Qatar Univ. Sci. J (2000), 20 : 205 - 218

CHANGES IN COPEPOD COMMUNITY STRUCTURE IN RESPONSE TO LAND-BASED ACTIVITIES ALONG ALEXANDRIA COASTLINE, MEDITERRANEAN SEA

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تغيرات تركيب مجاميع الكوبيبودا (مجدافية الأقدام) كنتيجة للأنشطة الأرضية على سواحل الاسكندرية في البحر الأبيض المتوسط

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جُمعت عينات كوبيبودا من أربعة مناطق على سواحل مدينة الأسكندرية (البحر المتوسط) معرّضة على التوالي للصرف الزراعي، الصرف الصناعي، الصرف الصحي وخليط من الصرف الزراعي/الصناعي لتتبع تأثير الأنشطة الأرضية على توزيع وتركيب مجاميع الكوبيبودا أثناء فترة أقصى وأدنى تدفق للصرف، كان تأثير الصرف الصناعي هو الأعلى حيث انخفضت أمامه كثافة الكوبيبودا إلى أقل مستوى (٥٠٠ كائن/م٣). بالرغم من إنخفاض أعداد الكوبيبودا أثناء أقصى تدفق للصرف الصحي فقد أظهرت المنطقة المتأثرة بالصرف الزراعي توافر الغذاء الطبيعي للكوبيبودا مما أثر على زيادة كثافة الكائنات وتنوعها. أظهرت بعض الكائنات مقاومة مرتفعة لمستويات التلوث فازدهرت بالقرب من مناطق الصرف، أثناء فترة أقصى تدفق للصرف الزراعي، انخفضت الملوحة لأقل من ١٠ وحدة ملوحة عملية، فظهرت بعض الكائنات المميزة لبحيرات المياه العذبة، بينما لم تؤثر توزيعات الحرارة والأكسجين في تغيير تركيب مجاميع الكوبيبودا على سواحل الإسكندرية في إنخفاض كثافة الكائنات في المناطق المتأثرة بالصرف الصناعي، أبرزت المعادلات الإحصائية زيادة تنوع الكائنات أمام الصرف الزراعي، الصرف الصناعي، الصرف الصحي، والصرف الزراعي/الصناعي.

Running Title : Copepod structure changed is response to pollution.
Key Words : Copepods, pollution, diversity, Mediterranean Sea, Alexandria.

ABSTRACT

Along the coastal water of Alexandria, Copepods were collected from four different areas subjected to agricultural/industrial mixed discharge, primary treated sewage flow, industrial effluent and agricultural runoff to trace the impact of land-based activities on their distribution patterns and community structure during high and low flow periods. Industrial discharge exerted the highest impact on the copepod population by decreasing its density to less than 500 ind./m^3. Despite the decrease in copepod abundance during high flow of sewage, the impacted area sustained the maximum copepod density low discharge i.e. 11,222 ind./m^3 due to presence of available food. The acceptable water quality characteristics and high nutritive nature of the agricultural runoff increased the copepod density and diversity. *Euterpina acutifrons, Oithona nana* and *Paracalanus parvus* showed high resistivity to pollution levels, blooming always near the discharge points. Harpacticoids showed high capacity to withstand industrial discharge more than Calanoids and Cyclopoids. Diversity indices for the area heavily affected by agricultural discharge (1.8 – 2.6) were higher than for the areas impacted by sewage (1.6 – 1.9), mixed agricultural/industrial (1.4 – 1.6) and industrial (0.6 – 0.8) discharge. Freshwater species were recorded at nearshore stations opposite agricultural runoff where salinity declined to < 10 psu. Multiple regression equations proved that the copepod community structure is influenced by various environmental factors which differed according to the water quality in the four investigated areas. While temperature and oxygen were not effectively involved in copepod community structure variations, pollution by Hg and oil seemed to suppress copepods abundance at areas impacted by industrial discharges.

INTRODUCTION

The waters of the Alexandrian coastline are considered to be among the most polluted sites of the Mediterranean Sea. They receive three types of discharge: sewage, agricultural and industrial. These anthropogenic inputs adversely affects the water quality of the receiving environment leading to sub-lethal and lethal effects on the marine biota in the coastal area.

Copepods dominate the marine zooplankton community often contributing over 80% of the total zooplankton counts in near-shore and estuarine habits. Variations in their abundance and community composition are a valid indicator of ecological succession and environmental conditions and have been used in numerous investigations in order to assess the degree of exposure to environmental stress [1-3].

During the last three decades, the distribution and abundance of copepods along the Egyptian Mediterranean coast have been studied by several authors [4-13].

The present study was undertaken to assess the impact of different land-based activities on the species composition, distribution and diversity of the copepod community along the Alexandrian coast and to serve as a baseline for further ecological monitoring of this ecosystem.

STUDY AREA

Mex Bay is located to the west of Alexandria city occupying an area of 19.4 km^2 with a mean depth of 10 m (maximum depth 18 m) yielding a water volume of 190 x 10^6 m^3. The bay receives approx. 2.4 x 10^9 m^3/y of brackish water from Maruit lagoon via the Ummum Drain, thorugh the Mex Pump Station. In addition, the bay receives 13 x 10^6 m^3/y of industrial discharge as well as 1.13 x 10^6 m^3/y from the Western Harbor of Alexandria. The maximum flow through the Ummum Drain is usually approached during winter (304 x 10^6 m^3/month) while the minimum (168 x 10^6 m^3/y) is recorded during summer [14].

A considerable amount of Alexandria's untreated domestic sewage is discharged into the coastal waters through a major outfall (Kayet Bey Pumping Station) i.e. > 0.5 x10^6 m^3/d [15]. This outfall discahrge is at a distance of 670 m underwater outside the Eastern Harbor and east of Al Anfoushi Bay. The discharge from the pipeline is variable with the maximum during summer matching the increase in sewage load.

Abu Qir Bay is a semicircular basin located 36 km east of Alexandria. The area of the bay is 360 km^2 with a maximum depth of 20 m. The southwestern region of the bay receives aboyt 2 x 10^6 m^3/d of industrial discharge from the Tabia Pump Station [16]. This discharge is a continuous flow with no seasonal peaks. Industrial wastes include fertilizers, textiles, chemical, dyes, food processing and canning wastes as well as paper mill efffluents. A few kilometers to the east of this discharge, the bay receives agricultural runoff from Lake Edku (about 1400 x10^6 m^3/y) through Bz. El-Maadia [17]. This discharge results in intermittent inputs of brackish water loaded with huge amounts of nitrogen, phosphorus and silicon.

SAMPLING

During the summer (July) of 1999 and winter (February) 2000, zooplankton samples were collected during daylight from 4 transects perpendicular to the coastline (Figure 1). These transects were located opposite to the Ummum Drain (UD), Kayet Bay Pump Station (KBPS), Tabia Pump Station (TPS) and Lake Edku (LE) representing mixed agricultural/industrial, sewage, Industrial and agricultural discharges, respectively. Zooplankton was sampled at four different stations from each transect (Figure 1).

Replicate vertical hauls were colelcted during daylight using a zooplankton net (mouth diameter 0.5m, mesh size 120 μm) fitted with a calibrated flow meter (General Oceanic Inc.) and samples were preserved using 5% buffered formalin. Aliquots from the original sample were taken for sorting, identification and counting of copepods. Copepods were identified to species level, and counted under a binocular research microscope.

Along with zooplankton, water samples were colelcted to determine temperature (reversing thermometer), salinity (conductivity), dissolved oxygen (winkler method), phosphate, nitrate, ammonia (spectrophotometrically), chlorophyll a (acetone extraction) and Total Suspended Matter (0.45 μm memberance filtration/gravimetrically) [18]; Biochemical Oxygen Demand (BOD_5)(5 days incubation at 20°C); Pb, Cd (GFAAS) and Hg (cold vapor/AAS) [19] as well as Oil & Grease (gravimetrically) [20].

The Shannon-Wiener (H') index [21] was calculated using the individual counts and species numbers to compute species diversity. Stepwise multiple regression equations were presented (confidence limit 95%) to show the correlation between the total number of copepods and the most relevant environmental factors.

RESULTS AND DISCUSSION

Landbased activities impact on coastal waters

Table 1 shows the range of water quality characteristics for the different sectors sampled along the Alexandrian coast. Of the four studied areas, El-Mex Bay (**Ummum Drain Sector**) seemed to be the most heavily impacted by various land-based sources and human activities. Near shore stations were influenced by both the discharge from Ummum Drain and water flowing from the Western Harbour. Low salinities (reaching 9 psu during winter) were observed inshore during the high flow period of brackish water from Lake Mariut. Oxygen levels declined to 2.4 mg/1 due to the anoxic condition of the lake water. During high flow the bay water sustained elevated BOD_5 levels (range between 3.4-8.1 mg/1. Despite the considerably high levels of pollutants (metals) present in the bay, the discharge of nutrients (nitrate and phosphate) rendered the bay a eutrophic system with chlorophyll a levels varying between 0.2-4.4 µg/l in summer and 0.4-1.8µg/l in winter. The bay was continuously exposed to pollution from oil spills probably originating from ballast water discharge along the western coast raising the Oil & Grease levels to 69 mg/l during winter. It is worth mentioning that the bay has been subjected for decades to Hg discharge from a chlor-alkali plant. Despite the cessation of such effluents, high mercury levels still appear in the by due to its remobilization from the sediments, especially during summer.

Kayet Bey Pump Station sector was impacted only by sewage discharge which peaks normally during the summer season, due to the increase in residents using Alexandria as a summer resort. This was clearly reflected on the slight reduction in salinity (minimum 28.9 psu), elevated levels of BOD5 (max. 39.3 mg/l and TSm (max. 154 mg/l). Ammonia levels were the highest amongst the coastal waters (32.5 µM/L) opposite to the outfall while other pollutants such as metals were the lowest in this area. The use of the Eastern Harbor as an anchorage for fishing vessels, yachts and sailing boats exposed the area outside the harbor to local maritime traffic. This subjected the area to the impact of oil pollution thus elevating the levels of Oil & Grease up to 9.3 mg/l during summer.

Tabia Pump Station sector was exposed to heavy industrial load from the Abu-Qir Industrial Complex. In contrast to the other sectors, the industrial flow shows no seasonal peaks but depends mainly on the alternating predominance of discharges from each of the 36 factories as well as the working schedule of the Tabia pumps. The near-shore sites were characterized by elevated metal levels specially Pb (range 4.9-8.2 µg/l), derived from chemical and dye industries, ammonia (3.2-16.7 µM/L) from fertilizer industries, BOD_5 (12.3-26.5 mg/l) and TSM (39-1401 mg/l) from food processing and canning wastes as well as paper mill effluents. Despite the appearance of high phosphorus & nitrogen levels, such pollutants impacted the productivity of this sector by lowering the chlorophyll a values to < 1.3 µg/l. Oil & Grease appeared in near-shore samples with a maximum of 26 mg/l, due to lubrication, oiling and maintenance within the industrial processes.

The increase in the fresh drainage water flow to Lake Edku during summer (347 x 10^6 m^3) compared to winter (147 x 10^6 m^3) induced a lake-sea current exposing the southern region of the bay (**Lake Edku sector**) to brackish water inflows lowering its salinity to 15.3 psu. The lake water induces high oxygen to the bay (6.2-8.3 mg/l), high loads of suspended matter (28-110 mg/l) and nutrient salts (0.3-6.4 µM/L phosphorus, 1.9-17.8 µM/L nitrate) which lead to increased primary producer biomass (chlorophyll a 3.5-5.9 µg/l). However, due to the anticlock-wise wind-current driven regime in Abu-Qir Bay, the near-shore locations of Lake Edku sector were also intermittently subjected to the input from TPS extending eastwards. This flow increased the levels of metals, specially Pb and Cd.

Copepod community structure

The copepod community alogn the ***Ummum Drain*** sector was characterized by an average standing crop of 1906 ind./m^3 constituting 61.4% of total zooplankton community. The highest abundance was observed during high flows (2,229 ind./m^3) while the lowest was recroded during low flows (1,582 ind./m^3) (Figure 2a). Copepods were represented by 41 species of which 22 belonged to calanoid (s), 14 to cyclopoid(s) and 5 to the harpacticoid(s) (Table 2).

Adults and copepodite stages of *Oithona nana, Euterpina acutifrons, Paracalanus parvus, Clausocalanus arcuicornis, Acartia clausi* and *Centropages kroyeri* dominated the taxonomic composition, together comprising 76% of total copepoda during the study period.

Total copepod abundance was significantly higher at the near-shore station (3,920 ind./m^3) during low flow from the

Ummum Drain while during high flow the abundance declined to 1,107 ind./m^3. There fresh water copepods, namely *Canthocamptus gracilis, Acanthocyclops americanus* and *Acanthocyclops vernalis* appeared (Table 2) at the near-shore location during high flow when salinity reached 9 psu.

Despite the variations in the abundance and consequently the dominance of species between near-shore and offshore stations, the same species were observed in both areas. The community of the offshore stations, the same species were observed in both areas. The community of the offshore station was dominated by *Paracalanus parvus, Oithona nana, O. plumifera, Acartia clausi* and *Centropages kroyeri* while near-shore stations were dominated by *Oithona nana, Euterpina acutifrons, Paracalanus parvus* and *Clausocalanus arcuicornis.* The contribution of harpacticoids, mainly *Euterpina acutifrons,* to the total copepod abundances, decreased seawards, constituting 16.5% and 14.9% for the offshore location compared to 32.9% and 29.3% for the near-shore area during high and low flow periods, respectively.

Studying the zooplankton assemblages for 1996 samples (Spring, early and late Summer and Fall), Hussein [11] recorded 33 copepod species belonging to 22 genera from El-Mex Bay. He observed high copepod densities, i.e. 16,573 ind./m^3 opposite the Ummum Drain, while densities decreased offshore. Similar to the present findings, *Oithona nana, Euterpina acutifrons, Paracalanus parvus* and *Acartia latisetosa* were the top list species of copepod counts in Nex Bay. Dowidar & El-Maghraby [4;5], Hussein [6], Samaan et al. [8] and nour El-Din [9] also reported that these species were dominant along the Egyptian Mediterranean coastline.

Receiving huge amounts of sewage discharge, renders the **Kayet Bey Pump Station sector** area a highly eutrophic site. This was reflected by the high levels of nutrients and consequently high chlorophyll a (Table 1). Despite receiving considerable amounts of oxygen demanding wastes, this sector harbored the highest copepod densities among the coastal waters i.e. 5,296 and 11,222 ind./m^3 during high and low flow from KBPS. *Paracalanaus parvus, Oithona nana, Euterpina acutifrons, Acartia latisetosa, Corycaeus species, Clausocalanus arcuicornis* and *Temora stylifera* were the dominant species. From 21 genera, *Paracalanus parvus, Oithona nana* and *Oithona plumifera* were observed as dominant copepods along the KBPS offshore area [12].

Previous research carried out inside the Eastern Harbor [6], [9], [22] and [23], led to the identification of variable numbers of copepod species: 75, 132, 112 and 126, respectively; while, for the offshore waters of the Harbor, Hussein [11] recorded 37 species compared to 42 species recorded for this sector during the present study.

For the offshore KBPS area (8-12 km from shore and 45-60 m depth) using an 80 μm mesh size net, copepods constituted approx. 58% of total zooplankton with an abundance of 3,342-7, 186 ind./m^3 during April-October 1996 [12], values close to those recorded for the near-shore area during high sewage flows in the present study.

The continuous discharge of industrial wastewater from **Tabia Pump Station** throughout the year not only reduced the copepod community density along TPS sector but also masked the appearance of a significant between the abundance during the both seasons (Figure 2c). MOreover, compared to the other sites, the community structure was altered and harpacticoids dominated the copepod assemblage, especially during summer. The ratio between calanoids: cyclopoids: harpacticoids was 1.2: 1.0: 1.4 in summer and 1.3: 1.1: 1.0 during winter. Near-shore stations opposite the Tabia Pump Station were very poor in copepods and most of the counts in this sector are derived from the offshore locations. In addition to the decline in the abundance in copepods, the diversity of the community along the sector was very low and only 16 genera were observed. The near-shore locations were characterized by relatively low dissolved oxygen content, high organic loads, low pH and elevated metals concentrations. *Euterpina acutifrons* was the dominant species followed by *Oithona nana*. Both species seem to be capable to tolerate the exposure to intensive pollution. In contrast, species like *Temora stylifera*, recorded in other sectors with considerable numbers, disappeared completely from this sectorl similarly, *Eucalanus spp., Euchaeta spp.* and Lucicutia spp. which were rare in other sectors were absent along TPS sector.

The sector opposite the **Lake Edku** was characterized by increased numbers of copepods i.e. average 5,126 and 7,840 ind./m^3 during high and low flow periods, respectively. This reflects the higher water quality and high nutritive nature of the agricultural water flowing from the lake (Table 1). However, lower numbers were observed during low flow period at station 14 (Figure 2d) due to the impact of industrial discharges reaching this area as a result of the wind-driven current regime in the bay, where water flows almost parallel to the coast from west to east. *Acanthocyclops americanus, A. vernalis, Canthocamptus gracilis, C. pygmaeus, Harpacticus species* and *Canuella perplexa* which are typical brackish water species were observed at the near-shore location during the high flow period (summer) driven by the outflowing lake water of salinity 15.3 pus. Almost 20 marine genera of copepods were recorded in this sector of which 12 were calanoids, 5 cyclopoids and 3 harpacticoids. *Oithona nana* was the most dominant species recorded along this sector followed by Euterpina acutifrons. Calanoid populations were dominated by **Paracalanus parvus, Acartia clausi, Clausocalanus furcatus** and *Temora stylifera* (Figure 2d). Calanoids contributed on average 40% of total copepods while cyclopoids and parpacticoids contributed 33 – 29% and 19 – 21% of the total numbers with no clear inshore/offshore trend. Copepodite stages and nuaplii constituted between 7 and 10%, respectively, of the total copepods during high and low flows from the lake.

Generally, copepod diversity along the coastline of Alexandria increae away polluted sites. Shnnon-Wiener diversity indices for the Lake Edku sector (1.8 – 2.6) were higher than for Kayet Bay Pump Station sector (1.6 – 1.9), the Ummum Drain sector (1.4 – 1.6) and much greater than for the Tabia Pump Station sector (0.6 – 0.8). However, variations withn the same area during the same season were not significant. It is worth mentioning that sewage discharges did not reduce either the species diversity or the population size of tolerant species indicating that the enrichment of the coastal waters may stimulate the population densities.

Copepod community response to different environmental conditions

The decrease in the diversity of copepods in polluted regions is considered a step towards habitat degradation, reflecting the poor and deteriorating quality of the receiving water. The absence of certain copepodd species indicates that these species are unable to tolerate the adverse effects of pollutants while higher densities of other species reflect their capacity to adapt to the deteriorating environmental conditions. Stepwise regression equation models showed the dependence of the copepod community distribution on the most significant environmental conditions as follows:

Umm Drain sector (agricultural/industrial discharge)

Total Copepods (ind./m^3) = 1357 + 63.4 S (psu) – 10.72 Hg (ng/l) + 16.3 Chl a (μg/l) – 37.5 Oil & Grease (mg/l) + 0.93 NH_4^+ (μM/l) (r = 0.8351, p = 0.076).

Kayet Bay Pump Station sector (sewage discharge) :

Total Copepods (ind./m^3) = 437 + 130.9 Chl a + 9.55 PO_4 – 8.01 BOD_5 (mg/l) – 41.6 TSM (mg/l) – 23.6 Pb (μg/l) (r=0.7483, p=0.1083).

Tabia Pump Station sector (industrial discharge) :

Total Copepods (ind./m^3) = 16.5-91.6Pb (μg/l) – 55.8 Cd (μg/l) + 83.4 NH_4^+ (μM/l) – 19.2 TSM (mg/l) – 3.1 BOD_5 (mg/l) (r=0.8187, p=0.007).

Lake Edku sector (agricultural discharge) :

Total Copepods (ind./m^3) = 77.3 + 11.1 Chl a (μg/l) + 7.51 S (spu) + 22.5 P (μM/l) – 2.33 NO_3 (μM/l) – 0.33 Cd (μg/l) (r=0.9011, p=0.002).

These equations show that the copepod community structure in each sector is influenced by various environmental parameters which differed between the sector according to the type of stress. Variables such as temperature and dissolved oxygen were not significantly involved in determining the copepod community structure. Whilst, chlorophyll a (food availability index) was a common factor for copepods variations, especially near to sectors impacted by agricultural discharges and in sewage stressed areas. Hg and Oil seemed to suppress copepod abundances in Mex Bay; while, Pb, Cd and NH_4^+ highly impacted copepod densities off TPS.

Correspondence Factor Analysis was used in an attempt to reduce the complexity within the similarity matrix of data collected during this study. The analysis was performed on a seasonal basis from a data matrix comprising 16 observations (sampling locations) and 13 variables (Table 1). Only factors 1 and 2 accounting statistically for 92.4% (summer) and 93.6% of the total variance were considered. Figures 3a and 3b show the plots of Factor 1 vs. Factor 2. Factor 1 accounted for 66.4% (summer) and 69.8% (winter) while Factor 2 for 26.0% (summer) and 23.8% (winter) of the total variance. Results from factor analysis suggested that on seasonal basis the ditribution of copepods along the Alexandrian coastline was governed by and can be interpreted in terms of environmental processes differing in their sequence and contribution.

During summer 1999, and in order of decreasing factor loading total copepods were positively affected by Pb>Cd>Temperature>BOD>DO>NH_4^+>Hg (Factor 1) and positively by TSM>Chl a>NO_3>P>Oil &Grease>salinity (Factor 2). However, during winter 2000, copepods were positively associated with BOD>Pb>TSMTemperature>Oil & Grease (Factor 1) and positively with Hg>NO_3>Cd but showed high negative assocaitions with salinity and DO. The total copepod density showed a close association with chlorophyll a, especially during the winter season. This indicates that the effets of the factors affecting copepod densities varied significantly between the two seasons. Variable like DO, salinity and temperature appeared to play a significant role when seasonal variations were considered.

ACKNOWLEDGEMENT

The author would like to thank Mrs, Nahla M. Nour El-Din (M.Sc. in Chemical Oceanography) for help in achieving the chemical analyses.

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Table 1
Water quality characteristics for different sectors along Alexandria coastline.

Location / Parameter	Ummum Drain Sector		Kayet Bey Pump Station Sector		Tabia Pump Station Sector		Lake Edku Sector	
	Summer 1999	Winter 2000	Summer 1999	Winter 2000	Summer 1999	Winter 2000	Summer 1999	Winter 2000
Temperature (°C)	27.9-28.5	14.6-15.2	28.4-29.6	14.2-14.7	29.6-30.2	15.9-16.5	28.0-28.5	15.0-15.6
Salinity (psu)	24-36	9-27.1	28.9-36.1	37.2-38.9	31.6-38.4	29.5-36.7	15.3-36.2	37.0-39.2
Dissolved oxygen (mg/l)	3.3-5.6	2.4-4.9	3.0-4.1	4.6-6.2	2.9-4.8	3.5-5.2	6.2-6.9	6.2-8.3
BOD_5 (mg/l)	3.8-6.6	3.4-8.1	9.8-39.3	2.5-10.6	12.3-20.5	16.9-26.5	1.1-3.4	2.2-3.5
TSM (mg/l)	17-36	12-53	97-154	37-92	39-72	57-140	93-110	28-49
Phosphate (µM/L)	0.09-1.03	0.3-2.2	0.1-2.6	0.15-0.45	0.2-3.6	0.5-3.2	0.6-3.9	0.3-1.4
Nitrate (µM/L)	0.6-6.2	2.0-14.5	0.7-8.8	0.9-1.2	2.5-4.4	2.6-11.8	3.15-17.8	1.9-2.5
Ammonia (µM/L)	6.9-20.6	2.2-3.4	4.3-32.5	1.2-11.4	5.8-12.4	3.2-16.7	1.1-3.8	0.4-1.2
Pb (µg/l)	0.6-4.6	0.8-3.3	0.2-1.3	0.6-1.1	4.9-5.3	6.6-8.2	0.4-2.6	0.3-3.2
Cd (µg/l)	0.11-0.83	1.1-1.64	0.14-0.3	0.2-0.3	1.1-3.5	1.1-2.2	0.2-0.7	0.1-0.5
Hg (ng/l)	49-197	89-161	22-37	20-26	59-103	78-126	nd-30	nd-38
Oil & Grease (mg/l)	2.3-43	0.9-69	0.1-9.3	0.01-2.6	1.1-18	3.9-26	0.2-3.5	0.6-1.7
Chlorophyll a (µg/l)	0.2-4.4	0.4-1.8	6.9-12.5	4.4-8.3	0.8-1.3	0.3-1.1	3.5-5.1	4.0-5.9

Table 2
List of copepod species at different sectors from the Alexandria coastline.

Sector / Season / Species	UD Sum.	UD Win	KBPS Sum.	KBPS Win.	TPS Sum.	TPS Win.	EDKU Sum.	EDKU Win.
Calanoida								
Acartia clausi	+	+	+	+	+	+	+	+
A. grani	+	-	-	-	-	-	+	-
A. Latisetosa	+	+	-	-	-	-	+	+
A. Longiremis	+	+	+	+	-	-	-	+
A. Negligens	+	+	+	+	+	+	+	+
Calocalanus pavo	-	+	+	+	-	-	-	-
C. styliremis	-	-	+	+	+	-	+	+
Candacia bispinosa	-	-	-	+	-	-	-	+
C. simplix	-	+	+	-	-	-	-	-
C. varicans	-	+	+	+	-	+	+	+
Centropages kroyeri	+	+	+	+	+	+	+	+
C. typicus	-	+	+	-	-	-	-	+
C. violaceus	+	+	+	+	-	-	-	+
Clausocalanus arcuicornis	+	+	+	+	+	+	+	+
C. furcatus	+	+	+	+	+	+	+	+
Eucalanus attenuatus	-	+	-	+	-	-	-	+
E. elongatus	-	+	-	+	-	-	-	-
Euchaeta marina	-	-	+	-	-	-	+	+
E. spinosa	-	+	+	+	-	-	-	+
Isias clavipes	+	+	+	+	-	+	+	+
Lucicutia flavicornis	-	+	-	+	-	-	-	+
Mecynocera clausi	-	+	+	+	-	+	-	+
Paracalanus aculeatus	-	+	+	+	+	+	+	+
P. parvus	+	+	+	+	+	+	+	+
Temora stylifera	+	+	+	+	-	-	+	+

Cyclopoida								
Acanthocyclops americanus	-	+	-	-	-	-	+	-
A. vernalis	-	+	-	-	-	-	+	-
Corycaeus clausi	+	+	+	+	+	+	+	+
C. limbatus	-	+	+	+	+	+	+	+
C. speciosus	-	+	+	+	-	-	-	-
C. typicus	-	-	+	-	-	+	+	-
Faranulla carinata	-	-	+	-	-	-	-	+
F. rostrata	+	+	+	+	-	-	-	+
Oithona linearis	-	-	+	-	-	-	-	-
O. nana	+	+	+	+	+	+	+	+
O. plumifera	+	+	+	+	+	+	+	+
Oncaea conifera	+	+	+	+	-	+	-	+
O. mediterranea	-	+	+	+	-	-	-	+
O. subtilis	-	+	-	+	-	+	+	-
O. venusta	-	+	+	+	-	+	+	+
Sapphirina angusta	-	+	+	+	-	-	-	-
Sapphirina spp.	+	+	+	-	-	+	+	-
Harpacticoida								
Canthocamptus gracilis	-	+	-	-	-	-	+	-
C. pygmaeus	-	-	-	-	-	-	+	+
Canuella perplexa	-	-	-	-	-	-	+	-
Euterpina acutifrons	+	+	+	+	+	+	+	+
Macrosetella gracilis	-	+	+	+	+	-	+	+
Microsetella norvegica	+	-	-	+	+	+	+	+
M. rosea	+	+	+	+	+	+	+	+
Copepodite stages	+	+	+	+	+	+	+	+
Copepod nauplii	+	+	+	+	+	+	+	+

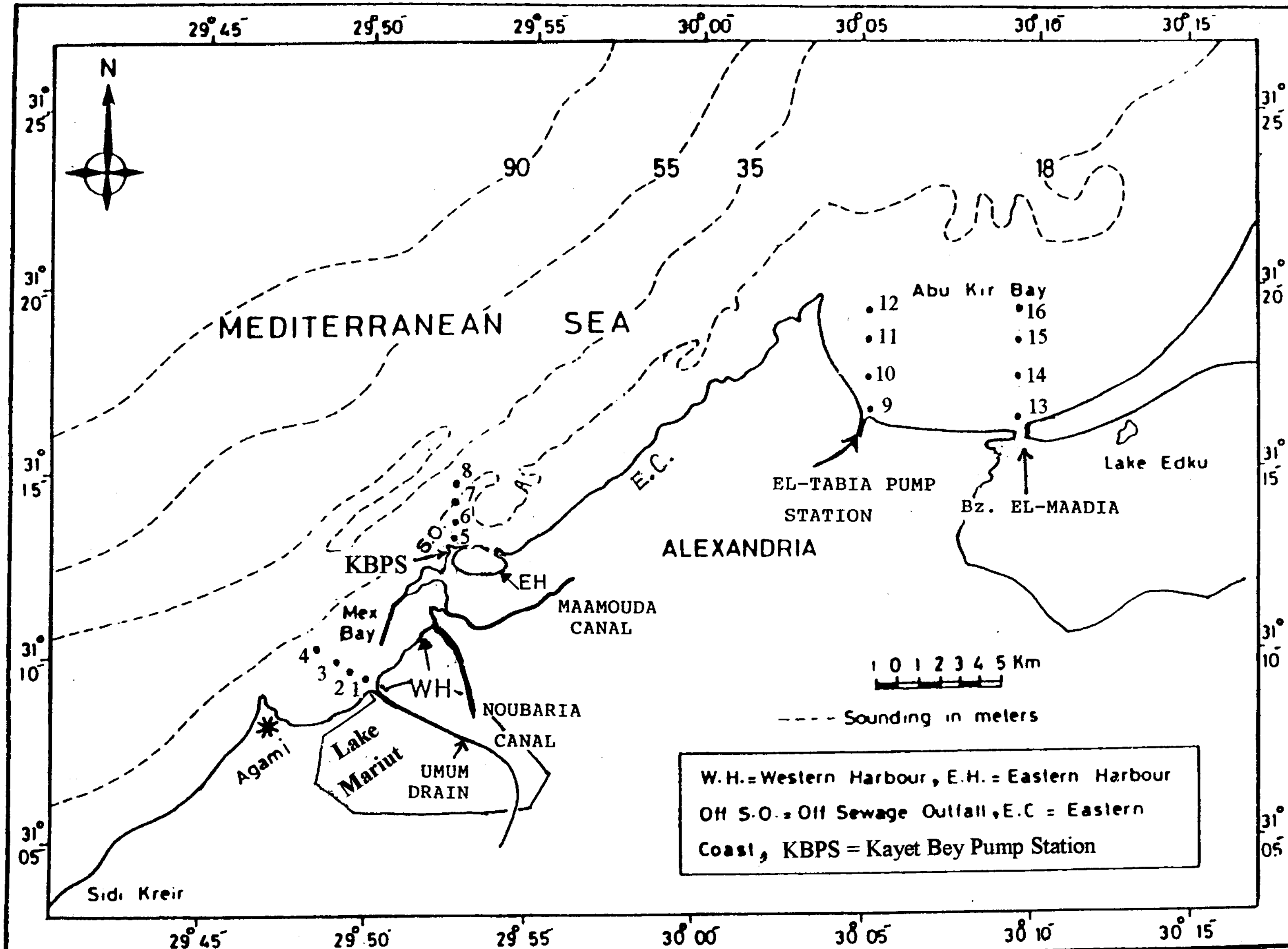

Fig. 1 : Area of study showing sampling stations.

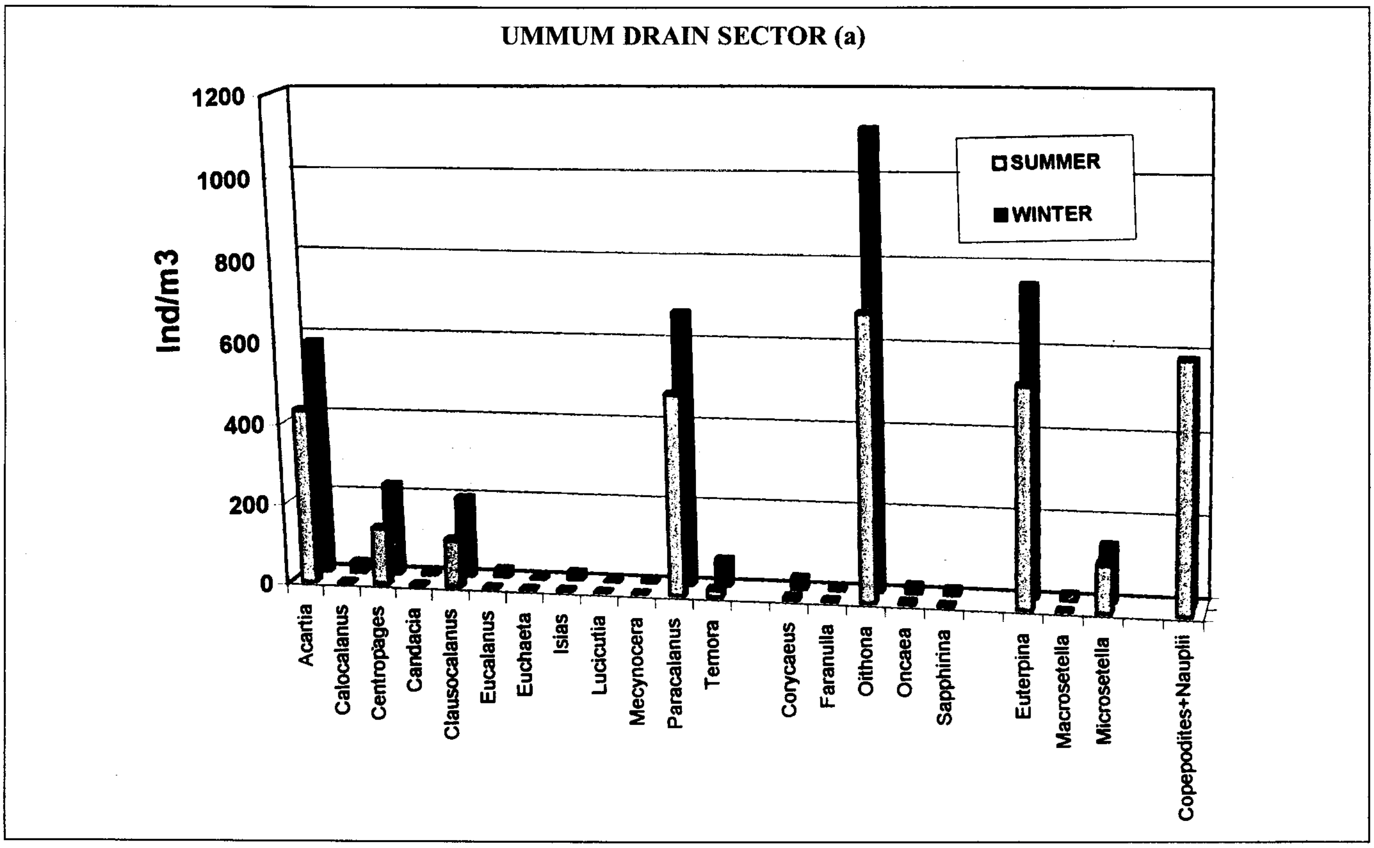

Fig. 2a : Copepod genera densities (average of 4 stations) during summer 1999 and winter 2000 along Ummum Drain sector.

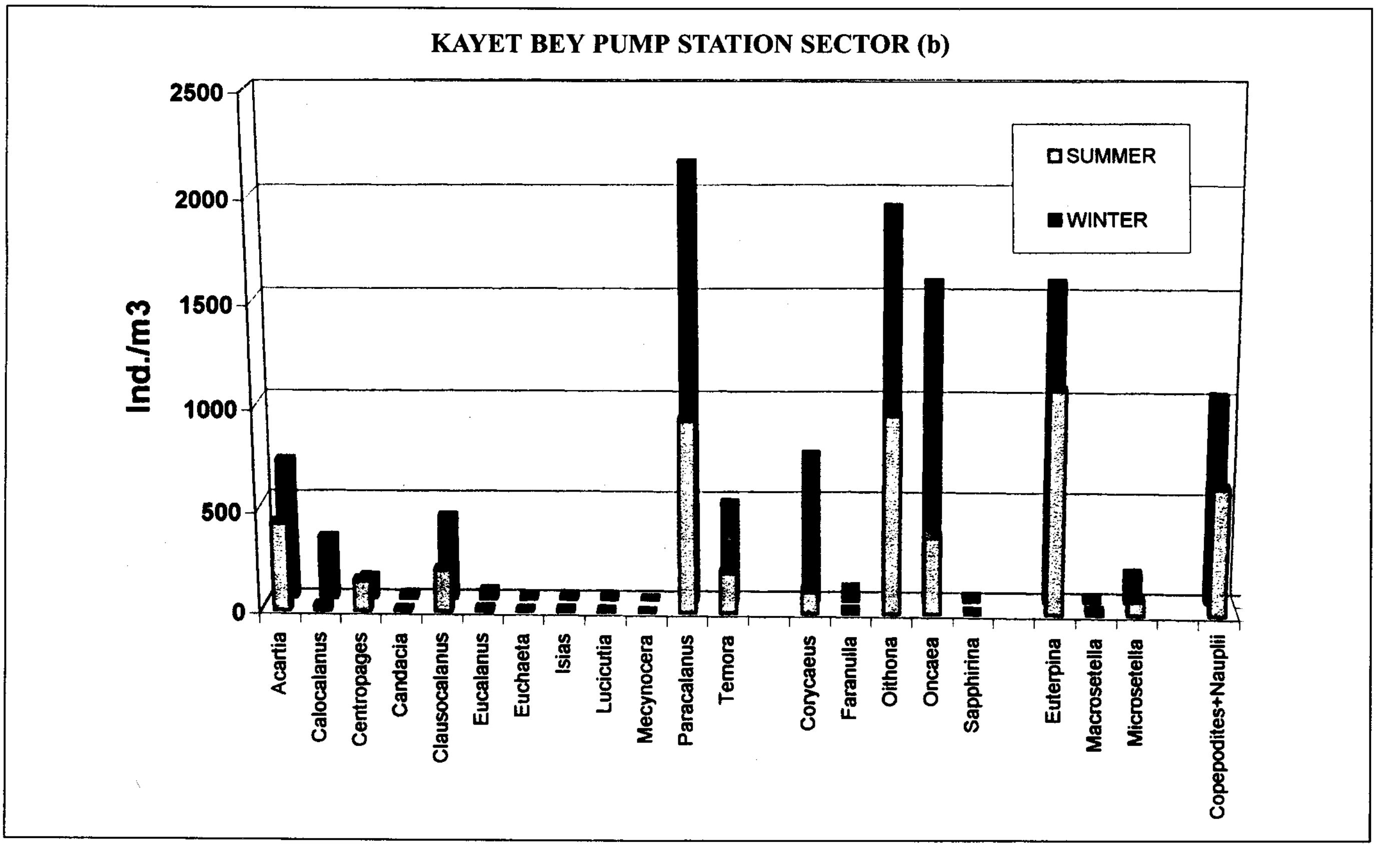

Fig. 2b : Copepod genera densities (average of 4 stations) during summer 1999 and winter 2000 along Kayet Bey Pump Station sector.

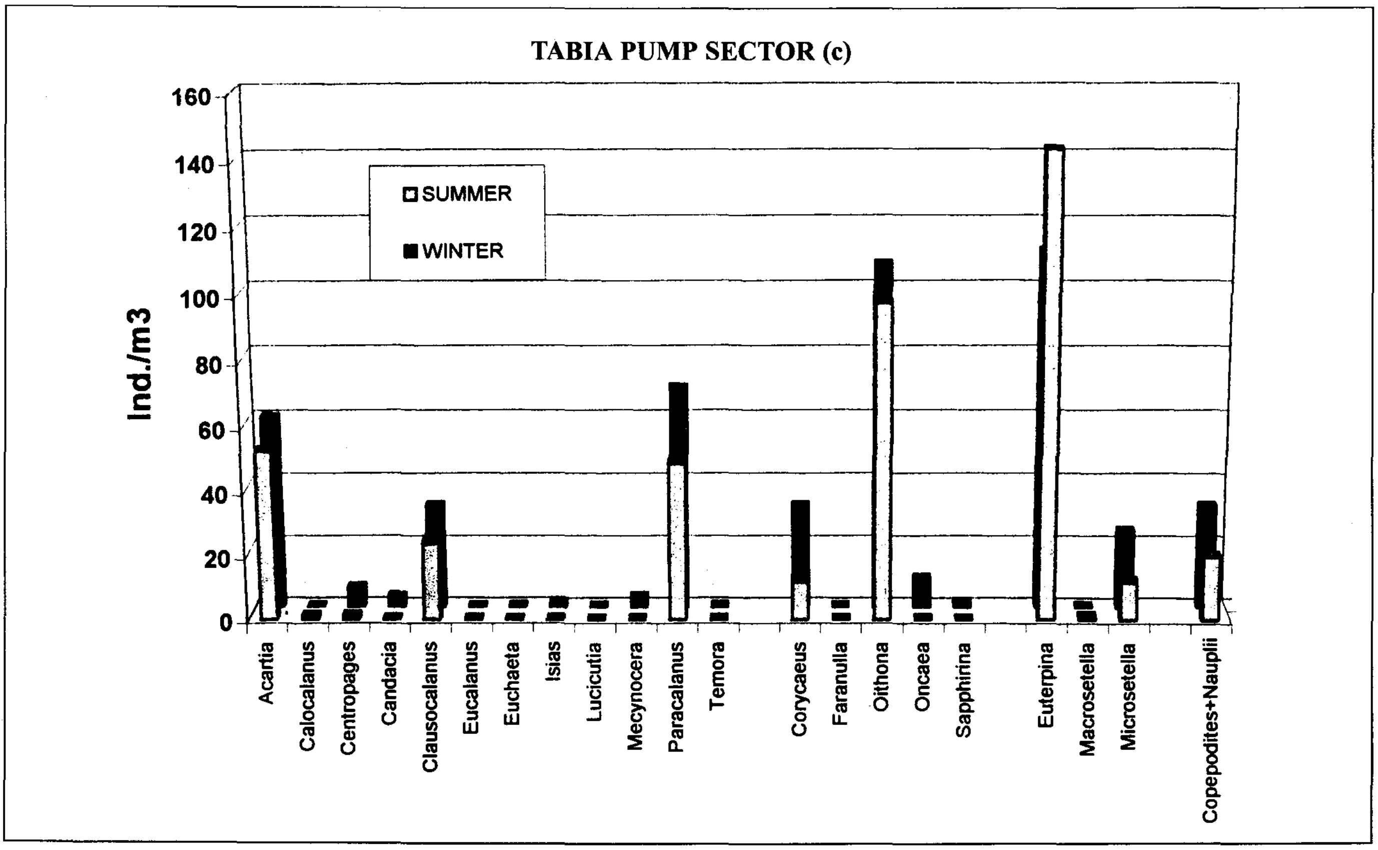

Fig. 2c : Copepod genera densities (average of 4 stations) during summer 1999 and winter 2000 along Tabia Pump Station sector.

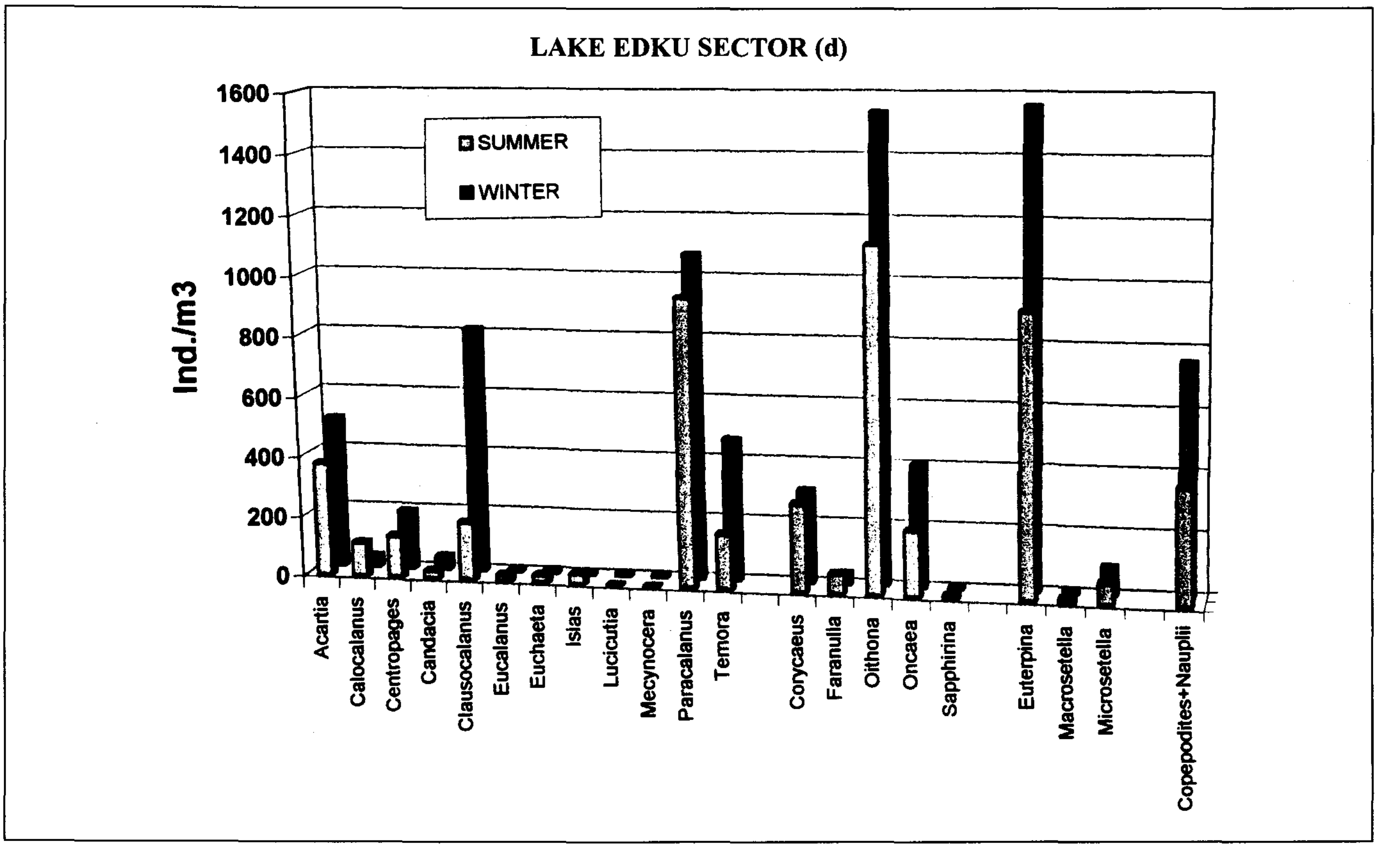

Fig. 2d : Copepod genera densities (average of 4 stations) during summer 1999 and winter 2000 along Lake Edku sector

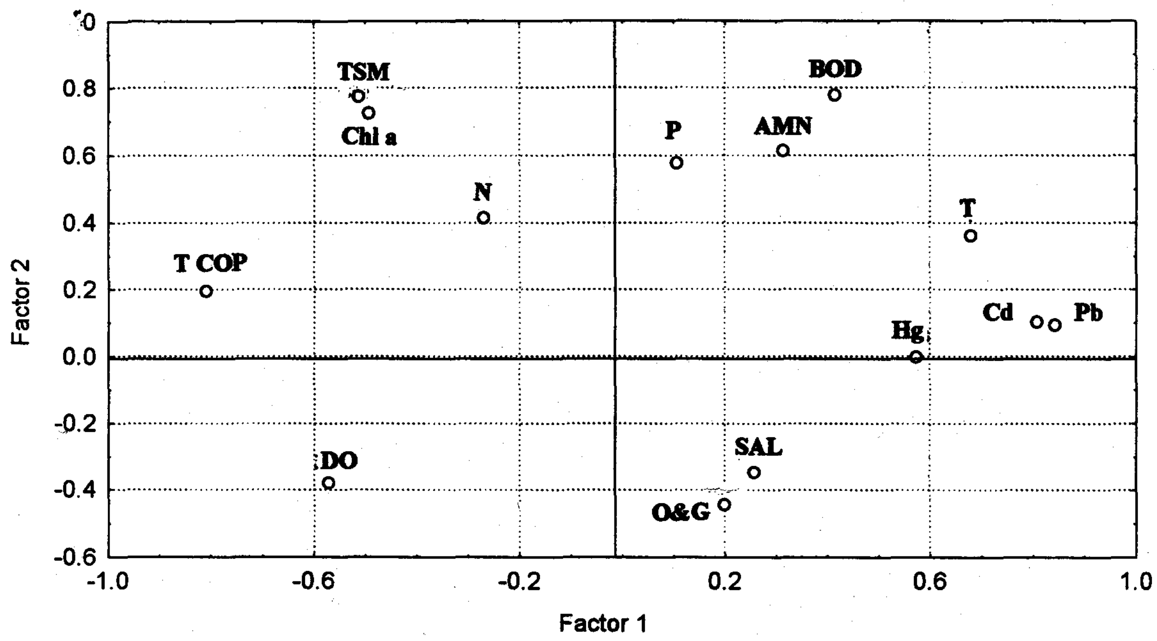

Fig. 3a : Correspondence factor analysis for different environmental variables (see Table 1) in relation to total copepod densities (TCOP) during summer 1999.

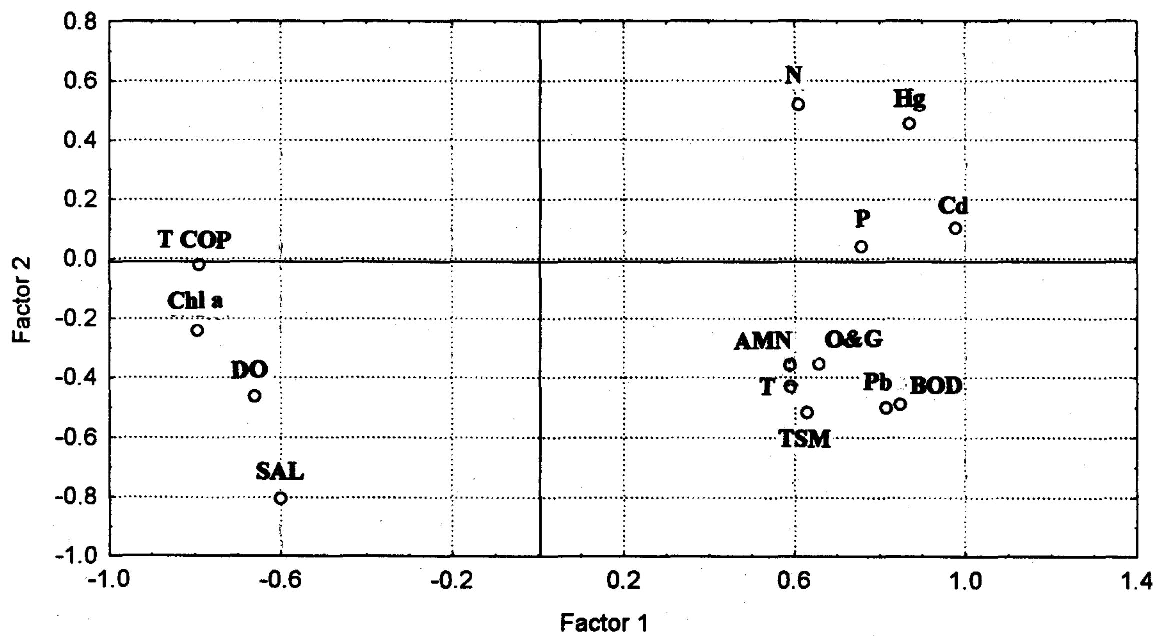

Fig. 3b : Correspondence factor analysis for different environmental variables (see Table 1) in relation to total copepod densities (TCOP) during winter 2000.

Abbreviations:

TCOP=Total Copepods
Chl a=Chlorophyll a
DO=Dissolved Oxygen
BOD=Biochemical Oxygen Demand
O&G=Oil and Grease
Pb=Lead
Cd=Cadmium
SAL=Salinity
AMN-Ammonia
N=Nitrate
TSM=Total Suspended Matter
P=Phosphorus
T=Temperature