P.S.Z.N. I: Marine Ecology, 2 (4): 343–352 (1981)
Accepted: 20. 11. 1981

ISSN 0173-9565/InterCode: MAECDR

Macrobenthic Communities of the Eastern Mediterranean Continental Shelf

B. GALIL & CH. LEWINSOHN

The George S. Wise Center for Life Sciences, Department of Zoology, Tel Aviv University, Tel Aviv, Israel

With 5 figures and 2 tables

Key words: benthos, Mediterranean, assemblage, numerical analysis, dendrogram

Abstract. The results of a year long study in which soft-bottom epibenthic invertebrates were collected by grab, dredge and beam-trawl, along the southern Mediterranean coast of Israel, are described in this paper. The classificatory analysis used for both normal and inverse analyses used two measures of dissimilarity – Canberra metric and Bray-Curtis, and both group-average and nearest-neighbour clustering. The results were displayed as dendrograms. Four site groups and five species groups characterised a total of 58 site samples and 245 species. The prominent species in each of the five species groups are mentioned. The applicability of "community concepts" and the effects of sediment properties on community structure are discussed.

Problem

Community studies of the continental shelf of Israel have been conducted for three decades. The earlier studies were considered fishery research and the invertebrates emphasized were those forming an important link in the food-chain (WIRSZUBSKI, 1953; GILAT-GOTTLIEB, 1959). It was only in the sixties that an extensive program was undertaken by GILAT (1964) to describe the macrobenthal communities. However, GILAT's community concept was derived from the BRAUN-BLANQUET school and the work of PÉRÈS & PICARD (1958), and thus resulted in subjective judgements in the recognition of associations and the selection of characterising species. TOM, in his M.Sc. thesis on the benthic associations of Haifa Bay (1976), subjected his material to numerical analysis, therefore enabling him to handle more data and consequently to expect more satisfactory results.

The purpose of the present study is twofold: (I) to determine the composition and distribution of soft bottom benthic invertebrate assemblages along the southern Israeli coast, and (II) to investigate the relationships between these assemblages and sediment properties.

U.S. Copyright Clearance Center Code Statement: 0173-9565/81/0204-0343$02.50/0

Material and Methods

The data discussed in this paper were obtained from a survey of eleven sampling sites in three transects (Palmahim A Sta. 1, 2, 3; B Sta. 4, 5, 6, 7; Nizanim Sta. 8, 9, 10, 11), perpendicular to the coast (Fig. 1). At each transect the bottom was sampled at four stations corresponding to 20, 35, 50 and 80 m depths (the 20 m site at Palmahim A was deleted). At transect Palmahim B an additional sample was taken at each location at night. The positions of stations were obtained from a Mini Ranger Radar aboard ship and two shore stations that continually gave exact bearings and were estimated to be correct to within 50 m. Samples were collected in January, May, July and October of 1977. Each site was sampled with a PETERSEN grab of 0.1 m^2 area, a triangular dredge with an arm of 0.6 m and a beam-trawl with a 1.15 m wide iron frame. The samples were sieved through a nest of four sieves, the finest of which had a mesh size of 1 mm.

Species identification was made in part by experts in the various groups and in part by comparison with the reference collection of the Zoology Department of Tel Aviv University*.

Material for the sediment analysis was removed from undisturbed grab samples. Sediment particle size distribution was determined by sieving and pipette analysis following procedures described by BUCHANAN (1971).

To simplify and extract information from the meristic data collected, we used both "normal" (sites classified using species as attributes) and "inverse" (species classified using their site of occurrence as attributes) classification.

Of the many coefficients of dissimilarity available we used two: the Canberra metric – known to be insensitive to large values and skewness and which can thus be used with untransformed data, and the Bray-Curtis measure which is sensitive to large values, ignores double zero matches and plays down the importance of rare species (LANCE & WILLIAMS, 1967; FIELD, 1971; CLIFFORD & STEPHENSON, 1975).

Clustering was accomplished using two agglomerative hierarchical clustering strategies: weakly clustering nearest-neighbour and space conserving group-average (CLIFFORD & STEPHENSON, 1975).

Because of the mass of data collected we recoursed to elimination of rarer species (occurring in less than 7 samples (< 7 recordings)) prior to analysis, following procedures by DAY *et al.* (1971) and HUGHES & THOMAS (1971).

* The collection of this study is deposited at the Zoology Department of Tel Aviv University.

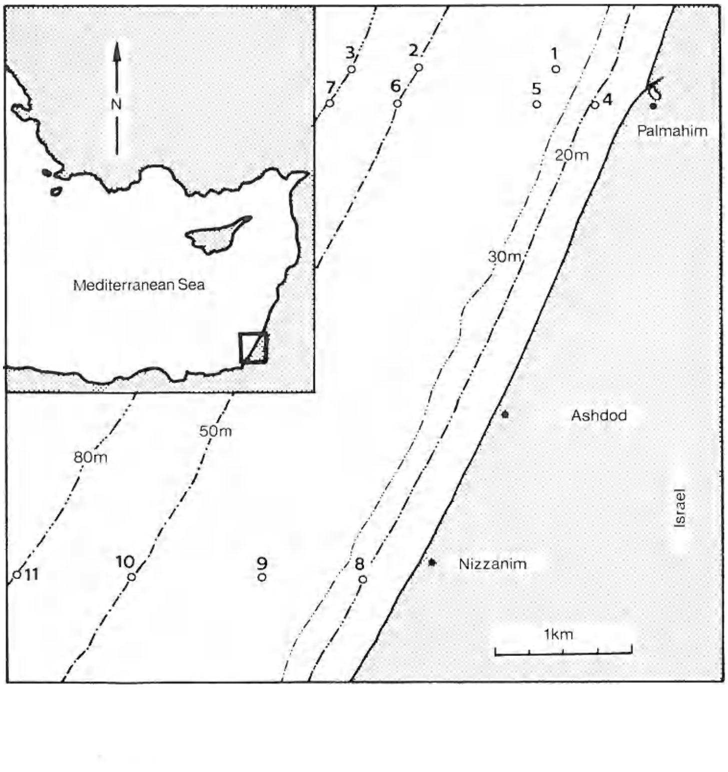


Fig. 1. Map showing location of sampling stations and isobaths.

Results

1. Sediment distribution

The substrate in the area changes with the distance offshore. The proportion of sand decreases with increasing depth, while the proportion of silt-clay increases. Median particle diameter and standard deviation were computed using formulas given by Folk & Ward (1957), from cumulative particle size curves plotted on arithmetic scale paper. These statistics together with the sediment composition are presented in Table 1. Wave action is important in determining sediment composition in shallow water as is evident from the well sorted sediment (S = 0.38) in station 4 located at 18 m, Palmahim. A sample taken in January at the same station had a standard deviation (S) of 0.36 due to winter storms. It should be noted that in the 35 m sites we find a marked difference between Palmahim (1;5) and Nizanim (9); the latter generally have a high silt-clay content.

Table 1. Depth, sediment medium particle-diameter (Md) and standard deviation (S) in phi units, sand, silt, clay percentages for each station sampled in October.

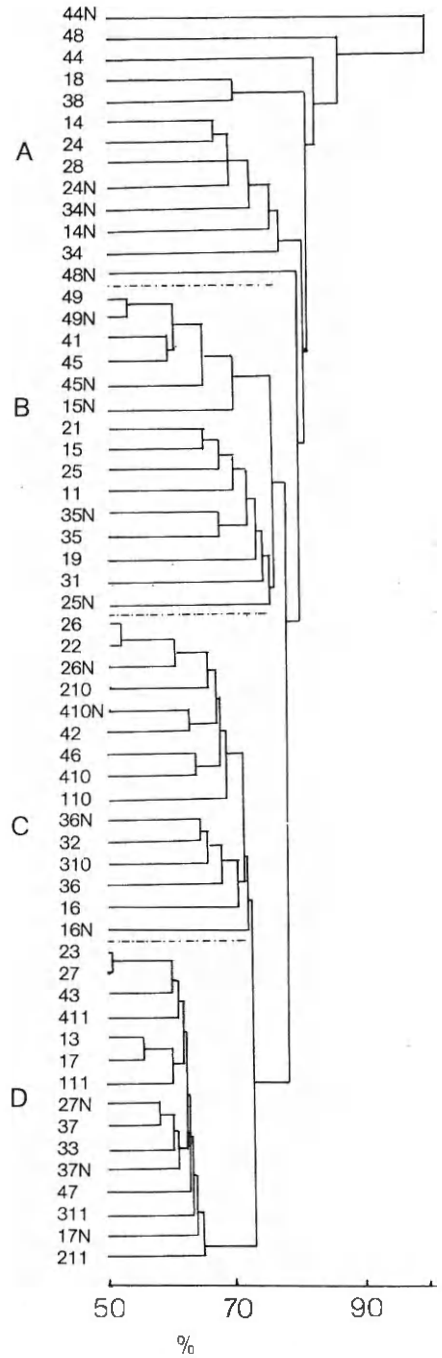
Depth (m)	Stations	Md ø	S ø	% composition sand > 0.062 mm	silt 0.062 mm - 0.002 mm	clay < 0.002 mm
18	4	2.96	0.38	95.5	3.82	2.28
20	8	3.1	1.08	87.2	8.94	3.86
35	1	4.26	2.0	65.5	20.97	13.46
35	5	4.41	2.4	64.6	21.57	13.8
35	9	6.2	1.54	2.6	65.82	31.56
50	2	5.9	1.68	10.49	56.62	32.88
50	6	5.88	1.74	10.53	61.09	28.37
50	10	6.62	1.4	2.66	58.26	39.09
80	3	6.43	1.44	1.15	63.26	35.6
80	7	6.36	1.42	0.99	65.71	33.29
80	11	6.46	1.7	9.8*	48.51	41.65

* The coarse fraction comprised of fragmented shells.

2. Faunal data

During the course of the work 33 000 specimens were identified and yielded 245 species. Higher taxa with the most species were *Mollusca* (66 species), *Crustacea* (61) and *Polychaeta* (50). For the classificatory analysis, results from same day replicates at a site were grouped together. To avoid a 3-dimensional data matrix (sites × species × times) we incorporated the season into the site sample and treated each site sample in a given season as a sample unit. Species which occurred at less than 7 of the 58 sites were eliminated from classification, leaving 51 species, while discarding less than 15 % of the total data.

Hierarchical grouping of sites using Canberra dissimilarity measure and both group-average and nearest neighbour clustering are presented in Figs. 2 and 3. The matrix contained the total numbers of species. This analysis produced



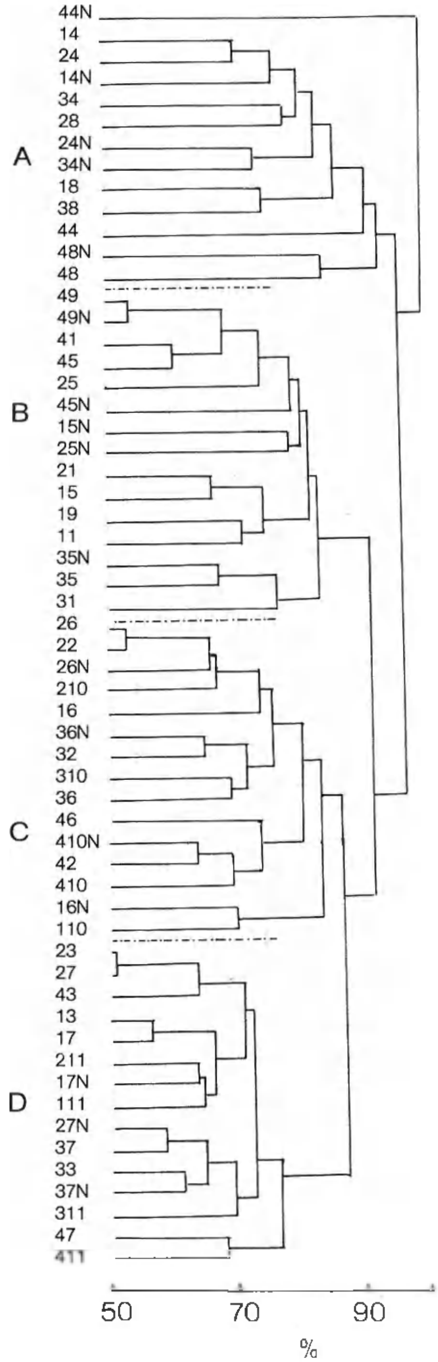


Fig. 2. Site dendrogram: Canberra coefficient and group average sorting. Scale shows percentage dissimilarity. First numeral of site designation refers to sampling period (1:January, 2:May, 3:July, 4:October). Next numerals are station numbers (1–11). N – night sampling. Broken lines indicate main groups.

Fig. 3 (right). Site dendrogram: Canberra coefficient and nearest neighbour sorting.

dendrograms which arranged the samples in four site groups in transect sequence from the shallowest sites to the deepest, accepting groups at different dendrogram levels. Acceptance at different levels has been due to group size dependence, a phenomenon inherent in sharply clustering strategies as employed here (see WILLIAMS *et al.*, 1971). Variation between sites is generally greater than between samples and the seasonal variation within a site. It revealed that depth and substrate were the main factors influencing site grouping. Assuming a correlation between sediment type and depth, the two were treated as one factor. There is an extraordinarily close similarity between the site groups generated by using species as attributes and the sediment classification of the sites (Table 1).

The main groups remain the same whether sorting is by group average or the nearest neighbour method. Within each group, samples are linked together in roughly similar sequences.

The dendrograms produced for species grouping utilised the Canberra metric and Bray-Curtis dissimilarity measures with group average sorting strategy. The matrix contained presence/absence values for species in sites. Characterising species were chosen from their high dominance/constancy values (Table 2). (Constancy was calculated as the frequency of occurrence of species in given site groups).

Table 2. Total numbers of characterising species of the species groups shown in Figs. 4 and 5.

Characterising species	stations										
	1	2	3	4	5	6	7	8	9	10	11
Sicyonia carinata				6				4			
Philocheras monacanthus				128				99			
Diogenes pugilator				359				290			
Sphaeronassa mutabilis				14				14			
* *Oratosquilla massavensis*	19	1			27				3		
* *Cerithium kochi*	1306				375			142	1023		
Trachypenaeus curvirostris	16	4			28	3		4	2	2	
* *Charybdis longicollis*	136	194	18		109	291	6		532	143	2
* *Myra fugax*	9	15			8	12		2	4	14	
Pontocaris cataphracta	71	210	49		58	140	43		25	38	7
Processa nouveli nouveli	18	178	45		2	13	12		8	16	28
Brissopsis lyrifera		139	134			6	84			153	270
Antedon mediterranea		22	3348				3375			942	1011
Parapenaeus longirostris		302	2042			357	558		34	114	536
Macropipus pusillus		73	70			30	45		12	19	38
Galathea intermedia		12	33			6	19			13	4
Alpheus glaber		7	43			8	20			4	11
Sabella pavonina		4	245			20	164			77	273
Turitella communis			82				69				20
Nucula sulcata			126				76				3
Sternaspis scutata			36				14				4
Alcyonium palmatum			4				1				26
* *Saurida undosquamis*	15		3	1	12	8		13	2	10	
* *Alpheus rapacida*	12	14	3		10	9			22	7	
Dentalium dentale	1	94	177			5	53			17	54
Goneplax rhomboides		10	59			13	35			6	24
Arnoglossus laterna	18	17	5	2	17	34	9		35	8	7

* of Indo-pacific origin.

It appears that the dendrograms contain five distinct clusters (Figs. 4 and 5) accepting groups at different dendrogram levels. Species group A is uniquely characterised by the decapod crustaceans *Sicyonia carinata* (BRÜNNICH), *Philocheras monacanthus* (HOLTHUIS), *Diogenes pugilator* (ROUX) and the gastropod *Sphaeronassa mutabilis* (LINNÉ), all frequent at the shallowest sandy sites (18; 20 m) (Table 2). A similar community was described by GILAT (1964)

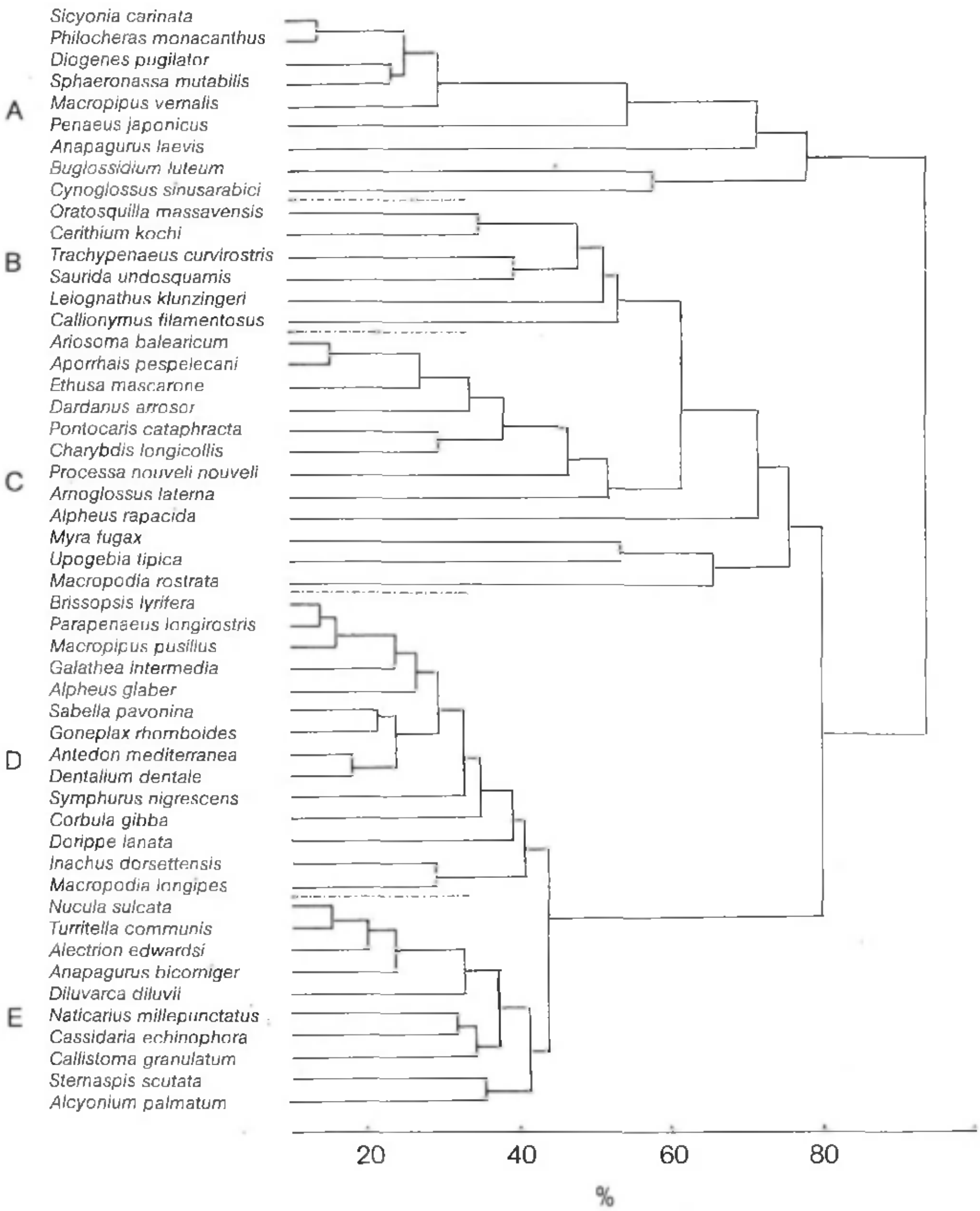


Fig. 4. Species dendrogram: Canberra coefficient and group average sorting. Scale shows percentage dissimilarity as given.

from Palmahim. *D. pugilator* and *S. mutabilis* are "community indicators" in the classical manner and mentioned as such in other parts of the Mediterranean (Gautier, 1957; Orel & Mennea, 1969; Vatova, 1975). Species group B contains species most frequent on the sandy-mud 35 m sites. The characterising species are the Indo-Pacific stomatopod *Oratosquilla massavensis* (Kossmann) and the Indo-Pacific gastropod *Cerithium kochi* (Philippi). The decapod

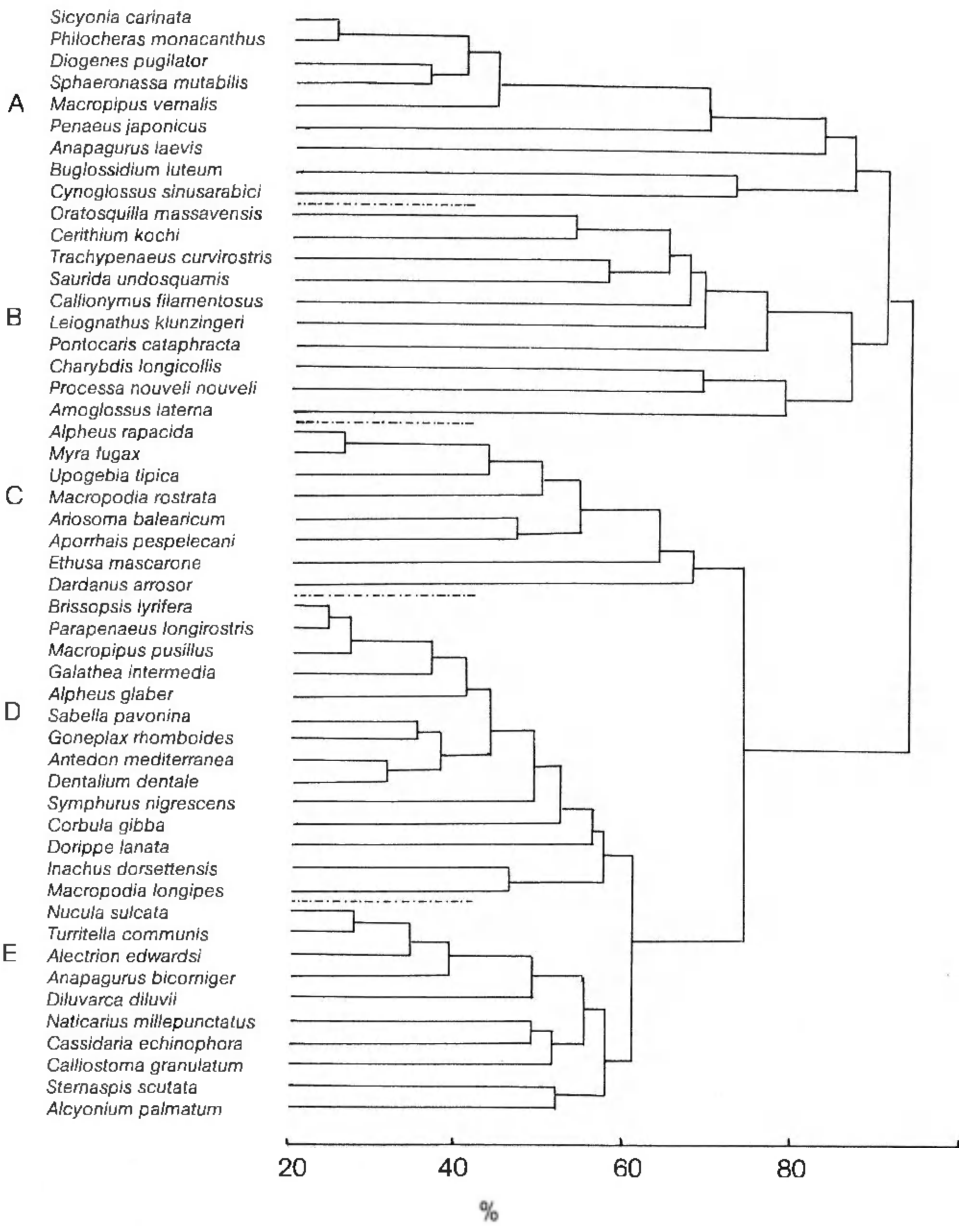


Fig. 5. Species dendrogram: Bray Curtis coefficient and group average sorting. Scale shows percentage dissimilarity as given.

Trachypenaeus curvirostris (STIMPSON) has a somewhat lower constancy. *C. kochi* characterise the 30 m assemblage in Haifa Bay (TOM, 1976) but with different co-dominants. Species group C is comprised of species ubiquitous in all sites, except those closest to shore, and is uniquely characterised by four decapod species of high dominance/constancy value: *Charybdis longicollis* LEENE and *Myra fugax* (FABRICIUS), both of Indo-Pacific origin, *Pontocaris cataphracta* (OLIVI) and *Processa nouveli nouveli* ALADHUB & WILLIAMSON the latter taken almost exclusively at night. Species group D is composed of species present in both 50 and 80 m sites and is uniquely characterised by seven species of high dominance/constancy values: echinoderms *Brissopsis lyrifera* (FORBES) and *Antedon mediterranea* (LAMARCK), decapods *Parapenaeus longirostris* (LUCAS), *Macropipus pusillus* (LEACH), *Galathea intermedia* LILLJEBORG, *Alpheus glaber* (OLIVI) and polychaete *Sabella pavonina* SAVIGNY. All of these are "community indicators" known from muddy grounds from the Israeli coast (GILAT, 1964, 1969; TOM, 1976) and other parts of the Mediterranean (GAMULIN BRIDA, 1967; PÉRÈS, 1967; VAMVAKAS, 1970). Species group E is composed of species found almost solely in the muddy-clay 80 m stations. It is uniquely characterised by mollusca *Turritella communis* RISSO, *Nucula sulcata* BROWN, polychaete *Sternaspis scutata* (RENIER) and octocoral *Alcyonium palmatum* (PALLAS). All of these appear as "community indicators" in previous studies of the Mediterranean benthos.

Discussion

Since MILLS (1969) there has been a tendency to regard populations of species as "being distributed in an overlapping manner along complex environmental gradients to form continuous rather than discrete units or communities". According to this view it is almost impossible to draw boundaries.

In order to explain complex benthic data we seek the best discontinuities in a nearly continuous system by means of classification methods. Since the selection of these methods is subjective and can be used to give a gradation from stress on dominancy (BRAY-CURTIS, untransformed data) to fidelity (Canberra metric without zero adjustment) (CLIFFORD & STEPHENSON, 1975), we used both. When different methods agree, the results can be interpreted with more confidence.

Site classification gave topographically coherent groups which followed an onshore-offshore sequence and hence, close correspondence between the site-groups and the sediment properties, masking possible effects of other abiotic factors. The species groups described are generally large and reveal only vague relationships to substrates. No site group was defined by the presence of a species group which occurs nowhere else. Of the five assemblages which were identified, two (A, E) were judged to be reasonably valid communities. The three questionable groups (B, C, D) showed substantial overlap and were essentially intergraded (Table 2). Few species were recorded as abundant and within their area of dominance they were associated with a large number of other species which extended beyond their areas. A close examination of the distributional patterns of individual species suggests that they integrade and that the apparent distinctiveness of site groups is caused by the distance between sampling stations. Thus, our findings suggest a view of communities as sections of continua of distribution, rather than the PETERSEN-THORSON theory of bottom communities (THORSON, 1957).

The species groups defined by the numerical analysis were compared with associations suggested by others working in this area and in other parts of the Mediterranean (GAMULIN BRIDA, 1962, 1967; GAUTIER, 1957; GILAT, 1964, 1969, 1974; MASSÉ, 1972; PÉRÈS & PICARD, 1958; THORSON, 1957; PICARD, 1965; TOM, 1976; VAMVAKAS, 1970). We have often found parallel dominant species with others parts of the Mediterranean; however, the sandy-mud associations that range from 35–50 m have no known parallels outside the Israeli coast. This is mainly due to the absence of typical Atlantic-Mediterranean species and the presence of Indo Pacific species which penetrated through the Suez Canal, became established and formed thriving populations, perhaps dominating former Atlantic-Mediterranean communities. Excellent examples are provided by the gastropod *Cerithium kochi* and the decapod crustacean *Charybdis longicollis,* both of which now form a characteristic feature of the Israeli coast. It is apparent that a continuously growing proportion of the macrobenthic fauna belongs to Indo-Pacific immigrants. Of the total 245 identified species found in the course of this work, 26 were of Indo-Pacific origin, some dominant and ubiquitous.

Summary

Based on data collected from beam-trawl and dredge samples taken between 18–80 m during a one year survey of 3 transects off the Israeli Mediterranean coast and using classificatory analysis to identify faunal boundaries across gradients, 4 site groups and 5 species groups were identified. Site classification gave a close correspondence between site-groups and sediment properties and were arranged in transect sequence. Variation between sites is greater than between sample and seasonal variations within a site. The 51 species classified were allocated into 5 species-groups.

Difference in methods of collection and subjectivity of community description make comparison with previous observations of the macrofauna of the Mediterranean difficult. However, we conclude that the sandy-mud associations have no known parallels outside the Israeli coast due to absence of typical Atlantic-Mediterranean species and the dominance of Indo-Pacific species which had penetrated through the Suez Canal.

The present study revealed a complex gradient of "distance from shore" which undoubtedly embodies several environmental factors. The distribution of individual species suggests that they intergrade and that the apparent distinctiveness of zones is due to the distance between sampling stations.

References

BUCHANAN, J. B., 1971: Sediments. In: N. A. HOLME & A. D. MCINTYRE (Eds.), Methods for the study of marine benthos. Blackwell Scientific Publications, Oxford & Edinburgh: 30–52.

CLIFFORD, H. T. & W. STEPHENSON, 1975: An introduction to Numerical Classification. Academic Press, New York, 229 pp.

DAY, J. H., J. G. FIELD & M. MONTGOMERY, 1971: The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. J. Anim. Ecol., **40:** 93–126.

FIELD, J. G., 1971: A numerical analysis of changes in the soft-bottom fauna along a transect across False Bay, South Africa. J. exp. mar. Biol. Ecol., **7:** 215–253.

FOLK, R. L. & W. C. WARD, 1957: Brazos River Bar: a study in the significance of grain size parameters. J. Sed. Petrol., **27:** 3–26.

GAMULIN BRIDA, H., 1962: Contribution aux recherches sur les biocenoses du circalittoral dans la région de l'Adriatique Orientale Moyenne. Pubbl. Staz. Zool. Napoli, **32:** 91–98.

– –, 1967: The benthic fauna of the Adriatic Sea. Oceanogr. Mar. Biol. Ann. Rev., **5:** 535–568.

GAUTIER, Y. V., 1957: Recherches sur les biocoenoses benthiques côtes de Camargue et du golfe de Fos. Recl Trav. Stn. mar. Endoume, **22:** 55–64.

GILAT-GOTTLIEB, E., 1959: Study on the benthos in Haifa Bay. Ecology and Zoogeography of invertebrates. Spec. Publ. Sea Fish. Res. Sta. Haifa: 1–131.

GILAT, E., 1964: The macrobenthic invertebrate communities on the Mediterranean continental shelf of Israel. Bull. Inst. Oceanogr. Monaco, **62** (1290): 1–46.

– –, 1969: The macrobenthic communities of the level bottom in the eastern Mediterranean. In: The Hebrew University of Jerusalem – The Smithsonian Institution Washington D.C. joint project. Biota of the Red Sea and the Eastern Mediterranean. Interim report: pp. 82–90.

– –, 1974: Macrobenthic communities off the Sinai Peninsula in the Mediterranean. Proceedings of the Fifth Scientific Conference of the Israel Ecological Society: pp. B1–B15.

HUGHES, R. N. & M. L. H. THOMAS, 1971: Classification and ordination of benthic samples from Bedeque Bay, an estuary in Prince Edward Island, Canada. Mar. Biol., **10:** 227–235.

LANCE, G. N. & W. T. WILLIAMS, 1967: A general theory of classificatory sorting strategies. I. Hierarchical systems. Comput. J., **9:** 373–380.

MASSE, H., 1972: Quantitative investigations of sand bottom macrofauna along the Mediterranean north-west coast. Mar. Biol., **15:** 209–220.

MILLS, E. L., 1969: The community concept in marine zoology, with comments on continua and instability in some marine communities: a review. J. Fish. Res. Bd. Can., **26:** 1415–1428.

OREL, G. & B. MENNEA, 1969: I popolamenti bentonici di alcuni tipi di fende mobile del Golfo di Trieste. Pubbl. Staz. Zool. Napoli, **37** (Suppl.): 261–276.

PÉRÈS, J. M., 1967: The Mediterranean benthos. Oceanogr. Mar. Biol. Amm. Rev., **5:** 449–533.

– – & J. PICARD, 1958: Manuel de bionomie benthique de la Mer Méditerranée. Recl Trav. Stn Mar. Endoume, **23:** 5–122.

PICARD, J., 1965: Recherches qualitatives sur les biocenoses mariné des substrats meubles dragables de la région marseillaise. Recl Trav. Stn Mar. Endoume, **36** (52): 1–160.

THORSON, G., 1957: Bottom communities. In: J. W. HEDGEPETH (Ed.), Mem. Geol. Soc. Am., Treatise on marine ecology and paleoecology, Vol. 1. Ecology: 461–534.

TOM, M., 1976: The benthic faunal associations of Haifa Bay. M.Sc. thesis, 113 pp. (in Hebrew).

VAMVAKAS, C. N., 1970: Peuplements stage bathyal du sud de la Mer Egée. Tethys, **2** (1): 121–129.

VATOVA, A., 1975: Qualitative and quantitative research on the benthic fauna of the Gulf of Taranto. Bull. Pesca Piscis. Idrobiol., **30** (1): 5–38.

WILLIAMS, W. T., H. T. CLIFFORD & G. N. LANCE, 1971: Group size dependence: A rationale for choice between numerical classifications. Comput. J., **14:** 157–162.

WIRSZUBSKI, A., 1953: On the biology and biotope of the Red Mullet, *Mullus barbatus*. Bull. Sea Fish Res. Stn. Haifa, **7:** 1–20.