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A SPATIAL STUDY OF THE MEIOFAUNA ON A SEWAGE-POLLUTED LEBANESE SAND BEACH

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MARCIA M. GOWING AND NEIL C. HULINGS

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INTRODUCTION

The effects of pollution on meiofauna have received little investigation. This is surprising in view of the characteristics of meiofauna such as abundance, ease of collection, and general short life span, that make them appropriate animals for pollution studies (Gray and Ventilla, 1971; Hulings and Gray, 1971). The few studies that have been conducted include laboratory and field investigations. Gray and Ventilla (1971) reported laboratory studies on the effects of industrial pollutants on the growth rate of a species of Archiannelida. It was found that the pollutants in combination depressed the growth rate more significantly than individual pollutants, emphasizing the synergistic effect of pollutants.

Field studies on the effects of pollution have been conducted by Oliff, Berrisford, Turner, Ballard and Mcwilliam (1967) on the sand beaches of Natal, South Africa. They found that on an open exposed beach, high numbers and a variety of species were associated with high sewage input. Gray and Ventilla (1971) were not able to conclusively relate decreased meiofaunal density to pollution (sewage and industrial) from the River Tees on the east coast of England. They reported visible sewage pollution at one of four sites; the population density was the lowest where the sewage was observed. O'Sullivan (1971) has reviewed the ecological effects of sewage in the marine environment. He cites the work of Date (unpublished) on beaches near Liverpool, England. Date found that ciliated Protozoa were less affected by sewage pollution than were Metazoa. The diversity of the Protozoa was found to be the same for polluted and unpolluted beaches whereas the number of species of Metazoa decreased in polluted beaches.

A study of the effects of sewage pollution in the Eastern Mediterranean is especially significant. The Eastern Mediterranean has been characterized by low productivity because of the low nutrient input via rivers and the circulation pattern whereby the surface water originating from the Atlantic is depleted of nutrients by the time it reaches the Eastern Mediterranean (Emery and George, 1963). The productivity is expected to become even lower with the damming of the Nile River, the primary source of nutrients in the Eastern Mediterranean. The possibility exists, however, that the discharge of sewage into the Eastern Mediterranean can to a degree compensate for the loss of nutrients from the Nile. The second reason for this study was to obtain an insight into the effect of sewage on meiofauna density and to establish baseline data for comparisons of polluted and unpolluted beaches.

Toward this end, a sand beach polluted by sewage was selected for a spatial study. The sand beach as a system in which to investigate the effects of organic input is appropriate because of the filtering nature which tends to concentrate pollutants and the abundance of meiofauna, among which are a variety of feeding types. A spatial study, with statistical design requiring replicate sampling, was considered of primary importance in determining the effect of sewage pollution on sand beach meiofauna. Such a study would require detailed sampling of sites along the beach to take into consideration differential exposure to sewage.

METHODS AND MATERIALS

Khalde beach, located 5 km south of Beirut near Beirut International Airport, was selected for detailed study. The beach in 2.2 km long, with an area of 1 x 10^6 m^2 and is tideless and fully exposed to wave action. Khalde beach is polluted by untreated discharge from one of the major sewer outfalls of greater Beirut. Although official figures on the volume of discharge were not available, unofficial estimates were around 700 L/sec.

The sewer outfall is situated about 70 m seaward of the beach and empties near the surface. From the sewer to the southern end, the beach is sandy and interrupted by one small rock outcrop. The vicinity of the sewer outfall is rocky and from the sewer to the northern end of the beach there are alternating stretches of rock outcrops and sand beach.

Three sites were chosen for detailed study of meiofauna, the sites being selected on the basis of proximity to the sewer. The sites were the north site, the sewer site and the south site. Each site was sampled 4 times during the year to take into consideration the sea temperature maximum of 32°C in August and minimum of 17°C in February (George, Athanassiou and Boulos, 1964). The specific sampling dates were June 11, 1971, August 14, 1971, November 13, 1971, and February 11, 1972. Six replicate, 4.4 cm diameter cores were taken with a hand-operated plastic coring tube from within a 0.5 × 0.5 m grid divided into 16 equal squares. The squares were designated 1 through 16 and those to be sampled were selected from a random number table.

For each site, two levels were sampled. The levels were the wave-wash zone (designated as WWZ), where the surface of the sand was saturated with water 90 percent of the time, and higher up on the beach where the water table was 40 cm below the sand surface (designated as WT). Previous studies by Hulings in Tunisia (1971) and Lebanon (1974) showed quantitative differences in meiofaunal densities between the two levels. In the wave-wash zone the cores were 20 cm deep; at the water table, 15 cm deep. For the latter, preliminary holes were dug to determine the location of the 40 cm water table. Then, for sampling, a 5 x 50 cm hole was excavated just to the level of the water table. The obtaining of hand-operated cores deeper than 15 cm at the water table was extremely difficult because of compactness of the sand. Each wave-wash zone and water table core was divided into 5-cm sections, placed in a separate plastic jar, and preserved with two volumes of 5 percent buffered formalin within 2 hours after collection. Formalin preservation caused considerable distortion of »soft« fauna, especially Turbellaria and Gastopoda. Observations were made on the effects of preservation on »soft« fauna by placing living specimens in formalin and noting characteristic changes in shape. Based on these observatins, the »soft« fauna could be identified at the group level.

Temperature was measured *in situ* in the wave-wash zone and at the water table with a mercury thermometer. Water samples for salinity determinations by conductivity were taken in the wave-wash zone; at the water table, the water sample was taken from and accumulated pool following meiofaunal sampling. During the November and February samplings, the water for salinity determinations was taken with the interstitial water sampler designed by Makemson (1972).

In the laboratory, the meiofauna was extracted by placing the individual samples in a 400-ml jar, adding 300 ml of fresh water, and shaking. After allowing the sand to settle, the liquid was poured through a 52-mμ mesh net. This process was repeated three times and the total extracted meiofauna collected on the net for each sample was preserved in 5 percent buffered formalin. The efficiency of this procedure was checked by adding Rose Bengal stain to the extracted sediment and repeating the extraction procedure. The results revealed a 97 percent extraction efficiency for most meiofauna, although for Nematoda, the efficiency was 95 percent when there were more than 500 specimens per sample. The protozoan fraction was ignored due to difficulty in extraction and counting, although ciliates can be important components of sand communities (Fenchel, 1969). The total meiofauna was counted under a binocular microscope at 25 x by placing the sample in a Petri dish over a grid. The numbers were recorded at the higher taxon level, i. e., Nematoda, Harpacticoida, etc. Counting efficiency, determined by recounting several random samples, was found to be 99 percent accurate in most cases; it was only 97 percent accurate, however, for Nematoda and *Protodrilus* when the density was very high.

Conductivity measurements of water samples were made using the Electronic Switchgear Conductivity Meter Type MCl. The conductivity was converted to salinity from a standard curve of conductivity vs. concentration of NaCl.

For granulometric analyses, one complete core nearest the middle of the grid at each level was retained following extraction of the meiofauna. Each 5-cm interval was analyzed at 0.5 ∅ intervals from 0.5 to 3.0 ∅ following the technique described in Hulings and Gray (1971). A measure of overall size, the graphic mean (Mz∅), and the inclusive graphic standard deviation (σI∅), a measure of sorting, were determined as given by Folk (1968).

Table 1 shows the raw meiofauna density by taxon for each site by sampling date. The density for each depth interval is the total of 6 cores. Each interval represents a volume of 75 ml of sand. For the statistical analyses, all samples at a particular site and sampling date were lumped to obtain the mean.

Table 1. Meiofaunal density for each sampling date and each site. Numbers are the total for 6 cores.

June 11, 1971

			North Site				
			WWZ			WT	
Taxon	0—5	5—10	10—15	15—20	0—5	5—10	10—15
Turbellaria	215	279	182	140	65	120	97
Gastrotricha	1123	872	163	73	1	1	2
Nematoda	750	1174	952	711	296	400	238
Archiannelida	1375	3413	211	154	310	450	468
Polychaeta	1	23	8	10	0	0	3
Oligochaeta	148	186	88	32	4	5	18
Gastropoda	0	0	0	0	0	0	0
Mystacocarida	0	1	1	2	173	231	209
Ostracoda	20	72	84	66	0	5	3
Harpacticoida	502	1188	1397	867	92	94	420
Halacarida	0	1	0	1	2	1	1
Tardigrada	7	14	26	8	5	12	12
			Sewer Site				
Turbellaria	180	163	256	159	140	172	82
Gastrotricha	1	17	87	107	0	0	1
Nematoda	2471	6754	6749	4262	471	451	380
Archiannelida	2	75	369	168	64	78	72
Polychaeta	4	13	16	19	0	3	4
Oligochaeta	5670	2334	1566	1639	27	61	14
Gastropoda	0	0	0	0	0	0	0
Mystacocarida	0	0	3	20	118	129	190
Ostracoda	6	8	11	7	1	0	1
Harpacticoida	9	107	1053	1812	199	371	472
Halacarida	1	1	2	3	2	2	2
Tardigrada	16	48	74	33	1	1	2
			South Site				
Turbellaria	19	75	86	66	71	102	81
Gastrotricha	3	11	8	10	2	0	0
Nematoda	966	972	628	400	376	461	370

Table 1. Cont'd.

Archiannelida	46	57	108	115	27	72	204
Polychaeta	11	4	20	29	6	32	38
Oligochaeta	0	4	1	0	3	3	2
Gastropoda	0	0	0	0	0	0	0
Mystacocarida	1	2	1	7	27	51	76
Ostracoda	3	3	1	1	6	7	6
Harpacticoida	20	84	153	500	56	110	175
Halacarida	1	0	1	1	1	0	0
Tardigrada	6	11	24	6	9	5	2

North Site

August 14, 1971

	WWZ				WT		
Taxon	0—5	5—10	10—15	15—20	0—5	5—10	10—15
Turbellaria	103	178	199	78	189	127	111
Gastrotricha	8	72	141	40	2	3	0
Nematoda	278	137	288	702	1222	504	317
Archiannelida	2360	2578	747	92	1370	175	83
Polychaeta	0	2	2	2	3	1	0
Oligochaeta	7	10	236	141	70	54	20
Gastropoda	26	57	10	11	9	5	5
Mystacocarida	0	0	0	0	0	3	1
Ostracoda	16	20	122	133	9	2	3
Harpacticoida	65	234	447	773	0	1	0
Halacarida	1	0	0	0	0	0	1
Tardigrada	0	0	0	0			
			Sewer Site				
Turbellaria	238	91	81	60	125	162	150
Gastrotricha	8	21	10	15	0	0	0
Nematoda	390	5984	3110	1212	303	233	108
Archiannelida	3499	3810	2168	110	4010	1886	517
Polychaeta	8	15	21	10	10	16	21
Oligochaeta	66	122	35	19	2	3	7
Gastropoda	1	17	4	12	7	4	0
Mystacocarida	8	0	0	1	262	171	126
Ostracoda	489	959	331	154	7	2	0
Harpacticoida	330	1582	2269	478	2779	3596	3623
Halacarida	1	2	0	1	2	3	0
Tardigrada	0	1	1	1	0	0	0
			South Site				
Turbellaria	312	208	210	69	49	83	44
Gastrotricha	14	34	20	4	0	1	0
Nematoda	2659	4528	3408	2031	112	54	40
Archiannelida	1467	3508	1192	122	62	40	37
Polychaeta	0	5	6	14	52	131	61
Oligochaeta	93	215	80	25	8	16	5
Gastropoda	17	13	8	4	0	0	0
Mystacocarida	26	21	40	5	1015	981	462
Ostracoda	498	346	364	166	5	0	0
Harpacticoida	152	527	506	400	1062	1929	717
Halacarida	6	7	12	8	11	17	3
Tardigrada	0	0	2	0	0	0	0

Table 1. Cont'd.

November 13, 1971

North Site

	WWZ				WT		
Taxon	0—5	5—10	10—15	15—20	0—5	5—10	10—15
Turbellaria	114	205	119	114	252	302	60
Gastrotricha	7	118	88	60	6	12	10
Nematoda	296	170	298	204	471	782	725
Archiannelida	1647	18917	18846	11628	60	100	33
Polychaeta	0	0	0	0	0	1	1
Oligochaeta	19	17	49	60	1	29	45
Gastropoda	44	44	42	9	2	3	2
Mystacocarida	1	0	0	0	1	0	4
Ostracoda	12	21	4	3	5	8	19
Harpacticoida	17	74	721	670	263	910	1310
Halacarida	0	0	0	1	3	0	0
Tardigrada	0	0	0	0	0	0	1

South Site

Turbellaria	154	606	127	93	52	49	98
Gastrotricha	1	2	1	0	0	0	2
Nematoda	538	653	187	177	852	873	679
Archiannelida	36	38	41	21	697	1192	2555
Polychaeta	1	0	0	2	1	2	2
Oligochaeta	19	289	185	185	0	3	9
Gastropoda	5	33	14	19	2	3	13
Mystacocarida	0	0	1	0	1	2	1
Ostracoda	388	475	49	27	10	4	5
Harpacticoida	21	153	200	306	280	263	572
Halacarida	1	26	7	8	0	1	4
Tardigrada	0	0	1	1	2	3	0

South Site

Turbellaria	142	145	118	108	195	280	247
Gastrotricha	3	17	3	1			
Nematoda	431	192	197	101	131	105	55
Archiannelida	1897	4281	1475	143	135	165	244
Polychaeta	1	0	2	0	7	8	17
Oligochaeta	21	18	32	28	4	5	4
Gastropoda	5	12	10	8	0	2	2
Mystacocarida	2	3	5	0	1	3	1
Ostracoda	83	35	45	65	58	34	24
Harpacticoida	60	231	190	195	214	204	216
Halacarida	10	51	74	48	8	3	1
Tardigrada	0	1	0	1	23	43	23

North Site

February 2, 1972

	WWZ				WT		
Taxon	0—5	5—10	10—15	15—20	0—5	5—10	10—15
Turbellaria	91	238	107	138	60	65	53
Gastrotricha	4	19	25	27	2	0	1
Nematoda	333	98	87	72	307	303	241
Archiannelida	1202	34957	16140	12651	86	40	19
Polychaeta	0	1	7	17	1	0	0
Oligochaeta	1	32	25	71	17	20	5
Gastropoda	0	0	0	0	0	0	0

Table 1. Cont'd.

Mystacocarida	0	0	0	0	373	534	485
Ostracoda	3	1	5	3	7	0	0
Harpacticoida	12	7	57	244	1059	1657	1491
Halacarida	0	0	0	0	0	1	0
Tardigrada	0	0	0	0	0	0	0
Sewer Site							
Turbellaria	350	388	190	148	123	121	90
Gastrotricha	1325	616	360	157	56	12	14
Nematoda	627	489	566	400	400	668	607
Archiannelida	1306	23191	55369	7878	57	83	55
Polychaeta	2	36	28	16	1	1	4
Oligochaeta	97	200	298	7	0	0	0
Gastropoda	0	0	0	0	0	0	0
Mystacocarida	5	0	1	0	0	0	1
Ostracoda	1903	676	1006	601	7	2	0
Harpacticoida	123	940	5694	3106	1225	489	416
Halacarida	3	5	18	12	8	6	4
Tardigrada	0	10	7	15	8	3	3
South Site							
Turbellaria	191	105	120	61	20	28	34
Gastrotricha	158	254	118	24	4	5	5
Nematoda	1220	156	178	123	78	59	28
Archiannelida	1048	3431	2841	1295	32	46	43
Polychaeta	1	9	13	11	3	7	5
Oligochaeta	0	0	0	0	0	0	0
Gastropoda	0	0	0	0	0	0	0
Mystacocarida	0	0	0	0	0	0	0
Ostracoda	222	104	87	27	17	25	21
Harpacticoida	33	82	324	374	26	44	28
Halacarida	26	40	49	17	1	0	2
Tardigrada	0	1	1	1	0	0	0

The sampling program of this study was designed so that comparisons of sites, months, and levels with respect to mean meiofaunal density could be made using two types of analysis of variance (hereafter referred to as anova) described by Sokal and Rohlf (1969). The least significant diference test of Sokal and Rohlf (1969) was used to determine differences between means. In order to use these anovas, the error variance must be homogeneous (Simpson, Roe and Lewontin, 1960; Sokal and Rohlf, 1969). Calculations of the mean and variance for the raw meiofaunal data (Table 2), based on the means of 10-cm cores, showed that the variance increased as the mean increased. The raw means were thus transformed to $\log_{10}$ to stabilize the variance (Sokal and Rohlf, 1969) as shown in Table 3. The assumption is made that the transformation for 10-cm cores is valid for deeper cores. Oliff et al. (1967), Gray and Rieger (1971) and Hulings (1971) have used similar anovas for analyzing meiofaunal data in terms of abundance and distribution.

Table 2. Variances and means for the raw meiofaunal numbers from 10-cm cores for two levels at each site.

A. WWZ

NORTH SITE			SEWER SITE			SOUTH SITE		
Month	Mean	Variance	Month	Mean	Variance	Month	Mean	Variance
(A)	1003	45,974	(N)	577	27,080	(J)	413	11,650
(J)	2054	92,246	(A)	2943	354,262	(F)	1440	349,470
(N)	3310	6,646,918	(J)	3487	467,512	(N)	1521	2,646,490
(F)	6170	13,076,175	(F)	5476	6,247,732	(A)	2441	301,798

B. WT

NORTH SITE			SEWER SITE			SOUTH SITE		
Month	Mean	Variance	Month	Mean	Variance	Month	Mean	Variance
(J)	404	10,564	(J)	392	195,697	(F)	66	1,660
(N)	528	381,995	(F)	432	15,058	(J)	182	522
(F)	774	79,107	(N)	778	95,234	(N)	295	21,434
(A)	1419	413,432	(A)	2308	849,254	(A)	917	214,779

J — June; A — August; N —November; F — February.

Table 3. Variances and means for the $\log_{10}$ transformed meiofaunal numbers from 10-cm cores for two levels at each site.

A. WWZ

NORTH SITE			SEWER SITE			SOUTH SITE		
Month	Mean	Variance	Month	Mean	Variance	Month	Mean	Variance
(A)	2.9927	0.0162	(N)	2.7456	0.0166	(J)	2.6015	0.0167
(J)	3.3086	0.0043	(A)	3.4599	0.0100	(F)	3.1245	0.0376
(N)	3.3861	0.1555	(J)	3.5356	0.0076	(N)	3.2996	0.0793
(F)	3.6924	0.1351	(F)	3.6816	0.763	(A)	3.3770	0.0117

B. WT.

Month	Mean	Variance	Month	Mean	Variance	Month	Mean	Variance
NORTH SITE			SEWER SITE			SOUTH SITE		
(J)	2.5949	0.0115	(J)	2.5717	0.0227	(F)	1.7537	0.0671
(N)	2.7029	0.0839	(F)	2.6195	0.0177	(J)	2.2567	0.0032
(F)	2.8627	0.0266	(N)	2.8630	0.0290	(N)	2.4265	0.3775
(A)	3.1111	0.0462	(A)	3.3331	0.0323	(A)	2.9037	0.0711

RESULTS

There are several limitations that must be imposed in the interpretation of the data obtained in this study. First, comparison of the wave-wash zone and the 40 cm water table based on meiofaunal density must take into consideration the fact that the two levels are significantly different. Second, the vertical distribution of the meiofauna on Khalde Beach below 20 cm for the wave-wash zone and below 15 cm for the water table is not known. Examination of Table 1 reveals that in the case of the total meiofauna, the peak of abundance was between 5 and 15 cm in the wave-wash zone. The majority of the individual taxa also peaked in abundance between 5 and 15 cm in the wave-wash zone. Makemson (1973) has shown higher meiofaunal density above the 40 cm water table. Thus the interpretation of the results for the 40 cm water table must be limited and the results for the wave-wash zone considered valid only for the upper 20 cm. And horizontal and vertical migration has not been taken into consideration. Third, only limited data on the degree of pollution of Khalde beach were available at the time of this study. Subsequent data collected by Haber (personal communication) during spring, summer and autumn 1974 along Khalde beach at sites equivalent to those of this study provide an indication of the pollution. The data include protein content of wave-wash zone sand and PO_4 — P, NO_3 — N and NH_3 — N concentrations of the water immediately adjacent to the wave-wash zone and are given in Table 4. It is important to note that Khalde beach is less polluted (using the above criteria as indicators of pollution) than other beaches in the greater Beirut area (Haber, unpublished).

Table 4 shows the physical and chemical environmental data for the two levels at the three sites for each sampling period. The variation in salinity for the wave-wash zone, ranging from 32.8 to 37.0‰, suggests the influence of fresh water input via the sewer plus ground water flow through the beach. Certain salinity values for the water table and more detailed studies of the chemistry of the interstitial water of Khalde beach by Makemson (1973) showing lowered salinities support the influence of ground water flow. The temperature in the wave-wash zone ranged from 15.0 to 29.0°C; in general, the temperature at the water table was about 2°C lower than in the wave-wash zone, the June measurement being an exception. The two levels and three sites are very similar with respect to grain size analysis; all were very well-sorted, medium-grained sand.

Table 4. A. Physical and chemical environmental data for the wave-wash zone and the water table.

Sampling date and site	Salinity (‰)		Temperature (°C)		M„Ø		σIØ	
	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT
June 11, 1971								
North	36.0	39.0	26.0	27.0	1.29	1.26	0.22	0.10
Sewer	35.0	30.0	26.5	27.0	1.30	1.30	0.17	0.16
South	36.0	35.0	26.0	27.0	1.34	1.30	0.19	0.15
August 14, 1971								
North	37.0	37.0	28.5	26.6	1.41	1.48	0,26	0.23
Sewer	37.0	37.0	29.0	27.5	0.98	1.17	0.22	0.19
South	—	23.0	29.0	27.0	1.62	1.35	0.26	0.21
November 13, 1971								
North	36.7	36.6	23.0	20.0	1.32	1.34	0.25	0.25
Sewer	34.5	<1.0	23.0	21.0	1.32	1.32	0.24	0.23
South	39.0	36.1	23.0	20.0	1.53	1.60	0.28	0.30
February 11, 1972								
North	34.0	32.4	16.0	14.0	1.04	1.30	0.25	0.19
Sewer	32.8	35.2	15.5	14.0	1.26	1.24	0.24	0.21
South	36.8	37.4	15.0	14.0	1.45	1.25	0.28	0.22

B. Protein (sand) and nutrient (wave-wash zone water) concentrations (data from Haber, unpublished)

Site and Season		Protein (μg/g sand)	PO_4-P (μg at/L)	NO_3-N (μg at/L)	NH_3-N (μg at/L)
South —	Spring	209	4.01	1.31	15.90
	Summer	213	5.33	2.94	16.51
	Fall	203	5.76	2.43	17.39
Sewer —	Spring	320	15.11	15.19	27.90
	Summer	353	15.24	15.44	31.17
	Fall	360	17.24	17.19	30.00
North —	Spring	250	8.80	13.13	27.78
	Summer	261	9.36	14.01	32.90
	Fall	268	10.55	14.91	34.22

For the statistical analyses, the 5 percent significance level was used as the rejection value by convention. One and two-way anovas were conducted on the mean meiofaunal numbers transformed to $\log_{10}$. In most cases, a two-way anova of sampling periods vs. sites showed a significant interaction value, indicating that differences in values could not be attributed to differences in months alone or in sites alone; a factor involved in measurements for months was also affecting sites. One-way anovas were then performed on the sampling periods and on the sites. A correction factor was needed to compensate for using the same date in more than one anova. The F ratio must be significant at the P/N level, where P is the desired significance level and N is the number of different anovas on the same data. This was not corrected for in the tests. In most cases, a maximum of four tests were performed on the same data, so F ratios significant at the 1 percent level are really significant at the 5 percent level. The results of the various anovas are summarized below.

Two-way anovas of sites vs months for total meiofauna in 20- and 15-cm cores for all wave-wash zone samples (Table 5A, C) revealed significant differences between the means for the sites and months. The significant interaction indicated that the conditions during the months affected the meiofauna at different sites differently. One-way anovas on the total wave-wash zone meiofauna in 20- and 15-cm cores for each site showed that the mean meiofauna numbers for each sampling period at each site were different (Tables 6A, C, D and 7A). The means for the sewer site were higher in three out of four sampling periods.

Two-way anovas of sites vs. months for the total meiofauna minus *Protodrilus* in 20- and 15-cm wave-wash zone cores (Table 5B, E, F) showed that there were significant differences between the means but there was less interaction between sites and months. The mean wave-wash zone numbers of total meiofauna minus *Protodrilus* for each sampling period at each site were significantly different as were the three sites and four months (Tables 6B, E, F and 7B). The removal of *Protodrilus* in the wave-wash zone, however, changed the relative orders of meiofaunal abundance for months and sites (Tables 5C, E; 6C, E; and 7C, E). The sewer site still had the highest overall abundance but the south site was second in abundance instead of the north, as was the case for the total meiofauna.

Table 5. Two-way anovas of sites vs. months.

	Source of Variation	*F ratio*	*Modified F ratio*	
A. Total in 20-cm WWZ cores	Sites	98.0870**		
	Months	101.5990**		
	Interaction	106.0060**		
B. Total minus *Protodrilus* in 20-cm WWZ cores	Sites	135.5671**	Sites/Interaction	5.8631*
	Months	86.2804**	Months/Interaction	3.7315
	Interaction	23.1219**		
C. Total in 15-cm WWZ cores	Sites	49.4764**		
	Months	53.7068**		
	Interaction	50.4973**		
D. Total in 15-cm WT cores	Sites	126.0732**	Sites/Interaction	6.2258*
	Months	80.8674**	Months/Interaction	3.9737
	Interaction	20.2502**		
E. Total minus *Protodrilus* in 15-cm WWZ cores	Sites	125.6745**	Sites/Internaction	5.0556*
	Months	65.7216**	Months/Interaction	2.6438 n. s.
	Interaction	24.8584**		
F. Total minus *Protodrilus*	Sites	58.0086**	Sites/Interaction	2.2845 n. s.
	Months	45.8913**	Months/Interaction	1.8073 n. s.
	Interaction	25.3913**		

$P_{0.05}$: $F_{(2)(60)} = 3.15$; $F_{(3)(60)} = 2.76$; $F_{(6)(60)} = 2.25$
$P_{0.01}$: $F_{(2)(60)} = 4.98$; $F_{(3)(60)} = 4.13$; $F_{(6)(60)} = 3.12$

$P_{0.10}$: $F_{(2)(6)} = 3.46$;
$F_{(3)(6)} = 3.29$
$P_{0.05}$: $F_{(2)(6)} = 5.14$;
$F_{(3)(6)} = 4.76$
$P_{0.01}$: $F_{(2)(6)} = 10.92$;
$F_{(3)(6)} = 9.78$

Analyses of meiofaunal data for the 40 cm water table revealed significant differences between sites and months based on a two-way anova (Table 5D). One-way anovas for sampling periods at each site (Table 6D) revealed that mean meiofaunal numbers were different. Analyses of sites for the sampling periods revealed the north and sewer sites had the highest meiofaunal means two out of four sampling periods (Table 7D).

Table 6. One-way anovas at each site. The source of variation is months.

A. Total meiofauna in 20-cm WWZ cores.

Site	*F ratio*
North	69.7637**
Sewer	239.2100**
South	38.1860**

B. Total meiofauna minus *Protodrilus* in 20-cm WWZ cores.

North	37.0611**
Sewer	80.2275**
South	35.8186**

C. Total meiofauna in 15-cm WWZ cores.

North	22.1539**
Sewer	160.1652**
South	32.6666**

Table 6. Cont'd.

D. Total meiofauna in 15-cm WT cores.	
North	9.2029**
Sewer	5771.0000**
South	30.7223**
E. Total meiofauna minus *Protodrilus* in 15-cm WWZ cores.	
North	19.9952**
Sewer	53.4809**
South	28.2305**
F. Total meiofauna minus *Protodrilus* in 15-cm WT cores.	
North	12.2690**
Sewer	9.3478**
South	11.9214**

* $P_{0.05} : F_{(3)(20)} = 3.10$ ** $P_{0.01} : F_{(3)(20)} = 4.94$

Comparisons of the two levels, the wave-wash zone and the water table, showed there were greater differences between sites and months at the water table than in the wave-wash zone (Table 5D); that mean meiofaunal numbers for each sampling period at the water table were different from those of the wave-wash zone (Table 6D); that, whereas the mean for the wave-wash zone sewer site was highest three out of four sampling periods, both the north and sewer sites had the highest mean two out of four sampling periods (Table 7D); and that the sites affected the levels differently most of the time (Table 8).

Table 7. One-way anovas for each sampling period. The source of variation is sites.

A. Total meiofauna in 20-cu WWZ cores.	
Month	*F ratio*
June	122.0607**
August	37.4375**
November	103.5163**
February	256.6790**
B. Total meiofauna minus *Protodrilus* in 20-cm WWZ cores.	
June	21.3181**
August	95.8571**
November	4.3897*
February	94.3005**
C. Total meiofauna in 15-cm WWZ cores.	
June	139.5593**
August	42.0168**
November	28.9761**
February	107.7462**
D. Total meiofauna in 15-cm WT cores.	
June	7.0849**
August	6.4803**
November	68.4230**
February	105.9812**

Tabela 7. Cont'd.

E. Total meiofauna minus *Protodrilus* in 15-cm WWZ cores.	
June	84.2700**
August	39.5646**
November	7.5603**
February	117.0337**
F. Total meiofauna minus *Protodrilus* in 15- cm WT cores.	
June	0.2543 n. s.
August	1.9937 n. s.
November	8.0970**
February	102.3027**

* $P_{0.05} : F_{(2)\ (15)} = 3.68$ ** $P_{0.01} : F_{(2)\ (15)} = 6.36$

Analyses of sites vs. months for total meiofauna minus *Protodrilus* for the water table (Table 5F) showed that the differences in sites and months were smaller than for the total meiofauna but the interaction was higher. One-way anovas for sites showed that all were significantly different (Table 6F). Similar analyses for each sampling period (Table 7F) showed that the effect of removing *Protodrilus* altered the relative abundance of meiofauna at the three sites and reduced the differences between sites for June and August.

Table 8. Two-way anovas of sites vs. levels for each sampling period.

	Source of Variation	*F ratio*	*Modified F ratio*	
Total in 15-cm cores — June	Levels	370.9980**	Levels/Interaction	14.2440
	Sites	74.9438**	Sites/Interaction	2.8774
	Interaction			
Total in 15-cm cores — August	Levels	6.1375 n. s.		
	Sites	10.4594**		
	Interaction	11.2959**		
Total in 15-cm cores — November	Levels	67.4524**		
	Sites	39.3549**		
	Interaction	48.2090**		
Total in 15-cm cores — February	Levels	720.1962**	Levels/Interaction	59.1236*
	Sites	194.6270**	Months/Interaction	15.9777
	Interaction	12.1812**		

$P_{0.05} : F_{(1)\ (30)} = 4.17;\ F_{(2)\ (30)} = 3.32$ $P_{0.10} : F_{(1)\ (2)} = 8.53;\ F_{(2)\ (2)} = 9.00$

$P_{0.01} : F_{(1)\ (30)} = 7.56;\ F_{(2)\ (30)} = 5.39$ $P_{0.05} : F_{(1)\ (2)} = 18.51;\ F_{(2)\ (2)} = 19.00$

$P_{0.01} : F_{(1)\ (2)} = 98.49;\ F_{(2)\ (2)} = 99.00$

The data for Khalde beach were compared to that for Sindbad beach obtained by Hulings (1974). Sindbad beach, located 32 km south of Beirut, is a nonsewage-polluted exposed sandy beach of well-sorted medium sand. Sampling at Sindbad beach was done at one area during June and August in the same manner as at Khalde with the exception that the cores were taken to a depth of 10 cm. For comparison, only the top 10 cm of the Khalde samples are considered here. The analyses (Tables 9 and 10) showed that for both the wave-wash zone and the 40 cm water table for June and August there was more total meiofauna at each of the three Khalde sites than at Sindbad. By removing *Protodrilus* there was still more meiofauna at Khalde than at Sindbad. The results of the two-way anova for sites and levels minus *Protodrilus* (a very minor component of the meiofauna at Sindbad beach) revealed (Table 9) that the differences between sites did not reflect the dominance of *Protodrilus* and that the differences between sites were more meaningful than the differences between levels.

Table 9. Two-way anovas of sites vs. levels for meiofauna in 10-cm cores from Khalde and Sindbad beaches.

	Source of Variation	*F ratio*	*Modified F ratio*	
Total — June	Levels	357.9980**	Levels/Interaction	12.5790**
	Sites	386.2050**	Sites/Interaction	13.5700**
	Interaction	28.4600**		
Total — August	Levels	0.0446 n. s.		
	Sites	12.4104**		
	Interaction	0.8913 n. s.		
Total minus *Protodrilus* — June	Levels	276.3000**	Levels/Interaction	12.2015*
	Sites	260.4140**	Sites/Interaction	11.8822*
	Interaction	21.9070**		
Total minus *Protodrilus* — August	Levels	0.2689 n. s.		
	Sites	11.1346**		
	Interaction	3.2386*		

$P_{0.05} : F_{(1)(40)} = 4.08;\ F_{(3)(40)} = 2.84$ $P_{0.05} : F_{(1)(3)} = 10.15;\ F_{(3)(3)} = 9.28$

$P_{0.01} : F_{(1)(40)} = 7.31;\ F_{(3)(40)} = 4.31$ $P_{0.01} : F_{(1)(3)} = 34.12;\ F_{(3)(3)} = 29.46$

Table 10. One-way anovas of 10 cm cores from Khalde and Sindbad beaches. The source of variation is sites.

Month	*Zone*	*F ratio*
June	WWZ	27.5742**
August	WWZ	3.4763**
November	WT	124.7206**
February	WT	35.6845**

$P_{0.05} : F_{(3)(20)} = 3.10$ $P_{0.01} : F_{(3)(20)} = 4.94$

DISCUSSION

Several factors related to beach dynamics are of importance in this study. According to Emery and George (1963) the prevailing currents along the coast of Lebanon are from south to north. Inshore, this pattern may be reversed or negated during periods of storms, which normally occur during the winter. Reversal of current flow was indicated by bacteriological coliform data in which the south site had higher numbers of coliforms than the north site in November.

Since Khalde beach is open, tideless, and fully exposed to wave action, the profile of the beach and the landward penetration of marine water are extremely variable. Because of the very steep profile of the continental shelf off the coast of Lebanon, waves reach the beach with high energy. Thus wave action is a dominant physical force that can alter many aspects of the beach in a short period of time. Water circulation in a sand beach is, obviously, an important physical environmental parameter. Delamare Deboutteville (1960) has proposed a model for circulation on a tideless beach, including inflow of continental ground water and input from the marine environment. This model appears valid for Khalde beach. Steele, Munro and Giese (1970) and Riedl and Machan (1972) have emphasized the importance of wave action in the circulation of marine water in beaches. Based on studies of interstitial water chemistry of several beaches in Lebanon conducted by Makemson (1973), freshwater or water of very low salinity was often found at 10 m landward of the wave-wash zone, depending on the profile of the beach. Interstitial salinities in the wave-wash zone, however, were close to those of the inflowing marine water. Oxygen content of the interstitial water 10 m landward of the wave-wash zone was significantly less than that of the wave-wash zone. It is important to point out, however, that the above pattern can be significantly altered through wave action.

Fenchel and Riedl (1970) have discussed the occurrence of a »sulfide system« or reducing layer on sand beaches, reporting that such occurrences are common on protected beaches. Given the high organic input via sewage onto Khalde beach (unofficial estimate, 700 L/sec), it might be expected that such a system would be encountered, at least landward of the beach. This was not the case; at least a readily identifiable reducing layer was not detected at the water table level. It would appear that through a combination of wave action and medium grained, well-sorted sand at both levels and the nearness of the water table to the wave-wash zone (usually less than 5 m), the circulation pattern in the beach is such that organic matter does not accumulate in sufficient quantities to result in reducing conditions. The utilization of the organic matter by bacteria and meiofauna may also be a significant factor in the absence of a reducing layer. The high density of the meiofauna at the water table at certain sampling periods, however, was such to suggest a significant input of organic matter.

A difference in environmental stability between the wave-wash zone and the water table is proposed. The wave-wash zone is considered more stable because of more constancy in salinity, oxygen (based on measurements by Makemson (1973) and organic input (not measured). The water table, in contrast, is considered more unstable because of variable salinity, oxygen and organic input.

Environmental parameters such as salinity, temperature, and granulometry have been emphasized by previous investigators as influencing the distribution of meiofauna (Swedmark, 1964; McIntyre, 1969; Jansson, 1971; Pollack, 1971). Only limited data were available in this study and these parametres and total meiofauna as compared by the Kendall-Tau Technique showed no correlation. The lack of correlation may be due to the level at which correlation was attempted, or may be because the parameters mesaured were not directly related to productivity resulting from organic input. Results obtained from other studies indicate the importance of organic input in controlling meiofaunal density (Hulings, 1974). A range comparison of total wave-wash zone meiofaunal densities was 489 to 2907 specimens from Sindbad beach (Hulings, 1974) and 2479 to 37,023 specimens for Khalde beach. The range at the water table was 46 to 924 specimens for Sindbad beach and 395 to 13,853 for Khalde beach. All totals were based on 10-cm cores. Makemson (1973) found values of ammonia (μg at NH_3-N/L) in the wave-wash zone at Khalde beach to be 20 to 25 whereas at Sindbad, < 0.1. Phosphate concentrations at Khalde were between 3 and 6 μg at PO_4-P/L and < 0.1 to 1.0 at Sindbad. Protein values (based on Lowry determinations) were 269 μg/g wet sand at Khlade and 130 at Sindbad. Data from a bacteriological investigation of Sindbad (Khiyama, 1972; Khiyama and Makemson, 1973) for viable bacteria per gram of sand for August show numbers up to an order magnitude lower than those found at Khalde. Given the fact that the beach studied by Hulings and the one reported on here are open marine, and fully exposed to wave action, tideless, essentially of the same temperature and salinity variation and granulometry, essentially the same meiofauna, the only noticeable difference was the presence or absence of organic enrichment, resulting, in the case of Khalde beach, in a very significant increase in meiofaunal density.

The results of the various anovas for Khalde beach show statistically significant differences in the mean meiofaunal numbers for sites, months, and levels. Table 11 shows the means and the least significant differences between the means.

For the wave-wash zone, all sites do not have the same monthly sequence if the means are considered in decreasing magnitude (Table 11A). Thus for all sites there is no seasonal pattern in terms of meiofauna density.

The problem of determining a seasonal pattern for each site is complicated by spatial and temporal variation in meiofaunal distribution. In England, Gray and Rieger (1971) sampled three different sites on one beach during one day and two different sites on another beach in one day. On both beaches, they found that the sites were different. Hulings (1971) sampled the same two sites on one beach in Tunisia three times over a period of ten days. Again, differences in sites were found. It was concluded by Hulings that the meiofauna density was significantly different in the areas (sites) at different times of sampling and that there were significant differences in numbers of total meiofauna with time. According to Gray and Rieger (1971), much of the variation in meiofaunal numbers has been reported to be due to the »clumped« distribution of the meiofauna. Gray and Rieger found that their major groups of meiofauna exhibited a highly contagious distribution. Calculations of the index of dispersion for total meiofauna at Khalde beach (Table 12) show the same result.

If each month is considered separately, (Table 11A), there is an obvious consistency in that the sewer site was highest 3 out of 4 times and the south site was lowest 3 aut of 4 times. Assuming that meiofaunal density was a function of organic input, the sewer and north sites consistently receive a greater amount of sewage than the south site. This reflects the distribution of sewage relative to currents and wave action.

Table 11. Log_{10} means and least significant differences (LSD).

A. Total meiofauna in 15-cm WWZ cores at each site.					
		Log_{10}			LSD
	North	Sewer	South	$t_{0.05}$	$t_{0.01}$
June	3.3981	3.6515	2.9365	0.0926	0.1281
August	3.1328	3.5879	3.1993	0.2676	0.3701
November	3.7401	2.8486	3.1993	0.2510	0.3471
February	3.9331	4.1973	3.2565	0.1412	0.1953
LSD $t_{0.05}$*	0.2225	0.1284	0.1232		
$t_{0.01}$**	0.3035	0.1752	0.1681		
B. Total meiofauna in 15-cm WT cores at each site.					
June	2.7995	2.7646	2.5906	0.1259	0.1741
August	3.2204	3.4553	2.9868	0.2772	0.3834
November	2.9678	3.0958	2.6017	0.0886	0.1226
February	3.0610	2.8472	1.9364	0.1748	0.2418
*	0.1706	0.0120	0.2363		
**	0.2327	0.0165	0.3155		
C. Total meiofauna minus *Protodrilus* in 15-cm WWZ cores at each site.					
June	3.1857	3.6439	2.9011	0.1202	0.1663
August	2.6291	3.3745	3.4079	0.2110	0.2918
November	2.5841	2.8372	2.5368	0.1771	0.2449
February	2.2429	3.4165	2.7368	0.1637	0.2263
*	0.2378	0.1383	0.2065		
**	0.01743	0.1886	0.2816		
D. Total meiofauna minus *Protodrilus* in 15-cm WT cores at each site.					
June	2.6640	2.7376	2.8104	0.4366	0.6038
August	3.1616	3.2603	2.9640	0.3109	0.4300
November	2.9615	2.7226	2.4725	0.2589	0.2694
February	3.0526	2.8170	1.8202	0.1948	0.2694
*	0.1798	0.2451	0.4360		
**	0.2452	0.3343	0.5946		

Table 12. Indices of dispersion (I) for the total meiofauna (n-1 = 5).

A. WWZ Month	North	Sewer Site	South
June	224	670	141
August	229	601	618
November	10040	234	8701
February	10596	5704	1213
B. WT Month		Site	
	North	Sewer	South
June	130	12480	5450
August	1456	1839	1171
November	3617	612	363
February	511	174	125

$P_{0.05} = 11.07$; $P_{0.01} = 15.09$

As for the wave wash zone, at the water table the sites were significantly different (Table 11B). There is a degree of seasonality in that August had the highest meiofaunal densities at the three sites, but the pattern was by no means consistent. If each month is considered separately, the conclusions are the same as for the wave-wash zone. In addition, it is postulated that there was organic input into the water table, indicated by the consistently high meiofaunal densities at the north and sewer sites.

In considering months, there are no conclusions other than those for sites. The interrelationship of months and sites causes a high statistical interaction. The reason for this is that the entities of »month« and »sites« are not mutually exclusive with respect to many environmental parameters. Even if the only significant parameter is organic input, it may be varying from site to site due to distribution, and from month to month also due to distribution by currents and circulation within the beach.

A comparison of sites, wave-wash zone and water table, showed that there was more difference among sites at the water table than in the wave-wash zone. This supports the hypothesis that the water table is a much more variable environment than the wave-wash zone. The general lower meiofaunal densities in the water table compared to the wave-wash zone indicate reduced organic input although organic content was not measured during this study. A subsequent study by Makemson (1973) supports this conclusion. The nutrient (interstitial water) and protein concentrations (sediment) in the wave-wash zone and at a site 10 cm back from the wave-wash zone were: ammonia (μg at NH_3-N/L), 20 to 25 in the wave-wash zone, $<$ 0.1 to 2.5 at 10 m back from the wave-wash zone; phosphate (μg at PO_4-P/L), 3 to 6 and 1.3 to 1.8; protein, 169 μg/g wet sand and 54. The sampling at the 40 cm water table was approximately 5 m back from the wave wash zone instead of 10 m.

The large numbers of *Protodrilus* of Khalde beach suggested that the analyses may have been reflecting its numerical dominance, and raised questions about the distributional relationships of the rest of the meiofauna. In the wave-wash zone, removal of *Protodrilus* resulted in high interaction between sites and months, but less interaction than for total meiofauna. This result was expected since, according to Swedmark (1964), *Protodrilus* is a detritus feeder. Therefore, removal of a component directly related to organic input would tend to lower interaction. Thus the presence of *Protodrilus* in such high densities in the wave-wash zone reflected its role in the community and suggested that it was an opportunist species in an environment such as Khalde beach. This idea is supported by the low densities and sporadic presence of *Protodrilus* at Sindbad beach (Hulings, 1974).

If the sites are considered separately with respect to months for total meiofauna minus *Protodrilus* in the wave-wash zone, there is a degree of consistency. The mean meiofaunal numbers for June and August were higher for all three sites than for February and November (Table 11C). For the total meiofauna (including *Protodrilus*), however, there was no consistent pattern whatsoever, and it was concluded that there was no seasonality. By eliminating *Protodrilus*, a seasonal pattern in density appeared to exist.

Analyses of sites for each month minus *Protodrilus* in the wave-wash zone showed the sewer site to have the highest numbers for all sampling periods. These results tend to support the previous conclusion that the sewer and north sites receive the highest organic input. Instances of no difference among the order of the sites as well as reversals in relative densities could occur if *Protodrilus* were or were not dominant. Such occurrences, therefore, do not inconclusively support the dominance of *Protodrilus*.

The pattern at the water table was less clear-cut due to the heterogeneity of the water table as a habitat compared to the wave-wash zone and the generally lower densities of *Protodrilus* in the water table than in the wave-wash zone. Studies by Gray (1965, 1966a, b) suggest that the water table may not be a suitable environment for another species of *Protodrilus*. The anova for sites vs. months showed a greater difference between sites for total meiofauna than for meiofauna minus *Protodrilus*, indicating that on an overall level, in spite of varying months and interaction, *Protodrilus* does have a relationship with sites. As for total meiofauna, removal of *Protodrilus* at the water table at each site (Table 11D) resulted in an indication of seasonality with mean meiofaunal numbers highest in August. Here the effect of *Protodrilus* was shown only by changes in the significance between months other than August.

If months are examined separately after removal of *Protodrilus* (Table 11D) the differences between sites for February remained the same as for total meiofauna, while the differences between sites for the other months have become less significant by removal of *Protodrilus*. This may mean that *Protodrilus* densities reflect differences in organic input at the sites at the water table more strongly than the rest of the meiofauna.

Much emphasis has been placed on the relationship of *Protodrilus* to the rest of the meiofauna; in fact, *Protodrilus* was not always the dominant component. The approach seems to be justified, however, since only one species, *Protodrilus similis* Jouin, was present whereas the other dominant groups, Nematoda and Harpacticoida, consisted of several species. Thus within the framework of the above qualifications, *Protodrilus* was an important component of the meiofauna influencing interpretation of wave-wash zone data, and was an opportunist species. The effect of *Protodrilus* densities at the water table was less clear, perhaps because the water table was a less suitable habitat for *Protodrilus*.

Anovas comparing meiofaunal densities at Khalde beach with those for Sindbad beach for August (a peak month in Sindbad densities) and June (a low month in Sindbad densities) show that the meiofaunal densities at Khalde beach were significantly higher than those for Sindbad beach. This was true for the wave-wash zone and the water table and for total meiofauna at Khalde beach and meiofauna minus *Protodrilus* at Khalde beach. Although three sites were sampled at Khalde beach, and only one at Sindbad beach, there was less difference among Khalde beach sites than between Khalde beach and Sindbad beach and both at water table and in the wave-wash zone.

Hulings (1974) has found, based on monthly sampling of one site over a ten-month period (November 1970 to September 1971), two definitive seasonal peaks in mean meiofaunal density in the wave-wash zone at Sindbad beach. These peaks were March-April-May and August-September-November. Essentially the same peaks occurred in the water table but the mean meiofaunal density was much less. Presumably, in the absence of sewage, the only source of organic input into Sindbad beach is from the coastal waters. Lakkis (1971) has reported similar seasonal peaks for the zooplankton in Lebanese coastal waters. In the case of the wave-wash zone at Khalde beach there was no seasonality. At the water table there was a slight indication of seasonality in that the mean meiofaunal density for the three sites was highest in August. Although species identifications for Khalde meiofauna were incomplete at the time of this study, subsequent preliminary analyses of the taxa at Khalde at the same level as for Sindbad have revealed no definitive trends or patterns for Khalde as was found of Sindbad by Hulings (1974). It is suggested, therefore, that the continuous high organic input was masking seasonality at Khalde beach.

This study demonstrates the effects of sewage on sand beach meiofauna. The effects include increased meiofaunal density and no obvious seasonal pattern. It is proposed that continual input of organic matter via sewage permits the meiofaunal community to maintain itself at a high, relatively constant density.

The input of sewage into Khalde beach is not sufficient to alter community structure although it has been proposed that at least one »opportunistic species«, *Protodrilus similis,* is present. That sewage input has an effect in altering community structure of the rocky beach at Khalde is evident. Basson, Hardy and Lakkis (1975) conducted a study of the effect of pollution on marine macroalgae along the Lebanese coast. Their results showed a marked reduction in algal biomass and a reduction in species diversity. They attributed this to high levels of nutrients (NO_3 and PO_4) at the Khalde sewer. By comparison, rocky beaches in unpolluted areas south of Khalde had high species diversity, up to 26 species. But, in the case of the sand beach meiofauna community at Khalde, the same species are present as at Sindbad beach, an unpolluted beach. Thus there are no apparent differences in species diversity between the two beaches.

The question arises as to whether or not sewage input into a sand beach will alter community structure and/or species diversity. It must be kept in mind that the beach studied is in the extreme Eastern Mediterranean, a region of very low productivity to begin with. In the case of Khalde beach, with an outfall located within 70 m of the beach and a discharge of 700 L/sec, the effect on the sand beach community is not the same as observed on the rocky beach community at Khalde or reported by others on hard and soft bottom macrobenthic communities (reviewed by Pérès and Bellan, 1970). This does not rule out the possibility that the sewage input into Khalde beach is not sufficiently high to have a negative effect such as altering species diversity. On the other hand, the fact that a sand beach is a giant filtering system and that the meiofauna community is composed of a large number of mobile detritus feeding species, has to be considered.

SUMMARY

The density of the meiofauna at Khalde beach, a sewage-polluted beach, was from 1 to 2 orders of magnitude greater than that of Sindbad beach, an unpolluted beach. This difference in density was attributed to organic input via sewage.

The frequent high density of *Protodrilus similis* Jouin, a detritus-feeding archiannelid, at Khalde beach indicated that it was an opportunist species in a sewage polluted beach. There were no significant differences in species diversity between Khalde and Sindbad beaches.

There was no seasonal pattern in total meiofaunal density in the wave-wash zone at Khalde beach. There was an indication of seasonality at the water table but the pattern was not consistent. Sindbad beach exhibited spring and autumn peaks in meiofaunal density. The lack of seasonality in the Khalde beach wave-wash zone for the total meiofauna was attributed to continuous high organic input. The indistinct seasonality at the water table for the total meiofauna suggested reduced organic input.

The high meiofaunal density in the wave-wash zone and the low density at the water table of Khalde beach were attributed to differences in organic input and the heterogeneity of the environment at the water table.

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REFERENCES

Delamare Deboutteville, C. 1960. Biologie des eaux souterraines littorales et continentales. Hermann, Paris, 740 p.

Emery, K. O. and C. J. George. 1963. The shores of Lebanon. Amer. Univ. Beirut Misc. Papers Nat. Sci., No. *1*, pp. 1—10.

Fenchel, T. 1969. The ecology of marine microbenthos. IV. Structure and function of the benthic ecosystem, its chemical and physical factors and the microfauna communities with special reference to the ciliated protoza. Ophelia, *6*, pp. 1—182.

Fenchel, T. and R. J. Riedl. 1970. The sulfide system: a new biotic community underneath the oxidized layer of marine sand bottoms. Mar, Biol., *7*, pp. 255—268.

Folk, R. L. 1968. Petrology of sedimentary rocks. Hemphills, Austin, Texas, 170 p.

George, C. J., V. A. Athanassiou and I. Boulos. 1964. The fishes of the coastal waters of Lebanon. Amer. Univ. Beirut. Mics. Papers Nat. Sci., No. *4,* pp. 1—27.

Gray, J. S. 1965. The behaviour of *Protodrilus symbioticus* (Giard) in temperature gradients. J. Anim. Ecol., *34,* pp. 455—461.

Gray, J. 1966a. Factors controlling the localizations of populations of *Protodrilus symbioticus* Giard. J. Anim. Ecol., *35,* pp. 435—442.

Gray, J. 1966b. The attractive factor of intertidal sands to *Protodrilus symbiotics.* J. Mar. Biol. Ass. U. K., *46,* pp. 627—645.

Gray, J. and R. M. Rieger. 1971. A quantitative study of the meiofauna of an exposed sandy beach, at Robin Hood's Bay, Yorkshire. J. Mar. Biol. Ass. U. K., *51,* pp. 1—19.

Gray, J. and R. J. Ventilla. 1971. Pollution effects on micro- and meiofauna of sand. Mar. Poll. Bull., *2* (3), pp. 39—43.

Hulings, N. C. 1971. A quantitative study of the sand beach meiofauna in Tunisia. Bull. Inst. Oceanogr. Pêche, Salammbô, *2* (2), pp. 139—158.

Hulings, N. C. 1974. A temporal study of Lebanese sand beach meiofauna. Cah. Biol. Mar., *15,* pp. 319—335.

Hulings, N. C. and J. S. Gray. 1971. A manual for the study of meiofauna. Smithsonian Contr. Zool., No. 78. 84 p.

Jansson, B. O. 1971. The »Umwelt« of the interstitial fauna. *In:* Proceedings of the First International Conference on Meiofauna, pp. 129—140. Ed. by N. C. Hulings. Smithsonian Contr. Zool., No. 76.

Khiyama, H. 1972. Bacterial populations of a Lebanese sandy beach. M. S. Thesis, American University of Beirut.

Khiyama, H. and J. C. Makemson. 1973. Sand beach bacteria: enumeration and characterization. Appld. Microbiol., *26* (3), pp. 293—297.

Lakkis, S. 1971. Contribution à l'étude du zooplancton des eaux Libanaises. Mar. Biol., *11* (2), pp. 138—148.

Makemson, J. 1972. An interstitial water sampler for sandy beaches. Limnol. Oceanogr., *17,* pp. 626—628.

Makemson, J. 1973. Oxygen and carbon dioxide in interstitial water of two Lebanese sand beaches. Neth. J. Sea Res., *7,* pp. 223—232.

McIntyre, A. D. 1969. Ecology of marine meiobenthos. Biol. Rev., *44,* pp. 245—290.

Oliff, W. D., C. D. Berrisford, W. D. Turner, J. A. Ballard and C. D. McWilliam. 1967. The ecology and chemistry of sandy beaches and nearshore submarine sediments of Natal. 1. Pollution criteria for sandy beaches in Natal. Wat. Res., *1,* pp. 115—129.

O'Sullivan, A. J. 1971. Ecological effects of sewage discharge in the marine environment. Proc. Roy. Soc. London, ser. B., *177,* pp. 331—351.

Pérès, J. M. and G. Bellan, 1970. Aperçu sur l'influence des pollutions sur les peuplements benthiques. FAO Tech. Conf. on Marine Pollution and its Effects on Living Resources and Fishing, Rome, Italy, 9—18 December 1970, FIR: MP/70/R-33, 25 p.

Pollock, L. W. 1971. Ecology of intertidal meiobenthos. In: Proceedings of the First international Conference on Meiofauna, pp. 141—148. Ed. by N. C. Hulings. Smithsonian Contr. Zool., No. 76.

Riedl, R. J. and R. Machan. 1972. Hydrodynamic patterns in lotic intertidal sands and their bioclimatological implications. Mar. Biol., *13,* pp. 179—209.

Simpson, G. G., A. Roe and R. C. Lewontin. 1960. Quantitative zoology. Harcourt, Brace and Co., New York, 440 p.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman, San Francisco, 776 p.

Steele, J. H., A. L. S. Munro and G. S. Giese. 1970. Environmental factors controlling the epipsammic flora on beach and sublittoral sands. J. Mar. Biol. Ass. U. K., *50,* pp. 907—918.

Swedmark, B. 1964. The interstitial fauna of marine sand. Biol. Rev., *39,* pp. 1—42.

STUDIJ PROSTORNE RASPODJELE MEIOFAUNE NA LIBANONSKIM PJEŠČANIM PLAŽAMA ZAGAĐENIM KANALIZACIONIM VODAMA

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KRATAK SADRŽAJ

Gustoća meiofaune na pješčanoj plaži Khalde, koja je pod utjecajem kanalizacijskih otpadnih voda, je za jedan do dva reda veličine veća nego na pješčanoj plaži Sindbad, koja nije zagađena. Smatra se da je ta razlika nastala zbog unošenja organske tvari putem kanalizacije.

Često nađena velika gustoća *Protodrilus similis* Jonin, potrošača detritusa, na obali Khalde ukazuje da je to vrsta prilagođena kanalizacijskom zagađenju. Različitost vrsta na dvije istražene obale nije značajna.

Materijal je sakupljen u dvije zone: u zoni oplakivanja valova (WWZ), u kojoj je površina pjeska 90% vremena zasićena vodom, i u zoni udaljenijoj od mora, u kojoj je razina mora na 40 cm dubine (WT).

Gustoća ukupne meiofaune u zoni WWZ na plaži Khalde nije pokazivala sezonske razlike, dok se u zoni WT one nejasno pokazuju. Na plaži Sindbad je nađen proljetni i jesenski maksimum gustoće meiofaune. Smatra se da trajan donos organske materije na obali Khalde uzrokuje otsutnost sezonskog kolebanja. Nejasno sezonsko kolebanje ukupne meiofaune u zoni WT ukazuje na smanjeni donos organske tvari.

Velika gustoća meiofaune u zoni WWZ i mala gustoća u zoni WT plaže Khalde pripisana je različitom donosu organske tvari i heterogenosti sredine u zoni WT.