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Zooplankton of Highly Eutrophic, Sewage Polluted Coastal Lagoons Off Jeddah, Central Red Sea

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ABSTRACT. The occurrence and abundance of zooplankton in sewage polluted coastal areas of Jeddah in Al-Arbaeen and Al-Shabab lagoons were studied monthly during the period November 1990 to October 1991. Based on the physicochemical parameters studied in both lagoons (*i.e.* salinity, pH and dissolved oxygen), the environment of Al-Shabab lagoon was comparatively less polluted than that of Al-Arbaeen lagoon. In Al-Arbaeen lagoon surface values of salinity and dissolved oxygen varied between 8‰ and 37‰ (mean 26.6‰) and 0.04 mg/l and 7.1 mg/l (mean 1.83 mg/l); the corresponding values in Al-Shabab lagoon were: 16‰ and 41‰ (mean 33‰) and 0.29 mg/l and 9.41 mg/l (mean 4.11 mg/l). Generally a significant positive correlation was found between each of dissolved oxygen and pH with salinity. However, the total zooplankton crop in Al-Shabab lagoon (average 1850 ind/m^3) was relatively lower than in Al-Arbaeen lagoon (average 3560 ind/m^3). The standing crop of copepods in Al-Arbaeen and Al-Shabab lagoons were 86% and 34% of the total zooplankton respectively. The low standing crop of Al-Shabab lagoon was due to the low copepod density. In both lagoons the copepod populations were not diversified taxonomically and only a limited number of species were recorded. Of calanoid species: *Pseudodiaptomus* sp. (was the most dominant species constituting on average more than 90% of the total copepods), *Clausocalanus* spp., *Paracalanus parvus*, *Paracalanus* spp. *Oithona nana*, *Oithona helgolandica*, *Corycaeus speciosus* were the main cyclopoid species recorded only in Al-Shabab lagoon.

Over 50 copepod species were recorded in the collected samples at the offshore station in Al-Qita Al-Kabera. Holoplanktonic groups other than copepods, *i.e.* tintinnids and rotifers, constituted 10.1% of the average zooplankton community in Al-Arbaeen and 34% in Al-Shabab lagoon. The meroplanktonic groups recorded in both lagoons were limited; cirripeds larvae and gastropods veligers were the most important constituting on the average 4% and 30% of the total zooplankton in Al-Arbaeen and Al-Shabab lagoons respectively.

Introduction

Old literature on the zooplankton of the Red Sea has been reviewed by Halim (1969). Recently, Echelman and Fishelson (1990) reviewed published work on the zooplankton of the northern part of the Gulf of Aqaba. In the Red Sea, proper, Ponomareva (1968) studied the quantitative distribution of zooplankton over the period May to June 1966. Gordeyeva (1970) studied the quantitative distribution of zooplankton in the northern and central Red Sea. Weikert (1980a, 1980b, 1981, 1982 & 1987) worked on the zooplankton in the Atlantis II Deep area of the central Red Sea. Beckmann (1984) studied the mesozooplankton distribution on a transect from the Gulf of Aden to the central Red Sea. Al-Aidaroos (1984, 1988) worked on the zooplankton community with special reference to the copepods and decapod larvae of north Jeddah, Red Sea. Most of these studies were made on oceanic water and coastal waters not affected by sewage pollution. No particular work has been done on the zooplankton of the coastal water of Jeddah.

The main aim of the present work was to study the composition and abundance of the zooplankton community in sewage polluted coastal areas of Jeddah.

Material and Methods

Two sites were selected to represent the sewage polluted coastal waters of Jeddah: Al-Arbaeen and Al-Shabab lagoons.

Al-Arbaeen lagoon (Figs. 1, 2) is a semiclosed basin having the following dimensions: length 1500 m, maximum breadth 400 m, average of 246 m; depth varies between 3 and 7 m, with an average of 4 m. The lagoon is connected to the coastal waters of the Red Sea by a channel about 1 km long at its western side. The bottom of the lagoon is covered by dark loose mud, which smells hydrogen sulphide (MEPA, 1986, Al-Rayis *et al.*, 1988). Two bridges were built over the lagoon connecting its northern and southern sides; the depth of water under the bridge is about 2 m. The lagoon receives sewage and waste water effluent through two outfalls. However, discharge from one of the outfalls was stopped one month before starting our sampling programme. It is now used to discharge excess rain water during periods of heavy rain, which generally occur once or twice a year. The second outfall is still running and discharging amounts of about 62,000 m^3 per day of partially treated sewage. Four stations were sampled in Al-Arbaeen lagoon as shown in Fig. 2. A1 in the middle of the eastern basin, A2 under Baeshin bridge, A3 in the western basin near the functioning sewage outfall and A4 is located in the connecting channel outside the lagoon proper.

Al-Shabab lagoon (Figs. 1, 2) is an elongated lagoon having the following dimensions: length 1257 m, maximum breadth 405 m and minimum of about 121 m surrounded by land from all sides except the western side which opens directly to the coastal waters of the Red Sea (MEPA, 1986; Al-Rayis *et al.*, 1988). The lagoon is topographically divided into three connected basins by the concrete bars supporting the two bridges constructed across the lagoon, *i.e.* eastern, middle and western basin. The depth

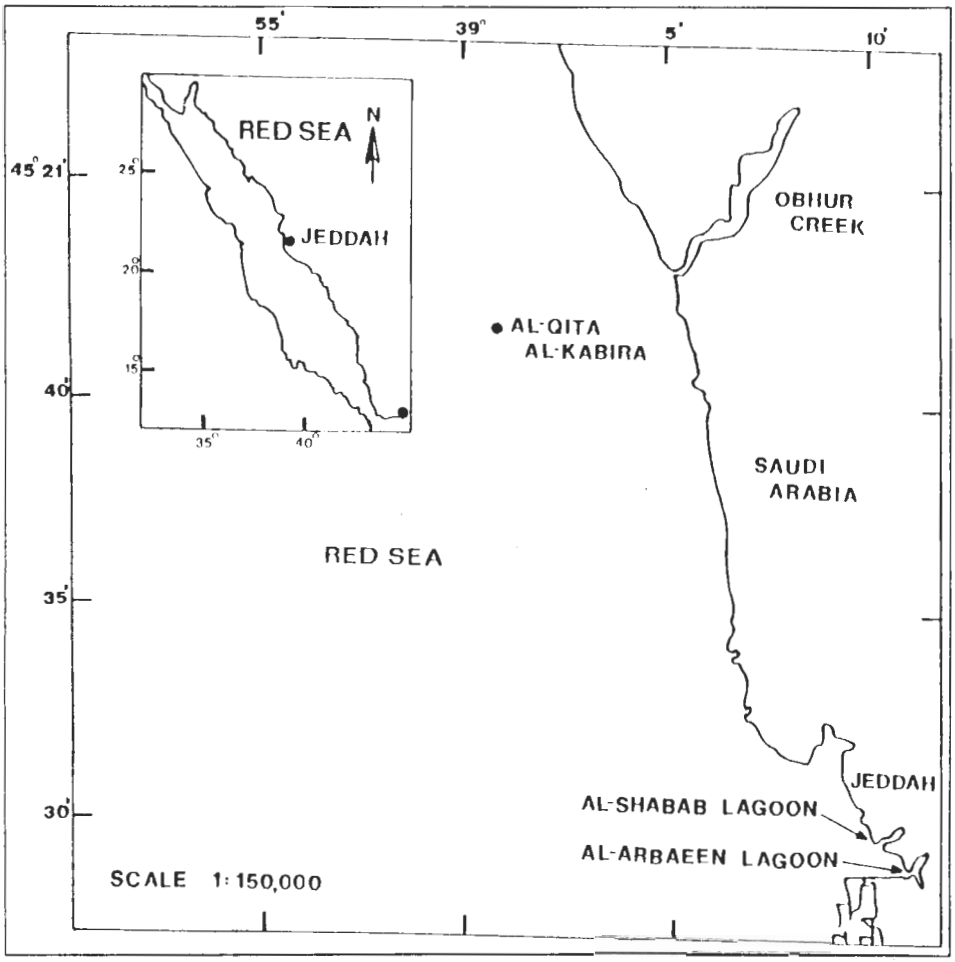

FIG. 1. A map showing the location of station K at Al-Qita Al-Kabera and the lagoons of Al-Arbaeen and Al-Shaʻbab. Inset shows position of Jeddah in Red Sea.

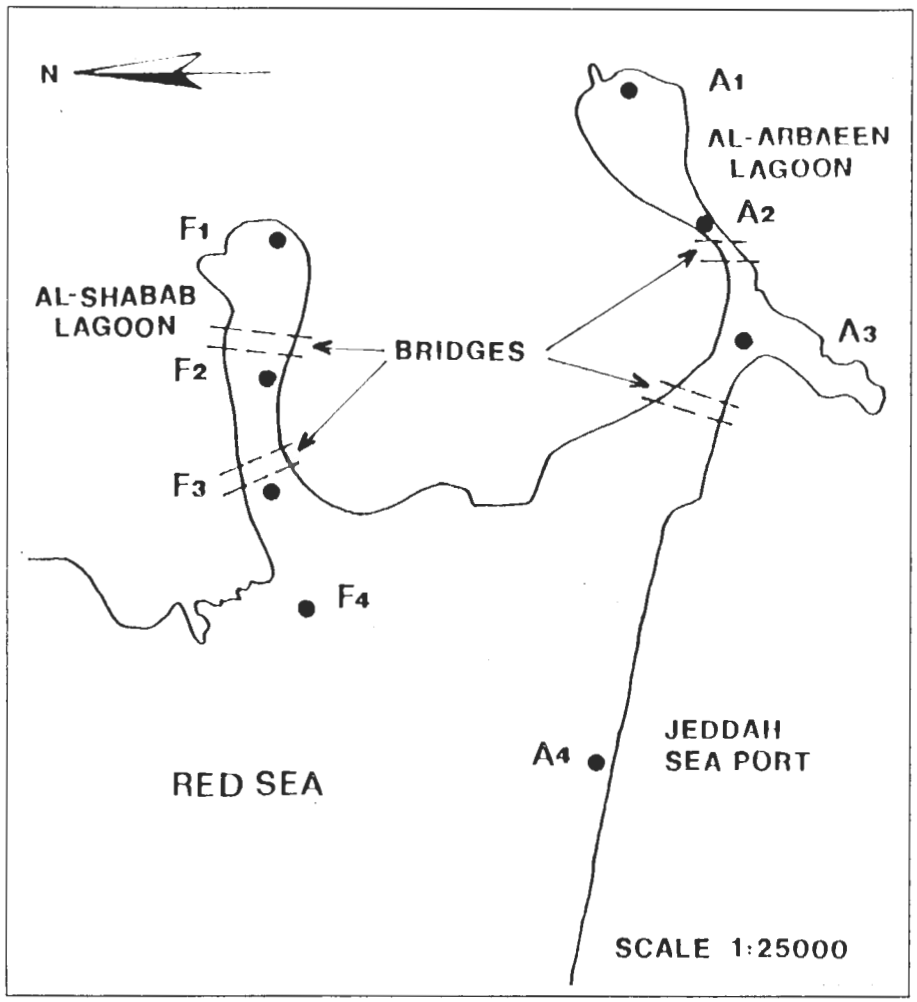

FIG. 2. A map showing the location of sampling stations at Al-Arbaeen (A) and Al-Shabab (F) lagoons.

of water under the bridges reaches 2 m. The depth of water in the eastern and middle basins is 4 m, while in the western basin the depth increases gradually seawards reaching to about 5.5m at its entrance. The bottom is covered by loose mud, the colour of which varies from deep black in the eastern basin to light brown in the western basin. The lagoon receives about 30,000 m^3 per day of partially treated sewage through one outfall which opens at its eastern side. Four stations were sampled from this lagoon. F1 in the middle of the eastern basin very near to the sewage outfall, F2 in the middle basin, F3 in the middle of the western basin and F4 is located in the coastal water of the Red Sea adjoining Al-Shabab lagoon.

Al-Qita Al-Kabera is an island located at about 10 km west of Obhur Creek (Fig. 1). It was chosen to represent unpolluted waters of Jeddah region. Surface samples from

this site were taken monthly at one station (St. K), where the depth of water was about 10 m.

Monthly samples of surface zooplankton were taken at each station in both lagoons using a plankton net of 38 cm diameter, and 180 µm mesh size. A digital flowmeter (Hydro-bios) was used with the plankton net to calculate the volume of filtered water, and the samples were fixed in 4% formalin. In the laboratory, 5 ml aliquots of each sample were investigated, species identified and counted under compound microscope. This procedure was repeated at least twice. The average number obtained was calculated and expressed in terms of numbers of zooplankton individuals per cubic meter. The sampling programme was continued for a complete year, from November 1990 to October 1991.

Surface water samples for the determination of dissolved oxygen were directly collected from the surface layer and were fixed in the field and analyzed immediately in the laboratory (APHA, 1985). Temperature, salinity and pH were also measured and analyzed for each station in Al-Arbaeen and Al-Shabab lagoons.

Results

I - Some physio-chemical characteristics of the study area

Temperature

The annual average surface temperature of Al-Arbaeen and Al-Shabab lagoons was 30 and 30.8°C respectively (Table 1). The lowest temperature was recorded in February in both lagoons, averaging 25.5°C in Al-Arbaeen and 27°C in Al-Shabab. The highest temperature in both lagoons were recorded in September with 33°C in Al-Arbaeen and 33.3°C in Al-Shabab lagoon. These values reflect the tropical character of both lagoons.

TABLE 1. Annual mean values of temperature, °C; salinity; ppt; pH, and dissolved oxygen in mg/l of the stations sampled in Al-Arbaeen and Al-Shabab lagoons.

Al-Arbaeen stations	A3	A2	A1	Mean	A4
T °C	29.3	29.5	31.2	30.0	29.2
S ‰	19.6	27.8	32.5	26.6	33.8
pH	7.7	8.05	8.17	7.97	8.25
D. O. mg/l	0.18	2.1	3.2	1.83	4.64
Al-Shabab stations	F1	F2	F3	Mean	F4
T °C	31.1	30.6	30.6	30.8	30.3
S ‰	27.8	34.3	37.2	33.0	38.8
pH	7.43	7.92	8.04	7.8	8.38
D. O. mg/l	0.83	4.56	6.93	4.11	7.73

Salinity

The monthly variations of surface salinity at the different stations are shown in Tables 1 & 2. Because of the large amounts of sewage water discharging in both lagoons,

the salinity was remarkably lower than that of the adjoining Red Sea coastal waters. In Al-Arbaeen lagoon, surface salinity varied widely between 8.0 and 37.0‰ with an annual mean of 26.6‰. The corresponding range in Al-Shabab lagoon was 16.0 to 41.0‰ with an annual mean of 33.0‰. The horizontal distribution of surface salinity in both lagoons displayed wide variations at the different stations. The lowest values were recorded at stations A3 & F1 located near the outfalls with annual average, 19.6 and 27.8‰ respectively.

TABLE 2. Monthly variations of salinity (‰) at Al-Arbaeen (A) and Al-Shabab (F) lagoons from November 1990 to October 1991.

Month	Stations									
	A1	A2	A3	Mean	A4	F1	F2	F3	Mean	F4
Nov.	29.0	19.0	12.0	20.0	30.0	16.0	25.0	34.0	25.0	39.0
Dec.	30.0	23.0	16.0	23.0	36.5	28.0	35.0	39.0	34.0	40.0
Jan.	31.0	36.0	21.0	29.3	40.0	27.0	38.0	40.0	35.0	41.0
Feb.	35.0	37.0	24.0	32.0	39.0	32.0	35.0	35.0	34.0	40.0
March	30.0	32.0	20.0	27.3	40.0	22.0	37.0	38.0	32.3	40.0
April	23.0	25.0	35.0	27.7	31.0	20.0	30.0	35.0	28.3	35.0
May	36.0	33.0	19.0	29.3	30.0	26.0	35.0	41.0	34.0	41.0
June	36.0	30.0	22.0	29.3	27.0	32.0	35.0	37.0	34.7	37.0
July	36.0	8.0	8.0	17.3	33.0	32.0	35.0	32.0	33.0	36.0
August	35.0	36.0	27.0	32.7	37.0	33.0	37.0	40.0	36.7	40.0
Sept.	34.0	22.0	12.0	22.7	28.0	33.0	35.0	37.0	35.0	37.0
Oct.	35.0	33.0	20.0	29.3	35.0	33.0	35.0	39.0	35.7	39.0

The magnitude of the monthly variations of surface salinity at stations A4 and F4 were comparatively limited; the mean values being 33.8‰ (27.0-40.0‰) and 38.8‰ (35.0-41.0‰) at stations A4 and F4 respectively (Table 2). The monthly variations in surface salinity at both stations are mostly controlled by the nature of water exchange between the lagoons and the adjoining coastal waters. Normally, the surplus water in the lagoons flows seaward as a surface layer. However, under the effect of prevailing wind the coastal water outside the lagoon may be forced to flow across the connecting channel into the lagoons. The penetration of this high salinity water into the lagoons is more obvious during winter months and also in August when high salinity values (36-40‰) were recorded at stations inside the lagoons (Table 1, 2). The admixture of the invading high salinity water with the normal diluted surface water of the lagoons disturbs the normal stratification of the water inside the lagoons by sinking, in a manner analogous to what occurs in some Norwegian fjords.

As pointed out by Al-Rayis *et al.* (1988), the subsurface water layer at depths 4-6 m (in both lagoons) is completely anoxic with high values of H_2S and NH_3. Thus the intrusion of the high salinity water into both lagoons and the subsequent vertical mixing processes results in bringing up large amounts of anoxic water into the surface which would have a deleterious effect on the surface biota in these lagoons.

pH

The pH of both lagoons was on the alkaline side. In Al-Arbaeen lagoon the pH varied between a maximum of 8.8 and a minimum of 7.3. On the average the lowest value (7.7) was found at station A3 which is directly affected by the sewage outfall. The average pH of the other stations increased gradually away from the outfall reaching 8.17 at station A1 (Table 1).

The pH in Al-Shabab lagoon varied between 7.0 and 8.53. Low values were recorded at station F1 directly affected by the sewage discharge, with an average of 7.43; the highest average, 8.04 was recorded at station F3 (Table 1).

Dissolved Oxygen

The distribution of dissolved oxygen in the surface water of both lagoons is shown in Table 1, 3. As a result of the high amounts of organic matter discharged into the lagoons with the sewage effluents, the concentration of dissolved oxygen was very low. The condition was more severe in Al-Arbaeen lagoon, which receives the highest amount of sewage water. In this lagoon the average dissolved oxygen was 1.83 mg/l. However, station A3 was almost anoxic eventhough water samples were taken from the surface layer. Dissolved oxygen varied between 0.04 and 0.48 mg/l with an annual average of 0.18. The conditions were improved at stations A2 and A1 where the average values of dissolved oxygen were 2.1 and 3.2 mg/l respectively.

TABLE 3. Monthly variations of dissolved oxygen concentration in mg/l in the surface water of Al-Arbaeen (A) and Al-Shabab (F) lagoons from November 1990 to October 1991.

Month	Stations									
	A1	A2	A3	Mean	A4	F1	F2	F3	Mean	F4
Nov.	2.47	0.47	0.04	0.99	4.62	0.61	4.28	8.76	4.55	9.81
Dec.	1.70	0.08	0.05	0.61	2.52	0.80	5.39	7.05	4.41	9.30
Jan.	1.60	1.35	0.08	1.01	2.32	0.90	4.36	6.30	3.85	7.27
Feb.	0.77	0.50	0.35	0.54	4.36	0.29	2.90	8.33	3.84	7.27
March	5.65	4.60	0.25	3.50	11.31	1.24	6.12	6.55	4.64	7.59
April	3.90	1.24	0.15	1.76	5.86	0.86	6.66	6.59	4.70	7.81
May	2.70	4.36	0.48	2.51	6.01	1.16	3.58	5.81	3.52	7.07
June	0.62	7.10	0.11	2.61	4.62	1.24	3.10	5.09	4.13	6.66
July	7.07	1.50	0.17	2.91	2.42	0.38	5.04	6.20	3.87	8.33
August	2.50	1.35	0.23	1.36	2.60	0.96	4.94	6.49	4.13	8.33
Sept.	1.60	0.67	0.06	0.78	4.36	1.06	4.30	6.60	3.99	5.13
Oct.	6.90	2.88	0.05	3.28	4.62	0.59	4.01	9.41	4.67	8.13

In Al-Shabab lagoon, low values of dissolved oxygen were recorded at station F1 varying between 0.29 and 1.24 mg/l with average of 0.83 mg/l. The condition at stations F2 and F3 were much improved where the mean values were 4.56 and 6.93 mg/l respectively.

Except in winter and during July-August, the surface water at station A4 was well oxygenated with average of 4.64 mg/l. An exceptional high value (11.31 mg/l) was re-

corded in March. The highest values of dissolved oxygen were recorded at station F4 ranging between a minimum of 5.13 mg/l in September and a maximum of 9.81 mg/l in November with an annual average of 7.73 mg/l.

II- The standing crop of the total zooplankton community

Table 4 shows the monthly variation of the standing crop of zooplankton at the sites sampled.

TABLE 4. Monthly variations of the standing crop of zooplankton at (No. of ind. m^{-3}) Al-Arbaeen (A) and Al-Shabab (F) lagoons from November 1990 to October 1991.

Month	Stations									
	A1	A2	A3	Mean	A4	F1	F2	F3	Mean	F4
Nov.	5463	2121	2014	3196	7431	440	222	1442	701	2039
Dec.	16	596	1771	795	5284	5250	7012	2602	4955	582
Jan.	49	1188	361	531	2036	1574	863	2750	1730	2986
Feb.	8	0	0	3	1108	1216	1294	1560	1356	2617
March	3959	15760	9277	9665	3500	3830	2683	3773	3426	4262
April	13237	802	1853	5298	1719	1919	3270	2573	2589	1886
May	785	2832	1257	1625	4021	978	710	973	874	1122
June	18408	18799	5919	14376	2881	508	1319	1965	1268	2444
July	2955	1891	732	1860	1634	4721	2934	1428	3025	1008
August	53	156	731	313	1112	193	419	633	414	1001
Sept.	20	246	682	315	1192	655	77	287	340	751
Oct.	10089	998	3206	4764	1283	804	2344	1453	1533	1272
Annual mean	4587	3782	2317	3563	2767	1841	1929	1787	1853	1831

In Al-Arbaeen lagoon, the highest density (average, 4587 ind. m^{-3}) occurred at station A1 (average salinity 32.5‰ and dissolved oxygen 3.2 mg/l). This figure represents the highest zooplankton density recorded throughout the present study and is much higher than that recorded in the neritic water off Jeddah (Al-Aidaroos, 1984). The zooplankton, density decreased gradually approaching the outfall reaching a minimum of 2317 ind./m^3 at station A3 which is about half that of A1 (average salinity 19.6‰, dissolved oxygen 0.18 mg/l). This figure is quite high considering the nearly anoxic conditions prevailing at this station. It is not known with certainty which components of the zooplankton community at this site are permanent residents or temporary visitors. The animals may be passively driven towards the site by the local water circulation or they may be attracted towards the lower salinity near the outfalls. Considering the whole basin of Al-Arbaeen lagoon the phenomenon is more interesting, the annual mean concentration of dissolved oxygen was 1.8 mg/l; yet the average standing crop was remarkably high (3563 ind. m^{-3}); copepods were the most dominant group, naupliar and copepodite stages were recorded indicating that the populations are autochthonus and capable of reproduction in such an environment.

The zooplankton community displayed pronounced seasonal variations, the lowest

crop was recorded in winter with the minimum in February (Table 4), coinciding with the period of vertical mixing caused by intrusion of more saline water from the adjoining coastal region; such period represents the most worse condition for the zooplankton community in the lagoon. Peaks of abundance were recorded in March, June, October and November and probably related to steady state conditions.

Despite the apparently improved conditions of dissolved oxygen and salinity in Al-Shabab lagoon, the standing crop of zooplankton was much lower than that in Al-Arbaeen lagoon. The average density being 1853 ind. m^{-3} varying between a minimum of 1787 ind. m^{-3} at F3 and a maximum of 1929 at F2. Further peaks of abundance did not necessarily coincide in time with those in Al-Arbaeen lagoon. A pronounced peak (4955 ind. m^{-3}) was recorded in December, other peaks occurred in March, July and October. The lowest crop was recorded in August and September which was also paralleled with low values in the Al-Arbaeen lagoon (Table 4). The low zooplankton density of Al-Shabab lagoon compared to that of Al-Arbaeen lagoon is not easy to explain as the conditions in Al-Shabab lagoon are apparently more suitable, mean salinity 33.8‰, mean dissolved oxygen 4.64 mg/l. No significant correlation was found between the zooplankton crop and dissolved oxygen or salinity in this lagoon.

III - Species composition and population density of the most important groups of zooplankton recorded

Copepoda

The Copepod populations in both Al-Arbaeen and Al-Shabab lagoons were less diversified. Calanoids were by far the most dominant group of copepods constituting on the average 99.9% of the copepod populations in Al-Arbaeen lagoon, 92.3% in Al-Shabab lagoon, 92.2% at A4 and 91.0% at F4 stations. In both lagoons *Pseudodiaptomus* sp. was by far the most dominant species constituting on the average more than 90% of the total copepods.

At the offshore station, K, calanoid copepods also dominated the copepod standing crop but with only 78%. On the other hand, cyclopoids were almost completely absent in the Al-Arbaeen lagoon. However, they were represented in Al-Shabab lagoon by 7.6% of the total copepods. The cyclopoids were present in low numbers at station A4 (7.7%) and F4 (10.0%), and reached their maximum abundance at station K, where they constituted about 20% of the total copepods.

Harpacticoids were the least represented in the study areas. Members of this group were almost absent from the samples collected in Al-Arbaeen and Al-Shabab lagoons and the adjoining water. At station K, harpacticoids constituted on the average 2.0% of the total copepods.

In both Al-Arbaeen and Al-Shabab lagoons, the copepod populations were taxonimically not diversified and few species were recorded:

Pseudodiaptomus sp. (was the most dominant species).
Clausocalanus spp.
Paracalanus parvus

Paracalanus spp.

Oithona nana, Oithona helgolandica, Corycaeus speciosus were the main cyclopoid species recorded in Al-Arbaeen lagoon as well as in A4 and F4 stations.

At the offshore station K, the species diversity of copepods were much higher than in the lagoons. Over 50 copepod species were recorded in the collected samples of which the following were identified (Sewell, 1947; Rose, 1933):

Calanoida

Acartia spp.	*Calausocalanus* spp.	*Mecynocera clausi*
A. negligens	*C. arcuicornis*	*Nannocalanus minor*
Aetideus armatus	*C. furcatus*	*Neocalanus gracilis*
Calanopia spp.	*Euchaeta* spp.	*Paracalanus indicus*
Calocalanus spp.	*Haloptilus longicornis*	*P. parvus*
C. pavo	*Labidocera* spp.	*Pleuromamma india*
C. plumulosus	*Lucicutia* spp.	*Pseudodiaptomus* sp.
Candacia spp.	*L. flavicornis*	*Temora stylifera*
Centropages spp.		

Cyclopoida

Copilia mirabilis	*Farranula (Corycella) rostrata*	*Oncaea* spp.
Corycaeus spp.	*Oithona helgolandica*	*O. conifera*
C. limbatus	*O. nana*	*O. media*
C. speciosus	*O. plumifera*	*O. venusta*
C. typicus	*Lubbockia squillimana*	*Sapphirina* spp.

Harpacticoida

Euterpina acutifrons	*Macracrosetella gracilis*	*Microsetella rosea*

The present results indicate that Al-Arbaeen lagoon harboured the highest crop of copepods with an annual average of 3060 ind. m^{-3}. The highest density of copepods in this lagoon occurred in June (13626 ind. m^{-3}). The standing crop of copepods reached its minimum density during December, August and September, during these months the standing crop varied between 12 and 79 ind. m^{-3}; copepods were not represented in the samples collected in February (Fig. 3).

The standing crop of copepods in Al-Shabab was much lower than that in Al-Arbaeen lagoon. The annual average being 629 ind. m^{-3}. The peaks of abundance were recorded in March and October (1270 and 1239 ind. m^{-3}, respectively) and the low densities were recorded in November, August and September. Otherwise the magnitude of the standing crop of copepods was comparable in the other months (Fig. 3).

The standing crop of copepods at station A4 was comparatively higher than that at station F4, the annual average being 1004 and 814 ind. m^{-3} respectively. At A4 peaks occurred in November and December (maximum 3112 ind. m^{-3} in November) while the corresponding peaks at F4 occurred later in January and February with the maximum recorded in February (1941 ind. m^{-3}). The lowest density occurred in March at station A4

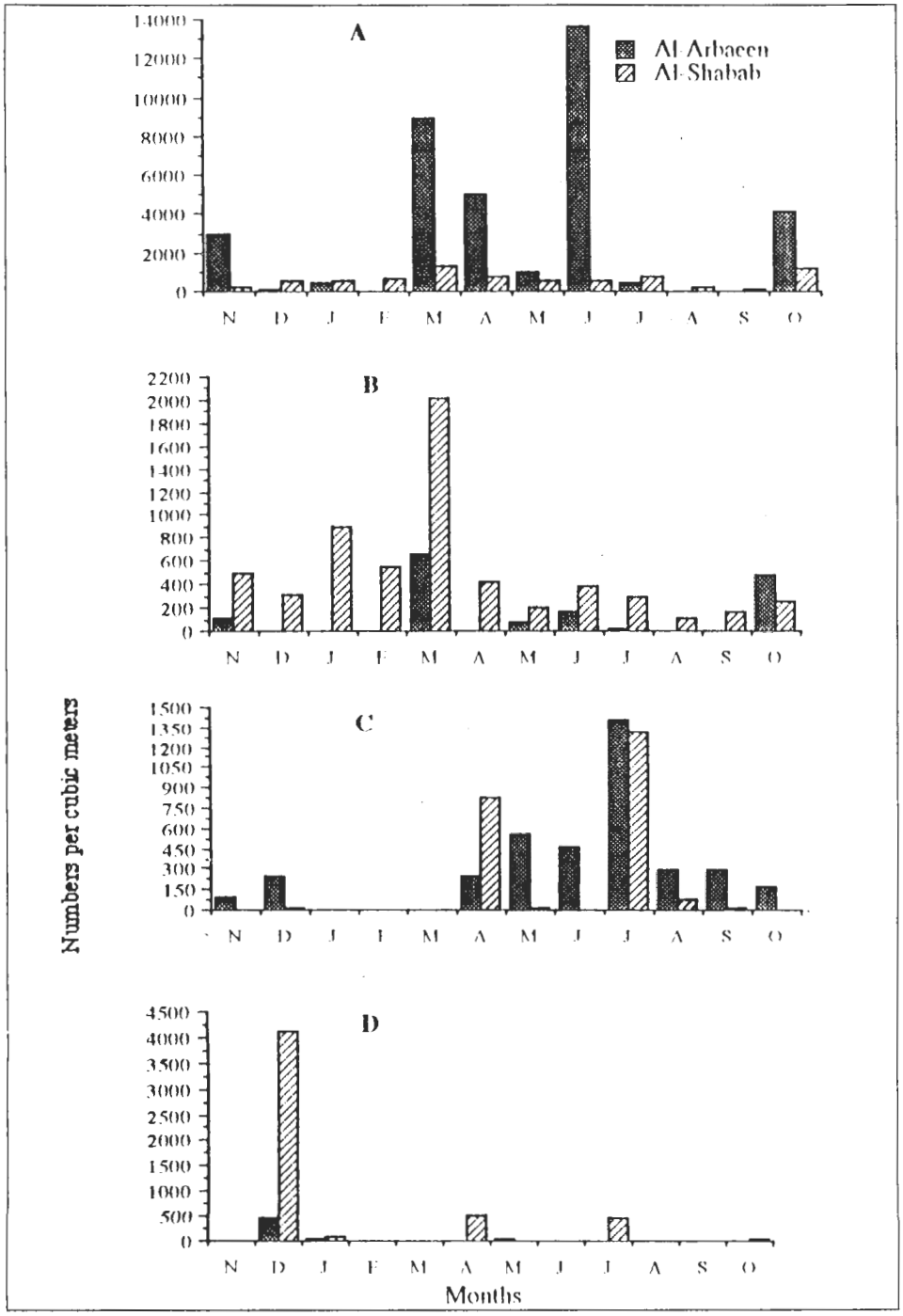

FIG. 3. Monthly variations of : A. copepods, B. cirripeds, C. rotifers and D. tintinnids densities in Al-Arbaeen and Al-Shabab lagoons.

and in December at station F4.

The standing crop of copepods at Al-Qita Al-Kabera (station K) average 917 ind. m^{-3} assumed an intermediate density between A4 and F4. The highest density of copepods was in April (2694 ind. m^{-3}), and the low values were recorded in January, February, May and July.

Cirriped Larvae

In the study areas, cirripeds were represented by their meroplanktonic stages mainly nauplius and cypris stages. It was not possible to relate these stages to their respective species.

In Al-Arbaeen lagoon cirriped larvae were less represented. The standing crop being on the average 125 ind. m^{-3}, representing 3.5% of the total zooplankton, of which 82.7% were represented by nauplius stages. The seasonality of this group was not regular in Al-Arbaeen lagoon, higher densities occurred in March and October (Fig. 3). In Al-Shabab lagoon the average standing crop of cirriped larvae was much higher being 508 ind./m^3 representing 27.4% of the total zooplankton. Nauplii of cirripeds constituted about 90% while cypris stages constituted about 10% of the total cirriped crop; as in Al-Arbaeen lagoon the highest density was recorded in March. However, contrary to the case in Al-Arbaeen lagoon cirriped larvae represented a permanent component in the zooplankton of Al-Shabab lagoon, low values occurred in August and September (Fig. 3).

At stations A4 and F4 the standing crop of cirriped larvae was higher than that in the adjoining lagoons and reached its highest density, *i.e.* 1104 ind. m^{-3} (39.9%) at station A4 against an average of 697 ind. m^{-3} at station F4. Naupliar stages constituted 95.7% and 92.8% of the meroplanktonic stages of cirripeds at both stations A4 and F4 respectively. At both stations cirriped larvae showed a remarkable peak in March. However, the most pronounced peak at station A4 occurred in November. A remarkable observation was the low density of cirripeds larvae at both sites throughout the period from April to October, with the minimum in August at station A4 and in September at station F4.

Cirriped larvae were very rare in the plankton samples of Al-Qita Al-Kabera (station K), their contribution to the total zooplankton was totally insignificant.

Rotifers

Rotifers were mostly represented in the sewage polluted lagoons, the average density being 313 and 188 ind. m^{-3} in Al-Arbaeen and Al-Shabab lagoons representing 8.8 and 10.2% respectively. The populations of rotifers were not diversified and dominated by only one species, probably belonging to the genus *Synchaeta*. Rotifers were rather frequent in Al-Arbaeen lagoon except in January, February and March. High density occurred in summer with a pronounced density in July (Fig. 3).

In Al-Shabab lagoon the occurrence of rotifers displayed two major peaks occurring in April and July. Otherwise rotifers were either absent or rare. At station A4 a pro-

nounced density occurred in May, comparatively high densities were also recorded in July and August. Otherwise rotifers were absent or very rare throughout the period from October to March. The overall annual average of rotifers at this station was 211 ind. m^{-3} constituting 7.6% of the total zooplankton (Fig. 3).

At station F4 the condition more or less resembled that of Al-Shabab lagoon. Thus comparable peaks were also recorded in April and July, in other months rotifers were either rare of completely absent. The similarity in species composition and seasonality of rotifers at station A4 & F4 with the adjoining lagoons may indicate that these animals may be used as tracers of the outflowing sewage polluted waters from both lagoons. In all sites the rotifers were dominated by the same species. The overall average of rotifers at station F4 being 42 ind.m^{-3} representing 2.3%. In Al-Qita Al-Kabera rotifers were almost completely absent.

Tintinnids

The diversity of tintinnid populations in the sewage polluted lagoons was low. Of more than 60 species known from the Red Sea (Halim, 1969) only 5 species were recorded in both Al-Arbaeen and Al-Shabab lagoons as well as the adjoining stations A4 and F4: *Favella azorica, F. campanula, F. panamensis, Helicostomella* sp., *Tintinopsis* spp.

The lowest density occurred in Al-Arbaeen lagoon with the average 47 ind. m^{-3} (1.3%) (Fig. 3). The standing crop of tintinnids was comparatively higher in Al-Shabab lagoon with an average 436 ind. m^{-3} representing 23.5% of the total zooplankton community (Fig. 3). At station A4 the population density of tintinnids averaged 152 ind. m^{-3} and represented 5.5% of the total zooplankton. In contrast, the average tintinnid density at station F4 was 78 ind. m^{-3} representing 4.2% of the total zooplankton.

The seasonality of tintinnids in both Al-Arbaeen and Al-Shabab lagoons was similar with the most conspicuous peak occurring in December in both lagoons.

The December peak was also recorded at stations A4 and F4 but was more pronounced at station A4, while at station F4 the highest peak occurred in April, otherwise the seasonality at both stations was nearly similar with minor peaks in June or July.

At Al-Qita Al-Kabera station, the tintinnid populations were more diversified being composed of 25 species, although quantitatively constituted less than 1% of the total zooplankton with no obvious seasonal pattern.

Discussion

The zooplankton community in the sewage polluted waters studied during the present investigation showed wide variations in magnitude, composition and diversity compared with that of the Red Sea offshore water.

In Al-Arbaeen lagoon the annual average of the standing crop of total zooplankton, showed direct correlation with increasing salinity up to an average salinity of 32.5‰ ($r^2 = 1$). The same correlation was found with the total copepods which constituted the

major component of zooplankton (average 85.9%). In the sewage polluted sites studied, low salinity was accompanied by low pH and low dissolved oxygen; these conditions are not suitable for successful propagation of many zooplankton species. The average concentration of D.O. at the stations affected directly by the sewage outfall was 0.18 mg/l in Al-Arbaeen lagoon and 0.83 mg/l in Al-Shabab lagoon.

Based on the physico-chemical parameters studied in both lagoons and the adjoining coastal water, the environment of Al-Shabab lagoon was comparatively less polluted than that of Al-Arbaeen lagoon. However, the total zooplankton crop in Al-Shabab lagoon was relatively lower than in Al-Arbaeen lagoon. It is worth to mention that in Al-Shabab lagoon the standing crop of copepods was much lower averaging about 34% of the total zooplankton. The low standing crop of Al-Shabab lagoon was due to the low copepod density. This condition may indicate that the environment of Al-Shabab lagoon is less suitable for copepods to built up large populations. However, the copepod population in both lagoons were dominated by almost the same species, particularly with respect to calanoid copepods; cyclopoid were in the other hand represented only in Al-Shabab lagoon and avoided the heavily polluted water in Al-Arbaeen lagoon.

It is of interest to mention that at stations A4 and F4 where the pH, S ‰ and D.O. approached the normal values in less polluted coastal water, the standing crop of zooplankton was lower than the corresponding average of the adjoining lagoons. At both stations copepods constituted less than 50% of the total zooplankton. This is contrary to what was recorded in either the sewage polluted lagoon or in the offshore water. Other holoplanktonic groups played an important role in the zooplankton density at both stations.

At Al-Qita Al-Kabera (station K) where the average salinity varied between 39 and 40‰, the magnitude of the zooplankton crop was rather comparable to that of Al-Shabab lagoon and averaged 1556 ind. m^{-3} and the copepods constituted 59% of the total zooplankton. In the oceanic plankton of the Red Sea, copepods are the major components of the zooplankton community (Halim, 1969; Weikert, 1981, 1982).

Several authors (*c.f.* Weikert, 1987) mentioned that the diversity of copepods of the Red Sea is low compared to other areas of the Indopacific region. For example, more than 300 species of calanoid copepods are known from the Arabian Sea, whereas only 60 species have been reported as common in the southern Red Sea, 46 species in the northern part and about 35 species in the Gulf of Suez and Gulf of Aqaba.

However, compared with the coastal waters particularly in the stressed environments the zooplankton of the offshore water was more diversified. At station K, the diversity of the zooplankton community was higher than that of the coastal polluted water. This is due to the presence of several groups (both holo- and meroplankton) which contributed a considerable part of the total zooplankton. Of the holoplanktonic groups other than copepods recorded at station K, the following are worth to mention: appendicularians, pteropods, siphonophores, *Sagitta* spp., *Lucifer* sp., tintinnids, all of them contributed 22% of the total zooplankton, of which gastropod veligers, fish eggs and larvae, euphausid larvae, polychaete and decapod larvae are important.

Although the same species were present in both lagoons, yet their relative abundance varied in each one. Thus holoplanktonic groups other than copepods, *i.e.* tintinnids and rotifers, constituted 10.1% of the average zooplankton community in Al-Arbaeen and 34% in Al-Shabab lagoon (Fig. 4). The meroplanktonic groups recorded in both lagoons were limited. Cirripeds larvae and gastropods veligers constituted on the average 4% and 30% in Al-Arbaeen and Al-Shabab lagoons respectively (Fig. 4). Both groups were more common at stations A4 and F4, where they constituted 48.4% and 47.3% of

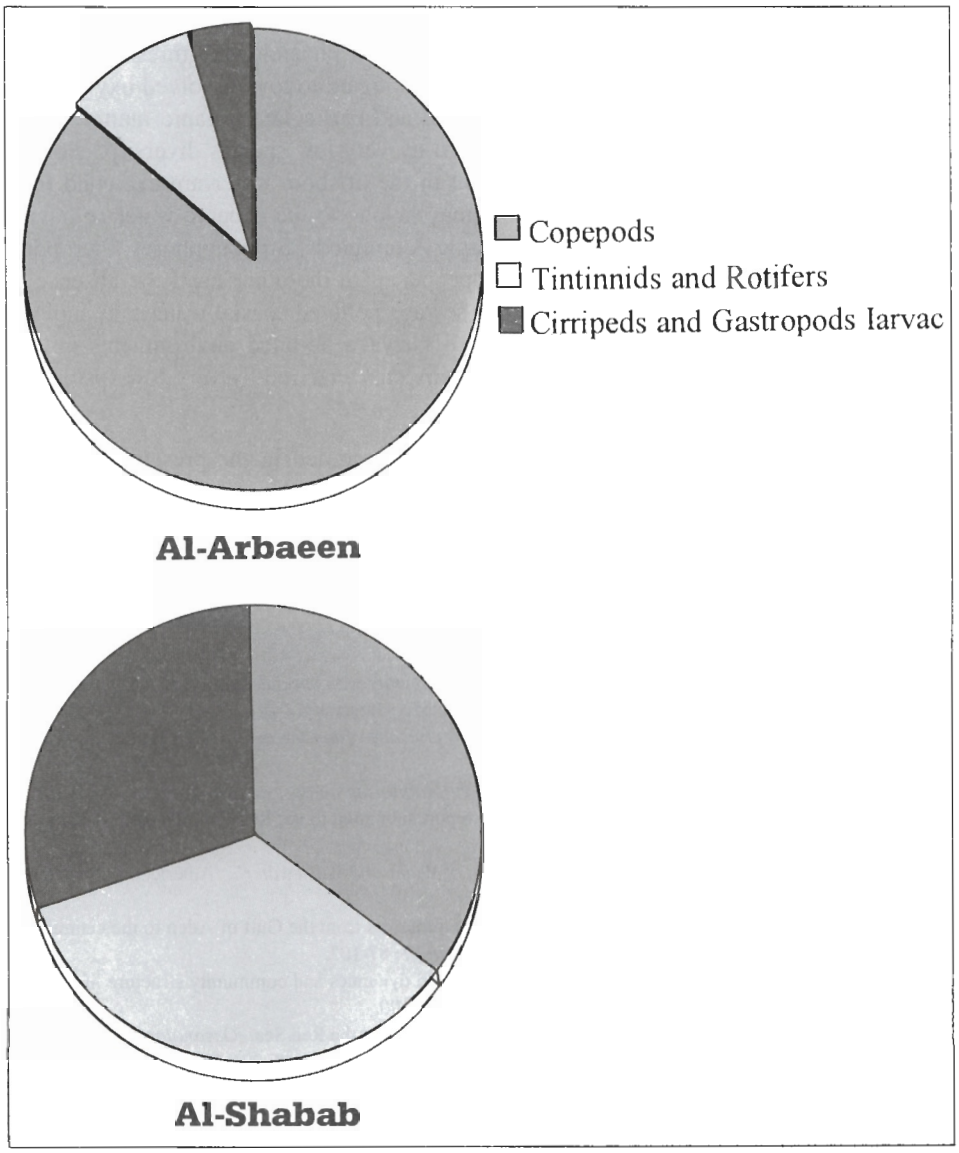

Fig. 4. Annual average percentages of the main groups of zooplankton in Al-Arbaeen and Al-Shabab lagoons.

the total zooplankton respectively. The relative abundance of these larvae in the coastal water is probably due to the presence of large population of their adults. In addition to water quality, the benthic environment at stations A4 and F4 seems to provide suitable grounds for the adults of both groups. The comparatively high percentage abundance of cirriped larvae in Al-Shabab lagoon relative to Al-Arbaeen lagoon is mostly due to the presence of rocky substrata suitable for settlement of cirriped animals.

The environment in both Al-Arbaeen and Al-Shabab lagoons represent extreme conditions for many of the marine zooplankton organisms. Several species and groups are excluded from such environments simply because their physiological threshold can not tolerate these extreme conditions, particularly with regard to low dissolved oxygen concentration and high concentrations of dissolved and particulate organic matter. Consequently these environments are characterized by very low species diversity. Several groups and/or species of zooplankton present in the offshore water are excluded from the sewage polluted water. Some of them may belong to the oceanic water or having oceanic affinities such as: Euphausiids, Pelagic Amphipods, Siphonophores, Pteropods, several species of appendicularians, and copepods. On the other hand the absence of many species with neritic affinities from the sewage polluted coastal water may indicate that both lagoons provide typical examples of sewage polluted environments not favoured by these species. These environments are characterized by very low species diversity and high dominance.

The preliminary list of the zooplankton species recorded in the present study may provide information on the species thriving in the sewage polluted areas and sewage indicator species. In this concern informations on species taxonomy, diversity and density in sewage polluted tropical environment would be very important.

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الهائمات الحيوانية في بحيرتين شاطئيتين عالية الإثراء الغذائي ملوثة بمخلفات المجاري بجدة وسط البحر الأحمر

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المستخلص . تمت دراسة تواجد ووفرة الهائمات الحيوانية في كل من بحيرتي الأربعين والشباب الملوثة بالمخلفات العضوية استناداً إلى دراسة العوامل الفيزيائية والكيميائية في كلا البحيرتين ، اتضح أن بحيرة الشباب أقل تلوثًا بالنسبة لبحيرة الأربعين حيث تراوحت قيم الملوحة ، الأكسجين في المياه السطحية في بحيرة الأربعين بين ٨‰ ، ٣٧‰ بمتوسط ٢٦,٦‰ للملوحة ، ٠,٤ ملجم/ لتر ، ١,٧ ملجم بمتوسط ١,٨٣ ملجم في اللتر للأكسجين الذائب بينما كانت القيم المقابلة في بحيرة الشباب ٦‰ ، ٤١‰ بمتوسط ٣٣‰ بالنسبة للملوحة ، ٠,٢٩ ملجم/ لتر ، ٩,٤١ ملجم لتر بمتوسط ٤,١١ ملجم/ لتر بالنسبة للأكسجين الذائب . وقد وجدت علاقة طردية بين كل من الأكسجين الذائب والأس الأيدروجيني والملوحة ولكن المحصول الكلي للهائمات الحيوانية في بحيرة الشباب أقل من بحيرة الأربعين حيث بلغ في المتوسط ١٨٥٠ فرد/ م^3 ، ٣٥٦٠ فرد/ م^3 على الترتيب .

نسبة المحصول الحالي لأحياء الكوبيبودا في بحيرتي الأربعين والشباب ٨٦٪ ، ٣٤٪ من العدد الكلي للهائمات الحيوانية بالترتيب ويعود سبب انخفاض المحصول الحالي لبحيرة الشباب إلى قلة كثافة الكوبيبودا ، ولوحظ قلة تنوع في الهائمات الحيوانية في كلا البحيرتين وأنواع محددة فقط تم تسجيلها من رتبة الكالانويدا ويعتبر النوع *Pseudodiaptomus* sp. الأكثر سيادة حيث تبلغ نسبته ٩٠٪ من أعداد الكوبيبودا ، إلى جانب أنواع أخرى بنسبة بسيطة مثل :

Clausocalanus sp., *Paracalanus parvus*, *Paracalanus* spp.

ومن رتبة السيكلوبويدا وجدت الأنواع الرئيسة :

Oithona nana, *O. helgolandca*, *Corycaeus speciosus*.

في بحيرة الشباب فقط . أكثر من ٥٠ نوعًا من الكوبيبودا تم حصرها في المحطة البعيدة عن الساحل عند منطقة القطعة الكبيرة . من الهائمات الحيوانية الدائمة تبلغ نسبة التنتنيدات والروتفيرا ١٠,١٪ من العدد الكلي للهائمات الحيوانية في بحيرة الأربعين و ٣٤٪ في بحيرة الشباب . الهائمات الحيوانية المؤقتة محدودة في كلا البحيرتين حيث وجد أن يرقات السيربيدا والجاستروبودا الأكثر أهمية وتبلغ في المتوسط ٤٪ ، ٣٠٪ بالترتيب في كل من بحيرتي الأربعين والشباب .