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Effect of Dredging and Dumping Operations on Zooplankton Community During the Construction of East Branch Harbor, Port Said, Eastern Mediterranean, Egypt

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ABSTRACT

During the dumping and dredging operations of East Branch Harbor, Port Said, Eastern Mediterranean, zooplankton community of the surrounding water was studied versus the prevailing environmental conditions between 1999 and 2000. The most affected environmental variable was total suspended solids which showed significant increase at different disposal sampling sites. Other conditions of temperature, salinity, pH, dissolved oxygen content and chlorophyll *a* were in normal range. The diversity and abundance of zooplankton community were in normal range recorded in the area without significant variation between the dumping and the control sites. In total 68 taxa were recorded in the study area. The density of the total zooplankton standing crop varied between 5021 and 14390 individuals/m^3 to 6702 and 16135 individuals/m^3, with an average of 8563 and 10071 individuals/m^3 at disposal and control sites, respectively. Copepods outnumbered the total zooplankton (average 65.3%) and are dominated by *Centropages kroyeri*, *Paracalanus parvus*, *Clausocalanus arcuicornis, Oithona nana* and *Euterpina acutifrons*. The results revealed that during the construction of the East Branch Harbor, the dredging and dumping processes may had a very minor effect on zooplankton community but it was not significant.
Key words: Zooplankton, dumping, dredging, Port Said, Eastern Mediterranean.

INTRODUCTION

On the eastern coast of Port Said, an industrial port complex was constructed between 1999 and 2000 to promote the national economy of Egypt. The marine ecology of the coastal area under investigation was studied in 1998 by Gab-Alla *et al.* (2006). Many zooplankton studies were carried out along the Egyptian coast of Eastern Mediterranean particularly around Alexandria (Dowidar and El-Maghraby, 1970a and b; Aboul-Ezz 1975; Hussein, 1977; Nour El-Din, 1987; Zakaria, 1992). Ichthyoplankton was studied by El-Rashidy (1987). More recently, zooplankton samples were analyzed near Port Said by Abdel-Rahman (1997) and Aamer (1999).

Imbalance in loading of suspended matters to aquatic systems is considered one of the greatest causes of water quality impairment (U.S.EPA, 2003). Pelagic and benthic communities in coastal marine environments are subjected to siltation process and turbidity, which in turn are considered as stress factors to these organisms (Rogers, 1990; Anthony and Fabricius, 2000). A typical by-product of dredging activities is the resuspension of sediments into the water column, which have effects on marine organisms. Dredging-related suspended-sediment plumes may differ in scope, timing, duration and intensity from those natural conditions, thus potentially causing conditions not normally experienced by the organisms (Snigdha, 2005). Effects of suspended sediments are highly species-specific and can vary greatly (Clarke and Wilber, 2000). Increase in suspended materials in the water column will diminish the light penetration with potential adverse effects on the photosynthetic capability of phytoplankton and other aquatic plants (Iannuzzi *et al.,* 1996). On the other hand, resuspended nutrients released with the overspill may stimulate phytoplankton productivity (ICES, 1992). Zooplankton feeding and respiration in the presence of dense accumulations of fine suspended sediments may also be diminished (Parsons *et al.,* 1986).

A further effect of dredging may be that the disturbance of sediments, releases sufficient organic materials to enhance the species diversity and population density of organisms outside the immediate zone of deposition of suspended material (Jones and Candy, 1981; Poiner and Kennedy, 1984). Crushed organisms returned to the sea with the overspill may also cause organic enrichment (Newell *et al.,* 1999). As reported by Joseph *et al.* (1998) and Clarke and Wilber (2000), we know less about the effects of suspended sediment on zooplankton. So, the objective of this study was to assess the impacts of dredging and dumping operations at the disposal sites on zooplankton community during the East Branch Harbor construction, east of Port Said.

MATERIALS AND METHODS

The present study was carried out during 1999-2000 at 7 sites at the disposal area of East Branch Harbor, Port Said, Eastern Mediterranean, in addition to, a control one (site 8) located north to disposal sites (Fig. 1). The samples for hydrographic measurements and total suspended solids (TSS) were collected from the upper half meter using a bucket. The water temperature was measured with an ordinary thermometer; salinity with hand refractometer; pH with pH meter (Jenway model 2070) and dissolved oxygen (DO) according to Winkler method (Thompson and Robinson, 1939). For measuring TSS, two liters of surface water were filtered on dry pre-weighted GF/C glass filter papers (APHA, 1985). Chlorophyll *a* was extracted with 90% acetone and measured spectrophotometrically using Spectronic 601 Milton

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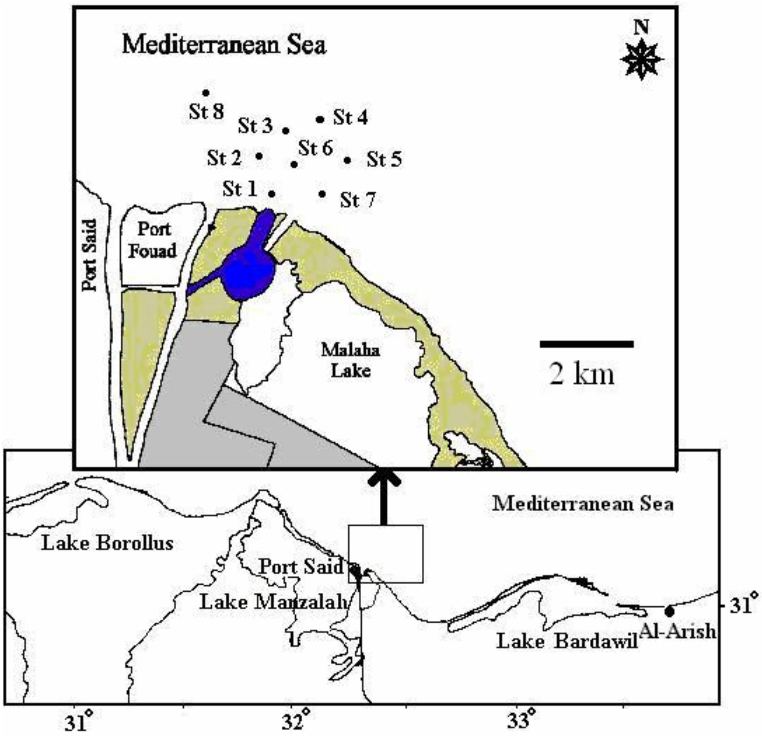


Figure (1): Location map of the sampling sites.

Roy spectrophotometer according to Parsons *et al* (1984).

Zooplankton samples were collected at disposal and control sites during dredging operations in day time, using plankton net of 1 m length, 40 cm mouth diameter and 150 µm mesh size. Horizontal subsurface hauls (at 0.5 m depth) were made at each site for 5 minutes. A flowmeter (Hydrobios, Kiel) was fitted onto the opening of the net to measure the volume of water filtered. The samples collected were preserved in 5-10% buffered formaldehyde/seawater solution. Zooplankton species were identified (according to Giesbrecht, 1892; Tregouboff and Rose, 1957; Gonzalez and Bowman, 1965) and taxon abundance per cubic meter was determined from three replicates of a 5 ml subsample, taken with a Stempel-pipette of the entire sample (200-500 ml). The data of the affected sites (1-7) were pooled together and compared to the control site for the physicochemical parameters (temperature, pH, salinity, TSS and Dissolved oxygen), chlorophyll *a* content and number of zooplankton species and their abundance. Data were statistically tested using ANOVA to compare the difference in zooplankton community at the affected and unaffected sites. Also, Canonical Correspondence Analysis (CCA) was used to study the effect of different environmental factors on zooplankton dominant groups and species. This analysis was done using PC-ORD version 4.01 (McCune and Mefford, 1999).

RESULTS

During the period of study, temperature ranged from 14.2°C to 26.3°C reaching minimum and maximum values in January and June, respectively. pH values fluctuated within a narrow range of 7.9 to 8.3 (average 8.1), without significant variations between sites and months ($p > 0.05$). Salinity ranged between 36.1‰ in January and 38.8‰ in April without significant differences among sites ($p > 0.05$).

Dissolved oxygen concentrations did not show significant differences between all sites ($p > 0.05$). At the surface water, DO content ranged from 4.1 to 6.7 mg/l (average 5.55 mg/l) during the period of study (Fig. 2). The values were almost similar at all sites indicating well-aerated conditions in both disposal and control sites. In November and January, DO remained at much higher concentrations (averaged 6.6 and 6.7 mg/l, respectively), while the lower values were observed at all sites during other months with minimum in April. Total suspended solid (TSS) concentration was much higher at all disposal sites (averaged 126.7 mg/l) than the control site (averaged 24.9 mg/l). At the disposal sites, the values were slightly different ranging between 87.9 mg/l in June at site 6 and 199.9 mg/l in January at site 2 (Fig. 2). At the control site, it varied between 18.5 mg/l in September and 37.8 mg/l in January. Data analysis showed that there is a high significance difference between the concentration of TSS at the disposal sites and control ($F=17.181$ and $p < 0.05$).

Chlorophyll *a*, which is a measure of phytoplankton biomass, remained sufficiently higher at the control site (averaged 11.5 mg/m^3) than disposal sites (averaged 8.1 mg/m^3). Its maximum concentration appeared in January at all sites but was higher at the control site (35.2 mg/m^3) than the disposal sites with an average of 26.6 mg/m^3 (Fig. 2).

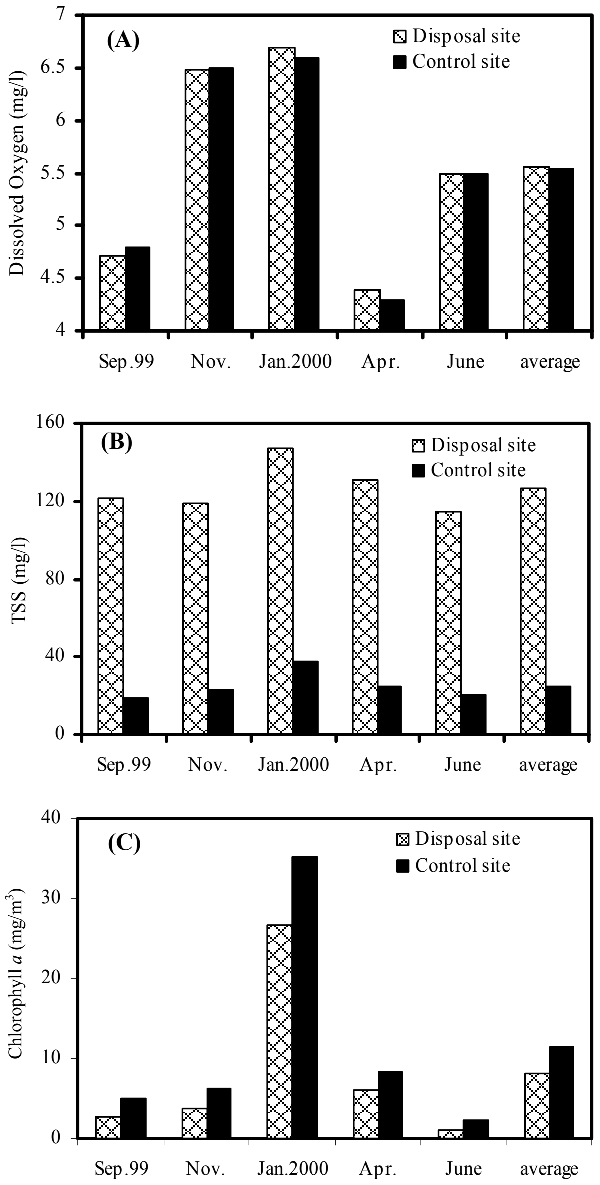


Figure (2): Monthly variations in the concentrations of (A) dissolved oxygen (mg/l), (B) TSS (mg/l) and (C) Chlorophyll *a* (mg/m^3) recorded at disposal and control sites.

A total of 68 taxa (genus, species and larval stages) were recorded at the study area (Table 1) during dumping operations of East Branch Harbor of Port Said. Total zooplankton standing crop was highly variable during the study period. The average densities of zooplankton ranged between 5021 individuals/m^3 (in November) and 14390 individuals/m^3 (in April) at disposal sites and 6237 individuals/m^3 in January and 16135 individuals/m^3 in April at control site (Fig. 3 and Table 2) with averages of 8562 and 10071 individuals/m^3 at disposal and control sites, respectively. In general, the highest abundance of total zooplankton was recorded in April at all sites (an overall average of 14608 individuals/m^3), while the minimum appeared in November (an overall average of 5231 individuals/m^3). Copepods (from nauplii to adults) dominated the zooplankton community throughout the sampling sites averaging 66% and 60.7% of the total

Table (1): Average density of zooplankton (individuals/m^3) recorded at disposal and control sites during the study.

Taxa	Disposal	Control
FORAMINIFAERA		
Globigerina inflata d'Orbigny, 1836	49	68
CNIDARIA		
Hydromedusae	4	5
Trachymedusae	50	76
MOLLUSCA		
Gastropoda (larvae)	359	428
Bivalvia (larvae)	745	708
Creseis acicula (Rang, 1828)	9	18
ANNELIDA		
Polychaeta (larvae)	46	37
Temopetris spp.	<1	1
CRUSTACEA		
Cladocera		
Evadne tergestina Claus, 1877	32	44
Evadne spp.	24	36
Podon polyphemoides Leuckart, 1859	66	55
Ostracoda		
Conchoecia spp.	5	8
Copepoda		
Calanoida		
Acartia clausi Giesbrecht, 1889	49	70
A. danae Giesbrecht, 1889	65	108
A. latisetosa Kriczayuin, 1873	4	8
A. longiremis (lilljeborgi, 1853)	55	72
A. negligens (Dana, 1848)	301	456
Acrocalanus gibber Giesbrecht, 1888	63	76
Anomalocera patersoni (Templeton, 1837)	5	6
Calanopia elliptica (Dana, 1849)	7	11
Calanus tenuicornis (Dana, 1849)	Rare	Rare
Calocalanus pavo (Dana, 1849)	28	18
Clausocalanus arcuicornis (Dana, 1849)	533	766
C. furcatus (Brady, 1883)	135	171
Centropages kroyeri (Giesbrecht, 1892)	805	960
C. typicus Kroyer, 1849	4	8
Eucalanus attenuatus (Dana, 1849)	Rare	Rare
Euchaeta marina (Prestandrea, 1833)	1	6
Labidocera brunescens (Czerniavsky, 1886)	9	3
L. wallastoni (Lubbock, 1857)	9	30
Lucicutia flavicornis (Claus, 1863)	5	5
Nanocalanus minor (Claus, 1863)	14	41
Neocalanus gracilis (Dana, 1849)	<1	1
N. robustior Giesbrecht, 1888	2	8
Paracalanus aculeatus Giesbrecht, 1888	42	48
P. parvus Claus, 1863	630	770
Paracandacia bispinosa (Claus, 1863)	4	0
P. simplex (Giesbrecht, 1892)	4	7
Pleuromamma abdominalis (Lubbock, 1856)	Rare	Rare
Pontellina plumata (Dana, 1849)	2	3
Rhincalanus naustus Giesbrecht, 1888	Rare	Rare
T emora discaudata Giesbrecht, 1889	87	44
T. stylifera (Dana, 1848)	160	91
Cyclopoida		
Oithona nana Giesbrecht, 1892	402	444
O. plumifera Baird, 1843	28	42
Poecilostomatoida		
Corycaeus gibbulus Giesbrecht, 1891	2	2
C. speciosus Dana, 1849	8	14
Corycaeus spp.	66	68
Lubbockia squillimana (Claus, 1863)	4	4
Oncaea spp.	42	58
Sapphirina spp.	4	4
Harparcticoida		
Euterpina acutifrons (Dana, 1852)	380	468
Macrosetella gracilis (Dana, 1848)	5	12
Microsetella norvegica (Boeck, 1864)	11	12
M. rosea (Dana, 1847)	3	12
Cirripedia		
Nauplius larvae	260	212
Cypris larvae	249	246
Gammaridae	Rare	Rare
Lucifer spp.	3	4
Decapoda larvae	394	750
ECHINODERMATA		
Echinoderms larvae	195	288
CHAETOGNATHA		
Sagitta enflata Grassi, 1881	270	314
Sagitta spp.	11	10
CHORDATA		
Larvacea		
Doliulum spp.	8	10
Oikopleura spp.	110	273
Teleostei (eggs and larvae)	9	12

zooplankton count at disposal and control sites, respectively (Fig. 3), with an overall average of 65.3%.

As shown in table 2 , the most abundant zooplankton groups, other than copepods, were pelagic mollusc (averaged of 1117 and 1158 individuals/m^3, forming 13.1% and 11.5% of total zooplankton) at disposal and control sites, respectively, decapod larvae (averaged 394 and 750 individuals/m^3, representing 4.6% and 7.5% of total zooplankton at disposal and control sites respectively), chaetognaths (averaged 280 and 324 individuals/m^3, forming 3.3% and 3.2% of total zooplankton at disposal and control sites, respectively), echinoderms larvae (averaged 195 and 288 individuals/m^3, constituting 2.3% and 2.9% of total zooplankton at disposal and control sites, respectively), and cirripede larvae (averaged 509 and 458 individuals/m^3, forming 5.9% and 4.6% of total zooplankton at disposal and control sites, respectively).

Copepods were the most diversified group (43 genus and species). Their highest abundance appeared in April coinciding with the zooplankton peak at both disposal and control sites (9958 and 10605 individuals/m^3, respectively), while at other months it ranged between 2073 individuals/m^3 in November and 6339 individuals/m^3 in September at disposal sites and between 2324 in November and 6127 individuals/m^3 in June at the control site (Table 2). Copepod larval stages (nauplii and copepodites) constituted about 29.5% and 24.6% of total copepods; i.e. 19.5% and 14.9% of total zooplankton at disposal and control sites respectively. Eight copepod species were identified which contributed more than 55% of the total copepods; the calanoid *Centropages kroyeri*, *Paracalanus parvus*, *Clausocalanus arcuicornis*, *Acartia negligens*, *Temora stylifera* and *Clausocalanus furcatus*; the cyclopoid *Oithona nana* and the harpacticoid *Euterpina acutifrons*. Comparing the abundance of these species at the disposal and control sites, *C. kroyeri*, *P. parvus* and *A. negligens* were slightly higher in unaffected control site, while *T. stylifera*, *O. nana* and *E. acutifrons* showed slightly larger numbers at disposal sites.

Despite the variable temporal pattern displayed by zooplankton as a whole, which tend to mask seasonal signals, most of the dominant copepod species exhibited seasonality (Fig. 4). This was especially apparent for *C. kroyeri* which dominated in September and April; for *A. negligens* in January; for *Clausocalanus* in September and June. While the other species (*P. parvus*, *T. stylifera*, *O. nana* and *E. acutifrons*) displayed high abundance in April. The statistical analysis of the data using one way and two way ANOVA showed there was no significant differences between abundance of total zooplankton at dumping disposal sites and control one, where F ratio = 0.110 and $p > 0.05$. The results of multivariate analysis (CCA) showed a slightly low

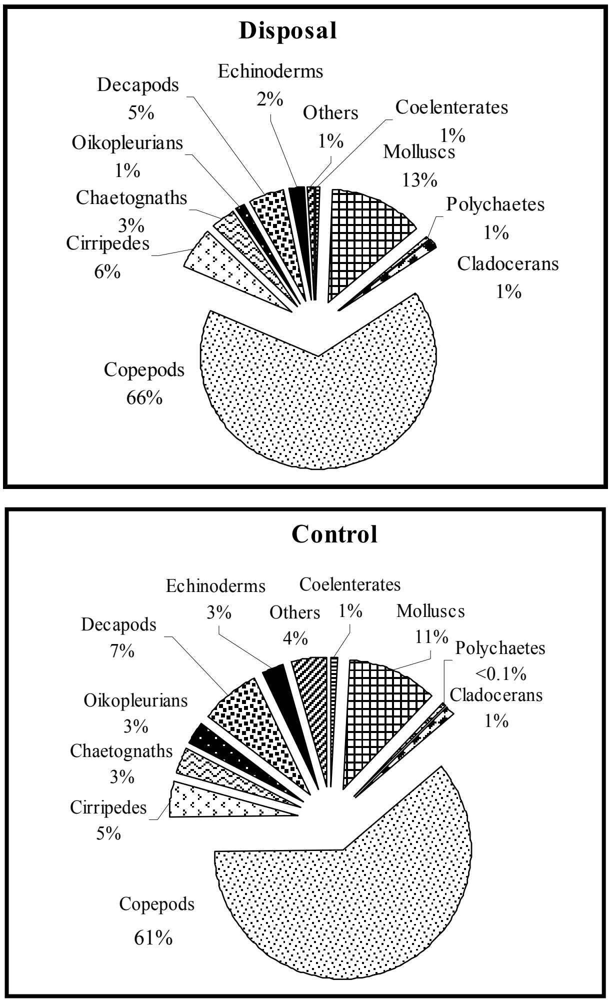


Figure (3): Percentage composition of zooplankton groups recorded at disposal and control sites during the study.

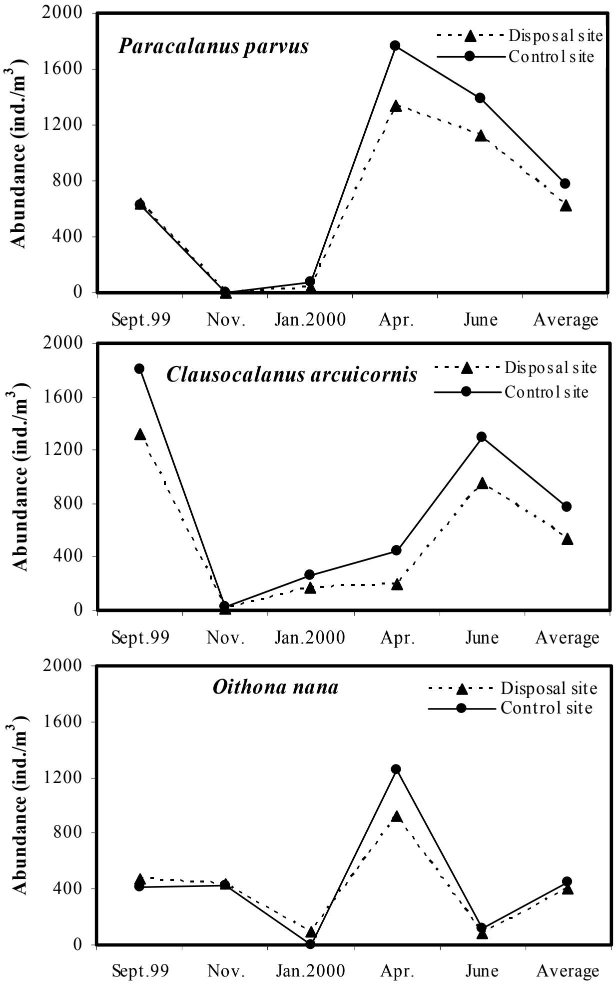
Table (2): Average density of the major zooplankton groups (individuals/m^3) recorded during the study.

Group	September 1999		November 2000		January 2000		April 2000		June 2000		Average	
	Disposal	Control	Disposal	Control	Disposal	Control	Disposal	Control	Disposal	Control	Disposal	Control
Coelenterates	5	1	72	155	37	20	21	50	136	180	54	81
Molluscs	89	80	1163	1480	330	270	2118	2300	1884	1659	1117	1158
Polychaetes	48	15	74	50	17	20	36	58	56	45	46	38
Cladocerans	288	250	28	15	17	0	11	30	260	380	121	135
Copepods	5299	6127	2073	2324	4604	5450	9958	10605	6339	6072	5655	6116
Cirripedes	318	250	72	42	18	30	1330	1320	805	650	509	458
Chaetognaths	139	132	73	47	21	6	40	60	1129	1375	280	324
Appendicularians	32	157	240	510	70	126	0	0	251	620	119	283
Decapods (larvae)	91	250	794	1480	177	162	224	690	683	1170	394	750
Echinoderms (larvae)	11	20	264	420	46	0	623	950	31	50	195	288
Others	1	6	168	179	136	153	29	72	33	1791	73	440
Total zooplankton	**6321**	**7288**	**5021**	**6702**	**5473**	**6237**	**14390**	**16135**	**11607**	**13992**	**8562**	**10071**

effect of different environmental factors on the main zooplankton groups but proportionally chlorophyll *a* and TSS had more weight on bivalve larvae and appendicularians. While the effect of TSS on appendicularians was low and in negative direction (Fig. 5). Concerning dominant copepod species, it is clear that the weight of environmental factors is almost the same and low. The effect of TSS is positively on the copepod *Temora stylifera* and negatively on *Acartia negligens* (Fig. 6).

DISCUSSION

Dredging and reclamation activities in the sea are not the permissible activities as per the environmental action. This is because these activities could produce major harms to the pelagic and benthic organisms living in the marine environment (Clarke and Wilber, 2000). Ports and harbors are often exposed to siltation process and hence deepening of navigational channel and berthing area for ships is necessary. Marine organisms are known to be adaptive in nature to the changes in environment but they have certain tolerance limit beyond which serious ecological damages could occur (Clarke and Wilber, 2000). However, limited work has been carried out so far on the effects of dredging on the



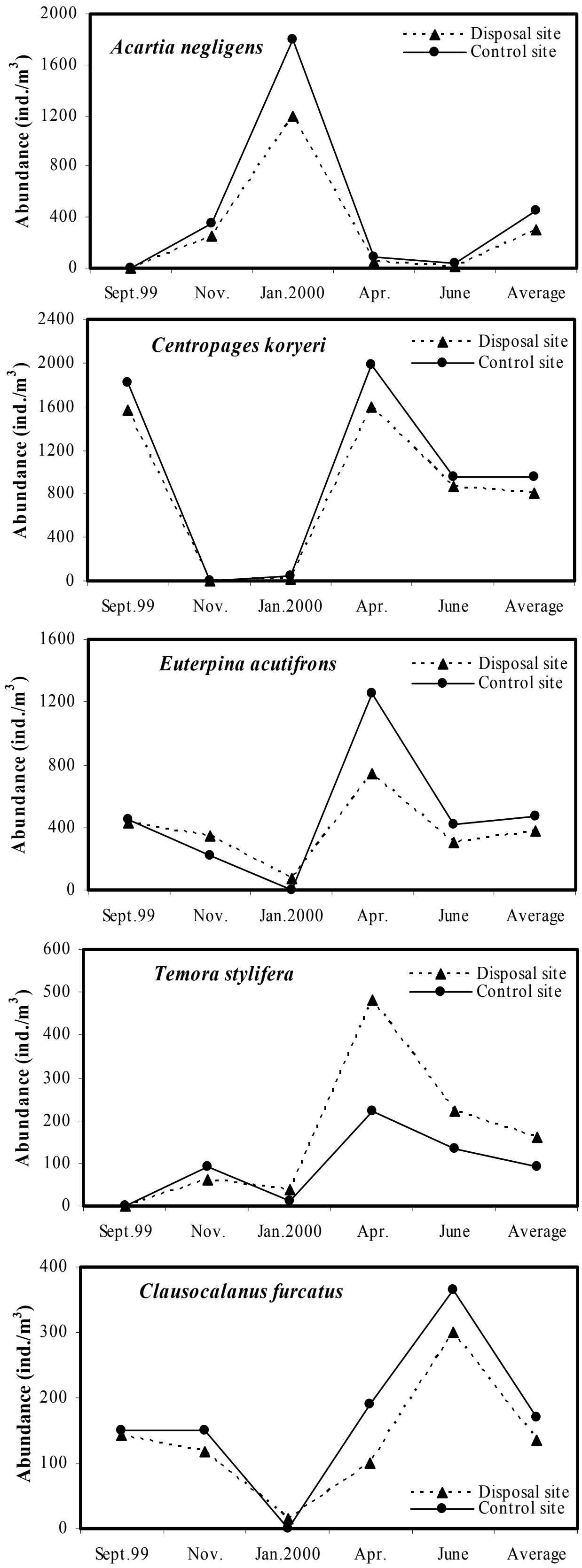


Figure (4): Monthly abundance of most common copepod species (individuals/m^3) recorded at disposal and control sites.

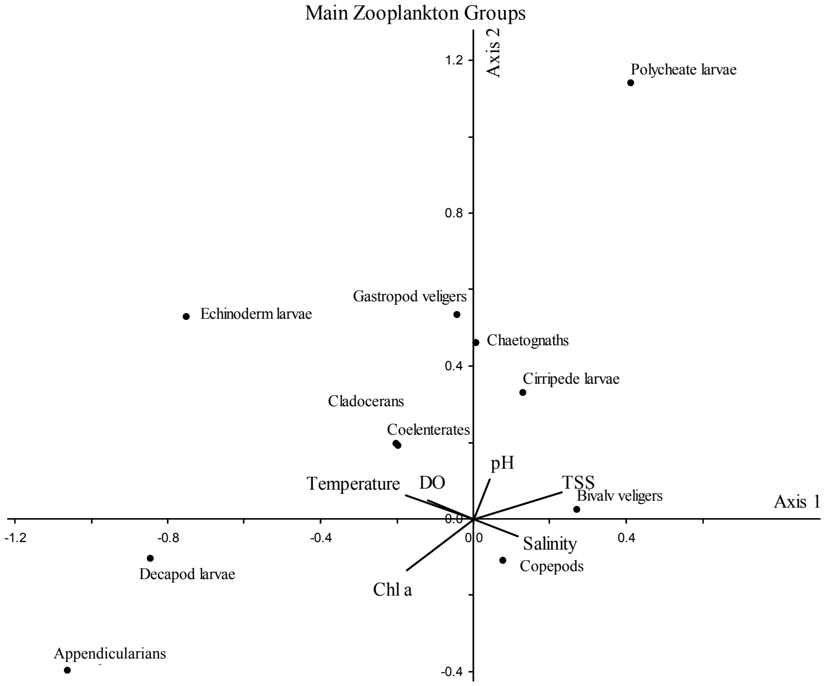


Figure (5): Ordination graph showing distribution of dominant zooplankton groups and different environmental factors on axis 1 and 2.

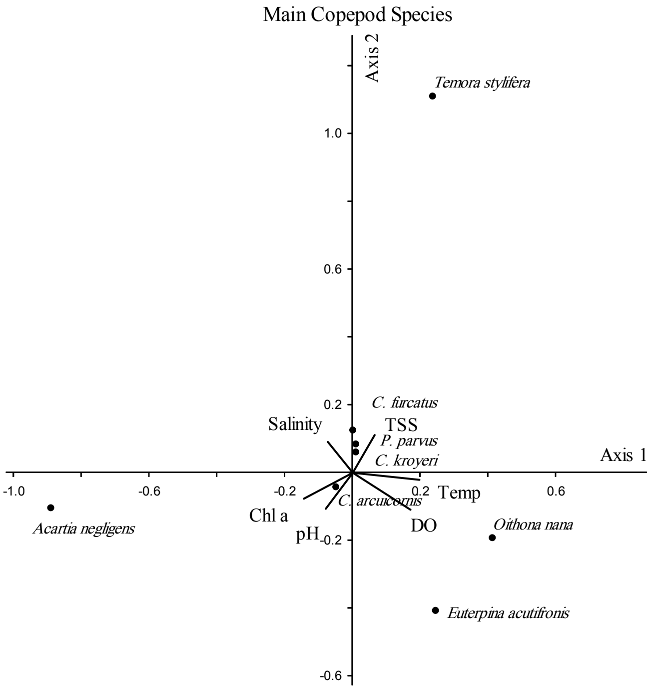


Figure (6): CCA graph showing effect of different environmental factors on the dominant copepod species along axis 1 and 2.

pelagic organisms (Iannuzzi *et al.*, 1996; Joseph *et al.*, 1998). These effects can vary depending on the degree of turbidity, duration of exposure, sediment composition and the quality of sediments being dredged. In the present study, TSS was only the parameter which showed significant variations between disposal and control sites presumably these variations could be related to the dredging and dumping activities which increase the levels of TSS concentration in the area of study during harbor construction. The low chlorophyll *a* content observed at the disposal sites is affected by the high content of suspended matters which usually reduce the light intensity. This is comparable to other studies (e.g. Jonge, 1983; Neumann *et al.*, 1998; Koening *et al.*, 2002). The results of TSS showed a significant difference (one way ANOVA) between disposal sites and control one (p <0.005). But these concentrations did not show an effect on zooplankton abundance and diversity in the present study. Some authors have suggested that suspended organic detritus is an important secondary food source for estuarine and neritic zooplankton (Heinle and Flemer, 1975; Day Jr *et al.*, 1982; Roman, 1984).

In the study area as a whole, the standing crop of the total zooplankton (average 8751 individuals/m^3) is comparable with the study of Aamer (1999) at the same area (average 7624 individuals/m^3) just before the construction activity of the port. But still higher compared with earlier data of Hussein (1977) and Nour El-Din (1987) in the Egyptian waters of the Eastern Mediterranean (annual averages of 3700 and 2010 individuals/m^3, respectively). This may be due to the intense fresh water influx from Manzalah Lake which have fertilizing effect on the coastal area near Port Said City as mentioned by Dowidar (1988). The most dominant copepod species (*Centropages kroyeri*, *Paracalanus parvus*, *Temora stylifera*, *Clausocalanus furcatu*s, *Oithona nana* and *Euterpina acutifrons*) were the same for all above mentioned earlier workers. These species are usually classified as neritic and were typical of the Egyptian coastal waters of the Mediterranean (Hussein, 1977; Nour El-Din 1987; Dowidar, 1988; Abdel-Rahman, 1997; Aamer, 1999). The other two dominant species namely *C. arcuicornis* and *A. negligens* are also recorded from oceanic water (Hussein, 1977).

It is clear that, appendicularians are characterized by low abundance at the disposal sites compared with control site. This may be related to the high TSS because their mucus house is probably clogged by silt immediately after it is secreted as mentioned by Alldredge (1976). The present study indicated that the standing stock of these organisms in the control sites was sufficiently high and comparable to the normal range of other earlier studies (Hussein, 1977; Nour El-Din 1987; Dowidar, 1988; Abdel-Rahman, 1997; Aamer, 1999). At the disposal sites, the variations observed at each site during dredging and dumping operations in the different months studied could be ascribed to changes in environmental parameters including TSS. So the results suggest that during building of the East Branch Harbor oh Port Said, the siltation processes may have an effect on the zooplankton community even though these effects were not statistically significant.

These results agree with experimental work of Ueda *et al.* (1989) who concluded that the siltation have no fatal effects on copepods, even if the silt load is extremely high. However, the extreme abundance of suspended, non-food particles in seawater reduces the feeding rate of copepods even though they can still feed selectively upon nutritious particles (Paffenhöfer and Sant, 1985). Other than copepods, siltation may have serious effect as for example on appendicularians (Alldredge, 1976). The results showed that there was no significant difference in the density of mollusc larvae between disposal and control sites. This result was confirmed by Clarke and Wilber (2000) for mollusc larval stages which showed no effects at suspended sediment concentrations < 750 mg/l. Decapod larvae were low at disposal sites compared with control. This may be related to dredging activities as reported by Paranagua (1986) and Silva *et al.* (2004). Also, some researchers (e.g. Jonge, 1983; Neumann *et al.*, 1998; Silva *et al.,* 2004) at Saupe Bay, Brazil, suggested that the siltation has a negative effect on phyto- and zooplankton standing crop. On the contrary, Chandramohan and Sreenivas (1998) and Rezai *et al.* (2003) showed that dredging activities have no effect on zooplankton in Gadesu Canal, south east coast of India and the straits of Malacca, respectively. Finally, it could be concluded from the present study that increasing of TSS (up to 200 mg/l) in marine environment through dredging and dumping operations during the current study has a minor but statistically non significant effect on zooplankton community.

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تأثير عمليات تكريك وإغراق النفايات علي مجتمع الهائمات الحيوانية أثناء بناء ميناء شرق التفريعة ببورسعيد، شرق البحر المتوسط، مصر

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الملخص العربـــى

بدراسة مجتمع الهائمات الحيوانية والعوامل البيئية المحيطة مثل درجة الحرارة، درجة الملوحة، تركيز الأس الهيدروجيني، تركيز المواد العالقة، تركيز الأكسجين الذائب، وتركيز الكلوروفيل"أ" أثناء عمليات تكريك وإغراق النفايات بعرض البحر لميناء شرق التفريعة بمنطقة بورسعيد، شرق البحر المتوسط.

أظهرت النتائج أن تركيز المواد العالقة يختلف معنويا عن المحطة المرجعية بينما كان الإختلاف في تركيزات العوامل الأخرى غير معنوي ويقع في المستوى الطبيعي للمنطقة. بالنسبة للهائمات الحيوانية فكان تنوعها وكثافتها داخل المستوى الطبيعي للمنطقة بدون وجود إختلاف معنوي بين المحطات المختلفة والمحطة المرجعية. تم تسجيل 68 نوعاً منها وتراوحت كثافتها العددية بين 14390 و 5021 فى منطقة إغراق النفايات وبين 16135 و 6702 فرد/م^3 فى المحطة المرجعية. وسادت مجموعة مجدافيات الأرجل حيث شكلت حوالي 65.3% من العدد الكلي للهائمات الحيوانية نتيجة لسيادة الأنواع الآتية: سنتروباچاس كرويرى، باراكالانس بارڤاس، كلوزوكالانس أركيوكورنيس، أوثونا نانا، أيوتربانا اكيوتيفرونز. ومن الدراسة يمكن الإستدلال على أن عمليات بناء ميناء شرق التفريعة متمثلة فى تكريك وإغراق النفايات كان لها تأثير ضعيف وغير ملحوظ على مجتمع الهائمات الحيوانية.