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MACROBENTHIC FAUNA DIVERSITY IN THE AEGEAN SEA, AFFINITIES WITH OTHER MEDITERRANEAN REGIONS AND THE BLACK SEA

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Abstract. Long-term sampling (1970-1997) of the macrobenthic fauna of the Aegean Sea provided an abundance of qualitative information on many taxa, including Porifera, Hexacorallia, Octocorallia, Polychaeta, Sipuncula, Polyplacophora, Gastropoda, Cirripedia Thoracica, Amphipoda, Tanaidacea, Cumacea, Decapoda, Echinodermata and Ascidiacea.

This original information, combined with that from the relevant literature, allowed analysis of the macrobenthic fauna of several Mediterranean areas and the Black Sea. According to the considered data, the number of species decreases as follows: Western Mediterranean, Aegean Sea, Adriatic Sea, Central Mediterranean, Levantine Sea and Black Sea.

Species with an Atlanto-Mediterranean distribution dominate in all areas and are followed in numbers by the Mediterranean endemics or cosmopolitan species, depending on the areas.

key words: *Macrozoobenthos, Distribution, Mediterranean, Aegean Sea*

Introduction

The benthic macrofauna of the Aegean Sea has been considered as a distinct subunity of the Mediterranean fauna (Pérès, 1967; Murdoch & Onuf, 1974). An inflow of populations native of the Aegean enriches the Black Sea fauna (Caspers, 1957, 1968; Bâcescu 1977; Motas, 1977), whereas Aegean fauna is influenced by the less

saline waters of the Black Sea (Bâcescu et al., 1971), that carried many Sarmatian and Paleo-Euxinic elements into the Aegean Sea (Bâcescu, 1985). The Aegean Sea also receives Indo-Pacific migrants and is enriched by warm-water species of Atlantic origin (Por, 1978; Koukouras, 1979a; Türkay et al., 1987; Türkay, 1989; Por & Dimentman, 1989). In addition, the Aegean contains endemic species not found in other Mediterranean areas (e.g., Koukouras & Sinis, 1981; Koukouras et al., 1995); part of them described in more recent years (e.g., Dounas & Koukouras, 1989; Vafidis & Koukouras, 1991; Koukouras & Türkay, 1996).

Up to the 1960s, the composition of the Aegean benthic fauna was poorly known even after the "Calypso" cruises of 1955 and 1960. Thus, various species well known in the Western Mediterranean, such as *Corallium rubrum* (Linnaeus, 1758) and *Leptometra phalangium* (J. Müller, 1841), were considered to be scarce or even missing in the Aegean Sea (Pérès & Picard, 1958; Pérès, 1967).

The later intensive sampling effort progressively covered the larger part of the Aegean Sea. Results from these samples have been published since 1972 by the research group of the Department of Zoology, Aristoteleio University of Thessaloniki (Table 1).

The results of these studies, including some additional information from recent publications of various authors on Echinodermata (Pancucci-Papadopoulou, 1996), Bivalvia (Zenetos, 1996) and Decapoda Crustacea (d' Udekem d' Acoz, 1993a, 1993b, 1995; Kevrekidis & Kevrekidis, 1996), have considerably changed the initial impression of the macrobenthic diversity of the Aegean Sea.

This study intends to (i) summarize available data on the macrobenthic fauna of the Aegean Sea, (ii) compare the Aegean Sea with other Mediterranean areas and the Black Sea, and (iii) explain the differences.

Material and Methods

The bulk of the information used here was derived from the papers listed in Table 1, whereas a smaller part represents otherwise unpublished data gathered recently from different areas of the Aegean Sea.

Sampling was originally confined to the area of Evoia Island before being extended all over the Aegean Sea. Jointly, the sampling effort was extended to a larger depth range and to more diversified substrates and habitats (soft, hard, artificial substrate, coralligenous formations, lagoons, etc.) or special microhabitats (various sponges and corals).

Altogether, sampling was done in more than 350 "stations" all over the Aegean Sea. Each "station" was sampled in various sites and at various depths. Most of the publications referred to, contain station data and maps (e.g., Koukouras et al., 1992;

Table 1. Recently (1972-1998) published data on the most important macrobenthic groups, including the treated information.

Benthic animal groups		Published data (1972-1998)
	Porifera	Voultsiadou-Koukoura, 1986; Voultsiadou-Koukoura & van Soest, 1991a, 1991b, 1993; Voultsiadou-Koukoura et al., 1991; Voultsiadou -Koukoura & Koukouras, 1993
Anthozoa	Hexacorallia	Doumenc et al., 1985; Chintiroglou, 1987; Doumenc et al., 1987; Vafidis, 1992; Chintiroglou & den Hartog, 1995; Vafidis et al., 1997
Anthozoa	Octocorallia	Vafidis & Koukouras, 1991; Vafidis, 1992; Vafidis et al., 1994
	Polychaeta	Arvanitidis, 1994; Arvanitidis & Koukouras, 1995, 1997
	Sipuncula	Akillas, 1989
Mollusca	Scaphopoda	Koukouras & Kevrekidis, 1986
Mollusca	Polyplacophora	Kattoulas et al., 1973; Karachle, 1998
Mollusca	Gastropoda and Bivalvia	Koutsoubas, 1992; Koutsoubas et al., 1992; Koutsoubas & Koukouras, 1993; Koutsoubas et al., 1997
Crustacea	Cirripedia Thoracica	Kattoulas et al., 1972; Koukouras & Matsa, 1998
Crustacea	Amphipoda	Kevrekidis & Koukouras, 1988; Stefanidou & Voultsiadou-Koukoura, 1995; Stefanidou, 1996
Crustacea	Isopoda	Dounas & Koukouras, 1986; Stefanidou, 1996
Crustacea	Tanaidacea and Cumacea	Stefanidou, 1996
Crustacea	Decapoda	Koukouras, 1972/73, 1979a, 1979b; Kattoulas & Koukouras, 1974, 1975; Koukouras & Kattoulas, 1974, 1975; Türkay & Koukouras, 1988; Dounas & Koukouras, 1989; Koukouras et al., 1992; Koukouras & Türkay, 1996
	Echinodermata	Koukouras & Sinis, 1981
	Ascidiacea	Koukouras & Siamidou-Efremidou, 1978/79; Koukouras et al., 1995

Koukouras et al., 1995).

Sampling covered a depth range of 0-1000m; at depths greater than 200 m, it was less intense.

Sampling was qualitative, semiquantitative or quantitative and was done with fishing nets (e.g., otter trawls, ring nets), various types of dredges, grabs, corers, square frames and by SCUBA diving.

The main Mediterranean territorial areas (Western Mediterranean, Central Mediterranean, Adriatic Sea, Aegean Sea, Levantine Sea), of which faunas are compared,

have been determined by Collier (1970), on the basis of bottom layer water movements and oxygen and phosphate distributions.

Abbreviations used in this text are: **M**, Mediterranean; **WM**, Western Mediterranean; **CM**, Central Mediterranean; **AD**, Adriatic Sea; **AS**, Aegean Sea; **LS**, Levantine Sea; **BS**, Black Sea; **AM**, Atlanto-Mediterranean species; **E**, Endemic species; **C**, Cosmopolitan species; **IM**, Indo-Mediterranean species (reported from both the Indo-Pacific and the Mediterranean, but it can not be ruled out that these are cosmopolitan or erroneously identified; **LM**, Lessepsian migrants (species formally confined to the Indo-Pacific, that colonized the Mediterranean, through the Suez Canal).

As this text is mainly based on published data (Table 1), it is necessary to define that:

(a) as "recently described species" and "recent records" are determined the descriptions of new species and the new records correspondingly, that are included in the above publications (published after 1972).

(b) diversity is considered as the number of the known species from a given geographic area.

(c) most recent literature data published after August 1998, are not taken into account in this study.

Results

All benthic groups studied during this long-term research on the Aegean fauna are presented in Table 2. For each of them, the species number for the Mediterranean as a whole (column M) and the number and percentage for each of the six territorial areas (WM, CM, AD, AS, LS, BS) are presented.

Figure 1 is the corresponding diagram, illustrating a general scheme of the distributional pattern of the Mediterranean macrobenthic organisms. Taken separately, only Octocorallia, Hexacorallia, Polychaeta, Cirripedia, Amphipoda, Isopoda, Decapoda and Echinodermata follow the general distributional pattern of the total fauna, in the territorial areas (Table 2).

Jointly, the proportion of four zoogeographical categories within the total number of recorded species (excluding Gastropoda, where such an evaluation would be premature) was also estimated for each territorial area (Table 3). The table shows that in all the Mediterranean territorial areas and the Black Sea, most dominant are the Atlanto-Mediterranean species. It also shows that in all areas, with the exception of the Western Mediterranean, cosmopolitan species dominate over the endemics. Indo-Mediterranean species show considerable proportion only in the Levantine Sea (8.3%) and the Aegean Sea (2%).

Table 2. Distribution of the taxa studied in the Mediterranean territorial areas (see material and methods) and the Black Sea, as percentages of the total number of the Mediterranean species (column M). Species number for each taxon in each territorial area is given in parenthesis. In the Aegean Sea (AS) column, recent species records (percentage and species number) and numbers of recently described species (in bold) are given in a separate column. For abbreviations, see material and methods.

	ANIMAL GROUPS	M	WM	CM	AD	AS			LS	BS
							Recent records	**Recently descr. sp.**		
	Porifera	524	88.7 (465)	15.6 (82)	39.9 (209)	32.4 (170)	17.5 (92)	**3**	15.8 (83)	6.3 (33)
Anthozoa	Hexacorallia	88	92.1 (81)	44.3 (39)	59.0 (52)	55.7 (49)	5.7 (5)		35.0 (31)	6.8 (6)
Anthozoa	Octocorallia	43	97.7 (42)	30.2 (13)	46.5 (20)	62.8 (27)	34.9 (15)	**1**	4.7 (2)	23.0 (1)
	Polychaeta	1015	84.6 (859)	46.1 (468)	51.6 (524)	55.3 (561)	11.0 (112)	**2**	35.5 (361)	30.6 (308)
	Sipuncula	28	89.3 (25)	39.3 (11)	25.0 (7)	32.1 (9)	–		35.7 (10)	3.6 (1)
	Polyplacophora	30	96.7 (29)	76.7 (23)	56.7 (17)	63.3 (19)	3.3 (1)		51.9 (14)	16.7 (5)
	Gastropoda	1294	88.7 (1148)	45.0 (582)	37.5 (462)	48.0 (622)	6.0 (78)		37.8 (490)	6.4 (83)
Crustacea	Cirripedia	34	100.0 (34)	50.0 (17)	50.0 (17)	52.9 (18)	17.6 (6)		32.5 (13)	20.6 (7)
Crustacea	Amphipoda	449	93.8 (421)	35.6 (160)	53.9 (242)	57.9 (260)	9.6 (43)		32.0 (144)	17.1 (77)
Crustacea	Isopoda	165	90.3 (149)	15.7 (26)	29.7 (49)	44.9 (74)	5.5 (9)		26.7 (44)	20.6 (34)
Crustacea	Tanaidacea	43	71.1 (32)	13.9 (6)	39.5 (17)	41.9 (18)	16.3 (7)		39.5 (17)	13.9 (6)
Crustacea	Cumacea	91	84.6 (77)	16.5 (15)	7.7 (7)	57.1 (52)	2.2 (2)		39.5 (36)	28.6 (26)
Crustacea	Decapoda	374	85.0 (316)	55.0 (205)	61.3 (228)	67.4 (252)	12.1 (45)	**2**	56.4 (211)	15.9 (59)
	Echinodermata	162	97.5 (158)	69.1 (112)	66.0 (107)	66.7 (108)	9.2 (15)		39.5 (64)	16.7 (27)
	Ascidiacea	187	88.2 (165)	49.7 (93)	45.5 (85)	35.8 (67)	12.8 (24)		24.1 (45)	5.3 (10)
	TOTAL	4527	88.4 (4001)	40.9 (1852)	45.1 (2041)	50.9 (2306)	10.0 (454)		34.6 (1565)	15.1 (683)

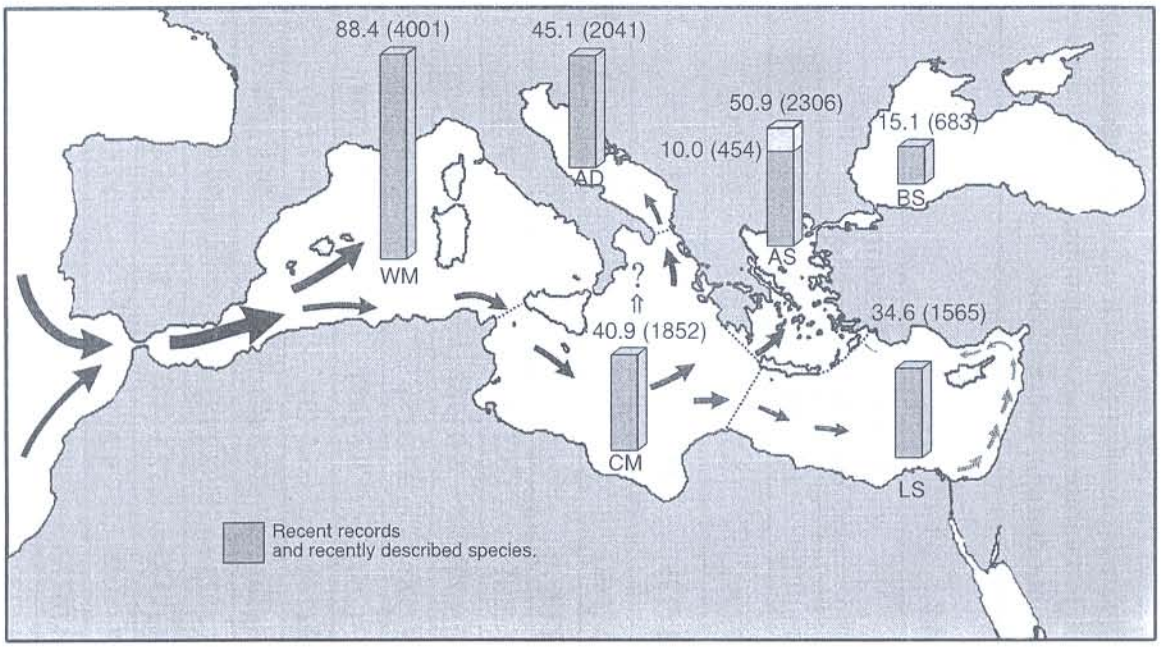

Fig. 1. Large-scale principal distributional paths of the bulk macrobenthic fauna from the Atlantic and the Red Sea in the Mediterranean based on the data of Table 1 and the relevant literature. For explanations, see text.

Discussion

The research data gathered from the Aegean Sea and the information obtained from the relevant literature, for the whole of the Mediterranean, were considered reliable enough in order to compare the faunas of the Mediterranean territorial areas and the Black Sea, expecting that this would reveal distributional patterns of the macrobenthic fauna. This assumption is based on two considerations: First, even though there is a lack of information concerning great depths, this should not bias significantly the result; the number of species living in great depths is relatively low, their distribution is relatively homogenous and the sampling effort is low in great depths all over the Mediterranean and the Black Sea (e.g., Fredj & Laubier, 1985). Second, the bulk of macrobenthic species is located on the continental shelf and slope, where the sampling effort has been intense almost all over the Mediterranean (Fredj & Laubier, 1985). If sampling in great depths increases, the numbers of species recorded from each region will increase only slightly. It seems improbable that this will change considerably the distributional patterns of the different benthic groups in the Mediterranean and the Black Sea.

Taking into account Figure 1, Tables 2 and 3, data on the Mediterranean water masses and circulation (Ovchinnikov, 1966; Collier, 1970; Lacombe & Tchernia, 1972; Béthoux, 1980; The POEM group, 1992; Theocharis et al., 1993; Perivoliotis et al.,

1997) together with data on temperature and salinity variations (Lacombe et al., 1958; Lacombe & Tchernia, 1960, 1972; Lipkin & Safriel, 1971; Delépin et al., 1987; Özsoy et al., 1993) and geographical aspects (Bianchi & Morri, 2000; Pinardi & Masetti, 2000) the following considerations can be made:

1. The Western Basin of the Mediterranean supports a considerably higher number of species than any other area. This is mainly due to the fact that the influx of Atlantic species is initially limited in this large basin, with its wide range of physico-chemical parameters that permit the settlement of both cold and warm water species in its northern and southern parts, respectively. This general trend does not seem heavily based on the more intensive sampling carried out in this area. This is also the area of the highest endemism (821 endemic species, 28.8% of the species known from this area, see Table 3) which can be explained by the great diversity of biotopes and the fact that the majority of these endemics are in fact "neoendemics" meaning they have derived from Atlantic species (Fredj, 1974; Tortonese, 1985).

2. Based on the relevant literature, the Central Mediterranean ranges fourth in species number. The restricted sampling effort for most animal groups in this area, and mainly on the continental shelf of Tunisia and Libya, seems to be the cause for the relatively low species number. The large surface of this basin and its proximity with the Western Mediterranean strengthens this interpreatation, which is also enhanced by the data concerning the ascidians (Table 2). More extensive samplings in this area (Pérès, 1954, 1956) brought the Central Mediterranean second in ascidian species number, after the Western Mediterranean (Koukouras et al., 1995). It is expected that with adequately increasing sampling effort, the number of species in the Central Mediterranean will approximate that in the western basin and it will exceed those in the other Mediterranean regions.

3. Although the Aegean Sea is more distant from Gibraltar (the main pathway of

Table 3. Percentages of the four zoogeographical categories in the Mediterranean territorial areas and the Black Sea, for the 14 benthic groups studied; calculations have been made for the total of species known from each area (excluding Gastropoda). For abbreviations, see material and methods.

Zoogeographical category	WM	CM	AD	AS	LS	BS
Atlanto-Mediterranean	47.8	49.2	49.4	49.5	42.3	41.5
Endemic	28.8	18.2	21.3	18.6	14.8	16.5
Cosmopolitan	22.2	31.7	28.7	24.9	34.8	40.7
Indo-Mediterranean	1.2	0.9	0.6	2.0	8.3	1.3
TOTAL (species number)	**2853**	**1270**	**1579**	**1684**	**1075**	**600**

enrichment for the Mediterranean fauna) than the Adriatic, it is inhabited by a greater number of species. Before the phase of investigation reported here, which added 454 species to the Aegean fauna (increase of 10%), the species number of the Aegean was similar to that of the Adriatic, although the latter had been studied for a much longer time. Some papers have been published since 1998 (e.g., Koukouras, 1998, 2000; Koukouras & Dounas, 2000; Koukouras et al., 1998; Morri & Bianchi, 1999; Morri et al., 1999; Arvanitidis, 2000; Koukouras et al., 2000) that increase furthermore the number of the known species from the Aegean Sea. Main reasons for the higher species number in the Aegean may be: (a) its more direct communication with the western basin (e.g., Ovchinnikov, 1966) and (b) the greater amplitude of the temperature variations (e.g., Delépine, et al., 1987). As in the other areas, Atlanto-Mediterranean species dominate in the Aegean (Table 3). However, Aegean fauna is second after the Levantine fauna by contribution of species with an Indo-Mediterranean distribution (Table 3). On the contrary, it has not incorporated many Lessepsian migrants because of the lower salinities and temperatures, prevailing especially in the northern Aegean (Lacombe et al., 1958; Lipkin & Safriel, 1971; Delépine et al., 1987), which may be prohibitive for the dispersal of, at least, the invertebrate migrants (Por, 1978). In fact, the present study did not confirm the presence of Lessepsian invertebrates in the Aegean, except around Rhodos Island (Kevrekidis & Kevrekidis, 1996; Kevrekidis et al., 1998). This area seems to be the northwest boundary of the invertebrate Lessepsian migrant expansion, as suggested earlier (Por, 1978; Por & Dimentman, 1989).

4. The Adriatic is only third in species number, although most of the groups are well studied there. Reasons for this lower species number could be (a) its considerably restricted communication with the western basin (Ovchinnikov, 1966; Theocharis et al., 1993), (b) the smaller amplitude of the temperature variations (e.g., Delépine et al., 1987), (c) the shallow waters of its northern part with relatively low winter temperatures and low salinity (e.g., Lacombe & Tchernia, 1960).

5. Por (1975) characterized the fauna of the Levantine Basin as "a most impoverished extension of the temperate Atlantic fauna". Por (1978) and Por & Dimentman (1989) argue that the Levantine Sea is an extremely stressed marine environment: oligotrophic conditions; quasi-tropical, high salinity, cul-de-sac situation; extreme instability of its environments on the subrecent geological scale; high sedimentation rate and extreme surface salinity fluctuations caused by the Nile run-off. They conclude that "The poor fauna of the Levantine Basin is without doubt a result of the fluctuations resulting from the last glacial cycle and much less of present restricting circumstances". Koukouras & Russo (1991) likewise showed midlittoral macrofaunal impoverishment of this area. The total number of species of all animal groups taken into account (Fig. 1) and the total species numbers of most other groups examined

separately (Table 2), indeed suggest that the fauna of the Levantine Basin is impoverished in comparison to other Mediterranean areas, representing only 34.6% of the total Mediterranean species.

The Levantine fauna seems even poorer when the Lessepsian migrants (Por, 1978) are excluded. In fact, some 122 Lessepsian species represent 8.3% (Table 3) of the total number of species known from this area. If we take into account 47 Lessepsian gastropod species the percentage rises to 12.7%. The Lessepsian migration of course continues, and an increase of the species number in this area can be expected. However, it has been ascertained that certain species with an Indo-Mediterranean distribution, occasionally considered as Lessepsian migrants, do not fulfil the criteria posed by Por (1978). This erroneous classification was due to misidentification, to an even wider but poorly known distribution, or to their rarity. For instance, out of 45 polychaete species known from the Indian Ocean and the Mediterranean and previously considered as Lessepsian migrants, only 12 really belong to this category (Arvanitidis, 1994). For ascidians, the numbers are 2 species instead of 7 (Koukouras et al., 1995), for gastropods, 47 instead of 60 (Koutsoubas, 1992), for isopods, 0 species instead of 5 (Stefanidou, 1996) and for sponges, 11 instead of 13 (Voultsiadou-Koukoura, 1986).

6. The Black Sea has a very low species number (Fig. 1), as already known, mainly due to its low salinities (e.g., Caspers, 1957; Longhurst, 1998).

This can be summarized as follows: The principal influx of the Atlantic macrobenthic species passes through the Western Mediterranean, into the Central Mediterranean and the Aegean Sea, with the number of species declining west to east (Fig. 1). Less species were able to settle in the Adriatic because of more adverse conditions. Even fewer species were able to reach and settle in the Levantine Sea, where particularly unfavorable conditions prevail (Por & Dimentman, 1989). Conversely, the eastern part of the Levantine basin is enriched by Lessepsian migrants. They extend their area, in declining number of species, along the Israeli, Lebanese and southern Turkish coasts and only few of them reach the area of Rhodos Island (Kevrekidis & Kevrekidis, 1996; Kevrekidis et al., 1998) in the south Aegean Sea. The extension of the Aegean macrobenthic species towards the Black Sea is almost stopped in the Bosporus, after having decreased considerably in the Sea of Marmara (e.g., Caspers, 1957).

As far as the percentage of the four zoogeographical categories is concerned, it proved difficult to draw general conclusions taking into account all the benthic taxa examined. Considering the whole fauna, results in mixing different patterns of distribution, as already noticed by Tortonese (1985). The percentage of each category per animal group reflects the dispersal capability of larvae or mature individuals, and conversely, the degree to which the conditions prevailing in the Mediterranean meet their demands. Information of this kind is still insufficient to draw general conclusions.

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