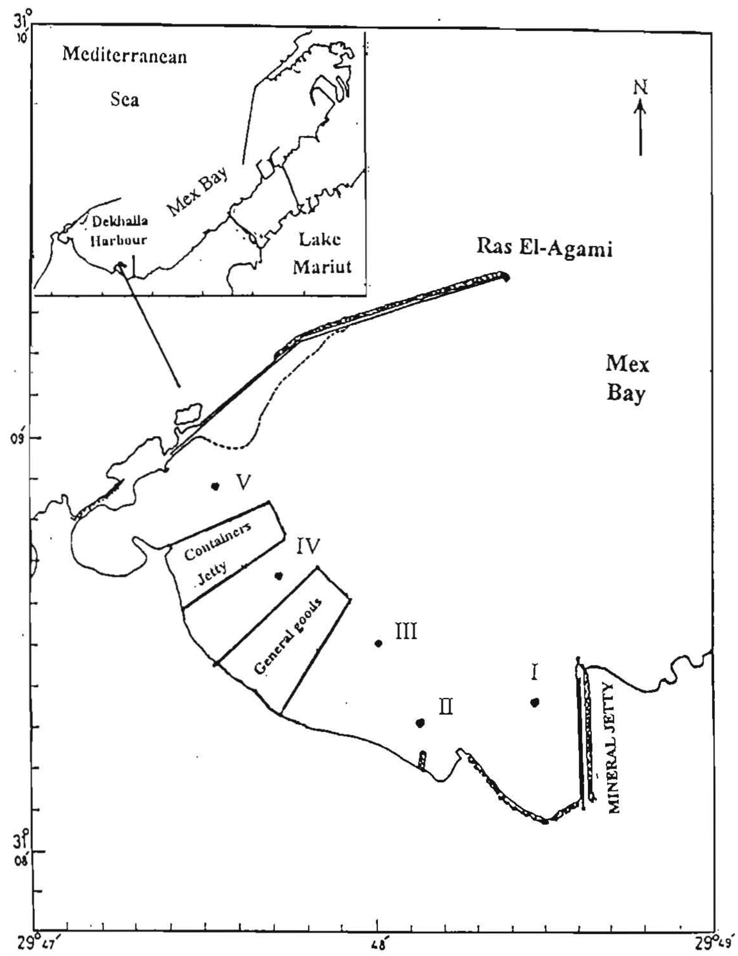

Fig. 1. Locations of sample collection in Dekhaila Harbour

The present work deals with a year's cycle of zooplankton dynamics relevant to ecological characteristics of Dekhaila Harbour, which was recently identified among eutrophic coastal embayments on the Egyptian Mediterranean coast.

Materials and Methods

During the period from April 1998 to March 1999 monthly samples were collected at five locations (Fig. 1) representing different water qualities. Physico-chemical parameters (temperature, salinity, dissolved oxygen and transparency) and chlorophyll a were measured in the surface water. Salinity was detemined argentometrically (Standard methods, 1980), dissolved oxygen and chlorophyll a according to Strickland and Parsons (1969).

Zooplankton samples were collected from the upper 10 m through vertical hauls using a net of 30 cm opening diameter and 55 mm mesh size at a spead of 0.5 m/sec. The samples were preserved in 5% neutralised formaline and after settling were concentrated to 100 ml each. Zooplankton species were identified under a research microscope and standing crop was calculated from the average counts in two aliquots of 5ml samples. Correlation coefficients between zooplankton density and ecological parameters, diversity index (Shannon and Weaver, 1956) and species richness were calculated. The index of biotal dispersity (IBD) of zooplankton species between the different stations was also found according to Koch (1957).

Results

a- Hydrographic conditions

The studied ecological characteristics of Dekhaila Harbour demonstrated wide temporal and spatial variations (Table 1). The surface water temperature followed the seasonal changes along the Egyptian Mediterranean coasts. Winter minimum (15-16^{o}C) was recorded in December-January and summer maximum (28-29^{o}C) in July-August. Throughout the stations, the differences were very small (0.5^{o}C).

The harbour water was often characterized by low transparency with Secchi depths of 45 - 105 cm most of the year, and comparably higher records (130-270 cm) in February, April and May.

The monthly average concentrations of dissolved oxygen showed three approximately similar peaks in March, July and October (4.7, 4.6 and 5.1 ml/L respectively), while they decreased markedly to 1.7-2.3 ml/L most of the year. The general trend of spatial oxygen distribution indicated little differences between the stations; however, summer months maintained large amplitudes of spatial variations, ranging from 1.9 to 2.9 ml/L. Abnormally high concentrations were recorded at station I (7.1 ml/L) in October and station V (8.3 ml/L) in March.

Salinity variation was one of the characteristic features of Dekhaila Harbour, where in the surface water it varied from 17.34 %^{o} in November to 39.18 %^{o} in February. The highest average salinities (31.86-38.33 %^{o}) were recorded from February to May, while most of the time they were markedly lower (19.14 - 28.39 %^{o}). Different spatial patterns were observed all the year round, with a wide amplitude (up to 9.01 %^{o}) in spring and summer, and a narrow one (1.48 - 3.35 %^{o}) in autumn and winter.

Chlorophyll a pointed to an advanced degree of eutrophication in Dekhaila Harbour. Two phases were detected during the study period, the first one extended from November to May with comparably lower values (average: 2.49 - 40.68 mg/m^3) and the second phase from June to October sustaining high values (average 123.8 - 444 mg/m^3). Abnormally high chlorophyll a concentrations (up to 1323.7 mg/m^3) were recorded.

Zooplankton community

Relatively low diversity (102 spp.) and low abundance (average: 22,640 organisms/m^3) characterized the zooplankton community in Dekhaila Harbour. Tintinnidae was the dominant group (29 spp.), followed by Copepoda (17 spp.), Foraminifera (15 spp.) and Rotifera (10 spp.). In addition, 31 species were also identified belonging to minor groups such as *Coelenterata*, *Larvaceae*, *Chaetognatha*, *Cladocera*, and other rarely occuring holoplankton groups. The temporary planktonic

Table 1- Ranges of physico-chemical conditions in Dekhaila Harbour from April 1998 to March 1999.

Parameter	St. I	St. II	St. III	St. IV	St.V
S%^{o}	18.2-38.4	18.8-39.2	17.3-38.1	19.9-38.5	20.4-37.5
Secchi depth(cm)	40-260	40-260	60-300	50-300	30-240
O_2 ml/l	1.9-7.1	1.7-5.7	1.5-5.7	1.6-5.7	1.3-8.3
chl. a mg/m^3	2.9-344.5	1.8-344.5	3.3-202.6	2.9-318.6	1.6-1323

Table 2- Number of Holozooplankton species at different locations in Dekhaila Harbour (April 1998 - March 1999).

Month	St. I	St. II	St. III	St. IV	St.V	Total
April	46	15	33	22	18	48
May	21	19	18	20	22	34
June	21	10	14	21	22	35
July	19	18	28	21	24	42
Aug	11	8	10	12	18	30
Sep.	23	23	28	29	31	40
Oct.	20	23	26	23	27	46
Nov.	22	15	20	26	23	39
Dec.	15	8	11	16	12	25
Jan.	10	6	15	14	10	26
Feb.	13	9	16	17	11	25
Mar	17	16	18	24	12	35
Total	73	60	73	81	68	102

larvae of several benthic animals were also recorded including polychaetes, cirripedes, decapods, molluscs, echinoderms and ascidians.

The community structure showed monthly variations, from 25 species in December to 48 species in April, with the smallest number in winter and approximately close numbers in other seasons (Table 2). The species composition demonstrated also more or less pronounced variations throughout the stations, where station II sustained the poorest community over the year (60 spp.) and station IV harboured the richest one (81spp.).The index of biotal dispersity (IBD) of zooplankton community demonstrated monthly varying degrees of similarity throughout the stations (Table 3). The index values for the annual records of species indicated that station I harboured a community with comparatively high similarity to those at stations III, IV & V, but at station II, the similarity with other stations was low.

The diversity index of zooplankton species fluctuated between 0.26 and 2.32; however, the monthly means were approximately similar (1.69 - 1.77), except those in March (0.51) and October (2.21). At each station, different patterns were observed (Fig. 2). The species richness maintained low values most of the year, except for a comparably high one in April, without any clear seasonal pattern at the stations.

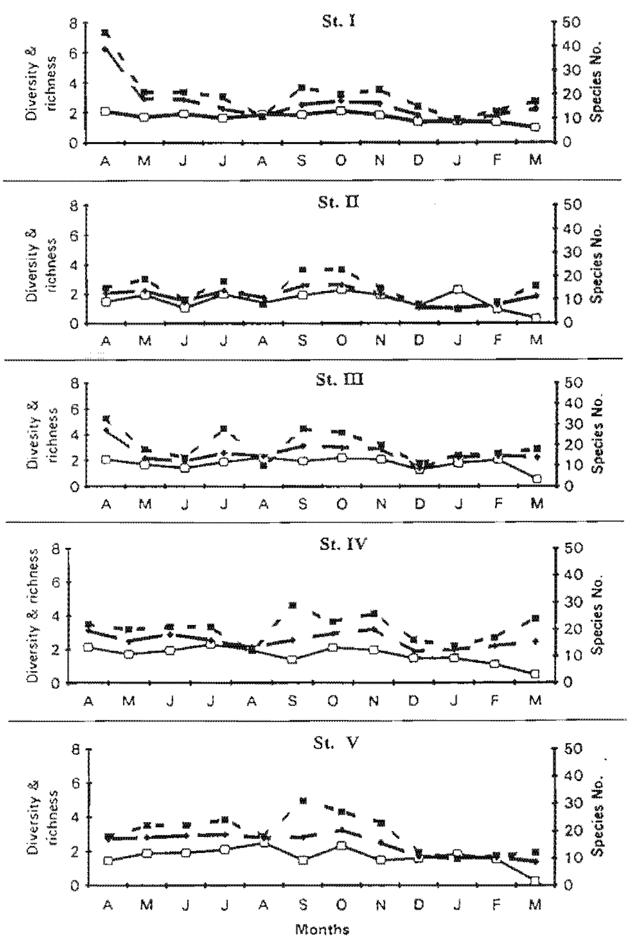

Fig. 2. Monthly variations of species number, diversity and richness of zooplankton community in Dekhaila Harbour (April 1998-March 1999)

Diversity —□— Richness —◆— Species No. - - ■ - -

Table 3 Index of biotal dispersity of zooplankton community between different stations in Dekhaila Harbour (April 1998-March 1999)

Month	I & II	I & III	I & IV	I & V	II & III	II & IV	II & V	II & IV	III & V	IV & V
April	37.10	67.50	64.70	36.80	40.0	40.70	36.00	54.00	39.50	50.00
May	62.50	58.30	48.10	51.90	76.2	69.60	42.90	62.20	50.00	41.40
June	30.40	36.00	46.40	35.50	41.2	40.90	33.30	66.70	44.00	48.30
July	54.20	42.40	33.30	43.30	39.4	30.00	40.00	48.50	48.60	55.20
Aug.	42.90	37.50	41.10	36.40	20.0	17.60	23.80	37.50	27.30	21.70
Sep.	42.40	73.30	60.60	61.80	50.0	57.60	54.30	67.60	63.90	57.90
Oct.	34.40	39.40	53.60	51.60	40.0	48.40	51.50	48.50	55.90	51.50
Nov.	50.00	51.90	44.80	46.70	59.1	50.00	46.20	41.40	53.60	51.70
Dec.	41.20	52.90	47.60	50.00	33.3	31.60	40.00	42.10	35.30	40.00
Jan.	45.50	38.90	9.10	42.90	31.3	11.10	45.50	26.10	38.90	33.30
Feb.	43.80	42.90	50.00	50.00	58.5	50.00	61.50	54.50	47.40	55.60
Mar.	52.40	59.10	42.90	45.00	50.0	46.20	50.00	51.90	50.00	45.80
Ann.	64.20	71.80	67.40	65.90	62.2	60.20	56.10	67.40	60.20	65.60

The standing crop suffered from wide variations in the whole area, from 781 to 236,644 organisms/m^3. The abundance cycle was bimodal with two distinguished peaks in September and March at all stations, with a markedly low density most of the year (Fig. 3). Both peaks were caused mainly by tintinnid species, of which *Tintinnopsis nana* was the majority in March (92% of total density) and *Favella serrata* (45.9%), *Tintinnopsis lata* (17.7%), *T. compressa* (12.8%) and *Eutintinnus lusus-undae* (9.8%) in September. From spatial distribution results, it was clear that station V sustained the densest zooplankton population (36,264 organisms/m^3) and stations I and III maintained the lowest densities of 12,888 and 11,007 organisms/m^3 respectively (Fig. 4).

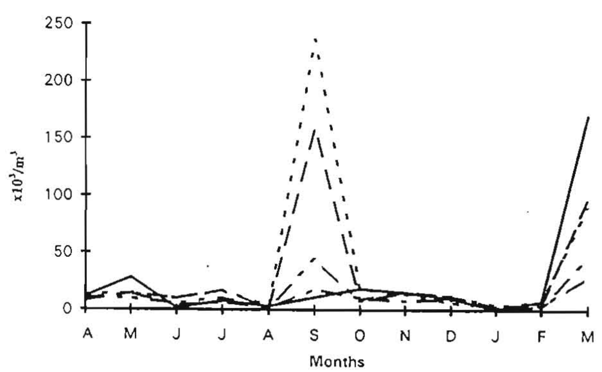

Fig. 3. Temporal variations of zooplankton density at different locations in Dekhalia Harbour (April 1998 - March 1999)

----St 1 —— St 2 -·- St 3 — — - St 4 ----- St 5

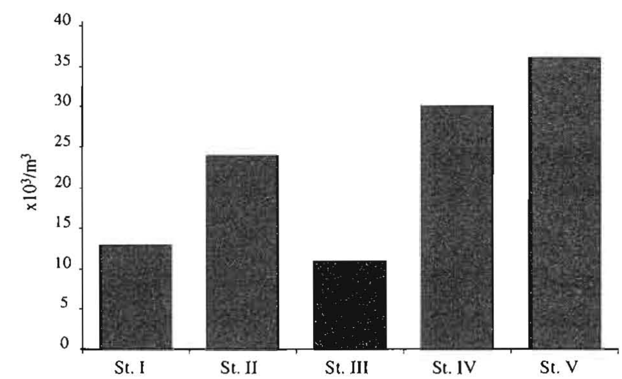

Fig. 4. Average zooplankton density at different stations in Dekhalia Harbour (April 1998 - March 1999)

In other months, the contribution of tintinnids was mostly limited, constituting 1.2-26.9% of total zooplankton density; however, some species played a relatively larger role, such as *Stenosemella nivalis* (11%) in May, *Metacylis mediterranean* (9.5%), *Protorhabdonella simplex* (5.4%), *Tintinnopsis radix* (4.4%) in October and *Protorhabdonella simplex* (5.5%) and *Metacylis mereschkowskii* (3%) in November. All the identified tintinnids are neritic temperate, except *Codonellopsis parva, Dictyocysta speciosa* and *Proplectella pentagona* which are referred to as oceanic forms. On the other hand, except for the markedly high density of tintinnids in September and March, copepods were pronouncedly the leading group most of the year, forming 51-89% of total zooplankton density (Fig. 5), but their nauplii larvae represented the major constituent (30.5-81.4% of total copepods). The euryhaline *Oithona nana* was the absolutely leading adult copepod constituting 15.4% of the annual average density of this group and 4% of zooplankton. Other euryhaline copepods such as *Euterpina acutifrons*, *Paracalanus parvus* and *Acartia clausi* appeared in relatively large numbers forming together 11% of total copepods and 2.9% of total zooplankton. The freshwater forms *Acanthocyclops americanus*, *Canthocamptus pygmaeus*, *Nitocera lacustris* and *Schizopera clandestina* were observed in the harbour. *Acanthocyclops americanus* was found all the year round in relatively large numbers, constituting 4.6 % of copepods. Apart from the above mentioned species, fresh and marine, all other copepods were found occasionally in the study area with remarkably low counts. On the other hand, the majority of the recorded copepods are neritic temperate, some are found in both neritic and oceanic water, while a few oceanic species were intermittently recorded, namely *Microsetella rosea* and *Sapphirina angusta* (Table 4).

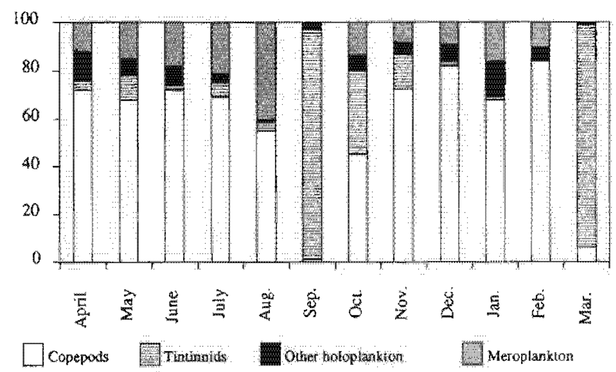

Fig. 5. Contribution (%) of the major groups to total zooplankton in Dekhalia Harbour (April 1998 - March 1999)

The seasonal peaks of the important copepods showed different timing; both *Oithona nana* and *Acanthocyclops americanus* demonstrated two peaks in July and autumn, but the latter species had lower counts. *Euterpina acutifrons* and *Acartia clausi* reached their maximal densities in May, while *Paracalanus parvus* showed two peaks in July and December (Fig. 6).

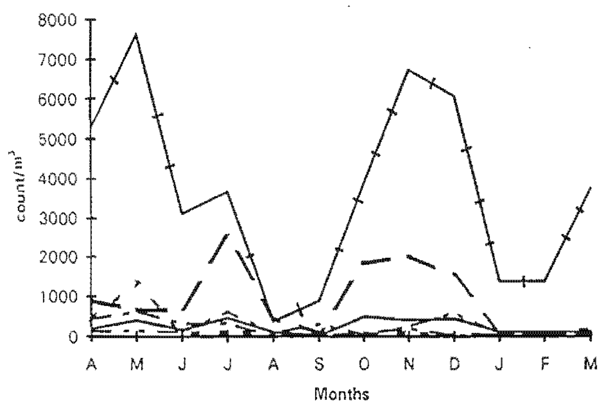

Fig. 6 Temporal abundance of dominant copepod species in Dekhalia Harbour (April 1998 - March 1999)

Eut. Acut. Acar. clau. Parac. par. Acanth. amer
Oith. nana Naupl.

Rotifers were recorded sporadically, but mostly in low densities having an annual average of 103 organisms/m³. However, *Synchaeta oblonga* was found most of the year with relatively high density, reaching a maximum of 1783 organisms/m³ in October at station V.

The other holozooplankton groups played small roles (Fig. 5) with a comparably pronounced contribution of *Larvaceae*, which appeared most of the year (annual average of 297 organisms/m³). The assemblages of this group (5 spp.) appeared sporadically, except for the perennial species *Oikopleura longicauda*, which sustained the highest count in spring and autumn, attaining a peak (1953 organisms/m³) in April at station V. Chaetognatha comprised *Sagitta friderici*, *S. enflata*, *S. elegans* and *S. serradentata*. The latter two species were observed once a year in small numbers (28 organisms/m³), while *S. friderici* existed all the year round in numbers varying between 28 and 85 organisms/m³.

The meroplankton components constituted a limited role in Dekhaila Harbour, forming 5.3 % of total count, and were dominated by larvae of polychaetes and cirripedes.

Table 4. Seasonal frequency of zooplankton species in Dekhaila Harbour during April 1998 - March 1999

	Spring	Summer	Autumn	Winter
A- HOLOPLANKTON				
Protozoans				
Freshwater Amoeba and Ciliata				
Arcella discoides	R	—	—	—
Centropyxis aculeata	R	—	—	—
C. ecornis	—	R	—	—
Amphileptus claparedei	—	—	F	R
Glaucoma scintillans	R	R	R	R
Tillina magna	—	R	—	F
Oxytricha fallax —	—	A	—	
Tintinnidae				
Codonellopsis morchella	R	—	F	R
C. parva	—	—	—	R
Dictyocysta speciosa	—	—	R	—
Eutintinnus lusus-undae	R	F	D	R
Favella adriatica	R	—	R	—
F. azorica	—	—	D	—
F. ehrenbergii	R	R	C	F
F. markusovszkyi	F	—	R	R
F. panamensis	—	—	F	—
F. serrata	F	R	D	R
Helicostomella subulata	—	—	R	R
Metacylis Mediterranean	F	F	C	R
M. mereschkowskii	—	R	A	—
Proplectella pentagona	—	—	R	—
Protorhabdonella simplex	R	R	C	—
Stenosemella nivalis	A	R	R	—
Tintinnopsis beroidea	R	F	A	R
T. campanula	R	—	D	R
T. compressa	—	—	D	—
T. cylindrica	R	F	F	R
T. lata	—	—	D	—
T. lobiancoi	F	—	F	—
T. magna	R	—	R	—
T. nana	D	R	R	—
T. nordguisti	—	—	F	—
T. patula	—	—	F	R
T. plagiostoma	—	R	R	—
T. radix	R	F	C	R
T. vosmaeri	—	—	R	—
Foraminifera				
Adelosina elegans	R	R	R	R
Agglutinella compressa	—	R	—	—
Ammonia beccarii	R	R	—	—
Cibicides refulgens	R	R	R	—
Cyclofornia contorta	F	F	R	F
Eponides repanda	R	—	—	—
Globorotalia truncantuloides	R	R	—	—
Globigerina bulloides	R	R	R	R
G. inflata	R	R	R	R
Loxostomum plaitum	R	R	R	R
Massilina quadrata	—	R	—	—
Nonion boueanum	R	—	—	—
Quinqueloculina stelligera	—	R	—	R
Q. seminulum	—	—	—	R
Spirillina vivipara	—	R	R	—
Cnadaria				
Obelia spp.	R	F	R	—
Phialidium hemisphericum	F	R	R	—
Solmundella bitentaculata	R	—	—	—
Rotifera				
Asplenchna priodonta	R	—	—	R
Brachionus angularis	R	—	—	—
Br. budapestinensis	R	—	—	—
Br. calyciflorus	R	R	—	—
Br. plicatilis	R	R	R	R
Colurella adriatica	—	R	R	R
Eothinia sp.	R	—	—	—
Keratella cochlearis	R	R	—	—
Synchaeta oblonga	R	F	C	R
Trichocerca cylindrical	—	R	—	R
Nematoda				
Achromadora sp.	F	R	R	—
Anonchus sp.	R	F	F	R
Dorylaimus sp.	R	R	R	R
Dolichodorus sp.	R	R	R	—
Chaetognatha				
Sagitta elegans	—	—	—	R
S. enflata	R	—	—	—
S.friderici	R	R	R	R
S. serratodentata	R	—	—	—
Copepoda				
Achanthocyclops americanus	C	C	C	C
Acartia clausi	C	C	C	F
A. grani	R	R	R	R
A. latisetosa	—	R	—	—
A. longiremis	R	—	—	—
Canthocamptus pygmaeus	R	R	R	—
Centropages kroyeri	R	R	R	R
Clausocalanus arcuicornis	R	R	R	R
Euterpina acutifrons	A	F	F	F
Isias clavipes	R	—	—	—
Microsetella rosea	R	—	R	—
Nitocera lacustris	R	R	—	—
Oithona nana	A	D	D	A
Oncaea venusta	R	R	R	—
Paracalanus parvus	C	C	C	C
Sapphirina angusta	—	—	—	R
Schizopera clandestine	R	—	—	—
Nauplii larvae	D	D	D	D
Copepodite stages	C	C	C	C
Cladocera				
Evadne tergestina	—	—	R	—
Moina micrura	R	—	—	—
Podon polyphemoides	F	—	—	—
Ostracoda				
Cypridina mediterranean	F	R	R	R
Amphipoda				
Hypria latissima	R	R	—	R
Pteropoda				
Limacina inflata	F	R	R	R
Peraclis reticulata	R	—	—	—
Larvaceae				
Appendicularia sicula	—	R	—	—
Fritillaria borealis	—	—	—	R
Oikopleura dioica	R	R	R	R
O. longicauda	A	F	C	C
O. parva R	—	—	—	
Thaliacea				
Thalia democratica	—	R	—	—
B- MEROPLANKTON				
Polychaete larvae				
Eulalia viridis	F	F	F	R
Magelona papillicornis	R	—	—	—
Polydora ciliata	F	F	R	R
Sabellaria sp.	R	R	—	—
Serpula sp.	—	R	—	—
Spinoid larvae	A	D	A	C
Syllis sp.	—	R	—	—
Cirripede larvae	C	C	A	C
Decapod larvae				
Mysis stage	—	—	—	R
Lucifer acestra	—	—	—	R
Porcellana longicornis	R	—	—	—
Mollusc larvae				
Lamellibranch velliger	R	R	R	R
Gastropod velliger	R	—	—	—
Echinoderm larvae				
Tornaria larvae	R	R	—	—
Spatangus purpureus	R	—	—	—
Ascidian larvae				
Ciona intestinalis larvae	F	R	R	R
Phallusia mamillata larvae	R	R	R	—

The number of organisms/M^3 = 1-10: Rare, 10-100; Frequent, 100-500: Common, 500-1000: Abundant,>1000: Dominant.

Discussion

Dekhaila Harbour has been recently classified among the eutrophic bays on the Egyptian Mediterranean coast (Zaghloul *et al.*, 1995 and Zaghloul, 1996). Such classification was in agreement with the present study, which measured abnormally high concentrations of chlorophyll a most of the year. Although eutrophication impacts abundance and diversity of the zooplankton community in the study area, other ecological factors must be taken into consideration such as temperature, salinity,.. etc. The effect of water temperature appeared clearly in the qualitative and quantitative variations of zooplankton. The majority of tintinnids, including those causing September and March peaks, were found at temperatures between 19 and 28°C. It would appear also that the effect of water temperature was synchronized with the temporal abundance of phytoplankton, which demonstrated two peaks in August and March (Fig.7). The relationship between tintinnids and phytoplankton was reported by Capriulo and Carpenter (1983) and Verity (1986) in different coastal waters, where grazing stress of tintinnids caused the removal of 27-62% of the total primary production.

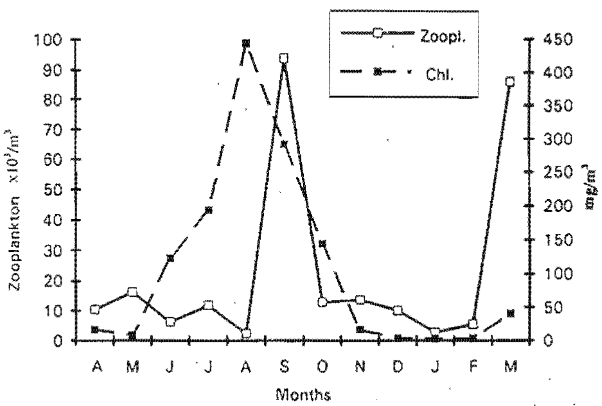

Fig.7. Temporal distribution of average zooplankton and chlorophyll a in Dekhalia Harbour (April 1998 - March 1999)

The wide salinity variations in Dekhaila Harbour (17.34 ‰ - 39.18 ‰) were closely related with the volume of the drainage water discharged daily to Mex Bay. Such volume varied seasonally and was reflected in the spatial amplitude of salinity variation, whereas the widest amplitude (4.03 - 9.01 ‰) was observed in spring and summer and the narrowest one (1.48 ‰ -3.35 ‰) in autumn and winter.

The distributional pattern of zooplankton was more or less related to that of salinity. The greatest annual average counts of zooplankton (29270 and 36264 organisms/m^3 respectively) were found at stations IV and V, where salinity experienced narrow changes, meanwhile the lowest average count appeared at station III, which sustained the widest salinity variations. It is to be noticed that stations I, II and III are nearer to the outflow of the land-based effluent than stations IV and V and this causes fewer variations in salinity at the latter stations.

The continuous changes of the environmental conditions in Mex Bay, including Dekhaila Harbour, were reflected in zooplankton abundance during the past four successive years (1995-1999). The present study indicated two peaks in September and March during 1998-1999 (93,856 and 85,920 organisms/m^3) in Dekhaila Harbour, as compared to one peak (44,366 organisms/m^3) in October 1996 (Hussein, 1997) and two peaks in April and October 1995 in Mex Bay, with annual average of 196.5x10^3 organisms/m^3.(Soliman and Gharib, 1998).

Salinity variations also affected zooplankton composition in the study area. In 1996, copepods were the primary dominant group (45.8%), followed by rotifers (11.06%) and larvaceans (4.6%), while protozoans shared only 3.6% of the total zooplankton (Hussein, 1997). During the present study (1998-99) tintinnids represented the most important group (65%) relative to the annual mean count of zooplankton and copepods were second (26.5%). However, those were not the actual positions of both groups, since copepods were the most abundant group most of the year forming 51-89% of total zooplankton against 1.2-26.9% for tintinnids. In contradiction, Soliman and Gharib (1998) reported protozoans as the most dominant group, followed by rotifers and copepods respectively. In any case, species composition varied monthly with the variations of the mixing processes that occurred due to the advection or changes of volume of the discharged waste water. This was clearly shown from the monthly variations of the IBD between the different stations.

It is to be noted that variations of dominance of the major zooplankton groups occurring in Mex Bay during the past four years (1995-1999) should be attributed mainly to the density of the most abundant group even if it only appeared for a short time. The greater density of such a group will affect directly the annual average counts of total zooplankton and consequently the relative abundance of other groups. In the present study, tintinnids attained remarkably greater counts during the peak times than other groups. This led to maximizing their contribution to the total zooplankton density although copepods dominated most of the year but with relatively low counts. Such a pattern indicates that copepods could not establish a healthy population in such an area due to unfavourable conditions.

Although tintinnids were the richest in species composition (29 spp.), few of them could flourish or exist in relatively high density, except for a limited time, such as *Tintinnopsis nana, Favella serrata, Tintinnopsis lata, Tintinnopsis compressa, Eutintinnus lusus-undae, Stenosemella nivalis, Metacylis mediterranean, M. mereschkoowskii, Protorhabdonella simplex* and *Tintinnopsis radix.* However, the majority of tintinnid species were observed sporadically, while *Eutintinnus lusus-undae, Favella serrata* and *Tintinnopsis beroidea* were perennial (Table, 4).

Copepods had a remarkably low diversification in Dekhaila Harbour (17 spp.), Five species were perennial and represented the main bulk of adult copepods counted, namely *Acanthocyclops americanus, Oithona nana, Euterpina acutifrons, Paracalanus parvus* and *Acartia clausi.* Similar to tintinnids, all other copepods were occasionally found in very small numbers. As compared to other Egyptian Mediterranean waters, copepods in Dekhaila Harbour were markedly less diversified than inshore (33-37 spp.) and offshore (83-132 spp.) areas (Table 5). This was also the case for those in the Eastern Harbour, which is an eutrophic bay. On the other hand, tintinnids showed clearly different diversities in both inshore and offshore water relative to the prevailing environmental conditions (Table 5). Such variations in the diversity of copepods and tintinnids in Dekhaila Harbour may reflect not only the effect of salinity variations but also that of eutrophication and other pollution sources as a growth inhibiting factor.

The limited role of meroplankton in the present study indicated that conditions in Dekhaila Harbour are not suitable for growth of the benthic fauna, particularly molluscs, while both cirripedes and polychaetes exhibited a degree of adaptation or tolerance to such conditions as they were the dominant meroplankton components over the year. Polychaetes were more reproductive during spring , early summer and October, while cirripedes attained their best reproduction in May and November.

The freshwater forms of rotifers, protozoans and copepods were represented by 21 species in Dekhaila Harbour, but mostly with low densities, which may indicate that freshwater only reaches the Harbour intermittently.

Zooplankton diversity showed a wide range of variations sustaining an index between 0.26 and 2.32. There were two types of relationships between the diversity index and the number of species, one directly proportional in late spring, summer and late autumn, and an inverse one during winter, September and March (Fig. 2). The low diversity in winter may be attributed to the low total count, whereas, those in September and March were related to the dominance of a few species irrespective of the abnormally high standing crop.

Several species were recorded previously in the offshore water of Alexandria, namely the chaetognaths *Sagitta serratodentata, Sagitta friderici,* the larvaceans *Appendicularia sicula, Oikopleura dioica, O. longicauda, O. parva* and *Fritillaria borealis,* the copepods *Microsetella rosea* and *Sappherina angusta* and the tintinnids *Codonellopsis parva, Dictyocysta speciosa, Proplectella pentagona.* Some of these species were dominant (El-Maghraby and Halim, 1965; Dowidar, 1965; Guergues, 1969; Dowidar and El-Maghraby, 1970; Halim, 1976; Hussein, 1977; Samaan *et al.*, 1983; Abdel-Aziz, 1997), while they all appeared in Dekhaila Harbour either permanently or occasionally, sometimes with high counts. The existence of these species in the study area indicates their transference from the offshore water.

The occurrence of early stages of copepods almost throughout the year in the warm seas implies that breeding is continuous in these waters (Raymount, 1983). The present study demonstrated several peaks of copepod nauplii over the year, coinciding with those of the dominant species, particularly *Oithona nana, Euterpina acutifrons, Acartia clausi, Paracalanus parvus* and the fresh water form *Acanthocyclops americanus.* From their abundance cycle, 2-3 generations could be supposed for each species during a year in the Harbour. In Alexandria sea water, Dowidar and El-Maghraby (1970) proposed 4-5 generations a year for some of these species. Regardless of density variations, the effect of water quality was reflected also in the temporal cycle of zooplankton abundance in Dekhaila Harbour as well as in the whole of Mex Bay since the peaks occurred at different times throughout the past four successive years (Table 6). It seems that this is a general characteristic of the Egyptian coastal water under stress of land based effluents, such as happened in the Eastern Harbour of Alexandria, where the long term records of zooplankton abundance revealed pronounced differences in peak timing during the past fifty years (Table 6).

Table 5- Number of copepod and tintinnid species in different areas of Egyptian Mediterranean coastal waters.

Area	Year	Copepods	Tintinnids	Reference
Off Alexandria Coast	1961-63	83	99	Dowidar (1965)
Off Alexandria Coast	1966	132	-	Dowidar & El-Maghraby (1973)
Off Alexandria Coast	1996	37	11	Hussein (1997b)
Alexandria Coast	1991	37	31	Abdel-Aziz (1997)
Egyptian Mediterranean	1970-71	112	-	Hussein (1977)
Egyptian Mediterranean	1984-85	126	-	Nour El-Din (1987)
Mex Bay	1996	33	13	Hussein (1997a)
Mex Bay	1982-83	-	46	Dorgham (1985)
Eastern Harbour	1986-87	15	4	Aboul-Ezz *et al.* (1990)
Dekhaila Harbour	1998-99	17	29	**Present study**

Table 6- Timing of zooplankton peaks in two eutrophic bays on Alexandria coast during the period from 1957 to 1996.

Year	Timing of peaks		Reference
Eastern Harbour:			
1957	April	July	El-Maghraby and Halim, 1965
1961	June	October	Dowidar, 1965
1962	May	August	Dowidar, 1965
1976	June	December	El-Zawawy, 1980
1986-87	February	April - August	Aboul-Ezz *et al.*, 1990
1989-90	March	August	Ismail, 1993
1991	May	October	Abdel-Aziz, 1997
Mex Bay:			
1995	April	August-October	Soliman and Gharib, 1998
1996	April	October	Hussein, 1997
1998-99	March	September	**Present study**

The copepods *Oithona nana, Euterpina acutifrons and Paracalanus parvus* were among the dominant zooplankters in the southeastern Mediterranean and found in remarkably greater densities than the present study (El-Maghraby and Halim, 1965; Dowidar and El-Maghraby, 1970; Hussein, 1977; El-Zawawy, 1980; Abdel-Aziz, 1997; Hussein, 1997). On the other hand, *Acartia clausi* was usually a less important species, with a maximum of 425 organisms /m^3 (Dowidar and El-Maghraby, 1970). However, in Dekhaila Harbour it became a persistent species attaining sometimes relatively high counts (up to 1132 organisms/m^3). It could be supposed that water quality of the Harbour became unsuitable for healthy populations of the above mentioned dominant species, except *A.clausi,* which could withstand the eutrophication as well as pollution effect in the study area, and it therefore may be referred to as an indicator species of such conditions. This was in agreement with the observations of (Paffenhofer, 1980), who found that the high concentration of cyclopoida and small calanoida such as *Paracalanus* may serve as indicators of phytoplankton blooms. It is to be noted also that the permanent existence of the fresh water form *Acanthocyclops americanus* in relatively high density (up to 1104/m^3) in the Harbour reflects its ability to adapt to high salinity and establish a well growing population.

The phytoplankton-zooplankton relationship was often inverse, with the exception of a few occasions. A zooplankton peak in September was preceded by a phytoplankton bloom in August, whereas the March peak occurred parallel to a phytoplankton bloom (Fig. 7). These observations were in partial agreement with those of Paffenhofer (1980), who admitted that a high zooplankton biomass is an indication of food abundance and/or low predation or advection.

It is worth mentioning that the nutritional level and phytoplankton density in Dekhaila Harbour, as well as in other coastal areas of Alexandria during the past decade greatly exceeded those recorded before the High Dam period, while zooplankton abundance dropped clearly after the construction of the High Dam. Also, the community structure was exposed to pronounced variations, especially in the dominance of groups, whereas tintinnids and rotifers sustained a greater role. This case is attributed mainly to the deterioration of the water quality, particularly along the Alexandria coast due to the continuous increase of wastewater discharge.

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