

Some Ecological Parameters and Macrobenthos Near Abandoned Sewer Outlets Around Abu-Dhabi Island, Arabian Gulf

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ABSTRACT. There are three abandoned sewer outlets around Abu-Dhabi Island which were formerly used for sewage disposal and are now used for water disposal. During November 1990 a total of 140 core samples (0.01m² to a depth of 10-15 cm) were collected from the low tide line at the three sewer outlets and two control stations away from the outlets. Results show that there is a slight accumulation of organic carbon in sediments at two of the sewer outlets. However, the faunal analysis revealed that this accumulation has no measurable effects on the community structure of macrobenthic invertebrates at these outlets. The faunal composition at one of these stations is similar to that at one of the control stations. The other station has a faunal composition similar to that reported from non-polluted sandy beaches with similar sedimentary composition along the Arabian Gulf.

Key words: Macrobenthos; Sewer outlets; Abu-Dhabi, Arabian Gulf.

Running title: Fauna near abandoned sewer outlets.

The rapid oil development in the United Arab Emirates within the last two decades has been accompanied by rapid urban and commercial development, particularly in coastal cities. Abu-Dhabi city, the capital of U.A.E., occupies an island of about 94 km² and is inhabited by some 400,000 people. It is surrounded by the Arabian Gulf water from three directions and separated from land by a narrow canal. The coastal areas of Abu-Dhabi consist mainly of sandy beaches and intertidal flats that are covered by mangrove. Abu-Dhabi used to dump its treated municipal and industrial wastes into the sea. This was completely stopped five years ago and all wastes are now collected into a major treatment plant outside the city, which extracts water to re-use it for irrigation. However, sewer outlets which were formerly used to release sewage are now used for rain water, any excess water from irrigation, and ground water which may appear during the construction of buildings. The aim of the present study is to assess some of the ecological parameters and if there is any effect of using these sewer outlets on macrobenthic invertebrates.

Materials and Methods

Study Area:

There are three sewer outlets that were used to release sewage effluent around Abu-Dhabi Island. The effluents were released at the low tide line of the intertidal zone. Two outlets are located on the western side of the island and one on the southern side (Fig.1). These are referred to here as S1, S2, and S3. Furthermore, two control stations were sampled one at Mussaffah and the other at Al-Ain Bridge. These are referred to here as C1 and C2.

Tides around Abu-Dhabi Island are of the diurnal type and range from 1 to 2.5 m. Sea water temperature ranges from 20.2 to 24.5°C during winter and from 32.5 to 37.5°C during summer months (Evans *et al.* 1973). Salinity is high and ranges from 43.5-48.7‰ (Desert and Marine Research Center, unpublished report).

Sampling and Analysis:

The composition and density of macrobenthic invertebrates were examined at the sewer outlets and control stations during November 1990. Sediment samples were collected, using a core (0.01 m² to a depth of 15-20 cm), at the mean low tide of each station. Five 0.05 m² samples per station, each composed of 5 cores, were taken. The samples were carefully sieved on a 1.0 mm screen. The fraction retained was fixed in 10% formalin, diluted with sea water and stained with Rose Bengal. Sorted animals were identified to lowest possible taxon and counted using a binocular microscope. Three additional core samples per station were taken for sediment grain size, organic carbon, and calcium carbonate analyses.

Percentages of organic carbon in sediments were determined using the potassium dichromate technique (Holme and McIntyre 1971). The calcium carbonate in sediment was determined by treatment with 1N HCl and the excess acid was determined by titration with 1N NaOH (Anwar and Mohamed 1970).

The grain size distributions of sediment samples were analyzed using the standard methods (ASTM Standards 1973). Median diameters (M_{50}) were derived from the cumulative curves of total grain size distributions. The degree of sorting (S_{50}) was calculated as of Trask (1932) sorting coefficient.

Species diversity was measured using the shannon-Wiener index (Shannon and Weaver 1963). Two additional measures, the evenness and species richness were also calculated (Krebs 1978). Faunal similarities among stations were calculated using the «Faunal Similarity Index» of Sanders (1960). The dominance of each taxon encountered was measured using the «Biological Index Value (BIV)» of McCloskey (1970). Analysis of variance was calculated for the major macrofaunal groups (polychaeta and mollusca) and for total macrofauna (Zar 1984). Similarly differences in mean levels of organic

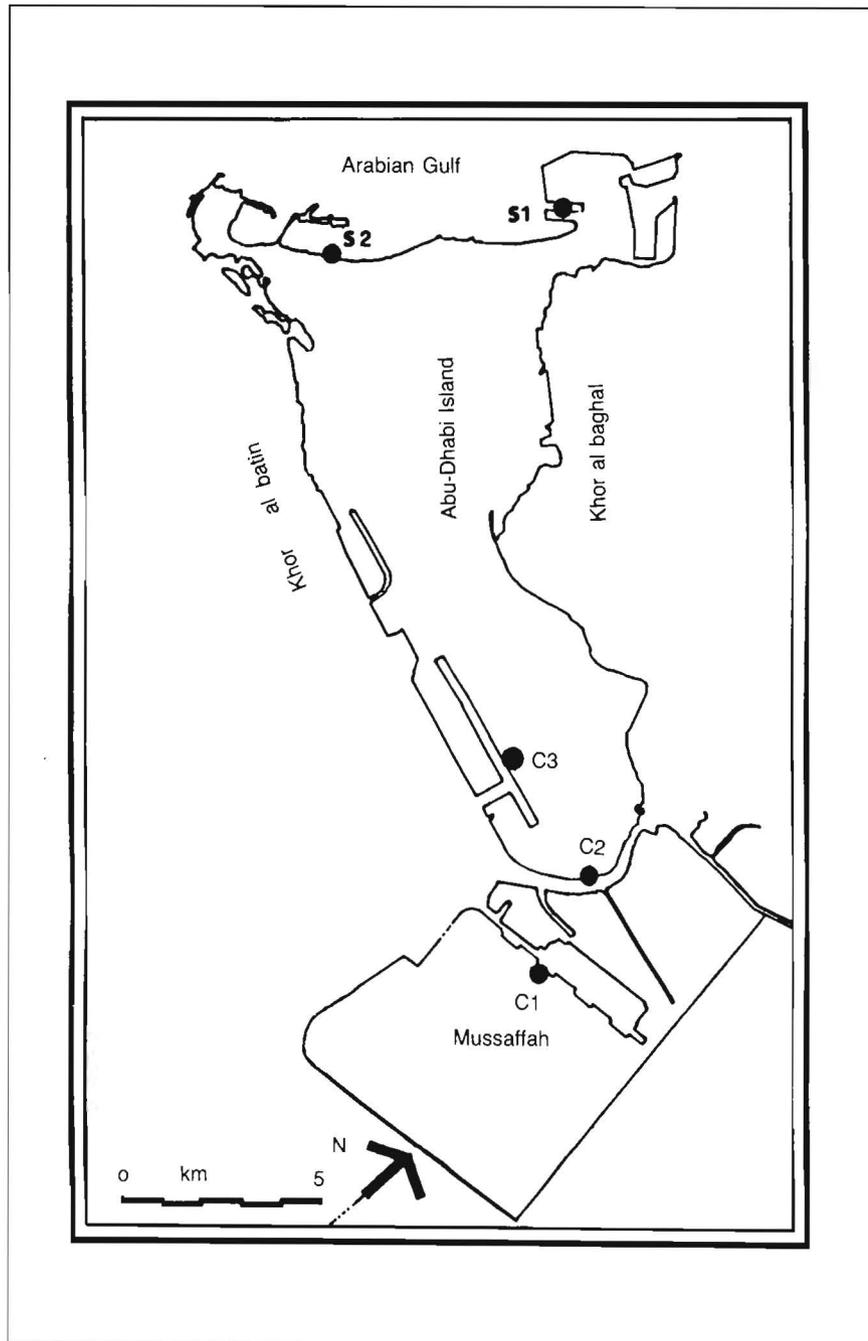


Fig. 1. Location map of sewer outlets S1, S2 and S3, and control stations C1 and C2 around Abu-Dhabi Island in the Arabian Gulf.

carbon and calcium carbonate were compared using the analysis of variance (ANOVAR). The statistical significance was tested by F-test and multiple range test at the 95% confidence level.

Results

Sediments:

The sedimentary composition at the control stations, C1 and C2, and at the sewer outlet S3 is similar. The sediments at these stations are made mainly (84.3-96.0%) of fine sand (Table 1). consequently the median grain sizes of these sediments range from 115 to 155 μm . Sediments at the other two sewer outlets, S1 and S2, are coarse (25.7-47.6%) and fine (46.1-68.0%) sands. The median grain sizes range from 395-540 μm . The sediments at all stations are well sorted (less than 2.5).

Table 1. Sedimentary composition at the sewer outlets (S1, S2 and S3) and control (C1 and C2) stations during November 1990

Station	Sample	% Coarse sand*	% Fine sand**	Median diam. (μm)	Sorting coefficient	% Organic carbon	% Calcium carbonate
C1	1	3.5	91.5	145	1.67	0.139	70.6
	2	6.5	88.1	140	1.60	0.133	64.3
	3	5.2	92.3	120	1.59	0.160	65.1
C2	1	3.2	96.0	120	1.45	0.210	57.3
	2	15.2	84.3	125	1.78	0.299	68.2
	3	3.8	95.4	115	1.46	0.186	58.9
S1	1	41.5	54.6	460	1.53	0.280	96.2
	2	35.6	64.3	450	1.40	0.217	94.4
	3	42.4	50.6	500	1.61	0.339	93.6
S2	1	35.2	58.3	430	1.57	0.172	96.1
	2	47.6	46.1	540	1.55	0.194	97.9
	3	25.7	68.0	395	1.41	0.199	95.8
S3	1	9.0	88.4	155	1.74	0.200	77.1
	2	8.7	86.5	140	1.72	0.260	71.7
	3	6.7	89.2	138	1.60	0.330	69.6

* > 500-< 2000 μm .

** < 500-> 63 μm .

In general, a relatively high organic content was found in sediments of all stations (Table 1). The ANOVAR showed a significant difference in mean levels of organic carbon among stations. The lowest mean level was found at C1 (0.144%) and S2 (0.188%). Significantly higher means of organic carbon were found at S1 (0.279%) and S3 (0.263%) (95% confidence level). High levels of calcium carbonate were found in

sediments of all stations. However, ANOVAR showed a significant difference in mean levels of calcium carbonate among stations. Significantly higher means were found in sediments of S1 (94.7%) and S2 (96.9%) than those in sediments of C1 (66.7%), C2 (61.5%), and S3 (72.8%).

Fauna:

A total of 2434 animals belonging to 45 taxa were collected during this study (Table 2). These include 24 species of polychaetes and 11 species of molluscs comprising 34.1% and 60.6% of the total number of animals, respectively. The analysis of variance showed a significant difference (99% confidence limits) in mean numbers of animals among stations. The highest mean was found at C2 (5992/m²), followed by 2740/m² at S3 (Table 3). Significantly lower means were found at S1 (44/m²) and S2 (68/m²). There was no significant difference in mean numbers of polychaetes among stations. However, mean numbers of polychaetes at S1 and S2 (32 and 36/m² respectively) were significantly lower than C1 (832/m²), C2 (760/m²), and S3 (1704/m²). Similarly, mean numbers of molluscs were significantly higher at C2 (5220/m²) and S3 (640/m²) than those at C1 and S2 (20/m² each). No molluscs were found at S1.

The highest number of taxa (25) was found at C1 (Table 3), followed by 16 and 14 at C2 and S3 respectively. Lower numbers of taxa were found at S1 and S2 (4 and 5 respectively). Similarly, the highest number of polychaete species was found at C1 (16). Lower numbers were found at other stations (2-7 taxa). Number of molluscan taxa were low at all stations, except at C2 where 7 taxa were found. Species richness was higher at C1 (4.44) and C2 (2.05) than sewer outlets stations (1.25-1.99). Species evenness, however, was relatively low at C2 (0.45) and S3 (0.50). Higher values were found at S2 (0.93) and S1 (0.74). The highest species diversity was, thus, calculated for C1 (3.15). Lower values were obtained for other stations. (1.49-2.16).

Table 2. Distribution of macrobenthic invertebrates at sewer outlets (S1, S2 and S3) and control (C1 and C2) stations during November 1990. Numbers of animals are per 0.25m²

Taxon	Stations				
	C1	C2	S1	S2	S3
Turbellaria (indetermined)	0	0	0	3	0
Nemertea (indetermined)	2	1	1	0	0
Nematoda (indetermined)	1	0	0	0	0
Oligochaeta (indetermined sp.1)	0	0	2	0	0
Oligochaeta (indetermined sp.2)	0	0	0	0	81
Polychaeta:					
<i>Aricia exarmata</i>	0	7	0	0	0
<i>Armandia lanceolata</i>	4	9	0	0	0
<i>Axiothella australis</i>	2	0	0	0	0
<i>Bookhoutia oligognatha</i>	0	0	7	5	0

Taxon	Stations				
	C1	C2	S1	S2	S3
Capitellidae	3	0	0	0	0
Capitellidae	2	0	0	0	0
<i>Cetatonereis costae</i>	78	125	1	1	346
<i>Cirratulus</i> sp.	2	0	0	0	0
<i>Glycera lancadivae</i>	0	1	0	0	0
<i>Heteromastus similis</i>	6	0	0	0	0
<i>Lumbriconereis</i> sp.	5	0	0	0	0
<i>Nainereis</i> sp.	23	0	0	0	0
Nereidae (indetermined)	0	5	0	3	0
<i>Notomastus latericeus</i>	13	0	0	0	0
<i>Perinereis cultrifera</i>	0	0	0	0	6
<i>Polydora antennata</i>	0	0	0	0	3
<i>Polydora kempii</i>	19	3	0	0	1
<i>Prionospio cirrifera</i>	1	0	0	0	0
<i>Scoloplos chevaliere</i>	31	0	0	0	0
<i>Tharyx</i> sp.1	3	0	0	0	0
<i>Tharyx</i> sp.2	4	0	0	0	0
<i>Tylonereis bogoyawlenskyi</i>	0	40	0	0	71
Unidentified sp.1	1	0	0	0	0
Unidentified sp.2	1	0	0	0	0
Mollusca: Gastropoda					
Cerithidae (indetermined)	0	1	0	0	0
<i>Cerithium scabridum</i>	0	0	0	0	4
<i>Mitrella blanda</i>	3	20	0	0	0
<i>Nassarius arcularis</i>	0	1	0	0	0
<i>Rhinoclavis kochi</i>	1	0	0	0	6
Mollusca: Bivalvia					
<i>Callista multiradiata</i>	1	0	0	0	0
<i>Codakia tigerina</i>	1	97	0	0	6
<i>Dosinia alta</i>	0	974	0	0	122
Lucinidae (indertemined)	0	8	0	0	0
<i>Tellina versicolor</i>	0	205	0	0	29
Tellinidae (indetermined)	0	0	0	5	0
Crustacea: Amphipoda					
Sebidae (indetermined)	0	0	0	0	1
unidentified sp.	3	0	0	0	0
Crustacea: Decapoda					
<i>Diogenes avarus</i>	0	0	0	0	3
<i>Scopimera crabricauda</i>	0	1	0	0	7
Sipuncula: Unidentified sp.	1	0	0	0	0

Table 3. Faunal analysis of macrobenthic invertebrates at sewer outlets (S1, S2 and S3) and control (C1 and C2) stations around Abu-Dhabi Island during November 1990

	Stations				
	C1	C2	S1	S2	S3
Total no. of species	25	16	4	5	14
No. of polychaete species	16	7	2	3	5
No. of mollusc species	4	7	0	1	5
Species diversity (H)	3.15	1.79	1.49	2.16	1.89
Species evenness (E)	0.68	0.45	0.74	0.93	0.50
Species richness (SR)	4.44	2.05	1.25	1.41	1.99
No. of animals collected	223	1498	11	17	685
Mean no. of animals per m ²	892 ± 160*	5992 ± 488	44 ± 14	68 ± 60	2740 ± 424
No. of polychaetes collected	196	190	8	9	426
Mean no. of polychaetes per m ²	832 ± 192	760 ± 328	32 ± 20	36 ± 30	1704 ± 1840
No. of molluscs collected	5	1305	0	5	160
Mean no. of molluscs per m ²	20 ± 30	5220 ± 2736	0	20 ± 30	640 ± 510

* One standard deviation.

Table 4. Dominant species according to biological index value (BIV) of McCloskey (1970) around Abu-Dhabi Island during November 1990

Taxon	% of total number	Ranking points	% freq.*	Ranking points	BIV	Rank
<i>Dosinia alta</i>	45.0	20	40	19	39	1
<i>Ceratonereis costae</i>	22.6	19	68	20	39	1
<i>Tellina versicolor</i>	9.6	18	36	18	36	3
<i>Tylonereis bogoyawlenskyi</i>	4.6	17	32	17	34	4
<i>Codakia tigerina</i>	4.3	16	28	16	32	5

* represents frequency of occurrence in 25 samples.

Using the «Faunal Similarity Index» of Sanders (1960), very low faunal similarities were found between each of S1 and S2 and each of C1, C2 and S3 (5.9-11.0%) (Fig.2). Relatively higher similarities were found among C1, C2, and S3 (34.1-36.1%). Similarly, the faunal similarity between S1 and S2 was relatively high (35.3).

Three species of bivalves, *Dosinia alta*, *Tellina versicolor*, and *Codakia tigerina*, and two species of polychaetes, *Ceratonereis costae* and *Tylonereis bogoyawlenskyi* were considered as the dominant species around Abu-Dhabi Island during November 1990. *Dosinia alta*, *T. versicolor*, and *T. bogoyawlenskyi* were particularly abundant at C2 and S3. Although, *C. costae* was found at all stations, it was abundant at C1, C2 and S3.

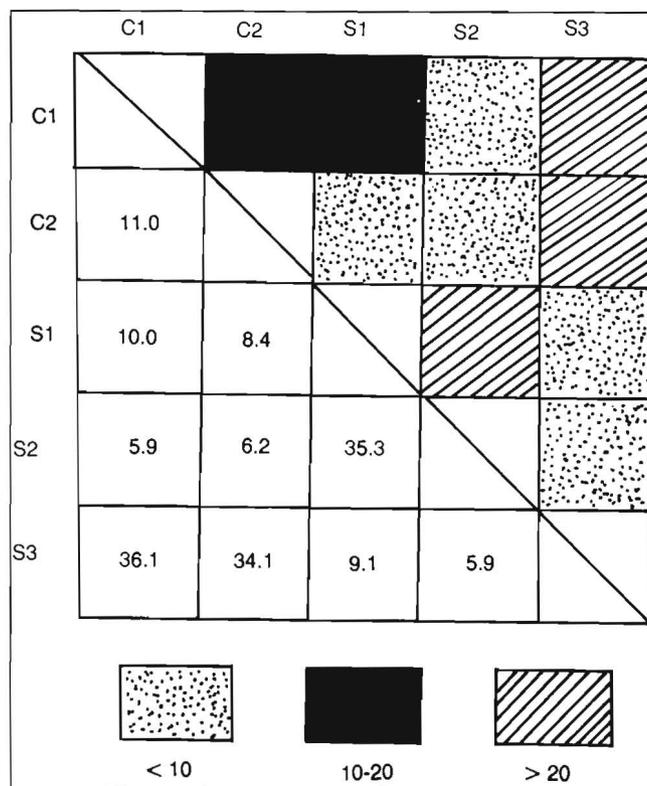


Fig.2. Trellis diagram showing the percentages of the faunal similarities among sewer outlets stations (S1, S2, and S3) and control stations (C1 and C2).

Discussion

The percentages of organic matter in a sediment has been shown to be directly related to percentage of calcium carbonate (Sverdrup *et al.* 1942, Ismail and Awad 1984), but inversely related to sediment texture (Bader 1954, Philips 1972, Ismail 1980). Although the sedimentary composition and the calcium carbonate levels are similar at C1, C2 and S3, higher organic content was found at S3, but this increase is not «extreme». Similar values have been reported from non-polluted intertidal flats in Khor Kalba on the Gulf of Oman (Ismail and Ahmed 1993). Elevated organic carbon values in polluted areas have been reported by many workers. For example, in the new York Bight, the organic carbon was higher at the sewage sludge dumping site (mean 1.95%) than the control station (mean 1.29%) (Botton 1979). Similarly, organic carbon was higher at the sewage dumping site (0.286%) than the control station (0.105%) in the Gulf of Aqaba (Ismail and Awad 1984). At S1 and S2 the sediments are coarser and contain more calcium carbonates than the other three stations. A relatively high level of organic carbon was

found at S1 (mean 0.279%) than S2 (mean 0.188%). Lower levels of organic carbon in sediments of similar texture and calcium carbonate at the low tide lines of non-polluted sandy beaches in Abu-Dhabi and other locations along the coastline of the United Arab Emirates have been reported (0.130-0.190%) (Ismail and Ahmed 1991).

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 Victoria Harbour, Hong Kong, where 800 million liters of sewage are dumped daily, the stressed community is within 15km² (Thompson and Shin 1983). In the Gulf of Aqaba, where 70-150 thousand liters of sewage are dumped daily, the total number of individuals, number of species, and species diversity were lower at the sewage outfall than at the control station (Ismail and Awad 1987). At another sewage outfall in the Gulf of Aqaba, where the sewage is discharged sporadically, Ismail and Awad (1987) found no measurable effects on the community structure of macrobenthic invertebrates. The slight accumulation of organic carbon at the sewer outlets around Abu-Dhabi Island, particularly at S1 and S3, has no measurable effects on the community structure of macrobenthic invertebrates at these outlets. The faunal analysis has shown that numbers of species, species diversity, and species richness and evenness at C2 and S3 are similar. Differences in mean numbers of animals at C2 and S3 are due to differences in mean numbers of dominant species at both locations. Three of these species, *Dosinia alta*, *Tellina versicolor*, and *Tylonereis bogoyawlenskyi*, were found only at C2 and S3. The other two dominant species, *Ceratonereis costae* and *Codakia tigrina*, were also found at C2 and S3 beside the other stations. The faunal characteristics at S1 and S2 are similar to the faunal characteristics on non-polluted sandy beaches which have similar sedimentary composition. Ismail and Ahmed (1991) reported low numbers of species and numbers of animals in some sandy beaches along the coastline of the United Arab Emirates on the Arabian Gulf.

Acknowledgement

The author wishes to thank Mr. Mohamed A. Ahmed and Mr. Hisham Halaq for their help in the field and laboratory. This study was supported by a grant from U.A.E. University.

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(Received 11/01/1992;
in revised form 17/03/1993)

بعض القياسات البيئية والحيوانات القاعية بالقرب من مصبات المجاري المهجورة حول جزيرة أبو ظبي في الخليج العربي

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هنالك ثلاثة مصبات مجاري حول جزيرة أبو ظبي كانت تستخدم سابقاً للتخلص من المياه العادمة وتم تحويلها الى مصبات للتخلص من مياه الأمطار. لقد تم جمع ١٤٠ عينة رسوبية (٠,٠١ م^٢ وعمق ١٠ - ١٥ سم) خلال شهر نوفمبر ١٩٩٠م من الحد الأدنى للمد والجزر عند هذه المصبات وعند محطتين للمقارنة وذلك لدراسة تركيبة مجتمع منطقة اللافقاريات البحرية القاعية الكبيرة وتركيز كل من الكربون العضوي وكربونات الكالسيوم. بالإضافة لذلك تم تحليل التوزيع الحجمي لهذه الرسوبيات.

تشير النتائج أن معدل تركيز الكربون العضوي في رسوبيات اثنين من المصبات (٠,٢٦٣ - ٠,٢٧٩%) كان أعلى منه عند محطتي المقارنة (٠,١٤٤ - ٠,٢٣٢%)، هذا على الرغم من أن تركيز كربونات الكالسيوم عند المصبات (٧٢,٨ - ٩٦,٩%) كان أعلى منه عند محطتي المقارنة (٦١,٥ - ٦٦,٦%).

وتم كذلك خلال هذه الدراسة جمع ٢٤٣٤ من اللافقاريات البحرية القاعية الكبيرة تنتمي الى ٤٥ نوعاً، منها ٢٤ نوعاً من الديدان عديدة الأشواك و ١١ من الرخويات.

أما بالنسبة لكثافة هذه الحيوانات فتشير التحليلات الإحصائية الى وجود فروق بين معدلات الكثافة في المحطات المختلفة، حيث تراوحت ما بين ٨٩٢ -

٥٩٩٢م^٢ عند محطتي المقارنة ومن ٤٤ - ٢٧٤٠م^٢ عند المصببات، واختلف كذلك عدد الانواع حيث تراوح ما بين ١٦ - ٢٥ نوعا في محطتي المقارنة ومن ٤ - ١٤ نوعا عند المصببات، لذلك اختلف معامل التنوع (H) ما بين ١,٧٩ - ٣,١٥ في محطتي المقارنة ومن ١,٤٩ - ٢,١٦ عند المصببات. إن سبب هذه الفروق بين محطتي المقارنة والمصببات قد يعود حقيقة الى اختلاف في التحليل الحجمي للرسوبيات عند اثنين من المصببات.

أما بالنسبة للمصبب الثالث والذي يشبه محطتي المقارنة من حيث التحليل الحجمي فان تركيبة مجتمع اللافقاريات كانت مشابهة لذلك عند محطتي المقارنة، ويتبين ذلك باستخدام مؤشر تشابه الانواع الذي استخدمه ساندرز (١٩٦٠) حيث كانت نسبة التشابه بين محطتي المقارنة وذلك المصب ما بين ٣٤,١ - ٣٦,١٪، بينما كانت محطتي المقارنة ١١٪.

بالاضافة لذلك فان الانواع السائدة عند محطتي المقارنة هي نفسها عند المصببات والتي تشمل ثلاثة انواع من الرخويات: (*Codakia tigerina*, *Tellina*) (*Versicolor*, *Dosinia alta*) ونوعين من عديدة الاشواك (*Ceratonereis costae*, *Tylonereis bogoyawlenskyi*).