A TEMPORAL STUDY OF LEBANESE SAND BEACH MEIOFAUNA

by

Neil **C.** Hulings

Faculty of **Science, University of Jordan,** Amman, Jordan.

Résumé

Variation **dans** le **temps** de la méiofaune d'une plage de sable libanaise.

Une étude quantitative d'une durée de dix mois, sur une plage de sable du Liban, avec emploi de méthodes statistiques, **a** révélé la présence de maximums saisonniers dans l'abondance de la méiofaune. Pour la totalité de la méiofaune, les maximums exprimés en densité numérique sont obtenus en mars-avril-mai et août-septembre-novembre.

Les groupes, pris individuellement, montrent des maximums saisonniers, **y** compris ceux de la zone de ressac. Les Epsilonimidés, *Hesionides arenaria, Petita* ***amphophthalma*** et les Ostracodes accusent deux maximums tandis que, dans cette même zone, les Turbellariés, les Gastrotriches, les Nématodes et les Oligochètes en présentent un seul.

Au niveau de la nappe d'eau, **à 40** cm, les groupes suivants **:** Epsilonimidés, Opisthobranches, Mystacocarides et Halacariens montrent deux maximums. **Dans** ces trois derniers groupes, la variation est limitée **à** la nappe d'eau **à** ce même niveau. Les Turbellariés, les Gastrotriches, ***Hesionides arenaria*** et ***Petita amphophthalma*** présentent un seul maximum. Les Harpacticides ne montrent aucune variation saisonnière.

Introduction

There is little quantitative data on the sand beach meiofauna of the southern and eastern parts of the Mediterranean and even less data on seasonality. Delamare Deboutteville (1953 a, b) conducted faunal surveys of several beaches in Tunisia and Algeria in november and december, 1952. More recently, Masry (1970 a, b) reported on studies conducted along the coast of Israel, the results of which are semi-quantitative and with little information on seasonality. Hulings (1971, 1972) has reported on quantitative studies conducted in Morocco, Tunisia and Lebanon, the emphasis being on absolute numerical density and community structure. Gowing (1972) investigated the spatial distribution of meiofauna on a Lebanese sewage-polluted sand beach. Studies on specific taxa include those of Por (1964, 1969), Masry (1970 a, b) and Masry and Por (1970) on the Harpacticoida, Isopoda, and Mystacocarida. Westheide (1970, 1971) and Westheide and Bunke (1970) have reported on the interstitial Polychaeta, Archiannelida and Oligochaeta from sand beaches in Tunisia.

This paper is a report on a quantitative, temporal, statistically designed study conducted on one Lebanese beach over a period of

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ten months. The results of the study show for the first time the seasonality, expressed in terms of density, of sand beach meiofauna in the southern and eastern parts of the Mediterranean Sea.

Materials and methods

The beach studied is locally known as Sindbad Beach and is located 32 km south of Beirut between Ouadi ez Zeini and Ras es Sakhre. The beach is 1.4 km long and has an average width of about 120 m. The beach is almost (less than 60 cm range) tideless, open marine and fully exposed to wave action.

Monthly sampling was conducted over a period of 10 months from november, 1970 through September, 1971 (data are lacking for december, 1970). Two sites on the beach were sampled each month, the wave-wash zone and a point landward of the wave-wash zone where the water table was 40 cm below the surface of the beach. The point in the wave-wash zone was about midway between where waves actually broke and the highest point reached by the surging waves.

At each site on the beach, six 10 cm deep, 4.4 cm diameter cores were taken with a plastic tube from within 0.25 m^2 frame divided into 16 equal squares. The squares to be sampled, numbered 1 through 16, were chosen by using random number tables. Each core was divided into 0 to 5 and 5 to 10 cm intervals and placed in separate containers for faunal analysis. Temperature measurements were made with an ordinary bulb thermometer by inserting it 2 cm into the sand; water samples were collected for conductivity measurements using the Electronic Switchgear Conductivity Meter (Type MCI Mkv). Conductivity was converted to salinity against a standard NaCl curve. Following extraction of the meiofauna, the sand from one core at each site was used for grain size analysis at 0.5 Ø intervals from 0.5 to 3.0 Ø. The sieving was done on a Ro Tap machine for 15 minutes. The graphic mean (M_z) and the inclusive standard deviation (σ I) of Folk (1968) were determined. Table 1 gives the salinity, temperature and granulometric data.

TABLE 1

Monthly salinity, temperature, graphic mean **(M_z) and** inclusive standard deviation ***(σ* I) for** the wave-wash zone **(WWZ)** and **40** cm water table **(WT)** at Sindbad beach.

	WWZ				WWZ			
	Salinity	Température (°C)	M_z	σ I	Salinity	Température (°C)	M.	cI
november	—	23	1.71	0.39	—	—	1.61	0.46
january	33	18	1.38	0.35	24	18	1.49	0.40
february	33	18	1.75	0.39	34	18	1.44	0.36
march	33	17	1.31	0.44	33	17	1.45	0.35
april	29	20	1.25	0.47	34	19	1.02	0.39
may	33	22	1.58	0.37	29	19	1.17	0.38
june	38	26	1.21	0.35	38	28	1.38	0.44
july	38	29	1.43	0.33	38	29	1.42	0.38
august	39	29	1.85	0.39	10	29	1.27	0.38
September	—	—	1.34	0.40	—	—	1.67	0.29

For the samples collected from november through july the fauna was extracted following the technique of Gray and Reiger (1971) and subsequently used by Hulings (1971). This extraction method, using isotonic $MgCl_2$ followed by 10 percent ethyl alcohol, yields almost 100 percent of the fauna whereas the use of only $MgCl_2$ or 10 percent ethyl alcohol yields less than 100 percent efficiency depending on the taxon. The august and September samples were preserved with 5 percent buffered formalin within two hours after collection and extracted with 3 washes in a large beaker, the fauna being concentrated in a 62-micron net.

TABLE 2

Mean and variance for total wave-wash zone and water table meiofauna.

A. Raw data

Month	Wave-Wash Zone Mean	Variance
june	82	1101
july	85	1774
february	90	738
january	90	919
april	186	6459
november	239	235
may	294	3459
march	341	21764
august	459	4492
September	484	98817

Month	Water Table Mean	Variance
july	8	26
june	42	25
march	51	25
September	65	269
february	74	2252
november	92	206
august	108	2972
may	152	274
january	154	12990
april	155	213

B. Log_{10} transformed data

Month	Wave-Wash Zone Mean	Variance
july	1.8	0.0425
june	1.8890	0.0197
january	1.9301	0.0258
february	1.9390	0.0191
november	2.3758	0.0007
april	2.3765	0.0318
may	2.4608	0.0069
march	2.4768	0.0776
September	2.5920	0.1180
august	2.6574	0.0044

Month	Water Table Mean	Variance
july	0.7897	0.1581
june	1.6204	0.0771
march	1.7044	0.0700
february	1.8036	0.0680
September	1.8047	0.0104
november	1.8460	0.0258
january	2.0812	0.1201
august	2.1262	0.0706
may	2.1811	0.0760
april	2.1896	0.0717

For statistical analysis of the data, the one-and two-way analyses of variance with replication of Sokal and Rohlf (1969) was used. The raw faunal data were transformed to log_{10} to stabilize the variance. Table 2 shows the mean and variance for the raw data and the log_{10} transformed data. To avoid dealing with zero occurrence in the log_{10} transformation, one specimen was added to each core within each month, i.e., a total of six specimens for one month. Gray and Rieger (1971), Hulings (1971) and Gowing (1972) followed this method of statistical analysis for studies on sand beach meiofauna in England, Tunisia and Lebanon, respectively.

The one-way analysis of variance was used to analyze difference between months within each site, i.e., the wave-wash zone and at the 40 cm water table. The two-way analysis compared sites and months.

RESULTS

The extraction efficiency obtained using the combination of $MgCl_2$ and ethyl alcohol is shown in Table 3. Included is a comparison of the results obtained by Gray and Rieger (1971) and Hulings (1971).

TABLE 3
Extraction efficiency using $MgCl_2$ and ethyl alcohol.

	$MgCl_2$ Total Meiofauna	$MgCl_2$ Percent	Ethyl Alcohol Total Meiofauna	Ethyl Alcohol Percent
Sindbad beach	10833	86	1676	14
Hulings (1971) Tunisia	4140	57	3138	43
Gray and Rieger (1971) England	1905	59	1350	41

Table 4 shows the total number of specimens by taxon for the wave-wash zone and the 40 cm water table. The totals are the combined sum of six 4.4 cm diameter by 10 cm deep cores from each site. Species identification is not yet complete. Where the species is known, it is given in the discussion of seasonality.

Two-way analysis of variance comparing levels (wave-wash zone and water table) and months were conducted for the total fauna and for individual taxa. The results of these analyses are shown in Table 5 and briefly summarized below.

For the total meiofauna, the levels were significantly different at the 1 percent level as were the months. Using the modified F ratio, the levels over interaction were significantly different at 1 percent whereas months over interaction were not significant at either 1 or 5 percent.

For the Turbellaria, levels and months were both significant at 1 percent. Levels over interaction was significant at 5 percent; months over interaction significant at 1 percent. For the Nematoda (other than Epsilonemidae), Epsilonemidae and Ostracoda levels and months were significantly different at 1 percent as was levels over interaction but months over interaction was not significant. Levels and months were found to be significant at 1 percent for *Phallodrilus monospermathecus* (Knöllner) but neither levels over interaction nor months over interaction were significant. The Harpacticoida were significantly different between levels but not between months; neither levels or months over interaction were significant. For the Gastrotricha and Halacaridae levels were significantly different at 1 percent but months only at 5 percent; levels over interaction but not months over interaction were significant. Levels, months and levels over interaction were significant for *Hesionides arenaria* Friedrich but not months over interaction. Similar results were found for *Petita amphophthalma* Siewing except that levels over interaction was

TABLE 4

Monthly quantitative distribution of the meiofauna from the wave-wash zone (WWZ) and the 40 cm water table (WT) at Sindbad beach.

	nov		jan		feb		mar		apr		may		jun		july		aug		sept		
	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT	WWZ	WT	
Turbellaria	210	88	87	142	120	39	102	31	92	50	426	40	69	47	186	1	863	20	152	47	2812
Gastrotricha	0	0	13	8	17	0	4	1	36	19	6	2	1	0	0	0	145	0	13	0	265
Nematoda (1)	113	99	207	127	132	23	51	26	46	21	173	88	209	66	127	31	602	113	291	110	2655
Epsilonemidae	377	19	0	0	0	0	0	0	52	19	0	333	3	0	1	0	522	0	1751	158	3235
Entoprocta	0	0	0	0	0	0	0	0	0	0	27	9	13	36	30	4	0	0	0	0	119
Archiannelida	4	8	0	15	2	19	2	4	0	14	1	8	0	6	0	0	1	1	6	20	111
Hesionides	43	0	19	65	53	5	26	2	33	6	18	9	17	11	2	0	3	0	3	8	323
Petita	24	2	0	0	69	3	0	24	0	0	42	0	0	0	0	0	3	0	0	0	167
Oligochaeta	7	30	11	25	6	0	50	2	1	50	891	12	104	15	31	5	39	31	60	35	1405
Opisthobranchia	0	49	2	55	4	7		62		31	0	0	1	22		70		50		34	171
Mystacocarida	0	94	1	42	0	16	3	9	1	370	0	1	0	18	0	0	0	16	4	11	586
Ostracoda	0	0	30	2	0	0	1159	7	404	12	71	12	4	0	0	0	37	15	156	1	1910
Harpacticoida	669	151	159	421	203	315	544	165	425	298	187	390	24	17	117	5	558	75	503	120	5346
Halacaridae	13	17	3	16	0	6	12	53	19	56	0	9	1	8		10	4	701	4	8	931
Tardigrada	5	0	5	0	0	2	3	0	0	1	0	1	0	0		20	1	0	1	0	21
Total	1465	557	537	918	606	435	1962	326	1112	917	1842	914	446	246	504	46	2783	972	2947	522	20057

(1) Minus Epsilonemidae

TABLE 5

Two-way analysis of variance and modified F ratios on levels and months for taxa from Sindbad beach.

Taxon	Source of variation	F	Modified F	
Total fauna	Among levels	274.9821	Levels/Interaction	16.4366
	Among months	16.2454	Months/Interaction	0.9710
	Interaction	16.7298		
Turbellaria	Among levels	195.8208	Levels/Interaction	8.6333
	Among months	344.7849	Months/Interaction	15.2504
	Interaction	22.6819		
Gastrotricha	Among levels	47.9945	Levels/Interaction	13.1667
	Among months	2.2073	Months/Interaction	0.6055
	Interaction	3.6451		
Nematoda (Minus Epsilonemidae)	Among levels	142.2317	Levels/Interaction	24.6075
	Among months	14.1717	Months/Interaction	2.4519
	Interaction	5.7800		
Epsilonemidae	Among levels	1418.4690	Levels/Interaction	12.0192
	Among months	12.7835	Months/Interaction	0.1083
	Interaction	118.0171		
Hesionides	Among levels	125.3593	Levels/Interaction	11.5242
	Among months	6.4208	Months/Interaction	0.5903
	Interaction	10.8779		
Petita	Among levels	400.9774	Levels/Interaction	8.3292
	Among months	7.8871	Months/Interaction	0.1638
	Interaction	48.1412		
Oligochaeta	Among levels	121.9660	Levels/Interaction	0.5337
	Among months	3.6186	Months/Interaction	0.0158
	Interaction	228.5455		
Opisthobranchia	Among levels	97.2422	Levels/Interaction	5.4258
	Among months	3.2362	Months/Interaction	0.1806
	Interaction	17.9222		
Mystacocarida	Among levels	601.3626	Levels/Interaction	9.0215
	Among months	46.2070	Months/Interaction	0.6932
	Interaction	66.6591		
Ostracoda	Among levels	498.1358	Levels/Interaction	17.2000
	Among months	26.3908	Months/Interaction	0.9112
	Interaction	28.9613		
Harpacticoida	Among levels	12.0703	Levels/Interaction	3.2351
	Among months	1.2045	Months/Interaction	0.3228
	Interaction	3.7311		
Halacarida	Among levels	410.9750	Levels/Interaction	154.7729
	Among months	2.2326	Months/Interaction	0.8408
	Interaction	2.6553		

Levels

$P_{0.01}$ (1,100), F = 6.90
$P_{0.05}$ (1,100), F = 3.94

Months and Interaction

$P_{0.01}$ (9,100), F = 2.59
$P_{0.05}$ (9,100), F = 1.97

Levels/Interaction

$P_{0.01}$ (1,9), F = 10.56
$P_{0.05}$ (1,9), F = 5.12

Months/Interaction

$P_{0.01}$ (9,9), F = 5.35
$P_{0.05}$ (9,9), F = 3.18

significant at 5 percent. For the Opisthobranchia and Mystacocarida, levels and months were significant, levels over interaction significant at 5 percent and months over interaction were not significant.

The results of the one-way analysis of variance (Table 6) show that, with the exception of the Opisthobranchia and the Mystacocarida in the wave-wash zone, the differences between months were significant at 1 percent for all groups. The Mystacocarida were significant at 5 percent in the wave-wash zone. There were no significant differences between months for the Opisthobranchia in the wave-wash zone.

TABLE 6
One-way analysis of variance on beach levels for taxa from Sindbad beach.

Taxon	Beach Level	F ratio
Total	Wave-wash zone	15.3514
	Water table	31.3240
Turbellaria	Wave-wash zone	16.4060
	Water table	2.9712
Gastrotricha	Wave-wash zone	4.2332
	Water table	6.9776
Nematoda (minus Epsilonemidae)	Wave-wash zone	16.6024
	Water table	7.5244
Epsilonemidae	Wave-wash zone	170.5914
	Water table	8.9776
Hesionides	Wave-wash zone	18.1033
	Water table	8.5211
Petita	Wave-wash zone	62.6864
	Water table	16.7248
Oligochaeta	Wave-wash zone	26.9316
	Water table	7.9561
Opisthobranchia	Wave-wash zone	1.2263
	Water table	37.4999
Mystacocarida	Wave-wash zone	2.1384
	Water table	11.5381
Ostracoda	Wave-wash zone	55.4558
	Water table	9.3897
Harpacticoida	Wave-wash zone	6.6183
	Water table	11.2949
Halacaridae	Wave-wash zone	5.3704
	Water table	78.0163

$P_{0.01}$ (9,50), F = 2.78 $P_{0.05}$ (9,50), F = 2.07

SEASONALITY

Seasonality as used here refers to variations of abundance of specimens with time. Little data is available on juvenile forms of most of the taxa considered. What data is available, based on observation, is noted below when individual taxa are considered.

The seasonality is based on arranging the means in descending order from the greatest to the least. A shortcut analysis of variance (Tate and Clelland, 1957) giving an allowance factor (designated as AF below) was used to determine differences between means. Signifance is at the 5 percent level throughout.

Total Fauna - As can be seen from Fig. 1, there are essentially two peaks of abundance in the wave-wash zone, one during march-april-may and the other august-september-november (data for october are lacking). The seasonality at the water table is not as well defined but generally follows that of the wave-wash zone. Statistically, the shortcut analysis of variance confirms the seasonality in the wave-wash zone (AF = .3168), i.e., the means for the peaks are significantly different from the means of the lows which were january, february, june and july at the 5 percent level. For the water table, the only break at the 5 percent level is in july (AF = .2805) ; other means are not significantly different.

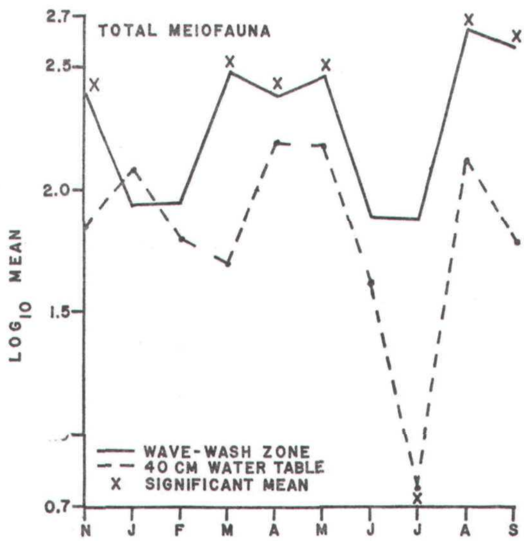

FIG. 1
Seasonal distribution **of** total meiofauna at Sindbad beach.

Turbellaria - Figure 2a shows the seasonality of the Turbellaria. In the wave-wash zone, the only statistically significant difference in the means is august (AF = .3443) ; all other means are not significantly different. For the water table, the only significant break is july (AF = .3258).

Gastrotricha - Figure 2b shows the monthly abundance with two peaks, one in each zone, statistically significant: august in the wave-wash zone (AF = .3630), april in the water table (AF = .1719).

Nematoda (other than Epsilonemidae) - As seen in Fig. 2c, the patterns for the wave-wash zone (AF = .3327) and the water table (AF = .3363) are similar in fluctuation except in august and September. The analysis of variance confirms the peak in august for the wave-wash zone; no other differences in means are significant.

Epsilonemidae - One of the most complex seasonal patterns is seen in this taxon. The peaks for the wave-wash zone as shown in Fig. 2d are august-september-november and april (AF = .2408). The presence

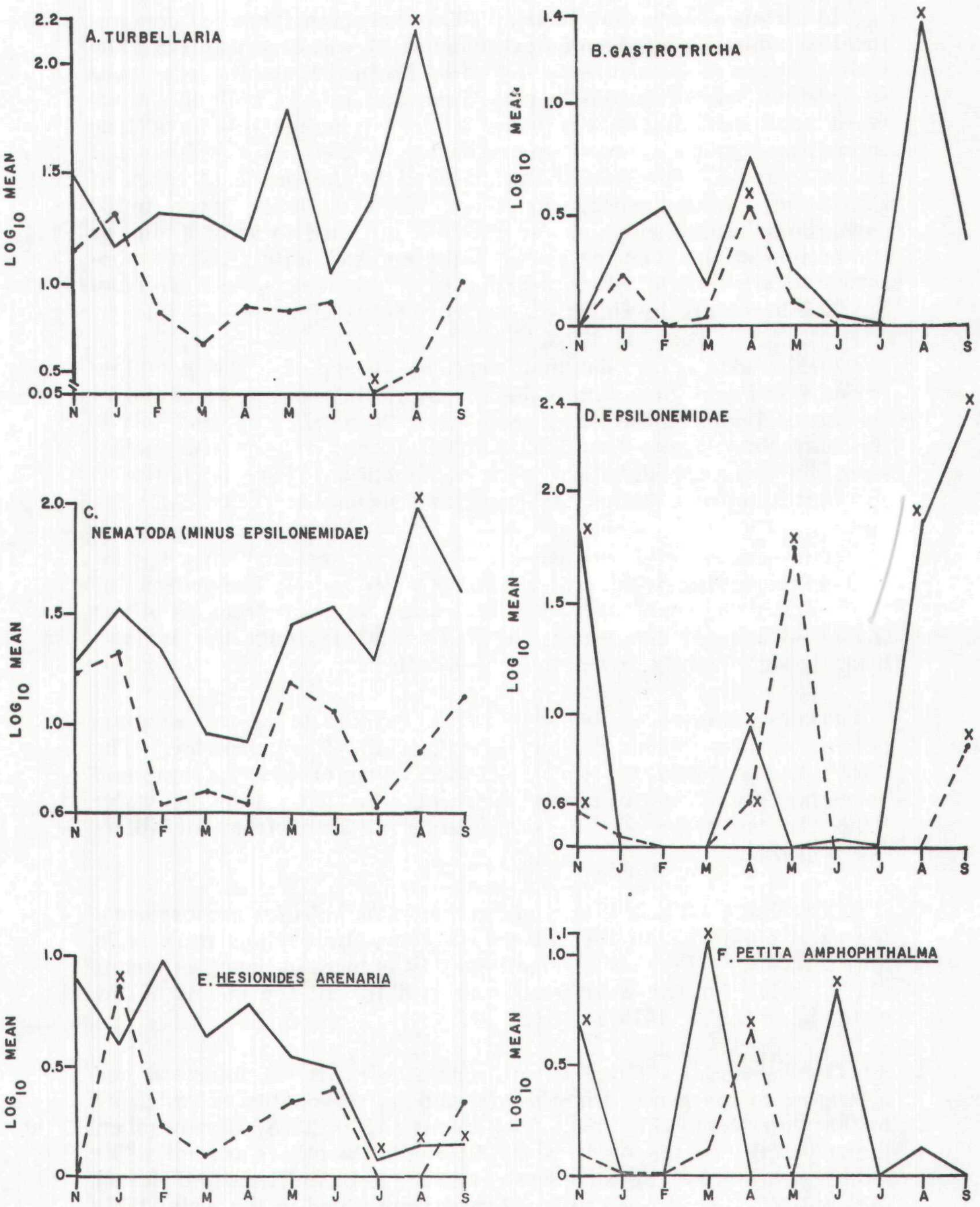

FIG. 2

Seasonal distribution of Turbellaria (A), Gastrotricha (B), Nematoda minus Epsilonemidae (C), Epsilonemidae (D), *Hesionides arenaria* (E) and *Petita amphophthalma* (F) at Sindbad beach.

of smaller specimens was noted for august and September. For the water table, the peaks are september-november and april-may (AF = .2068).

Entoprocta - According to Dr. P. Emschermann (personal communication) this is a species of *Loxosomella.* It was described from the Gulf of Aqaba as *Loxosoma fishelsoni* by Bobin (1970). Its occurrence in Lebanon was restricted to may, june and july in both the wave-wash zone and the 40 cm water table. Whether this is a true interstitial species remains questionable in view of the fact that Bobin found *L. fishelsoni* living attached to the inside of tubes of *Pectinaria.* Living specimens from Sindbad beach were noted "swimming" periodically, at other times, attached to sand grains or the bottom of the counting dish. Based on size and certain morphological characteristics, Emshermann feels that the specimens from Sindbad beach are juveniles.

Archianneiida - The dominant species throughout the sampling period was *Protodrilus similis* Jouin. In april, however, 11 of the 14 specimens found in the water table were *Diurodrilus* sp. and this is the only time it was found at Sindbad beach. The Archianneiida were not analyzed statistically for seasonality. There is, however, the suggestion of a january-february and September peaks.

Hesionides arenaria Friedrich - Fig. 2e shows that this species is a winter-spring species in the wave-wash zone. The means for july, august and September are significantly different from all others (AF = .3372). At the water table (AF = .3361), only the january mean is significantly different from all others.

Petita amphophthalma Siewing - The complexity of the seasonal pattern of this species resembles that of the Epsilonemidae. The means (AF = .1400) for the wave-wash zone of march, june and november are all significantly different (Fig. 2f). For the water table, the mean for april is significantly different from all others (AF = .1073).

Oligochaeta - There is only one species, *Phallodrillus monospermathecus* (Knöllner). In the wave-wash zone, the obvious peak is in may (Fig. 3a). There are no significant differences in the other means (AF = .4646) for the wave-wash zone and for all the means of the water table (AF = .4675).

Opisthobranchia - There is only one species as yet undetermined belonging to the genus *Microhedyle*, and its seasonality is restricted to the water table (Fig. 3b). The means (AF = .2398) of november, january and june are significantly different; the others are not. The monthly means for the wave-wash zone are not significantly different (AF = .2886). Gastropod veliger larvae were noted in the water table in april, may and june.

Mystacocarida - The species is *Derocheilocaris remanei remanei* according to Hessler (personal communication). The seasonal peaks (AF = .3701), november and april, are restricted to the water table (Fig. 3c). The seasonality in the water table is supported by the presence of juveniles in november, january, april, august and

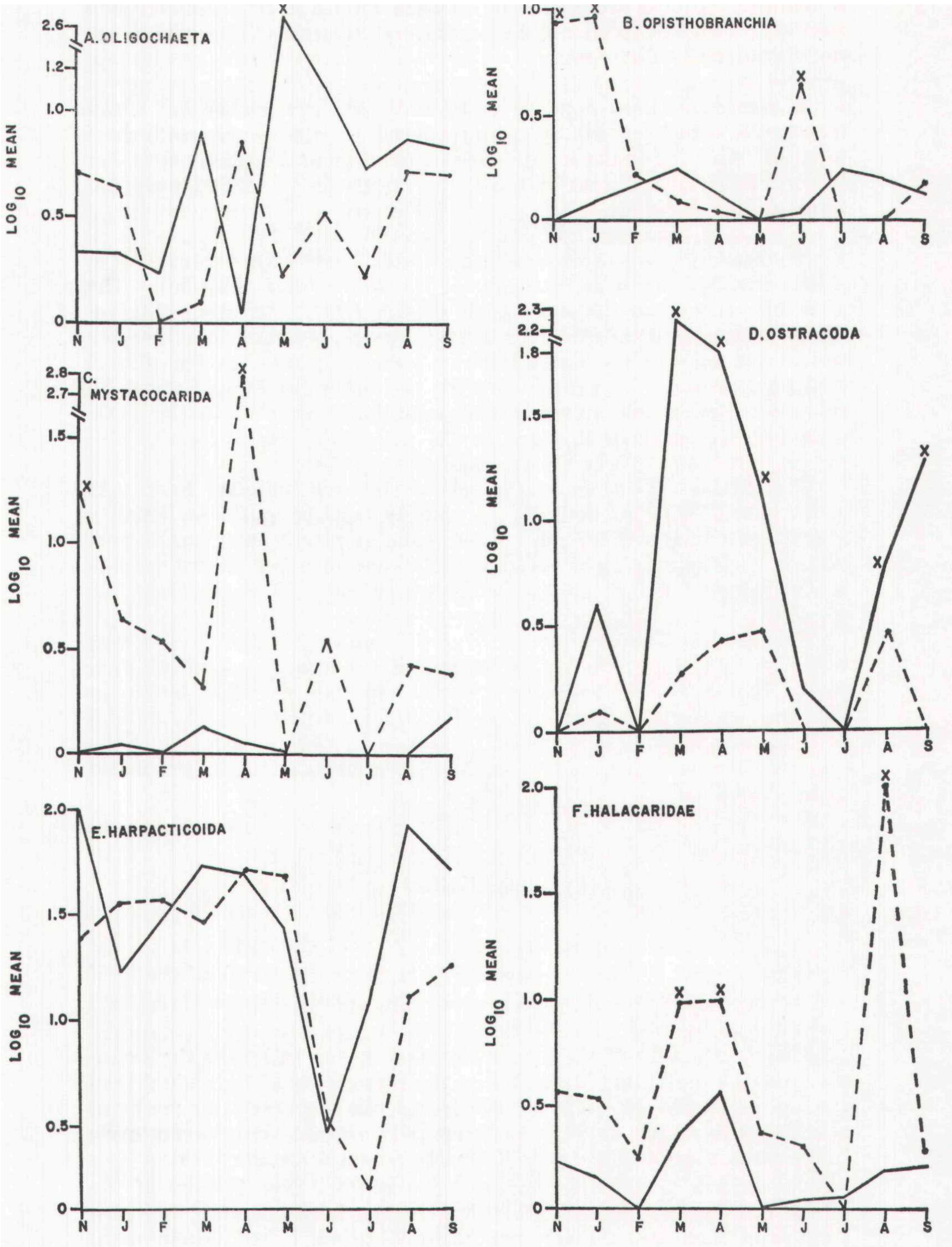

FIG. 3

Seasonal distribution of Oligochaeta (A), Opisthobranchia (B), Mystacocarida (C), Ostracoda (D), Harpacticoida (E) and Halacaridae (F) at Sindbad beach.

September. Adults were present in each month except january and august. The monthly means in the wave-wash zone (AF = .1167) are not significantly different.

Ostracoda - There appears to be only one species, as yet undetermined. The seasonality is restricted to the wave-wash zone (Fig. 3d) with the peaks being march-april-may and august-september (AF = .3949). At the water table, the means (AF = .2330) were not significantly different.

Harpacticoida - The only significant difference in means (AF = .4708) for this taxon is june-july at the water table (Fig. 3e). The allowance factor for the wave-wash zone is .6909. Based on observation, the Harpacticoida were noted as being ovigerous in either the wave-wash zone or the water table or both each month. The almost continual presence of nauplii and the metanauplius larva figured by Delamare Deboutteville (1960) adds additional support to the year-round reproduction of this group.

Halacaridae - Two undetermined species are included here. As in the case of the Opisthobranchia and Mystacocarida, the seasonality is restricted to the water table with peaks in march-april and august (Fig. 3f). There is no significant difference in other means for the wave-wash zone (AF = .2704) and the water table (AF = .3101).

Tardigrada - The abundance of *Batillipes* at Sindbad beach was very low and there was no indication of seasonality. Limited data from Khalde beach, an open marine, sewage polluted beach in Lebanon, suggests seasonality for *Batillipes.* In may, 1972, a total of 1182 specimens were recorded from 4 — 4.4X10 cm cores from the wave-wash zone. Many of the specimens were small and are presumed to be juveniles.

DISCUSSION

The temporal pattern of the meiofauna of Sindbad beach is, indeed, complex. When the seasonality is viewed in terms of the total meiofauna, two seasonal peaks are obvious, spring (march-april-may) and autumn (august-september-november).

The seasonality of the total meiofauna, however, masks the seasonality of the individual taxa. When the seasonality of individual taxa are analyzed, variable patterns are found ranging from two peaks of abundance to no seasonality. Differences in seasonality between levels (wave-wash zone and water table) were found for some taxa.

Swedmark (1964) has reviewed the reproductive biology of the interstitial fauna emphasing adaptations such as general low production of gametes, mechanisms of fertilization, brood development and viviparity, and suppression of pelagic larval stages. In addition, Swedmark states "Reproductive periods covering the greater part of the year have been observed in many species and seems to be the rule for the forms with a low production of gametes." Renaud-Debyser (1963) reported most of the species at Arcachon reproducing the year-round. Fenchel (1968) has calculated reproductive rates and generation time for several meiofaunal taxa emphasizing the "intrinsic rate of increase" (r) and its value in ecological studies. Fenchel found r values for meiofauna to be between 0.1 and 0.4 per day under optimal conditions and the "finite rate of increase" (λ) to be between 1.1 and 1.5 per day for Nematoda and Harpacticoida. Gerlach (1971) has pointed out the extreme diversity in number of generations per year and generation time for meiofauna. He estimates an average of three generations per year for meiofauna.

To attempt to resolve the complexity of data based on laboratory culture, the adaptive evolution of reproduction, and data derived from field studies is beyond the scope of this paper. As Gerlach (1971) has pointed out, it is necessary to know the life history of the components of meiofauna.

An evaluation of the role of environmental parameters in reproductive periodicity and, therefore, seasonality of meiofauna is, however, within the scope of this paper. Two factors, temperature and food, will be considered.

The relationship between temperature and seasonal abundance has been shown by several investigators. The general pattern in the seasonal abundance of total meiofauna on sand beaches, based on studies conducted over a period of one year is two peaks, one spring and the other autumn (Schmidt and Westheide, 1971; Harris, 1972). The abundance of meiofauna of the spring peak has been found to be less than the autumn. Furthermore, the spring peak is generally associated with an increase in water temperature whereas the autumn peaks occurs at maximum temperature or later as water temperature decreases. These spring-autumn peaks have been found in temperature ranges of 4 to 18°C (Schmidt and Westheide, 1971), 8 to 17°C (Harris, 1972). The seasonal distribution at Sindbad beach is essentially not different from that found by other investigators in that a spring peak (associated with an increase in temperature) and an autumn peak (associated with maximum followed by decreasing temperature) occur with the abundance being less at the spring peak. The temperature range for the peaks at Sindbad was 17 to 29°C.

For individual taxa exibiting seasonality, variable patterns were found. For six of the twelve taxa, the greatest abundance was found during both the spring and the autumn (Gastrotricha, Epsilonemidae, *Petita amphophthalma,* Mystacocarida, Ostracoda, Halacaridae). The Oligochaeta had a spring peak whereas the Nematoda and Turbellaria has autumn peaks.

Thus there appears to be a positive relationship between temperature and seasonality of sand beach meiofauna based on results from Sindbad beach and other studies for total meiofauna and certain taxa. The relationship is obscure, however, in that increased abundance is associated with increasing water temperature (spring) and/or with maximum temperature followed by decreasing temperature (autumn). This suggests a wide differential response to temperature as a triggering or controlling mechanism for reproduction for total meiofauna and certain taxa. The relationship is further obscured based on the assumption that among the meiofauna, there are several generations per year. Based on monthly occurrence of statistically significant peaks of greatest abundance over the 10 month period for Sindbad beach, the one to five months range is as follows: one month - Turbellaria, Nematoda, Oligochaeta and *Hesionides;* two months - Gastrotricha and Mystacocarida; three months - Opisthobranchia and Halacaridae; four months - *Petita;* five months - Epsilonemidae and Ostracoda. Whether these can be interpreted as generation time is questionable in view of the high variability pointed out by Gerlach (1971).

Little attention has been given to the relationship of food availability and seasonality of meiofauna. When it has been considered, it has been as a secondary relationship, i.e., food availability associated directly with temperature.

Most of the meiofauna of Sindbad beach are detritus (including bacteria) feeders. Khyami (1972) reported the following viable, sea water bacteria numbers/gm of sand from Sindbad beach: april, 1971 - $1.0X10^3$ to $1.4X10^4$ for the wave-wash zone and $1.4X10^3$ to $4.0X10^4$ at the water table; July 1971 - $7.8X10^2$ to $5.2X10^3$ in the wave-wash zone, $8.3X10^2$ to $9.2X10^3$ at the water table; august, 1971 - $1.6X10^3$ for the wave-wash zone and $1.2X10^3$ at the water table. Thus, there is the presence of higher bacterial numbers coinciding with a portion of the spring peak of total meiofauna. Schmidt and Westheide (1971) found, seasonally, a positive correlation between increased bacterial numbers and meiofauna (and temperature).

Gowing (1972) conducted a spatial study of the meiofauna of Khalde beach which is polluted with sewage (discharge estimated at 700 L/sec). Replicate sampling was conducted at three sites and two levels (wave-wash zone and 40 cm water table) during june, august, november and february. She found total numerical abundance of meiofauna one to two orders of magnitude higher than at Sindbad beach and attributed the higher abundance to continued high organic input via sewage. More significantly, she found no seasonal pattern in the total meiofauna at Khalde beach and concluded that the absence of seasonality resulted from continued high organic input allowing the maintenance of high meiofaunal population densities.

Gowing also concluded that *Protodrilus similis* Jouin was an "opportunistic species" on the sewage polluted beach and when total meiofauna minus *Protodrilus* was analyzed, there was a suggestion of seasonality although there was no clear cut pattern. Subsequent preliminary analyses of the taxa of Khalde at the same level as for Sindbad have revealed, however, no definitive trends or patterns for Khalde as was found at Sindbad.

Makemson (1973), in a comparative study of Sindbad and Khalde conducted during june and july, 1972, has shown significant differences in bacterial numbers and nutrients. He found interstitial and viable (fresh - and seawater) bacterial numbers to be significantly higher at Khalde than at Sindbad. He also found the ammonia concentration of the interstitial water in the wave-wash zone at Sindbad beach was less than 0.1 µg-at NH_3N/L whereas at Khalde, it was between 20 and

25. Similar differences were found in the phosphate concentration between 0.1 and 1.μ.g-at PO_4-P/L for Sindbad and between 3.0 and 6.0 for Khalde beach. Protein content (based on the Lowry determination) was found to be 130(μ.g/gm of wet sand at Sindbad and 269 at Khalde.

Lakkis (1971) reported spring and autumn seasonal peaks in zooplankton abundance. The abundance was greater in spring than in autumn. That the seasonal pattern of the total meiofauna of Sindbad beach and that of zooplankton reported by Lakkis (1971) are similar is indicative assuming a direct relationship with primary productivity. Thus there appears to be a strong argument for seasonality of meiofauna being a direct function of "natural nutrient" input and available food for the meiofauna of Sindbad beach. Under conditions of continued high organic input or availability however, seasonality appears to be absent. McIntyre (1964) reported the absence of seasonal differences of meiofauna from sublittoral muds. Such habitats are richer in organic content than sand bottoms. It thus appears that in the presence of a continual high availability of nutrients whether it be a mud bottom or a sewage-polluted sand beach, seasonality in meiofauna does not occur.

Sampling frequency in temporal studies is important in view of the changes in density (and community structure) that occur from day to day at the same site on a beach. Hulings (1971) has documented such changes on one atidal beach in Tunisia by sampling two sites three times over a ten day period in december, 1970. The meiofauna of the wave-wash zone ranged in density from 873 to 2599 specimens (total meiofauna in six 4.4. cm diameter, 10 cm deep cores for each sampling time) at one site and 453 to 1096 at another site on the same beach. The density at the 40 cm water table for the same period and sites was 115 to 168 and 48 to 76.

Migration of meiofauna has been considered as important factor in seasonal distribution by a number of workers including Renaud-Debyser (1963). Schmidt (1969) and Harris (1972). This phenomenon may be more important on tidal beaches than atidal beaches. This leads one to suspect that there may be a significant difference between tidal and atidal beaches in terms of the seasonal and other patterns of distribution of meiofauna.

Based on considerable data from other beaches of Lebanon (Hulings, 1972), Sindbad beach has a consistently lower density of meiofauna, yet a definitive seasonal pattern exists. Thus, Sindbad beach can be considered as representative of seasonal distribution of sand beach meiofauna in the Eastern Mediterranean.

Summary

1. A quantitative temporal study of the meiofauna of Lebanese sand beach was conducted over a ten month period. The study was statistically designed, the meiofaunal data were statistically analyzed using one-and two-way analysis of variance with replication.

2. The total meiofauna had two peaks of seasonality, expressed in terms of numerical density, march-april-may and august-september-november. The peaks were most obvious in the wave-wash zone and less obvious at the 40 cm water table.

3. Individual taxa had varying seasonality. The Harpacticoida exhibited no seasonality. Those taxa exhibiting one seasonal peak in the wave-wash zone were the Turbellaria, Gastrotricha and Nematoda (minus Epsilonemidae) and Oligochaeta. Those with two seasonal peaks included the Epsilonemidae, *Hesionides arenaria, Petita amphophthalma* and Ostracoda.

4. The Turbellaria, Gastrotricha, *Hesionides arenaria* and *Petita amphophthalma* exhibited one peak at the water table whereas the Epsilonemidae, Opisthobranchia, Mystacocarida and Halacaridae exhibited two peaks.

5. The seasonality of the Opistobranchia, Mystacocarida and Halacaridae was restricted to the 40 cm water table.

6. Food supply is considered to be a primary factor in the seasonality of Lebanese sand beach meiofauna.

Zussamenfassung

1. Wahrend eines zehnmonatigen Zeitraumes wurde eine quantitative Untersuchung der Meiofauna eines libanesischen Sandstrandes durchgeführt. Die Untersuchung war statistisch aufgebaut und die Untersuchungsergebnisse der Meiofauna wurden durch ein — und zweib ahnige Variantenanalyse statistisch bestimmt.

2. Die Meiofauna hat zwei jahreszeitliche Hohepunkte die sich in numerischer Dichte ausdrucken März-April-Mai und August-September-November. Diese Höhepunkte sind am auffälligsten in der Brandungszone und weniger bemerkenswert beim 40 cm frundwasserspiegel.

3. Individuelle Taxa hatten unterschiedliche Jahres-zeitlichkeit. Die Harpacticoida zeigten keine Abhângigkeit von der Jahreszeit. Die Turbellarien, Gastrotrichen und Nematoden (Epsilonemidae ausgeschlossen) und Oligochaeten zeigten in der Brandungszone einen jahreszeitlichen Hôhepunkt. Diejenigen mit zwei jahreszeitflichen Höhepunkten schlossen die Epsilonemidae, *Hesionides arenaria, Petita amphophthalma* und Ostracoden ein.

4. Die Turbellarien, Gastrotrichen, *Hesionides arenaria* und *Petita amphophthalma* zeigten beim grundwasser einen Höhepunkt während die Epsilonemidae, Opisthobranchia, Mystacocarida und Halacaridae zwei Höhepunkt zeigten.

5. Die jahreszeitliche Abhângigkeit der Opisthobranchia, Mystacocarida und Halacaridae war auf das grundwasser beschränkt.

6. Die Nahrungszufuhr wird als primärer Faktor bei der jahreszeitlichen Abhängigkeit der libanesichen sandstrand meiofauna ausgesehen.

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