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Marine biogeography of the Mediterranean Sea: patterns and dynamics of biodiversity

Mediterranean Pycnogonida: faunistic, taxonomical and zoogeographical considerations

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Key words: Pycnogonida, Mediterranean Sea, taxonomy, biogeography.

SUMMARY

An up-to-date list of the Pycnogonida of the Mediterranean Sea is given. The total number of taxa registered is 56, some of which require a revision. Four species are to be considered as allochthonous: *Ammothea hilgendorfi, Anoplodactylus californicus, A. digitatus, Pigrogromitus timsanus.* As regards zoogeographic composition, the highest percentage (35%) is displayed by Mediterranean Atlantic elements, the lowest by Indo-Pacific species (found only in the Eastern Basin); cosmopolitan and endemic elements have the same percentage (24% each); the proportion of endemic species is comparable to that of sessile or relatively non mobile organisms, such as Hydroida, Bryozoa and Echinodermata.

INTRODUCTION

According to Chimenz Gusso (2000), the Pycnogonida fauna of the Mediterranean Sea (including the Black Sea) comprises 54 species, about 5% of the world total (1100 species according to Muller, 1993) and 37% of the European total (146, according to the European Register of Marine Species). For the Italian coasts (including Nizza and Istria) Chimenz Gusso (2000) cited 44 species, almost 79% of the Mediterranean Sea total. The object of the present article is to provide un update on available knowledge for the whole Mediterranean basin, as a starting-point for a zoogeographic characterization.

MATERIALS AND METHODS

The sites, for which data have been collected on Pycnogonida fauna, are shown in Tab. I. The symbols of the areas studied and the respective authors are as follows:

Alboran (Al): Stock, 1987; Arnaud, 1987; Munilla, 1993; Munilla and Nieto, 1999.
Spain, South of the Ebro River (SS): Munilla, 1993.
Spain, North of the Ebro River (NS): Munilla, 1993; Munilla and San Vicente, 2000.
Provence (Pr): Arnaud, 1987.
Liguria (Li): Faraggiana, 1940; Krapp, 1975; Arnaud, 1987; Chimenz Gusso, 2000.
Elba (El): Arnaud, 1987.
Corsica (Co): Arnaud, 1987.
Sardinia (Sa): Chimenz Gusso, 2000.
North Tyrrhenian Sea (Latium) (NT): Chimenz Gusso, 2000.
Central Tyrrhenian Sea (Campania) (CT): Chimenz Gusso, 2000; Krapp, 1973b.
South Tyrrhenian Sea (northern Sicily) (ST): Chimenz Gusso, 2000.
North Adriatic Sea (Tremiti Islands included) (NA): Stock, 1952; Krapp, 1975; Krapp-Schickel and Krapp, 1973; Schuller, 1989; Piscitelli, 2000; Chimenz Gusso, 2000.
South Adriatic Sea (SA): Chimenz et al., 1993; Chimenz Gusso, 2000.
Catania (Ca): Krapp, 1973a.
Pantelleria and Strait of Sicily (Pa): Krapp, 1973a; Chimenz Gusso, 2000.
Tunisia (Tu): Bourdillon, 1954; Arnaud, 1987.
Egypt (Eg): Helfer, 1936; Stock, 1962.
Israel (Is): Stock, 1958a,b; Arnaud, 1987.
South Turkey (STu): Stock, 1962.
Aegean (Ae): Arnaud, 1987.
Corinth (Cr): Arnaud, 1987.
Black Sea (BS): Bacescu, 1953, 1959.

Taxa were ordered into a species/station matrix. Each taxon was assigned to one of the following biogeographic categories: 1) Mediterranean Endemic *sensu stricto* (ME); 2) Mediterranean-Atlantic (MA, registered both in the Mediterranean and the eastern Atlantic); 3) Amphi-Atlantic (AA, in the Mediterranean and both western and eastern Atlantic); 4) Cosmopolitan (CO); 5) Indo-Pacific (IP); 6) with disjunct distribution (DI) (Tab. I).

For the study of zoogeographic composition the following sites were aggregated: North Spain, Provence, Corsica, Liguria (renamed NM = North Mediterranean); Elba, North Sardinia, North, Central and South Tyrrhenian (CM = Central Mediterranean); Egypt, Israel and South Turkey (EM = Eastern Mediterranean) (the resulting arrays thus number 11).

Tab. I - List of species, with their distribution in the sampled localities; circles (°) mark allochthonous species; asterisks (*) deep species (exclusively found at depths exceeding 150 m): see comment pg. 2. First column: biogeographic cathegories : CO=cosmopolitan; MA=Mediterranean-Atlantic; IP=Indo-pacific; ME=Mediterranean-Endemic; AA=Amphi-Atlantic; DI= disjunct distribution. Symbols of studied localities: Al= Alboran; SS=South Spain; NS= North spain; Pr=Provence; Li=Liguria; El=Elba; Co=Corsica; Sa=Sardinia; NT=North Tyrrhenian; CT=Central Tyrrhenian; ST= South Tyrrhenian; NA= North Adriatic; SA=South Adriatic; Ca=Catania; Pa=Pantelleria; Tu=Tunisia; Eg=Egypt; Is=Israel; STu=South Turkey; Ae=Aegean; Cr=Corinth; BS=Black Sea.

		Al	NS	SS	Pr	Co	Li	El	Sa	NT	CT	ST	NA	SA	Ca	Pa	Tu	Eg	Is	STu	Cr	Ae	BS
Achelia echinata Hodge, 1864	CO	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-
Achelia langi (Dohrn, 1881)	MA	+	+	+	+	-	-	-	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Achelia simplex Giltay, 1934	MA	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Achelia vulgaris (A. Costa, 1861)	MA	+	+	+	+	+	-	-	-	-	-	-	+	-	+	-	-	-	+	-	-	+	-
Ammothea hilgendorfi (Bohm, 1879)	IP	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Ammothella appendiculata (Dohrn, 1881)	CO	-	+	+	+	-	+	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Ammothella biunguiculata (Dohrn, 1881)	CO	-	+	-	+	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-
Ammothella longioculata (Faraggiana, 1940)	ME	+	-	-	+	-	+	-	-	+	+	+	+	+	+	-	+	+	+	-	-	-	-
Ammothella longipes (Hodge, 1864)	MA	+	+	+	+	-	+	-	-	+	+	+	-	+	-	-	-	+	-	-	+	+	-
Ammothella uniunguiculata (Dohrn, 1881)	MA	+	+	+	+	-	-	-	-	+	+	+	-	+	+	+	-	-	-	-	-	+	-
Ascorhynchus arenicola (Dohrn, 1881)	ME	-	-	-	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Ascorhynchus castelli (Dohrn, 1881)	AA	-	+	-	+	-	+	-	-	+	+	+	-	-	-	-	+	-	-	-	-	-	-
*Ascorhynchus pudicum** Stock, 1970	MA	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ascorhynchus simile Fage, 1942	MA	-	+	+	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Nymphonella tapetis Ohshima, 1927	DI	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*Paranymphon spinosum** Caullery, 1896	CO	-	+	-	+	-	+	-	-	+	+	-	+	+	-	-	-	-	-	-	-	-	-
*Paranymphon spinosum** Caullery, 1896	CO	-	+	-	+	-	+	-	-	+	+	-	+	+	-	-	-	-	-	-	-	-	-

Species		Al	NS	SS	Pr	Co	Li	El	Sa	NT	CT	ST	NA	SA	Ca	Pa	Tu	Eg	Is	STu	Cr	Ae	BS
Tanystylum conirostre? (Dohrn, 1881)	AA	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	-	+	-	+
Tanystylum orbiculare? Wilson, 1878	CO	+	+	+	+	+	-	-	-	+	+	-	+	-	+	-	-	+	+	+	-	+	-
Trygaeus communis Dohrn, 1881	ME	+	+	+	+	+	+	+	-	+	+	+	+	-	-	+	+	-	-	-	+	+	-
Anoplodactylus angulatus (Dohrn, 1881)	MA	+	+	+	+	-	+	-	-	+	+	+	+	+	+	-	-	-	+	-	-	-	-
Anoplodactylus californicus° Hall, 1912	CO	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	+	+	-	-	-
Anoplodactylus compositus Chimenz, Cottarelli & Tosti, 1991	ME	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Anoplodactylus digitatus° (Bohm, 1879)	IP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
*Anoplodactylus massiliensis** Bouvier, 1916	MA	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anoplodactylus petiolatus (Kroyer, 1844)	AA	+	+	-	+	+	+	-	+	+	+	+	+	+	+	-	-	-	+	-	-	+	+
Anoplodactylus pygmaeus (Hodge, 1864)	CO	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	-	-	+	-	-	+	+
Anoplodactylus robustus (Dohrn, 1881)	CO	+	-	-	+	+	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
Anoplodactylus stocki Bacescu, 1959	ME	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Anoplodactylus virescens (Hodge, 1864)	MA	+	+	+	+	+	+	-	-	-	+	+	-	+	-	+	+	-	-	-	-	+	-
Anoplodactylus sp Chimenz, Cottarelli & Tosti, 1993	ME	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
*Pallenopsis scoparia** Fage, 1956	CO	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhynchothorax alcicornis Krapp, 1973	ME	-	-	-	+	+	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-
Rhynchothorax mediterraneus A. Costa, 1861	CO	-	-	+	+	+	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	+	-
Rhynchothorax monnioti Arnaud, 1974	MA	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhynchothorax philopsammum Hedgepeth, 1951	CO	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		Al	NS	SS	Pr	Co	Li	El	Sa	NT	CT	ST	NA	SA	Ca	Pa	Tu	Eg	Is	STu	Cr	Ae	BS
Rhynchothorax voxorinum Stock, 1966	ME	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Callipallene acribica Krapp, 1975	ME	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Callipallene brevirostris (Jonston, 1837)	AA	+	+	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+
Callipallene emaciata (Dohrn, 1881)	AA	+	+	+	+	+	-	-	-	+	+	-	+	-	-	-	+	+	-	-	-	+	-
Callipallene phantoma (Dohrn, 1881)	CO	+	+	+	+	+	-	-	-	+	+	-	+	+	+	-	-	-	-	-	-	+	-
Callipallene producta (G O. Sars, 1888)	MA	+	+	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-	+
Callipallene spectrum (Dohrn, 1881)	MA	+	+	-	+	-	-	-	-	+	+	-	+	+	+	+	-	+	-	-	-	-	-
Callipallene tiberi (Dohrn, 1881)	MA	+	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-
Neopallene campanellae Dohrn, 1881	ME	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Pigrogromitus timsanus °Calman, 1927	CO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Pycnogonum nodulosum Dohrn, 1881	MA	+	+	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-
Pycnogonum plumipes Stock, 1968	ME	-	-	-	+	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Pycnogonum pusillum Dohrn, 1881	MA	+	-	-	+	+	-	-	-	+	+	-	+	+	-	-	-	-	-	-	-	-	-
Endeis charybdaea (Dohrn, 1881)	MA	-	-	-	+	-	-	-	-	+	+	+	+	-	-	-	+	-	-	-	-	-	-
Endeis mollis (Carpenter, 1904)	CO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Endeis mollis (Carpenter, 1904)	CO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Endeis mollis (Carpenter, 1904)	CO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Endeis mollis (Carpenter, 1904)	CO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Endeis spinosa (Montagu, 1808)	AA	+	+	+	+	-	+	-	-	+	+	-	+	+	-	-	+	-	-	-	-	-	+
Nymphon caldarium *Stock, 1986	ME	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		Al	NS	SS	Pr	Co	Li	El	Sa	NT	CT	ST	NA	SA	Ca	Pa	Tu	Eg	Is	STu	Cr	Ae	BS
Nymphon gracile Leach, 1814	MA	+	+	+	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-
Nymphon parasiticum Merton, 1806	ME	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Nymphon puellula Krapp, 1973	ME	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Hedgpethia atlantica * (Stock, 1970)	MA	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The data were processed with the Cluster Analysis, based on Bray-Curtis similarity index and square root transformation, performed with the PRIMER software applied to species presence-absence data (Clarke and Warwick, 1994). Localities with less than 10 species (Black Sea, Corinth, Catania) were eliminated (the resulting areas are thus 8: Fig. 1). Species found preferentially or exclusively at depth greater than 150 m were neglected, because deep samplings were taken in only a few stations; the same was true for *T. orbiculare*, *T. conirostre*, *Callipallene spectrum*, *C. emaciata*, *C. tiberi*, *C. phantoma*, *C. producta*, whose actual distribution is difficult to assess due to taxonomic uncertainties.

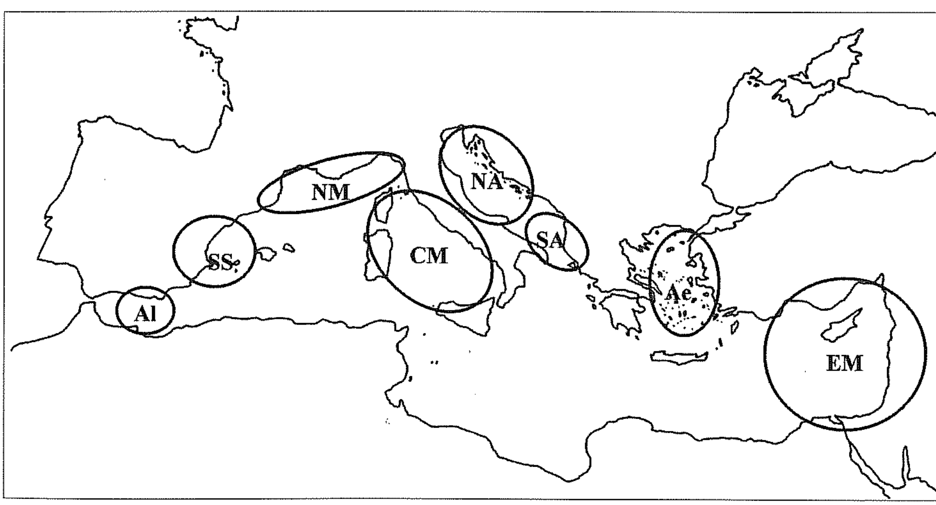

Fig. 1 - Map of the 8 areas with more than 10 species. Symbols: Al = Alboran; SS = South Spain; NM = North Mediterranean; CM = Central Mediterranean; NA = North Adriatic; SA = South Adriatic; Ae = Aegean Sea; EM = Eastern Mediterranean.

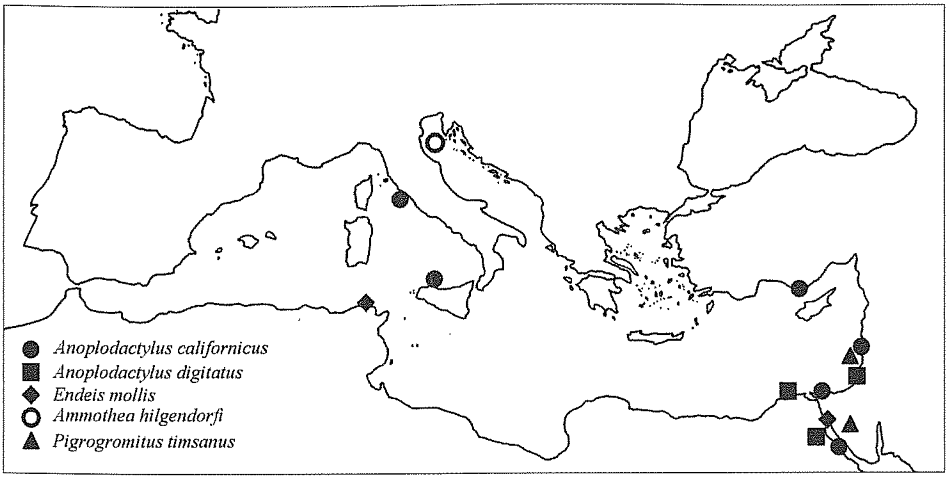

Fig. 2 - Distribution of allochthonous species.

RESULTS

The distribution of the 56 taxa is reported in Tab. I. Two other species have been added to those cited by Chimenz Gusso (2000): *Callipallene brevirostris* (whose presence in the Mediterranean Sea was only recently verified by Munilla and Nieto, 1999) and *C. tiberi*, whose specific identity is still being debated. The asterisk and the circle mark allochthonous and deep species, respectively. Some comments are needed: *Tanystylum conirostre* was clearly distinguished from *T. orbiculare* in 1973 by Krapp; therefore, it is not sure to which of these two species the previous citations of *orbiculare* from Israel (1958) and Egypt (1962) actually refer. *Callipallene phantoma* from the Black Sea cited by Bacescu (1953) is actually *C. producta*; a correct identification of the species of *Callipallene* will be impossible unless a revision of this genus is made.

One group of 32 species is widespread in the whole Mediterranean basin. A second group of 16 species is present exclusively in the western basin (the asterisk marks deep species): *Aschorhynchus arenicola*, *A. castelli*, *A. pudicum**, *Nymphonella tapetis*, *Anoplodactylus massiliensis**, *Pallenopsis scoparia**, *Rhynchothorax monnioti*, *R. philopsammum*, *R. voxorinum*, *Callipallene brevirostris*, *Neopallene campanellae*, *Endeis mollis*, *Pycnogonum nodulosum*, *Nymphon caldarium**, *N. parasiticum*, *Hedgpethia atlantica**. A third group includes 8 species found only in the eastern basin (including the Adriatic and Black Sea): *Achelia simplex*, *Ammothea hilgendorfi*, *Anoplodactylus compositus*, *A. digitatus*, *A. stocki*, *Anoplodactylus* sp.1, *Pigrogromitus timsanus*, *Nymphon puellula)*.

Alien species (*sensu* Relini, 2000) are *Ammothea hilgendorfi* (North Adriatic), *A. californicus* (Tyrrhenian Sea, South Turkey, Egypt), *A. digitatus* (Egypt, Israel),

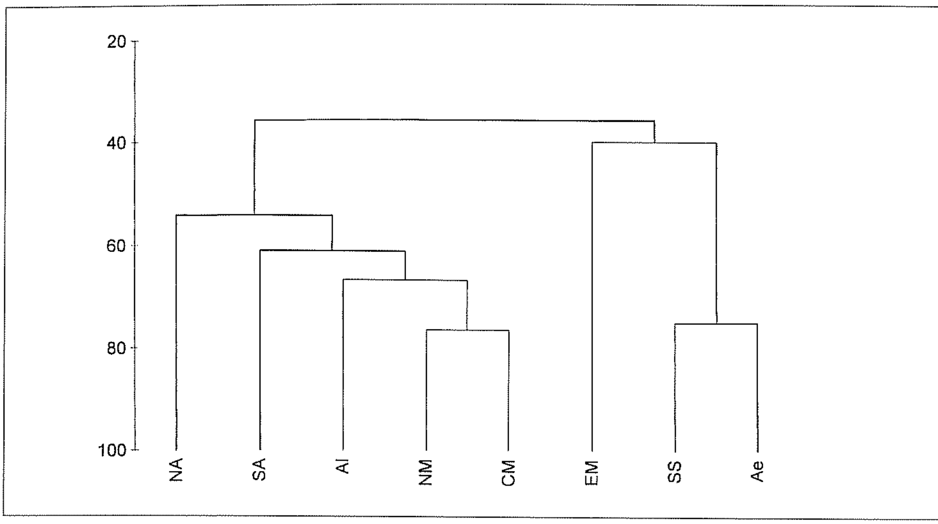

Fig. 3 - Faunistic similarity among the assemblages of the 8 areas with more than 10 species. Symbols as in Fig. 1.

P. timsanus (Israel) (Fig. 2). Deep species were cited only in the western basin, with the exception of *Paranymphon spinosum*, found also in both basins at depths lower than 150 m.

The analysis relevant to the faunistic similarity of the 8 selected areas (Fig. 3) shows two clusters: one including SS and Ae, plus EM in a isolated position; the other including all the Western and Adriatic stations, with the Northern and Central Mediterranean areas resembling each other most (76,4 %).

As regards the zoogeographic composition of the total Mediterranean fauna, MA species are the most frequently represented (35%), followed by CO (25%) and ME (24%); the percentage of AA is much lower (11%), whilst IP and DI show very low values (4 and 2%, respectively).

The zoogeographic composition of the assemblages in the 11 aggregated areas (Fig. 4) shows the dominance of MA in all areas except Tu (where CO are dominant) and NA, Pa and EM, where MA and CO display the same values; the highest percentages of MA were found in SS (57.2%), Al (52.9%) and Ae (50%). The highest percentages for ME were found at Pa (33.33%), SA (26.31%), Ca (25%) and the lowest in SS (7.14%), EM (9.09%), Ae (10%), and Al (11.8%). IP are reported only in NA (*A. hilgendorfi*) and EM (*A. digitatus*).

The cluster analysis carried out on the biogeographic groups (Fig. 5) reveals two clusters: one including the western Mediterranean (except SS) and the South Adriatic areas, the other with SS and the eastern areas. The highest similarity values are those between CM - SA and SS - Ae (93.9 and 93.3 %, respectively).

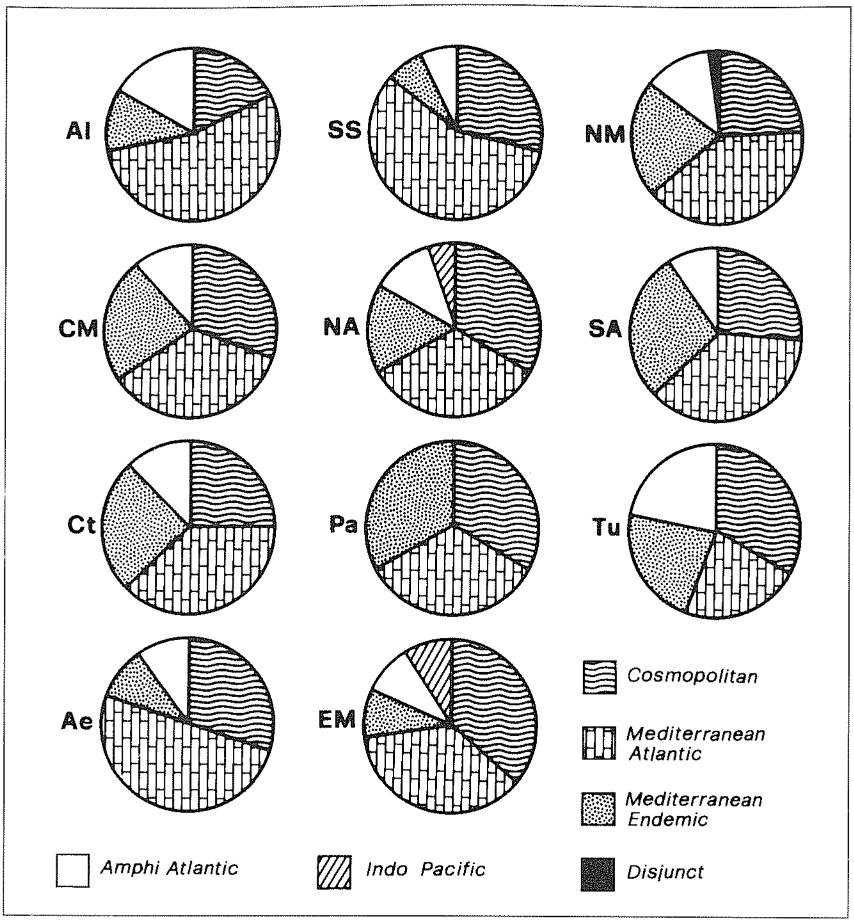

Fig. 4 - Zoogeographical composition of the assemblages of the 11 aggregated areas. Symbols: Al = Alboran; SS = South Spain; NM = North Mediterranean; CM = Central Mediterranean; NA = North Adriatic; SA = South Adriatic; Ct = Catania; Pa = Pantelleria; Tu = Tunisia; Ae = Aegean Sea; EM = Eastern Mediterranean.

DISCUSSION AND CONCLUSIONS

The results illustrated herein are an up-to-date synthesis of the available data on the Pycnogonida fauna of the whole Mediterranean Sea. Some obstacles still stand in the way of drawing definite conclusions about both faunistic composition and distribution:

– *Taxonomic problems*. The effective distribution of the Mediterranean species of *Callipallene* cannot be ascertained until a thorough revision of the genus has been made. The Mediterranean material of *Tanystylum* found before Krapp's redescription (1973a) must be reappraised.

- *Sampling and sorting methods*. As Pycnogonida are a by-product of research on benthic assemblages, the finding of tiny species (such as those of the genus *Rhynchothorax*) is the result of the sampling devices and sorting methods adopted. Moreover, some areas (usually those close to Scientific Institutions) are more intensively sampled than others; deep waters are poorly investigated.

Bearing these difficulties in mind, the following considerations may be made.

The different composition of the faunal assemblages in the eastern and western basin is partly ascribable to the presence of alien species in the eastern stations (see Fig. 2) and partly to the above-mentioned sampling artifacts. Indeed, the differences are mainly due to species found only once. The only real difference is perhaps *A. simplex* (only NA) and *A. arenicola* (only western basin). A realistic interpretation of the faunistic similarities among the areas with more than 10 species (see Fig. 3) is difficult owing to the very different sampling intensities in the various areas. At the present state of our knowledge, only the strong similarity between NM and CM can be considered as reasonably well founded.

As regards the zoogeographical characteristics of the Mediterranean as a whole, the dominance of the MA group is compatible with the fact that it is part of the Atlantic-Mediterranean Region (Sarà, 1985); the percentage of endemic species is comparable with that calculated for sessile or relatively non mobile taxa, such as Hydroida (27.1%, according to Sarà, 1985), Bryozoa (about 28%: Zabala, 1986), Echinodermata (24.3%: Tortonese, 1985), and intermediate between the low values typical of mobile taxa, such as Pisces (10.9%: Tortonese, 1985) and Crustacea Decapoda (13.2%: Sarà, 1985), and the very high values of Porifera and Ascidiacea (42.4 and 50.4, respectively: Sarà, 1985). Indeed, Pycnogonida are considered incapable of extensive movements except for a few species that can swim. Pycnogonida can move around by means of rafting on algae or other drifting objects, or on ship keels; moreover, accidental introduction together with species introduced for aquaculture purposes cannot be disregarded. Transportation by ships has been suggested for *A. hilgendorfi*, a Pacific species found in the port of Venice (Krapp and Sconfietti, 1983), for *A. californicus*, found in ports in Egypt and Israel (Stock, 1958a,b), South Turkey (Stock, 1962), Civitavecchia and Palermo (Chimenz Gusso, 2000); and for *A. digitatus* and *P. timsanus*, also found by Stock in Egypt and Israel. These species – except *A. hilgendorfi* – also live in the Suez Canal and could therefore be considered as lessepsian migrants. For all the above-mentioned reasons, it would be interesting to carry out sampling campaigns not only in little studied areas and depths, but also in ports and other sites prone to accidental introduction.

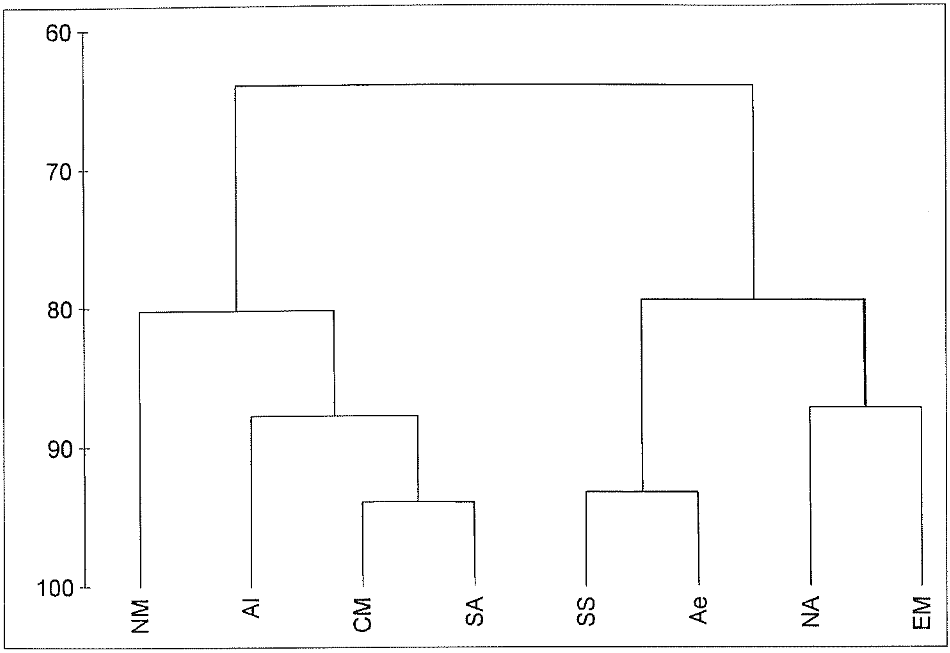

Fig. 5 - Zoogeographical similarity among assemblages of the 8 areas with more than 10 species. Symbols as in Fig. 1.

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