

A survey of the marine algae of Milos Island, Greece

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Abstract — The composition of the benthic macroflora was studied in an area of shallow-water gas-hydrothermal vents in the Palaeochori Bay (Milos Island, Aegean Sea). Some species, both taxonomically and biogeographically remarkable, were collected *Tribonema marinum* J. Feldmann, *Styopodium schimperi* (Buchinger ex Kützing) Verlaque et Boudouresque, *Amphiroa rubra* (Philippi) Woelkerling, *Cutleria* cf. *chilosa* (Falkenberg) Silva, *Womersleyella setacea* (Hollenberg) R.E. Norris). The large number of species with warm-water affinities [*Halopithys incurva* (Hudson) Batters, *Jania adhaerens* Lamouroux, *Laurencia microcladia* Kützing, *Tricleocarpa fragilis* (Linnaeus) Huisman et Townsend, *Styopodium schimperi* (Buchinger ex Kützing) Verlaque et Boudouresque, *Zonaria tournefortii* (Lamouroux) Montagne, *Anadyomene stellata* (Wulfen) C. Agardh, *Dasycladus vermicularis* (Scopoli) Krasser, *Microdictyon tenuius* Decaisne ex J. Gray] is mainly due to the southern location of the Milos Island but could be also related to a homogeneous influence of vent activity throughout the bay. © ADAC / Elsevier, Paris

benthic marine algae / biogeography / Greece / hydrothermal vents / Milos Island / Phytobenthos / rocky substrata / taxonomy

Résumé — La composition de la macroflore benthique a été étudiée dans une région de la baie de Palaeochori (île Milos, mer Egée) où sont situées des sources hydrothermales peu profondes. Quelques espèces remarquables aux plans taxinomique et biogéographique ont été récoltées : [*Tribonema marinum* J. Feldmann, *Styopodium schimperi* (Buchinger ex Kützing) Verlaque et Boudouresque, *Amphiroa rubra* (Philippi) Woelkerling, *Cutleria* cf. *chilosa* (Falkenberg) Silva, *Womersleyella setacea* (Hollenberg) R.E. Norris]. Le grand nombre d'espèces thermophiles [*Halopithys incurva* (Hudson) Batters, *Jania adhaerens* Lamouroux, *Laurencia microcladia* Kützing, *Tricleocarpa fragilis* (Linnaeus) Huisman et Townsend, *Styopodium schimperi* (Buchinger ex Kützing) Verlaque et Boudouresque, *Zonaria tournefortii* (Lamouroux) Montagne, *Anadyomene stellata* (Wulfen) C. Agardh, *Dasycladus vermicularis* (Scopoli) Krasser, *Microdictyon tenuius* Decaisne ex J. Gray] est principalement du à la situation de l'île Milos mais est peut-être aussi à mettre en relation avec l'activité hydrothermale dont l'influence est répartie de manière homogène dans toute la baie. © ADAC / Elsevier, Paris

algue marine benthiques / biogéographie / Grèce / sources hydrothermales / île Milos / Phytobenthos / substrats rocheux / taxinomie

INTRODUCTION

Currently about 550 different species of macrophytes are encountered along the Greek coasts. The greatest variability and diversity is observed in the Aegean Sea (Haritonidis, 1996). The benthic algal flora of the Aegean Sea has received much attention in the last 30 years: the knowledge of taxonomy and chorology of marine macroalgae has been gradually increased thanks to many recent floristic and biogeographical studies.

After the extensive collections made by Giaccone (1968), several studies were carried out between 1974 and 1978 along the northern coasts of Greece (Haritonidis & Tsekos, 1974; 1975; Haritonidis, 1978). Only about 10 years later, Athanasiadis (1987) provided a detailed account of species from the Sithonia Peninsula.

Macroalgae from the western Aegean coasts and phytobenthic communities have been studied by Haritonidis & Tsekos (1976), Diapoulis (1980), Diapoulis & Verlaque (1981) and Diapoulis & Haritonidis (1987), while poor information exists on the benthic flora of the central Aegean Sea.

The only preliminary surveys on the marine algae of the southern Aegean Sea were carried out by Nizamuddin & Lehnberg (1970).

Only one floristic paper concerning Milos Island (Lazaridou & Boudouresque, 1992) and two investigations on phytobenthic communities of the upper sublittoral zone (Coppejans, 1974; Diapoulis *et al.*, 1994) exist.

The presence of shallow hydrothermal vents at Milos has spurred increasing interest in this area, which is currently the subject of multidisciplinary research.

Previous authors investigated effects induced by underwater vents on the composition and distribution of macro- and meiobenthic soft bottoms (Dando *et al.*, 1996; Thiermann *et al.*, 1997), but, up to now, less information exists on hard bottom communities (Bianchi *et al.*, in press) and their perturbation connected to vent activities.

This paper provides a list of benthic macroalgae collected from different rocky habitats of Milos Island and briefly discusses, from both floristic and biogeographical points of view, some noteworthy taxa never recorded here before.

MATERIAL AND METHODS

The study area is located in the sea off Milos Island (Cyclades Archipelago, Aegean Sea), one of the most seismically active regions on earth (Bath, 1983; Makropoulos & Burton, 1984), situated in the northwest part of the Sea of Crete.

The study was performed off Palaeochori, a sandy bay approximately 1.4 km wide in the southeast part of Milos, characterized by a rocky coast. The sea-floor is colonised by the seagrass *Cymodocea nodosa* (Ucria) Ascherson, mainly present in the inner part of the bay and *Posidonia oceanica* (Linnaeus) Delile in the outer part of the bay (Aliani *et al.*, 1998).

The area is characterized by a high level of hydrothermal activity. Patches of active water outflows and gas bubblings consisting mainly of CO₂ and H₂S, were randomly distributed on rocky and sandy sediments from depths of 4 to 15 m.

In soft sediments, vents were surrounded by a white bacterial mat dominated by *Achromatium volutans*; *Thiobacillus* sp. and cyanobacteria were also present. Yellow sulphur deposits were sometimes present on the sediment surface (Dando *et al.*, 1995 a, b; Fitzsimons *et al.*, 1997).

In June 1996, samples of epiflora were collected at six rocky sites by snorkelling and diving: CR, VS, SR where vent activity was observed, E, ST and S without any vent activity (Fig. 1). In September 1996, an additional sample was collected in the site CR at 30 m depth (CR3).

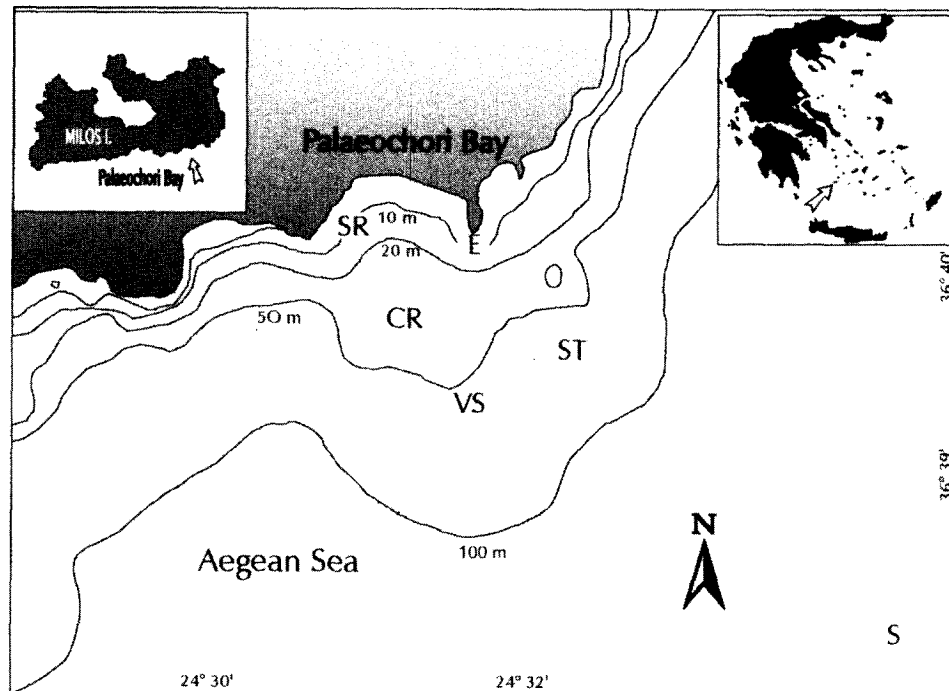


Fig. 1. Palaeochori Bay with the location of sampling sites.

In Tab. 1 stations are labelled by a letter indicating the site and a number corresponding to different depths.

The shoal CR is probably composed of volcanic rock. Continuous vent activity is still evident. This rocky shoal, extending north-south and partially hemmed in by a *Posidonia oceanica* (Linnaeus) Delile meadow, was explored between 26 and 30 m depth.

In the second shoal, the site VS, a low rocky platform emerging from the sandy bottom one mile offshore from Palaeochori Bay, biological samples were collected at depths of 45 m and 81 m.

Site SR was located in shallow waters (1–12 m) inside the bay on vertical substrata where samples were collected only by snorkelling.

Site E, corresponding to infralittoral rocks at Spathi Point, were investigated at a depth of 11 m.

Sites ST and S (Vrakhos Ktenia), where no thermal activities were observed, are situated half a mile east of Spathi Point and 3 miles offshore to the southeast, respectively.

The first of these two sites (site ST) is an underwater shoal, ranging between 4 and 30 m in depth, made up of two columnar peaks separated by a little canyon.

Samples were collected at 9 m. The second (site S) is a shoal that from the sea-floor, at more than 50 m depth, emerged at the surface with two pinnacles. It was explored from 15 to 40 m depth.

Biological samples were collected by hand or by scraping with a hammer and chisel when necessary. The material has been preserved in 5 % formalin-seawater.

For morphological observations, squash preparations and hand-made sections were stained with 1 % aqueous aniline blue and 0.5 % HCl, washed in seawater and made permanent in a mixture of 50 % Karo (corn syrup), 1 % aniline blue and 0.5 % HCl. Herbarium specimens and slide preparations are deposited in the *Herbarium Universitatis Florentinae* (FI).

RESULTS AND DISCUSSION

From the benthic samples collected in Palaeochori Bay, a total of 83 taxa at specific and infraspecific level were identified, comprising 36 Rhodophyceae, 33 Fuco-phyceae, 13 Chlorophyceae and 1 Tribophyceae (Tab. 1).

Except for sample CR3, our collection was obtained only from early summer samples collected on hard substrata, and therefore the number of taxa reported is not very high. Nevertheless, about half of them, marked with a full circle in the floristic list, are recorded for the first time at Milos Island. Most of these new records include deep water species and species growing as epiphytes on the larger algae such as *Beckerella mediterranea* and *Sargassum acinarium*.

B. mediterranea, never recorded here before, is a thermophilous species, apparently endemic, known from many islands in the Southern Archipelago, Peloponnese and Crete (Athanasiadis, 1987). In Palaeochori Bay this species was collected between 26 and 40 m. Older fronds are usually covered with many epibionts, among them the small red and brown algae: *Contarinia peyssonneliaeformis*, *Drachiella minuta*, *Halydictyon mirabile*, *Hydrolithon farinosum* var. *chalicodictyum*, *Ptilothamnion pluma*, *Titanoderma cystoseirae* and *Stilophora tenella*. In our samples only sterile plants are available, but anatomical features are distinctive and make *B. mediterranea* an easily recognisable species. Fronds, midribbed in lower parts, are up to 10 cm high and show well-developed, distichous, membranous alae (Fig. 2A). According to the original description (Huvé, 1962) older fronds develop cylindrical or irregularly ramified marginal proliferations growing into indeterminate laterals. However, formation of indeterminate branches occasionally occurs in lower regions of old damaged axes, either from the thallus midrib or from the membranous alae. Norris (1987) merged *Beckerella* Kylin with *Ptilophora* Kützing, citing the presence of surface proliferations on thalli of *Beckerella* and the lack of reliable distinguishing features. Silva *et al.* (1996), on the other hand, recognised both genera pending further studies on this group of the Gelidiaceae family.

Widespread and probably endemic in the Mediterranean, *Sargassum acinarium* is very abundant in the eastern basin where dense populations develop in the lower sublittoral up to depths of 50–60 m (Giaccone, 1968). In Palaeochori Bay it was found both in vent (VS) and non vent sites (S) at depths of up to 45 m. In our material 3–5 terete stems, 2–4 cm high and 3–5 mm in diameter, rise from a discoid holdfast. Each stem bears 2–4 terete or slightly compressed primary branches, 50–80 cm long and about 2 mm wide, with simple or duplicate spines scattered on the surface and giving rise to spirally arranged secondary branches. The pedicellate, fusiform receptacles, simple or rarely furcate, 6–12 mm long and about 1 mm wide, develop solitary or arranged in a short raceme on axillary branches up to 5 cm long (Fig. 2B).

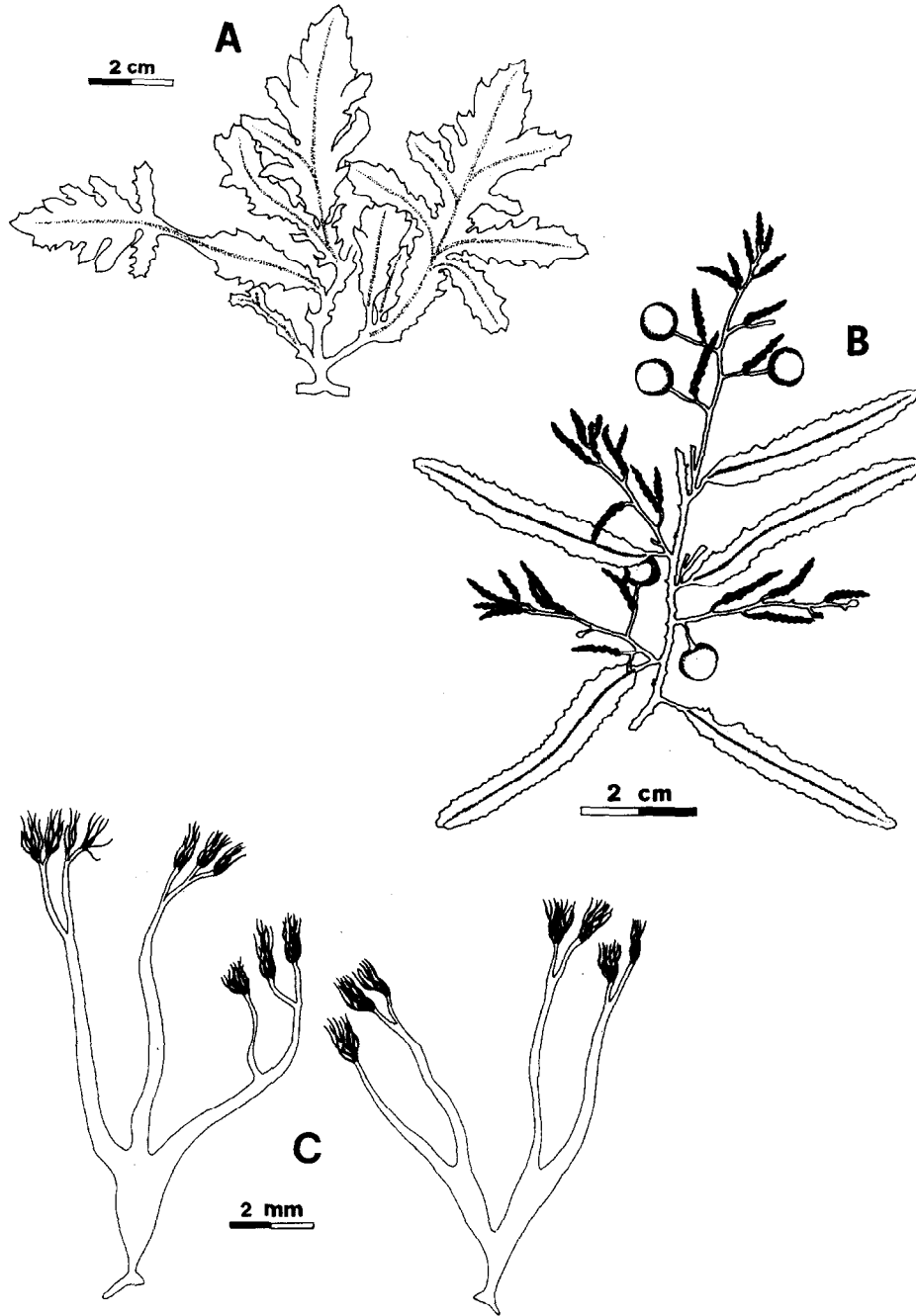


Fig. 2. A: *Beckerella mediterranea*: plant habit; B: *Sargassum acinarium*: portion of the thallus showing the leaves, vesicles and receptacle branches; C: *Cutleria cf. chilosa*: young plants.

Asperococcus bullosus, *Cladosiphon cylindricus*, *Dasya rigidula*, *Hydrolithon farinosum* var. *farinosum*, and *Polysiphonia subulifera* are the most common epiphytes found on this large species.

In our samples, numerous and widely distributed thermophilous species were recorded. Among them there were *Halopithys incurva*, *Jania adhaerens*, *Laurencia microcladia*, *Tricleocarpa fragilis*, *Styopodium schimperi*, *Zonaria tournefortii*, *Anadyomene stellata*, *Dasycladus vermicularis*, and *Microdictyon tenuius*.

The most interesting species from both taxonomic and biogeographical points of view are discussed below.

Styopodium schimperi: first recorded from the Milos coast, is an example of the Lessepsian migration process (Verlaque & Boudouresque, 1991). After its first report along the Syrian coastline [Mayhoub & Billard, 1991 as *S. zonale* (Lamouroux) Papenfuss], it has been reported from Cyprus and along the Turkish coasts (Verlaque & Boudouresque, 1991), where it was collected in a short bathymetric range, between 5 and 10 m. In Palaeochori Bay, the westernmost record in the Aegean Sea, this species showed a wider bathymetric distribution, between 15 and 41 m, and was recorded both in vent and non vent sites, on substrata with different slope and exposure.

Tribonema marinum: it was collected in small quantities growing on the branches of *Cystoseira barbata* and *C. crinita* at 26 and 15 m depth. It is an endemic species of the Mediterranean sea but it has been recorded only in the western areas (Coppejans & Boudouresque, 1983; Sartoni & Sonni, 1991), where it plays a remarkable role in determining the formation of benthic mucilaginous aggregates (Sartoni & Sonni, 1991; Sartoni *et al.*, 1993).

Previous observations on ultrastructural and biochemical characteristics rule out the possibility that this species is a member of the genus *Tribonema* and suggest that it could belong to the Chrysophyceae (Sartoni *et al.*, 1994).

Amphiroa rubra: among the Mediterranean species belonging to the genus *Amphiroa*, the ones with medullary cells arranged in prominent tiers with one series of long cells alternating with one series of short cells represent a difficult group. Aegean plants living exclusively on *Lithophyllum frondosum* have been identified by Athanasiadis (1987) as *A. rubra*. In external morphology and anatomical features this species seems very similar to the widespread *A. cryptarthrodia* which instead grows on other substrata.

Sterile plants living on *L. frondosum* and on other crustose coralline algae are available in our collection. Both species have genicula with only one or two tiers of medullary cells, interconnected by secondary pits, and in the intergenicula tiers with longer cells alternate regularly with tiers of shorter cells. In *A. cryptarthrodia* medullary cells attain a length of 125–135 μm and 60–70 μm in long and short tiers respectively, while *A. rubra* has slightly shorter cells measuring 100–110 μm and 50–60 μm respectively. Also the external microscopic characters of the intergenicular surface show little difference as seen with scanning electron microscopy. In both species apical ridges consist of overlapping layers of epithallial and cortical cells (Figs 3A, C) and there are no differences in shape and diameter of epithallial concavities surrounded by a relatively prominent intercellular matrix splitting at the middle lamella (Figs 3B, D) as in other Mediterranean species of this genus (Economou-Amilli *et al.*, 1990). *A. cryptarthrodia* differs from *A. rubra* in some apparently minor ways, such as having thinner cell walls and a larger number of trichocytes, but we have not examined sufficient material to determine the consistency of these features and whether or not they are of potential taxonomic significance. However, until proper comparative studies can be made, the opinion that they represent distinct species is followed here, considering the taxonomic identity of the host as a useful diagnostic feature (Cabiocch, 1972; Cremades *et al.*, 1997).

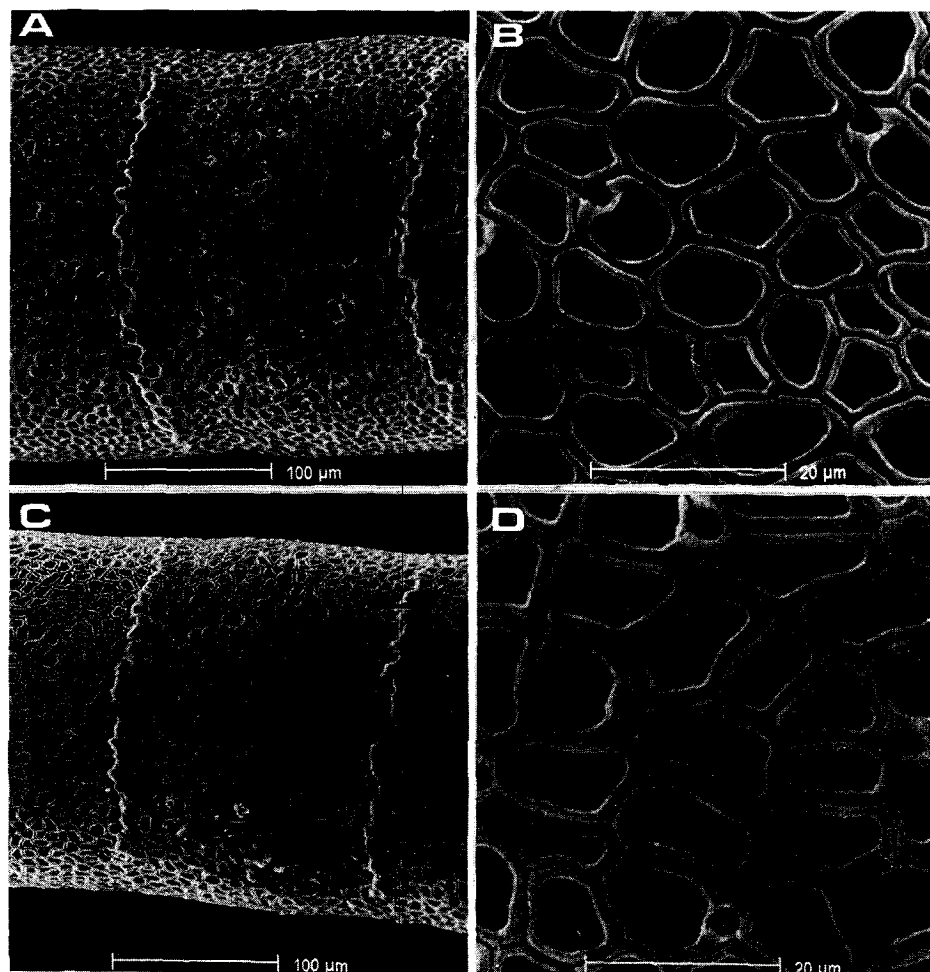


Fig. 3. *Amphiroa cryptarthrodia*. A: subapical ridges; B: detail of surface structure of intergenicula. *Amphiroa rubra*. C: subapical ridges; D: detail of surface structure of intergenicula.

Cutleria cf. *chilosa*: a single collection of female gametophytes was made at 40 m depth at site S. The plants are up to 30 cm long, pseudodichotomously branched at long intervals, with pale brown, subcylindrical branches about 1 cm in diameter in the basal portion of the thallus and gradually tapering towards the apex. Plants with similar morphology, always provided only by female gametangia, commonly occur in the northern Tyrrhenian Sea, growing on deep-water macroalgae or as epibionts of gorgonians (pers. obs.). Like the Aegean specimens, they fit well with the comments and figures of Feldmann (1937), who considers these plants as an abnormally dioecious, deep water form of *C. chilosa* (Falkenberg) Silva. Habit, vegetative morphology and ecology seem to justify his opinion, also considering that the phenological pattern and early stages of development differ from *C. multifida* (Smith) Greville. In the western Mediterranean *C. multifida* is a fairly short lived, spring-annual species with blades initially fan-shaped

and astipitate, whereas recruitment of the deep-water form attributed to *C. cf. chilosa* occurs in June and the young plants appear laxly branched, often in many ranks, with palmate or subcylindrical basal axes (Fig. 2C).

In the eastern Mediterranean *C. chilosa* has only been reported from the coast of Israel (Edelstein, 1964) and the Aegean collection represents a new eastern limit of its distribution.

Womersleyella setacea: Rindi & Cinelli (1995) have already reported the presence of this species at the Island of Milos. In Palaeochori Bay *W. setacea* has been found in a deep-range of 10–45 m and it appears to be of common occurrence as in other localities of the Aegean Sea (Athanasiadis, 1997). This fast growing species, which can strongly affect the sublittoral communities (Airoldi *et al.*, 1994; Di Martino & Giaccone, 1996), as well as influencing both the western and eastern Mediterranean has also been recently reported in the northern Adriatic Sea (Sartoni & Rossi, 1998).

CONCLUSIONS

In our work we collected a large number of species never recorded in the previous papers concerning the benthic flora of Milos Island.

Many of them (*Codium bursa*, *Osmundaria volubilis*, *Spatoglossum solieri*) are very common species. They have probably not been reported in literature because previous samples were incomplete and limited to the very shallow substrata. In addition, many species characteristic of the shallow photophilic habitats of the Mediterranean sea, colonise deeper substrata along the Milos coasts because of the clearness of the water.

S. schimperi, on the contrary, can be considered as a newly introduced species which is increasing its distribution, colonising further areas of the Mediterranean sea. This species is too widespread in Palaeochori Bay to have appeared at Milos Island only recently. According to Verlaque & Boudouresque (1991) the consequences of its introduction are still not predictable. In any case, *S. schimperi* seems to be a resistant and invasive species without competitors and predators in the Mediterranean sea.

T. marinum is another species that is extending its biogeographic boundaries. Small quantities were present in our sample, which led us to suppose that it was introduced recently because this species originates massive aggregates during the period of its active growth (spring–early summer).

Generally speaking, the species found, even the ones never recorded here before, cannot be considered species restricted to sites near vents, labelled by Barry *et al.* (1996) “obligate” species. According to previous authors, in deep hydrothermal vent areas very specialised communities are present, while shallow vent areas recruit their members from the surrounding non-vent fauna (Fricke *et al.*, 1989).

Studies carried out in the western Mediterranean sea (Acunto *et al.*, 1996, Acunto & Rindi, 1997) showed that benthic communities change their structure more than their composition as a symptom the influence of hydrothermalism.

Kamenev *et al.* (1993) also pointed out that the effects of shallow hydrothermal activity on bottom organisms are detectable only on a small spatial scale or in areas with reduced hydrodynamics.

In our study, no samples were collected in areas very close to vents where clear influences of the hydrothermal activity on the environment were observed (bacterial mats, microgradients of temperature, oxygen, pH and sulphide).

In comparing floristic assemblages collected in vent and non vent areas inside Palaeochori Bay, no remarkable differences in composition and species distribution along

the bathymetric gradient were observed. However, the absence of specialised species cannot be considered as a sufficient clue to exclude any local effects on the macroflora in Palaeochori Bay.

The high number of species with warm-water affinities counted in our floristic list could be related to a homogeneous influence of the vents throughout the bay.

Preliminary elaborations of temperature data sets (Aliani pers. comm.) showed that in winter water temperature minima were higher inside Palaeochori Bay than outside, while no significant differences were observed when comparing mean values over one year.

Standard deviation values of the temperature data (Aliani, pers. comm.) collected between September 1996 and June 1997 in the control site (Pollonia Bay, on the northwest side of the Milos Island), where no hydrothermal activity is present, are significantly higher than inside Palaeochori Bay.

According to Aliani's results, the vents' supply of hotter water is too small to modify annual temperature averages, but strong enough to influence minima, increasing them and reducing their variability range.

We can hypothesise that such an influence can not induce strong modifications on algal community composition nor allow the evolution of ecological niches with peculiar, extreme and unpredictable characteristics where only species with a high degree of specialisation can settle.

The larger spatial scale influence observed on the temperature makes it possible to explain the settling of the high number of thermophilous species widely present both in vent and non vent sites inside Palaeochori Bay.

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