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Recovery of Macrobenthic Invertebrates Near Abandoned Sewer Outlets in the Gulf of Aqaba, Red Sea, Jordan

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Abstract.- This study was initiated to follow up changes in the macrobenthic invertebrate population at different sites after stopping sewage discharge into the Gulf of Aqaba since 1986. A total of 199 taxa were isolated from all the four stations. Although there were significant differences in the number of species and the number of animals (density) between the control and the outlet stations in 1987, these differences disappeared in the present study. On the contrary, higher densities were found at the 100 m north and south stations. Moreover, the present community structure parameters including species diversity, species richness , and evenness were relatively similar among all stations. The pollution effects of sewage dumping was still evident after all these years by the presence of relatively high organic carbon content of sediments collected from the outlet, 100 m north and 100 m south stations. It ranged from 0.237% at the outlet to 0.614% at the 100 m north station, while it was 0.126% at the control station.

Key words: Macrobenthic invertebrates, Sewage dumping, Gulf of Aqaba, Red Sea, Jordan.

INTRODUCTION

The extent of damage caused by sewage dumping depends mainly on the volume of sewage effluent discharged into the marine environment. At the point of maximum discharge the benthic community is generally defaunated (Pearson and Rosenberg, 1978). In Izmir Bay, Turkey, complete defaunation at the point of sewage disposal was reported (Kocatas and Geliady, 1980). In the Gulf of Aqaba, Jordan, a sewage treatment station was built in 1964 to serve Aqaba City at the northern tip of the Gulf. It was estimated that 70–150 cubic meters of sewage effluent were released into the Gulf every day . The impact of this sewage disposal was seen in the increased death rate of coral colonies *Stylophara pistillata* and the excessive growth of *Ulva lactuca* and *Entermorpha clathrata* (Walker and Ormond , 1982). Ismail and Awad (1987) reported a sharp decrease in total number of macrobenthic invertebrates, number of species, and species richness at the outlet station compared to control station. Similarly, Ismail and Awad (1984) reported sharp increase in organic carbon content in sediment at the outlet station. As a result the disposal point was closed in 1986 and the sewage discharge was transferred to north of Aqaba City. This study was thus initiated to investigate the impact of stopping discharge of sewerage in the Gulf on the population of macrobenthic invertebrates.

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MATERIALS AND METHODS

The sewage outfall is located near the phosphate loading port. It is 9-11 m deep, depending on the tidal conditions. A control station was selected approximately 10 km from Aqaba, and hence away from sewage and phosphate pollution (Fig. 1). Additional two stations, one 100 m north of sewage outfall and another 100 m south of the outfall were also selected. Sampling procedures followed were as described previously by Ismail and Awad (1987). For each station a sampling area ($5X5m^2$) was selected. A total of 25 core samples ($0.01\ m^2$ to a depth of 15-20 cm) were collected from each of the sampling stations during September 1998 for faunal examination. Additional 15 cores from each station were collected for grain size analysis and organic carbon content. Sampling was done by SCUBA diving.

Samples which were collected for faunal

analysis were sieved through 1 mm sieve. The plus 1 mm fraction was fixed in 10% formaline – seawater and stained with Rose Bengal. Sorted animals were counted and identified to lowest possible taxon.

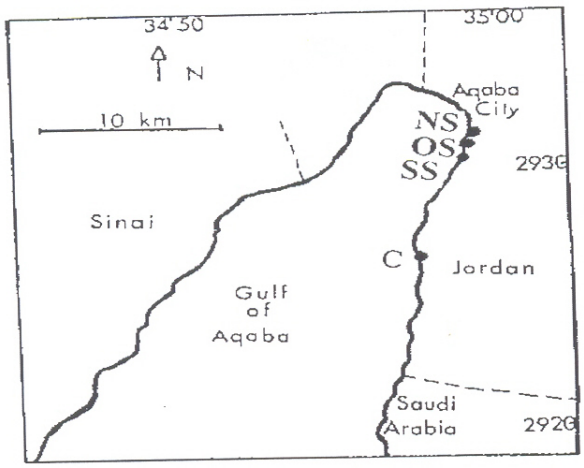

Fig. 1. Location map of the sewage outlet (OS), 100 m south (SS), 100 m north (NS), and control stations in the Gulf of Aqaba.

Species diversity was measured using the Shannon-Wiener index (Shannon and Wiener, 1963). Two additional measures, the evenness (E) and species richness (SR), were calculated as follows:

$$E = H' / H\,max \quad and \quad SR = S - 1 / 1n\ N$$

Where H max = $\log_2 S$, S is the number of species, and N is the total number of individuals (Krebs, 1978).

Faunal similarities among stations were calculated using the " Faunal Similarity Index " of Sanders (1960).

Percentages of organic carbon in sediments were determined using the potassium dichromate technique (Holme and McIntyre, 1971). The grain size distributions of sediment samples were analyzed using the standard methods (ASTM Standards, 1973). Median diameters (M_o) were derived from the cumulative curves of total grain size distributions. The degree of sorting (S_o) was calculated as of Trask (1932) sorting coefficient.

RESULTS

Sediments

Sediment analysis showed great variation among samples of all stations, except the control station (Table I). The median grain size of sediment (M_0) ranged from 117 to 790 um at the sewage outfall. Accordingly the S_o ranged from 3.1 to 7.4. Lower variation appeared at 100 north and 100 south stations. The median grain size ranged from 99 to 245 and from 71 to 427 µm and the S_o ranged from 3.7 to 14.7 at both stations, respectively. At the control station M_o ranged only from 95 to 117 µm and S_o ranged from 1.9 to 2.6.

The organic carbon content of sediments was highest at the 100-north station near the phosphate loading port (Table II). It ranged from 0.455% to 0.755% with an overall average of 0.614%. Lower content was found at the 100 m south station. It averaged 0.282% and ranged from 0.107% to 0.412%. At the outlet station the organic carbon content of sediment was similar to the south station. It ranged from 0.141% to 0.450% and averaged 0.237%. Statistically lower ($P<0.05$) content was found at the control station with an overall average of 0.126% and a range from 0.091% to 0.165%.

Fauna

A total of 199 different taxa were isolated from all stations, of which 101 taxa were of polychaetes, 36 molluscs, and 32 crustaceans. The highest number of taxa was at the 100 m south station (105) and the lowest at the control station (68) (Fig. 2). Similar trend was observed for polychaetes, where 52 taxa were found at the 100 m south station and 32 taxa were found at the control station. Molluscan species were also highest at the 100 m south station (15) and control station (16) and lowest at the 100 m north station(9) (Fig. 3). Crustacean species, however, were lowest at the control station (3) and highest at the 100 m south station.

The total density (number of animals/0.25m^2) was statistically higher at the 100 m south station (1588) and the 100 m north (1406) than at the control station (242) (Fig. 2). Similar results were found for the polychaete density. But the polychaete density was highest at the 100 m north station

Table I.- Particle size distribution of sediments (in microns) from the previous sewage outlet, control,100 m north, and 100 m south station in the Gulf of Aqaba. Values of sorting coefficients are dimensionless.

Station	Sample No.	Granules	Coarse sand	Fine sand	Median	Sorting Coef.
Outlet	1	24.8	34.2	40.1	526	7.4
	2	11.3	29.5	58.2	263	5.6
	3	15.2	15.3	67.6	117	6.6
	4	42.0	32.3	24.5	790	5.2
	5	2.7	18.9	76.4	123	3.1
North	1	18.4	16.7	62.6	128	8.7
	2	4.2	11.6	80.8	99	2.9
	3	11.7	12.8	71.5	100	3.7
	4	27.1	15.2	55.7	245	14.7
	5	12.3	16.4	67.7	128	5.5
South	1	1.7	53.1	44.0	275	4.7
	2	2.6	46.0	47.9	71	2.1
	3	0.4	9.6	82.8	263	5.3
	4	1.6	37.2	53.5	192	8
	5	9.4	50.2	37.0	427	4.7
Control	1	0.2	3.0	94.8	96	2.1
	2	1.2	8.1	89.6	117	2.6
	3	0.1	6.0	89.1	113	2.4
	4	0.2	7.9	89.8	100	1.9
	5	0.3	3.7	93.9	95	1.9

Table II.- Organic carbon content in sediments from the previous sewage outfall, control, 100 north, 100 south stations in the Gulf of Aqaba.

Station	n	Organic carbon (%) (Mean±SD)
Outlet	5	0.237±0.145
100 m North	5	0.614±0.152
100 m South	5	0.282±0.112
Control	2	0.126±0.035

(1299) and lowest at the control (148). The density at the 100 m south station was 1245. Crustacean densities were also highest at the 100 m south station (96) and lowest at the control station (5) (Fig. 3). Although molluscan densities were highest at the 100 m south station (50) it was lowest at the 100 m north station (18).

Comparing the diversity index, species richness, and evenness among stations it was found that these parameters were generally highest at the control station and lowest at the 100 m north station (Fig. 4). However , these parameters were also high at the outlet station and the 100 m south station. Diversity index was 5.25 at both the 100 m south and the outlet stations. At the control station (Fig. 4), this index was 5.19. At the 100 m north station , it was only 4.5. Species richness ranged from 14.11 at the 100 m south station to 12.21 at the control station. It was lowest (10.21) at the 100 m north station. Evenness was highest at the control station (0.85) and lowest at the 100 m north station (0.73).

Faunal similarities among stations were lowest (22.6%) between the control and the 100 m north station and highest (63.7%) between the 100 m south station and the outlet station (Table III).

Table III.- Faunal similarities among the 100 m north, 100 m south, outlet, and control stations in the Gulf of Aqaba. Numbers are percentages.

	North	South	Outlet	Control
North	100	63.4	55.5	22.6
South	63.4	100	63.7	31.4
Outlet	55.5	63.7	100	41.1
Control	22.6	31.4	41.1	100

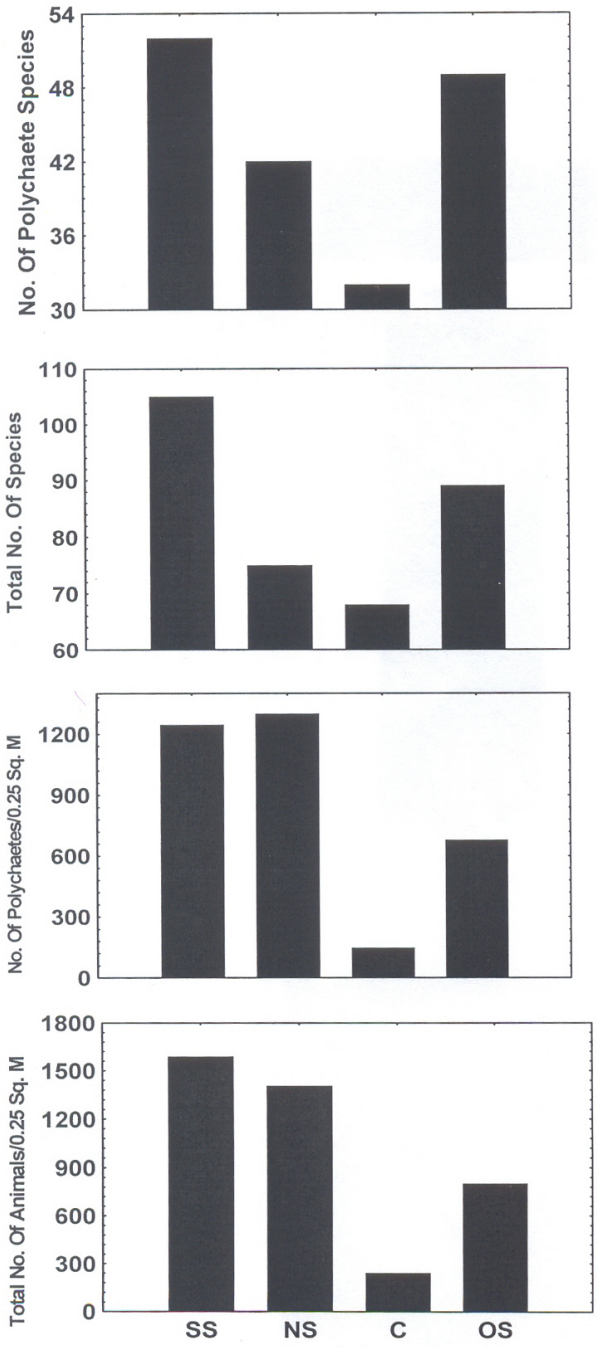

Fig. 2. Total number of species, number of polychaete species, and their densities (number of animals/0.25 Sq. meter) collected from all stations in the Gulf of Aqaba. SS, outlet; SS, 100 m south; NS, 100 m north; C, control.

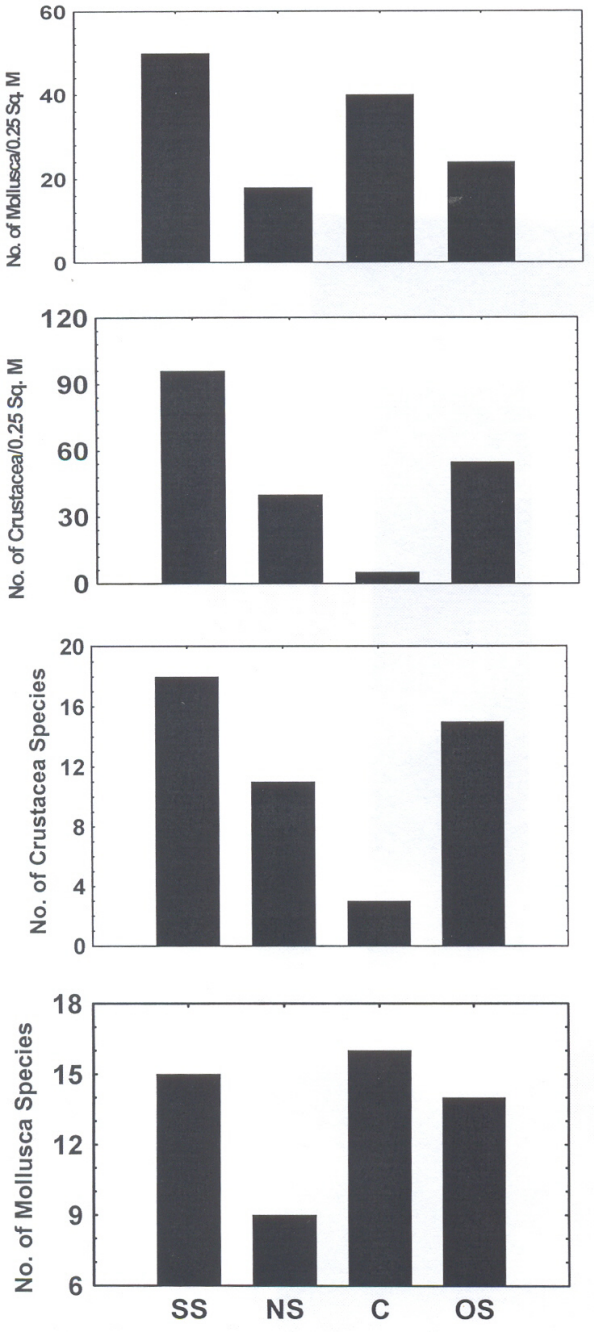

Fig. 3. Number of molluscan and crustacean species and their densities (number of animals /0.25 sq. meter) collected from all stations in the Gulf of Aqaba. OS, outlet; SS, 100 south: NS, 100 m north; C, control.

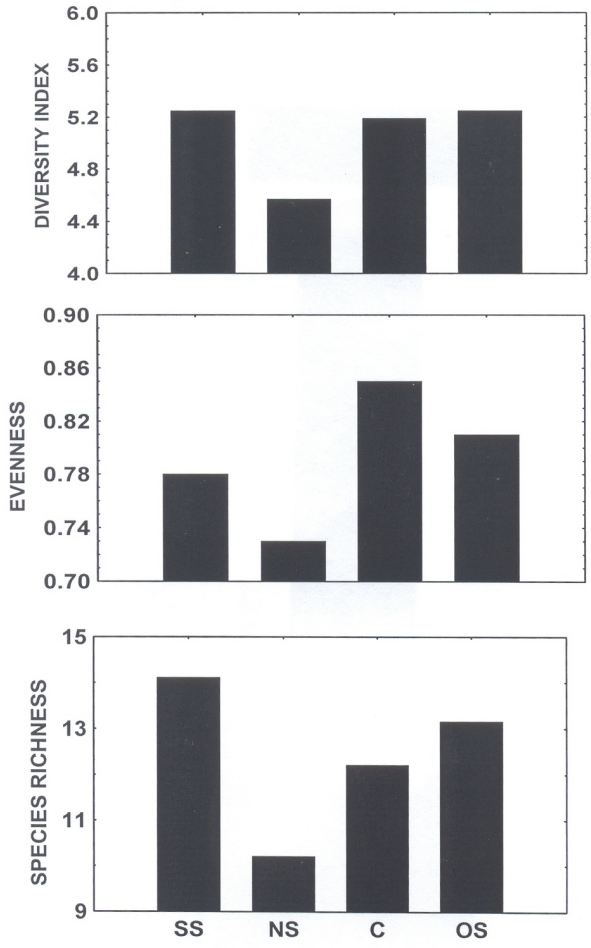

Fig. 4. Diversity index, species richness, and evenness of fauna at the 100 m south (SS), 100 m north (NS), control (C), and the outlet (OS) stations in the Gulf of Aqaba.

DISCUSSION

It is obvious that there is a great change in the community structure of macrobenthic invertebrates after stopping the sewage dumping into the Gulf of Aqaba. Ismail and Awad (1987) reported animal density (number of animals /0.25 m^2) of 45 during May 1983. This is compared to 802 during the present study. Similarly, polychaete density was 15 during May 1983, while it reached 680 during the present study. Although the number of species collected from the outlet station was lowest during May 1983 (Ismail and Awad, 1987) it was as high as other stations during the present study. The community structure parameters, represented by the diversity index , species richness, and evenness, were lowest at the outlet station during May 1983, while they were lowest at the 100 m north station during the present study . The species diversity ranged from 4.6 to 5.3 during the present study , while it was 1.5 to 3.9 during May 1983. Species richness ranged from 10.2 to 14.1during the present study compared to 2.7 to 7.9 during May 1983.

The extent of damage caused by sewage dumping depends mainly on the volume of sewage effluent discharged into the marine environment . At the point of maximum discharge the benthic community is drastically reduced (Pearson and Rosenberg, 1978). Following defaunation at the point of pollution the number and dominance of species rise sharply either spatially or temporally. This explains the sharp increase in animal density and number of species at the outlet station. Similar findings were reported from the Arabian Gulf (Ismail, 1992, 1993). Recently, Munari *et al.* (2003) reported improved conditions, using biotic data, in the Valli di Coacchio lagoon. However, they anticipated longer time for macrobenthos to recover completely. Qian *et al.* (2003) studied the recolonization of infaunal macrobenthos following the cessation of disposal of contaminated sediments in East Sha Chau, Hong Kong. The reported an increase in abundance and biomass after three years at the disposal sites.

In the Gulf of Aqaba, the effects of sewage pollution are still evident at the outlet. The organic carbon content is still elevated (0.237%). This is comparable to 0.267% during May 1983 (Ismail and Awad, 1984). But the organic carbon at the 100 m south station was 0.282% and the at the 100 m north was 0.614%. The elevated organic carbon at the latter station is probably due to phosphate pollution from phosphate loading port.

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