Distribution of Molluscs and Polychaetes in Coastal Lagoons in Greece

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Hydrochemical (salinity, dissolved oxygen) and sedimentological parameters were investigated in the Messologhi lagoonal area of Greece in July 1981 and compared to the distribution of molluscs and polychaetes by means of the Spearman rank correlation. Dissolved oxygen in bottom waters showed the most obvious correlation with the distribution of species. The grouping of sampling stations based upon their faunal affinities displays the zonal organization of lagoonal populations which may be accounted for in terms of extent of isolation from the open sea, as in other Mediterranean lagoonal systems.

Introduction

The area of Messologhi is one of the most important lagoonal systems in Greece as it supports extensive aquaculture of coastal euryhaline fish. Furthermore, its ecological features have placed it second in the list of protected areas in Greece according the Convention of Ramsar (Dorikos, 1981). In spite of these considerations, very little scientific work has been done in the area. Apart from a few technical reports, the only papers published are those by Hatjikakidis (1951, 1952) which supply some information on the hydrographic characteristics of the lagoons. The present study is the first one dealing with the benthic fauna of the area: it is an attempt to analyze the distribution of polychaetes and molluscs within the lagoonal system.

Materials and methods

Description of sampling area

The Messologhi lagoonal system is situated on the western coast of Greece (Figure 1). It consists of three parts, the inner Aetoliko lagoon, the Messologhi lagoon proper and Klissova lagoon, which are connected by shallow channels. The depth varies from a few

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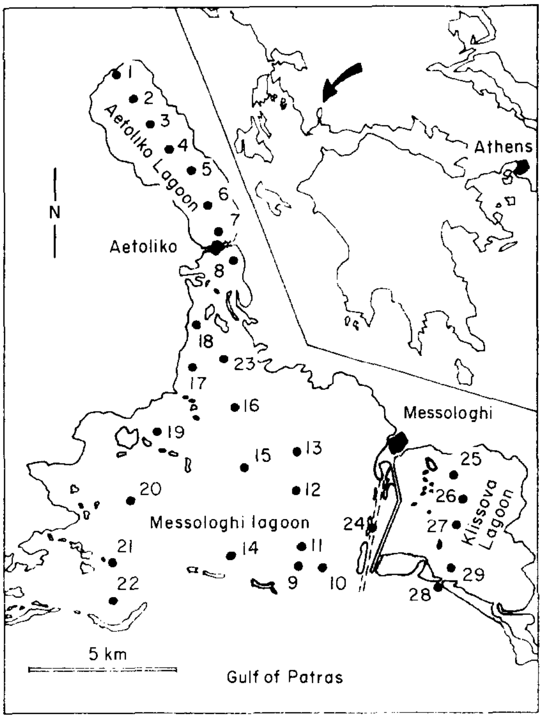

Figure 1. Situation of the Messologhi lagoonal area and the location of stations.

centimeters to about 2 m, except in the central part of Aetoliko where it reaches 30 m (Table 1, Figure 2).

Collection and treatment of samples

Samples of approximately the same volume were collected in July 1981 using a Forsters's anchor dredge (Forster, 1953) at 29 sampling stations (Figure 1). A small part of each sample was kept for sediment analysis and the rest was sieved through a 1-mm sieve and stained with Rose Bengal. The samples were preserved in sea water with formalin. Species were sorted and individuals counted. This method allows semiquantitative estimates of the density of each species.

Particle-size distribution of the sediments was determined by the mechanical and hydrometrical methods described in Bowles (1978). Mean particle size and standard deviation (sorting coefficient) were calculated according to the formula found in Briggs (1977). The nomenclature used for sediments is after Folk (1954).

Water samples were collected with a N.I.O. bottle. The dissolved oxygen concentration was measured by the Winkler method (Strickland & Parsons, 1968) and the salinity with a refractometer.

Analysis of data

Associations between fauna and sediment were investigated using a non-parametric test. The Spearman rank correlation coefficients (Zar, 1974) between the number of species and the mean grain size, and the mud content and the sorting were calculated. The same

TABLE 1. Depth, hydrochemical parameters (July 1981), sediment characteristics and number of species at each sampling station

Station	Depth (m)	Salinity (‰)	Dissolved oxygen (ml l^{-1})	Mean size, Φ	Mud (%)	Sorting, Φ	No. of species
1	3·5	15·0	4·44	—	—	—	9
2	27·0	35·0	0	7·05	83	3·65	2
3	20·0	30·0	0	7·17	92	2·79	2
4	20·0	30·0	0	7·20	93	2·30	2
5	9·0	20·0	0·48	8·03	94	2·45	3
6	7·5	16·0	1·57	8·87	98	3·18	7
7	2·5	18·0	0	6·93	81	3·45	10
8	1·0	25·0	0	5·90	64	4·12	6
9	1·4	39·0	2·27	2·49	3	0·93	47
10	1·8	39·5	3·93	—	—	—	51
11	1·1	40·0	3·37	7·57	85	3·79	23
12	1·1	43·0	2·25	7·10	85	3·30	5
13	1·5	42·0	3·83	—	—	—	17
14	1·0	44·0	3·48	3·35	66	3·10	24
15	1·2	42·5	3·30	6·87	88	2·89	15
16	0·8	40·0	3·43	1·80	8	1·37	22
17	0·7	30·0	4·75	7·44	82	4·34	22
18	0·4	23·0	3·90	7·86	87	3·52	15
19	0·8	51·0	2·77	7·28	85	3·38	19
20	1·2	48·0	3·50	1·97	8	1·65	21
21	0·5	45·0	4·58	—	—	—	18
22	1·3	44·0	3·83	—	—	—	22
23	0·7	10·0	2·91	5·77	68	3·19	17
24	7·0	40·0	3·66	6·89	83	3·45	37
25	0·6	49·0	3·20	—	—	—	19
26	0·5	50·0	3·45	7·46	89	3·35	15
27	0·8	50·5	2·82	5·31	62	4·47	7
28	0·7	48·0	2·11	4·05	62	2·02	16
29	1·2	58·0	2·82	6·76	82	3·35	13

test was employed to examine the relation between the number of species and dissolved oxygen and salinity.

Using binary (presence–absence) data, faunal affinity between stations was calculated by comparing all possible pairs of stations according to the formula of Czekanowski (Clifford & Stephenson, 1975). Stations were grouped using the nearest-neighbour strategy (Wishart, 1978).

Results

Environmental parameters

The hydrochemical parameters in the bottom water and the sediment characteristics are given in Table 1. The July 1981 salinity varied greatly between the three lagoons. Lower salinity values were recorded in Aetoliko lagoon where they ranged from 15‰ to 35‰. The majority of high salinities occurred in the shallow stations 25–29, all situated in Klissova lagoon (48–58‰). In the Messologhi lagoon proper, the salinity was close to sea water at stations 9 and 10 in the widest and deepest pass, increasing westward, and decreasing northward to 10‰ due to freshwater inflows (Figure 3). It appears, therefore, that salinity gradients (in summer) depend upon exchanges with the open sea and the water balance, i.e. evaporation *vs.* freshwater inputs.

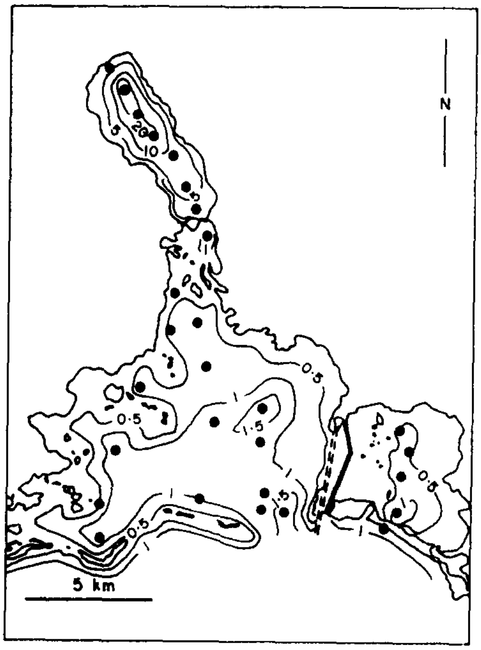

Figure 2. Schematic bathymetric map of the Messologhi lagoonal area (depth in m).

Figure 3. Salinity (‰) of the bottom waters in the Messologhi lagoonal area, July 1981

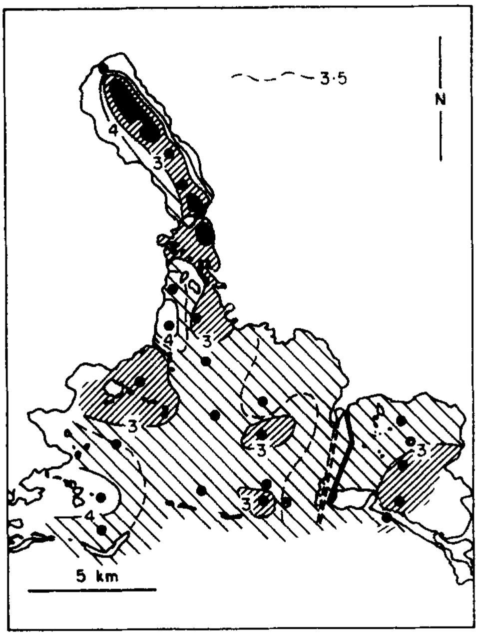

Figure 4. The dissolved oxygen content (ml/l) of bottom waters in the Messologhi lagoonal area, July 1981.

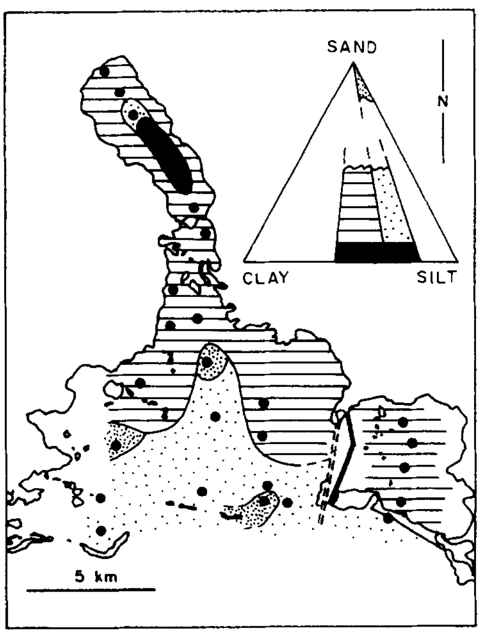

Figure 5. Sediments in the Messologhi lagoonal area.

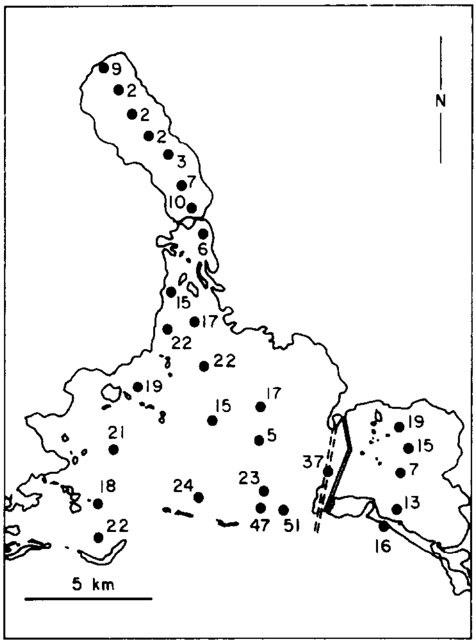

Figure 6. Distribution of species richness (mollusca and polychaeta) in the Messologhi lagoonal area, July 1981.

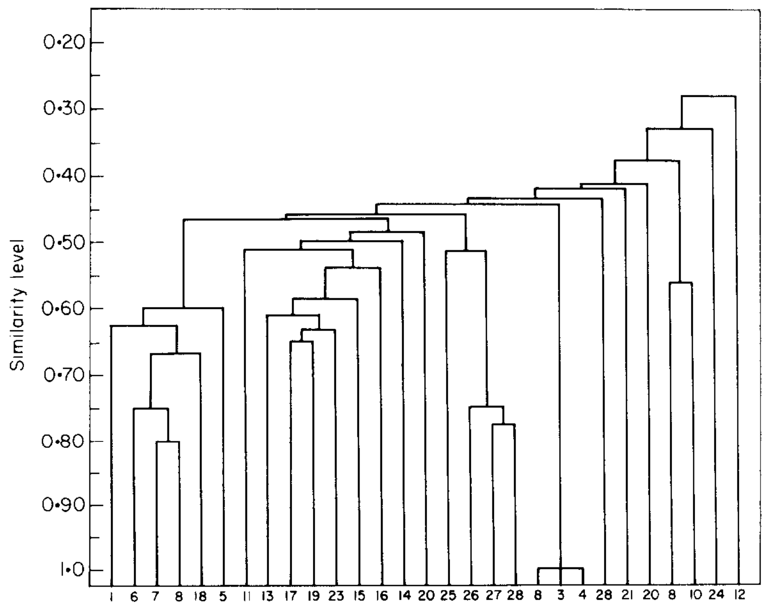

Figure 7. Dendrogram of faunal affinity between stations.

The concentration of dissolved oxygen is also variable and ranges from zero in the deepest parts of Aetoliko to 4·75 ml l^{-1} at station 17 (Figure 4).

The sediment in most stations is muddy, the amount of fines (grain size smaller than 0·0625 mm) ranging between 62‰ and 98‰. Only stations 9, 16 and 20 are sandy with a percentage of fines between 3% and 8%. At those stations the sediment is moderately to poorly sorted, while at all others it is either poorly or extremely poorly sorted (Table 1, Figure 5).

Benthic polychaetes and molluscs

139 species were identified over the whole area of which 93 are polychaetes and 46 molluscs. The number of species found at each station is shown in Table 1 and Figure 6. The most widely distributed species of polychaetes were *Heteromastus filiformis, Armandia cirrosa* and *Podarke pallida,* which were present at 45% of the stations. Of the molluscs, *Abra ovata* and *Parvicardium exiguum* were present at more than 50% of the stations, and were the most widely distributed.

The dendrogram in Figure 7 shows the grouping of stations according to their faunal similarities. At a similarity level of 0·55, five groups are apparent.

Group 1 includes the deeper stations (2, 3, 4) in the centre of the Aetoliko, characterized by anoxic conditions, a high percentage of mud in the sediment, and a great paucity of species. The polychaetes are completely absent and the molluscs are represented by only two species, namely *Brachydontes minimus* and *Hydrobia ventrosa.*

Group 2 comprises the shallow areas (stations 1, 5, 6, 7, 8, 18) of the Aetoliko where sediment characteristics are similar to the previous stations but salinity is lower and the dissolved oxygen content of the water is greater. Anoxic conditions were found at stations 7 and 8 in July 1981, but these were not azoic, with rather high densities of 10 and 6 species, respectively. Thus, the observed lack of oxygen was either a very recent or a very temporary phenomenon. The most widely distributed and most abundant species are *Nereis diversicolor, Brachydontes minimus, Abra ovata, Cerastoderma glaucum, Cyclope neritea* and *Hydrobia ventrosa.*

Group 3 comprises stations 26, 27 and 29 in Klissova lagoon where summer salinities are high. Nevertheless, the population was not very different from the previous group (Table 2). This group contained the additional species *Hydrobia ventrosa, Cerastoderma glaucum, Abra ovata,* but *Brachydontes minimus, Cyclope neritea* and *Nereis diversicolor* were lacking. A possible explanation could be the salinities; Mars (1966), for instance, found that *C. neritea* survives ' normally ' in salinities between 13‰ and 41‰. However, *B. minimus* and *N. diversicolor* are able to withstand high salinities at least up to 60‰. (Guelorget *et al.*, 1982). A better explanation could be the high organic-matter content of the sediment as indicated by the abundance of *Capitella capitata.* Such a phenomenon seems also to occur at stations 23 and 28.

Group 4 comprises stations 17, 23, 19 and 13 with a higher specific richness (17–22 species). Some of the previously found species were still present (*A. ovata, B. minimus*), but several additional species appeared such as *Gibbula adriatica, Loripes lacteus, Parvicardium exiguum, Staurocephalus rudolphi* and *Venerupis aurea.*

Group 5 is composed only by the two outermost stations (9 and 10) in the vicinity of the main pass of the lagoonal system. These stations display the highest specific richness, with 47 and 51 species, respectively, and low densities. Several species only occur in that particular area such as *Jujubinus striatus, Modiolus barbatus, Loripinus fragilis, Owenia fusiformis, Aonides oxycephala,* whereas *V. aurea* forms abundant populations and *Abra alba* is present instead of *A. ovata.*

The other stations of Messologhi lagoon bear intermediate features between group 4 and group 5 (Figures 8–10 and Table 2). The most widely distributed species are *G. adriatica, L. lacteus, P. exiguum, V. aurea, S. rudolphi* and *Polycirrus medusa.*

TABLE 2. Distribution of species in Messologhi lagoonal area: [a]numbers give semi quantitative density level for each species

	Station																												
	Group 1			Group 2						Group 3			Group 4													Group 5			
Species	2	3	4	1	5	6	7	8	18	29	27	26	17	23	19	15	13	25	16	12	20	21	22	11	24	14	9	10	28
Jujubinus striatus																											1	3	
J. miliaris																												1	
Tricolia pullus																											1		
T. tenuis																							2			2		3	
Cerithium vulgatum																	1										2	1	
Murex brandaris																									1				
M. trunculus																										1		2	
Gibberulina clandestina																											1		
Bela nebula																												1	
Atys jeffreysi																										2			
Williamia gussonii																												1	
Rissoa lineolata																							2						
Alvania montagui																						2							
Bittium reticulatum												2						2							2			1	
Sphaeronassa mutabilis																									1				
Hinia pygmea																					1				2				
Haminea navicula																	2						3			2	1		
Middendorfia caprearum													4						4										
Gibbula adriatica													4	1	1	2	2		2			4	2			2	3		2
Retusa truncatula														1	2			1	1				2						
Cyclope neritea							1	1	4				1																
Hydrobia ventrosa	2	3	1			3			4	2	4	2																	
Nucula sulcata																												1	
Modiolus barbatus																											2		

Modiolula phaseolina																												1	
Anomia ephippium																													1
Loripinus fragilis																												2	
Glans trapezia																										1	2	2	
Venerupis antiquata																										1	2	1	
Turtonia minuta																													1
Thyasira flexuosa																										1			
Spisula subtruncata																									1				
Abra tenuis																													4
A. nitida																									2				
A. alba																									3	1	2	2	
Corbula gibba																									2				
Gastrochaena dubia																												1	
Divaricella divaricata																		2							3		2	2	2
Loripes lacteus									1				4	2	4	1		1	1					2	1	2			
Parvicardium exiguum										2			3	3	4	2	2	2	4		2	2		2	1	1	2	1	
Venerupis aurea													1	1	1		1		2	1	1		1		2		4	3	
Cerastoderma glaucum				2		4	4	2	4	2	2	3	2	2				3											
Abra ovata				4	4	4	5	4	5	4	5	5	4	3	3	2	1	5								1	1		3
Brachydontes minimus	2	3	4	5	1	4	5	2	2				2				2												
Owenia fusiformis																											1	1	
Paradoneis lyra																			2		2	3		1			4	4	
Staurocephalus rudolphi									2				4	1	2	2	4		4	1	2			4		3	2	3	
Nereis caudata														2	4	4	1	1								2			2
Polycirrus medusa													2		3						3	2	2	1				4	
Nereis diversicolor				1		2	4	3	4				1					4			2	2					3		
Capitella capitata									2	4	4	2		3	2	1			2						1		2	1	3

1, one individual; 2, 2–5 individuals; 3, 6–10 individuals; 4, 11–100 individuals; 5, more than 100 individuals per sample.

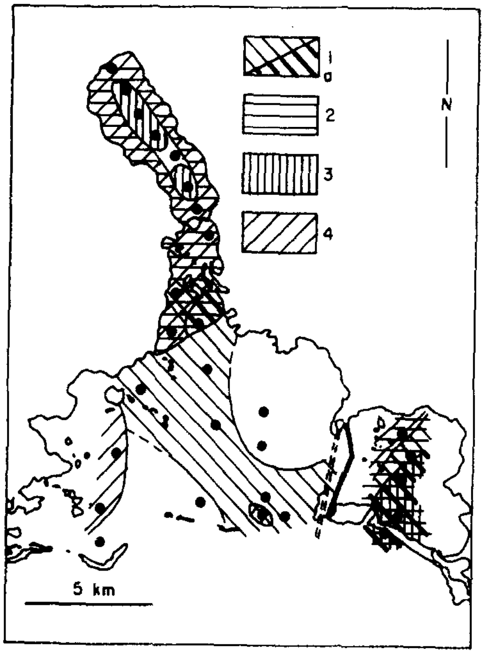

Figure 8. Distribution of *Capitella capitata* (1), *Cerastoderma glaucum* (2), *Hydrobia ventrosa* (3) and *Nereis diversicolor* (4). a, More than five individuals per sample.

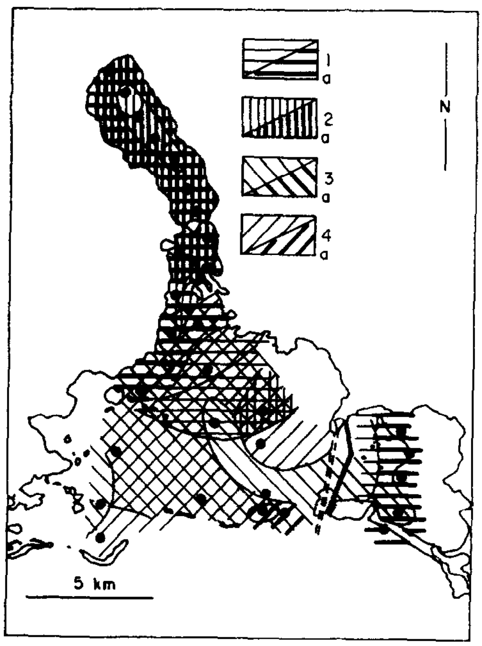

Figure 9. Distribution of *Abra ovata* (1), *Brachydontes minimus* (2), *Parvicardium exiguum* (3) and *Venerupis aurea* (4). a, More than five individuals per sample.

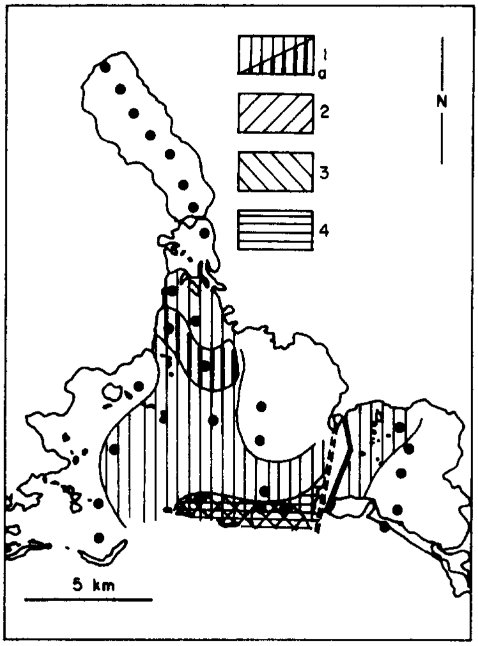

Figure 10. Distribution of *Loripes lacteus* (1), *Glans trapezia* (2), *Venericardia antiquata* (3) and *Abra alba* (4). a, More than 10 individuals per sample.

TABLE 3. Correlation coefficients between number of species and environmental parameters

No. of species correlated with:	Correlation coefficient	Degrees of freedom	Probability
Mean grain size	0·371	21	$0{\cdot}05 < p < 0{\cdot}10$
Percentage mud	−0·511	21	$0{\cdot}01 < p < 0{\cdot}02$
Sorting	−0·591	21	$0{\cdot}005 < p < 0{\cdot}01$
Dissolved oxygen	0·644	27	$p < 0{\cdot}001$
Salinity	0·278	27	$0{\cdot}10 < p < 0{\cdot}20$

Discussion

Table 3 shows the results of the Spearman rank correlations between the number of macrofaunal species and the environmental parameters measured. It can be seen that the number of species (species richness) roughly increases as the amount of fines in the sediment decreases and as the sorting of the sediment becomes poorer, but the correlations are rather weak. On the other hand, as might be expected, the number of species shows a still weak but better positive correlation with the concentration of dissolved oxygen. No significant correlation is found between the specific richness on the one hand and the mean grain size and salinity on the other, which is in accordance with other studies on lagoonal systems (Guelorget & Perthuisot, 1983), notably in Greece (Geulorget *et al.*, 1986), and means that salinity is definitely not an important ecological factor in lagoons.

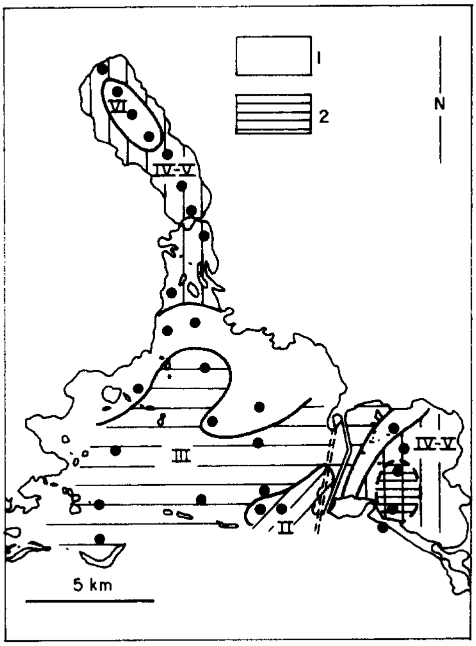

Figure 11. Tentative map of ' confinement ' zones in two Messologhi lagoonal area. II, Disappearance of marine stenobiotic species; III, dominance of intermediate species; IV–V, dominance of paralic species; VI, paucity of species. 1, Transition zone between zones III and IV, 2, organic enrichment.

From the analysis of the distribution of polychaetes and molluscs in the Messologhi lagoonal area (Figures 8–10, Table 2), and following Guelorget and Perthuisot (1983), it is possible to define three kinds of species.

The so-called ' thalassic ' species live in zones under prominent marine influence and form diversified populations with a high specific richness and generally low densities. Conversely, the so-called ' paralic ' species are restricted to localities farthest from the open sea. They form paucispecific populations with high densities. Some of them are able to withstand at least sporadic anoxic conditions such as *H. ventrosa* and *B. minimus* within the deep, highly restricted areas of Aetoliko. Most of the other species have an intermediate distribution; they are mainly suspension feeders with associated scavengers and predators. A few species are more ubiquitous such as *C. capitata* which, when abundant, is generally a good indicator of organic matter accumulation in the sediment (Guelorget *et al.,* 1984). Thus, the weak negative correlation between specific richness and the amount of fines (and the sorting) of the sediments appears to be secondary because the most restricted parts of the lagoonal system are also the hydrologically sheltered areas where fine sedimentation prevails, which of course, increases the sorting of particles.

From the above considerations, neither sedimentary characteristics nor salinity are the prominant parameters controlling the biological organization of the Messologhi lagoonal area. Even dissolved oxygen does not appear to be important except when oxygen depletion is total and more or less permanent, such as in the deepest central area of Aetoliko. In fact, the particular case of the Messologhi lagoonal system well illustrates the role of the ' confinement ', determined by the time of renewal with elements of marine origin at each given point of a lagoon, which according to Guelorget and Perthuisot (1983) primarily determines the biological organization and species distribution in lagoons. These authors have defined six ' confinement zones ' for Mediterranean lagoons, ranging from zone I, the nearest to the open sea, to zone VI which characterizes the farthest reaches of lagoonal systems, this zonation being based on macrobenthofaunal criteria. Using the same criteria, it is possible to draw a map of the ' confinement zones ' in the Messologhi lagoonal area (Figure 11). The previous group 5 (stations 9 and 10) is situated at the landward edge of zone II, in the small area neighbouring the main area under prominent marine influences. Conversely, group 1 is the most highly confined, probably due to water stratification in the deep central part of Aetoliko and must be considered as belonging to zone VI. Groups 2 and 3 may be put together in zones IV and V, zone V being generally exposed to organic matter enrichment (stations 27 and 29). Group 4 and station 25, where paralic and intermediate species co-exist, form a transition zone with zone III which occupies the central area of Messologhi lagoon where intermediate species are clearly dominating. Some problems still remain concerning stations 9, 14 and 28 where, surprisingly, thalassic species and paralic species co-exist. As an hypothesis, we think that areas such as these are near outlets of the lagoonal system where thalassic faunas are, perhaps temporarily, contaminated by a few paralic species; however, this point remains to be investigated further.

Conclusion

The grouping of stations according to faunal similarity presents a general view of the fauna distribution in the Messologhi lagoonal area. The use of presence–absence data and of semi-quantitative values for densities, even though only two animal groups are used, provide sufficient information for this purpose. This is in agreement with the view of Moore (1971) and Coleman & Cuff (1980) that the collection of qualitative data may be a useful initial approach, especially when surveying areas about which very little is known.

The distribution of molluscs and polychaetes in the Messologhi lagoonal area is clearly zonal and independent of salinity and sedimentary patterns. The distribution ranges from diversified populations with high specific richness, to paucispecific but dense populations in the most restricted parts of the lagoonal system. Thus, the hydrological parameters may account for the biological organization of lagoons better than do hydrochemical or sedimentological factors, mainly because they control in each locality the rate of exchanges with the open sea and, the ' confinement ' level.

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