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Comparison of the epiphytic macroflora of *Posidonia oceanica* leaves in different meadows of the western Mediterranean

Abstract

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Posidonia oceanica (L.) Delile leaves are one of the most important substrates for the establishment of epiphytic algae in Mediterranean coastal areas. To date most of the literature on epiphytic algae living on *Posidonia oceanica* focuses on their importance as primary producers and on the seasonal or low scale spatial variations of the community. The effects of nutrient enrichment on the biomass of seagrasses epiphytes have also been the subject of numerous publications. Nevertheless, studies considering the floristic composition of the epiphyte communities and high scale spatiotemporal (hundreds kilometres; several years) variations are scarce. The goal of this paper is to compare floristic inventories of *Posidonia oceanica* leaves algal epiphytes made in different regions of the Western Mediterranean. Compared inventories are those published between 1971 and 1999 by several authors and related to nine different meadows located in Spain, France, Corsica, Italy and Sicily. New records, made in the Revellata Bay (Calvi, Corsica, France) between 2002 and 2005 are presented and have been included in the comparison. Floristic inventories have been compared at the species level and at a higher taxonomical level using group-average clustering and non-metric Multidimensional Scaling (MDS) based on Bray-Curtis similarity measures. Results revealed that the overall diversity is huge: at least 199 taxa may occur on *Posidonia oceanica* leaves in the whole Western Mediterranean. However, in each meadow, the species richness is much lower (between 39 and 97 species) and the specific composition of *Posidonia oceanica* epiflora appears quite variable among meadows. Only 11 species are constantly represented and thus really characterise the association at the species level. The variability is mostly due to the *Ceramiales* (*Rhodophyceae*) which represent more than 50 % of the total diversity but *Chlorophyceae* can also be responsible by characterising shallow and/or eutrophicated meadows. Nevertheless, the similarities observed between French and Corsican meadows on one hand, between Southern Italian and Sicilian meadows on the other hand, as well as the apparent isolation of the Spanish meadow, allow to think that a geographical correlation in species composition exists. Some important features explaining the variability in species composition are discussed (e.g. seasons, depths, observational strategy and occurrence of occasional taxa). At the opposite of the high variability at species level, the general structure of floras at a higher taxonomical level (order) is generally preserved. The number of species belonging to each order thus appears as a strong characteristic of the association that could be used as a diagnostic tool to assess the ecological state of a *Posidonia oceanica* meadow in the Western Mediterranean. Shifts in the spectra of orders possibly reveal some degree of perturbation. Concerning the Revellata Bay, our results show that the specific composition and seasonal

variation of *Posidonia oceanica* epiphytic macroflora does not diverge from other localities of the same part of the Western Mediterranean. If compared to other meadows, the epiphytic species richness encountered in the Revellata Bay appears average.

Introduction

The epiphytic community of *Posidonia oceanica* (L.) Delile leaves, an essential element of the Mediterranean ecosystem, is involved in several ecological functions. Epiphytes may present a high diversity and are characterized by high productivity rates making them an important food source for those herbivores found in seagrass beds (Havelange & al. 1997; Lepoint & al. 2000; Vizzini & al. 2002; Heck & Valentine 2006; Lepoint & al. 2006). The calcareous ones also play a significant role in coastal sedimentary processes (Walker & Woelkerling 1988). However, several studies showed that, with eutrophication, epiphytes overgrowth can be responsible of seagrass regression. This is mostly due to limitation of light transmission to the leaves and/or by increasing grazing pressure to the host (Sand-Jensen 1977; Borum & Wium-Andersen 1980; Borum & al. 1984; Orth & Van Montfrans 1984; Silberstein & al. 1986; Pergent-Martini & al. 1995; Pedersen & Borum 1996; Wear & al. 1999; Ruiz & al. 2001; Ruiz & Romero 2003; Drake & al. 2003; Short & al. 2006). Some authors also introduce the idea that epiphytes could be used as diagnostic tools to estimate the quality and/or degree of nutrient enrichment of water (May 1982; Borum 1985 and Cattaneo & al. 1995 in fresh water).

The epiphytes of *Posidonia oceanica* leaves have been the subject of numerous studies during the last decades. Bathymetric or spatio-temporal variations linked or not to anthropogenic disturbance (Cinelli & al. 1984; Mazzella & Ott 1984; Alcoverro & al. 1997; Lepoint & al. 1999; Piazzi & al. 2004), as well as the epiphyte distribution on the host plant and influence of host phenology on community structure (Novak 1984; Casola & al. 1987; Dalla Via & al. 1998; Cebrian & al. 1999; Alcoverro & al. 2004) have been the subject of several studies. Nevertheless, few papers deal with the algal epiphyte community *in toto*. Van der Ben (1971) was the first to depict in detail the community composition and the relationships between the epiphytes and the host plant. His study was conducted in two locations of the French Mediterranean Coast: Banyuls-sur-Mer and Villefranche-sur-Mer. Panayotidis (1980) also provided a list of *Posidonia oceanica* leaves epiphytes found in three other localities in France: Gulf of Marseille and Port-Cros Bay (south coast of France) and in the Gulf of Galeria (west coast of Corsica). Other authors presented a comprehensive list of epiphytic taxa found on *Posidonia oceanica* leaves of south Sicily: Vendicari Island and Capo Passero (Buia & al. 1989; Blundo & al. 1999). Mazzella and collaborators also worked in Italy and provided a list of the algal and animal communities in a *Posidonia oceanica* meadow located along the northwest coast of the island of Ischia (Gulf of Naples) (Cinelli & al. 1984; Mazzella & al. 1989). We also have informations concerning the floristic composition of *Posidonia oceanica* leaves epiphytes in the province of Murcia (S-E of Spain) provided by Soto Moreno (1992). We must also cite several papers dealing with the other important fraction of the *Posidonia oceanica* epiphytic com-

munity: the macroalgal assemblages of the rhizomes (Boudouresque 1974; Panayotidis 1980; Piazzi & al. 2002). Finally, a detailed study of the *Posidonia oceanica* leaves epiphytes has been performed in the meadow of the Revellata Bay (Calvi, Corsica, France), the floristic part of which has already been published (Jacquemart & Demoulin 2007). The Revellata Bay is a model ecosystem from several standpoints, making this study necessary. The present paper compares these data to the floristic inventories made in other places of the European Western Mediterranean basin (France, Spain and Italy).

Material and Methods

Study site. - Samplings were performed in Revellata Bay (Gulf of Calvi, Western Corsica, France) (Fig. 1), in the vicinity of the marine research station STARESO (42°35'N, 8°43'E). A *Posidonia oceanica* seagrass meadow grows here to 40 m depth, close to the deepest limit recorded for this species in the Western Mediterranean (Bay 1984). This meadow, which covers 70 % of the seafloor of the Revellata Bay, is one of the most productive *Posidonia oceanica* beds of the NW Mediterranean.

Sampling design. - A first set of samples has been taken at 15 m depth, between April 2001 and April 2002, at the vicinity of the marine research center STARESO. The sampling site was visited twice a month on average but no samples were taken in September and October 2001, nor in February and March 2002. Additional samples have been collected at depths of 3, 8, 15 and 20 m in August 2002 and May 2003. Ultimately three other sets of samples have been collected on seven locations chosen to maximise the environmental conditions (hydrodynamics, temperature, presence/absence of sewage) in the whole bay (Fig. 1). These locations have been visited three times: in March, May and July 2004. All samples were collected by SCUBA diving. Each sample was made of three randomly selected *Posidonia oceanica* shoots harvested from within a homogeneous area.

Sample processing. - In the laboratory, two external leaves plus one internal were selected from each shoot and used for the examination of the epiphytic assemblages. We selected the oldest leaves, as a pilot study had shown that younger leaves usually did not present specific taxa. This pilot study, taking into account Kendrick and Lavery prescriptions (Kendrick & Lavery 2001), and based on species-area curves, also showed that apical parts of the oldest leaves are the most appropriate to present mature epiphytic assemblages. For this reasons, only the apical parts (the first 5 cm from the tips) and the external face of each leave was observed, using a stereo microscope. Epiphytes taxa were identified to species when possible.

Data manipulation. - To allow comparison between different sets of data (obtained from several authors who often used synonyms to record the same specie), all taxa are presented according to the taxonomy and nomenclature of Algae Base web site (Guiry & Guiry 2006; see also Hardy & Guiry 2006) or, for some cases, of the "Seaweeds of the British Isles" series (Dixon & Irvine 1977; Irvine 1983; Fletcher 1987; Maggs & Hommersand 1993; Irvine & Chamberlain 1994; Brodie & Irvine 2003).
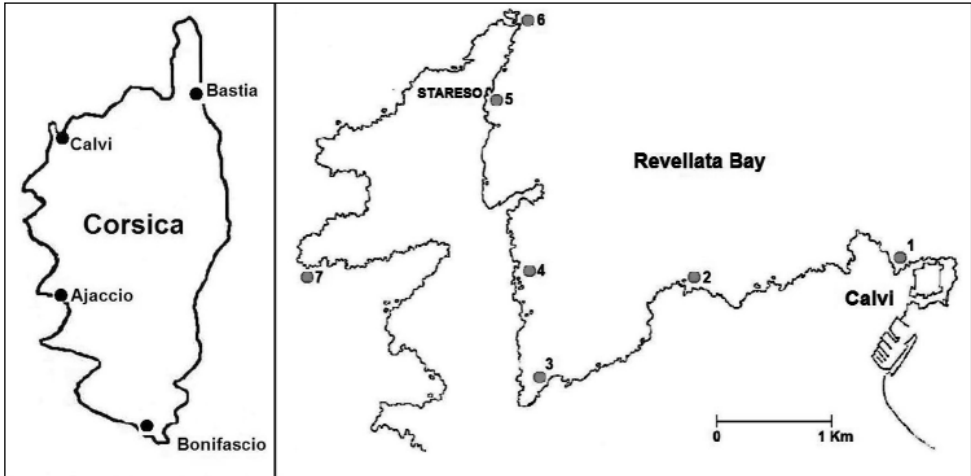
Fig. 1. Revellata Bay (Calvi, Corsica) and location of the seven sampling sites.

To compare the floristic composition related to the different meadows, we performed hierarchical clustering with group-average linking based on non-ranked Bray-Curtis simi-larities calculated on presence-absence species data. Ordination of meadows has been achieved using non-metric Multidimensional Scaling (MDS) based on ranked Bray-Curtis Similarities (Bray & Curtis 1957; Clarke 1993; Clarke & Warwick 2001). We also com-pare the different meadows at a higher taxonomic level by pooling species-sample data to the order level prior to multivariate analysis. Analyses were conducted using PRIMER-v5 software package (Clarke & Gorley 2001) and STATISTICA-7.1 (StatSoft France 2005).

Results and Discussion

Posidonia oceanica leaf epiphytes found in the Revellata Bay. - A list with description and illustrations of the *Posidonia oceanica* (L.) Delile leaves epiphytes observed in the Revellata Bay is to be found in Jacquemart & Demoulin (2007). This epiphytic communi-ty is composed of 60 species (*Cyanophyceae* included). The *Rhodophyceae* account for the highest number of species with a total of 39 taxa (Qualitative Dominance DQ: 65 %) (Fig. 2). Among those, the order *Ceramiales* presents the greatest diversity with 28 taxa (DQ: 47 %). This group consists of erect species (filamentous, corticated-filamentous and foliose algae) and is particularly represented during the summer when it composes most of the upright layer of the epiphytic community. Note that the *Polysiphonia* spp. could not be identified to species because of the quasi-systematic absence of fertile specimens. Nevertheless, it seems that the diversity of *Polysiphonia* spp. occurring on *Posidonia oceanica* leaves in the Bay of Calvi is poor (one or two species). Although qualitatively important, the *Ceramiales* never reach huge cover values if compared with other compo-nents of the epiphytic macroflora, particularly the encrusting species (e.g. the calcareous *Corallinaceae* and the soft encrusting algae *Myrionema orbiculare* J. Agardh). Among the
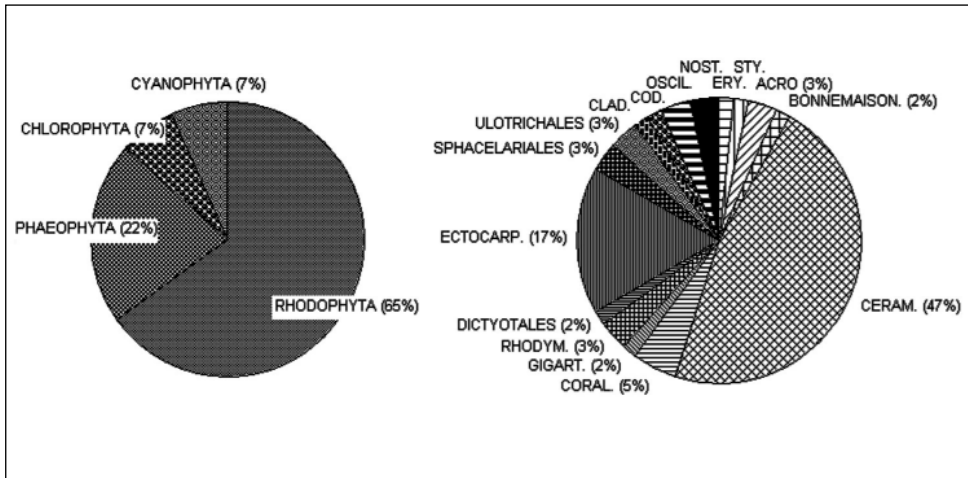
Fig. 2. The relative contribution of phylum and orders composing the *Posidonia oceanica* leaves epiphytic macroflora in the Revellata Bay.

other red algae, the *Corallinaceae*, even if represented by fewer species (DQ: 5 %) (Fig. 2), appear of prime importance as they are able to reach great cover values and colonise the basal parts of the youngest leaves. Furthermore, they persist all the year, even on the oldest parts of the plant. In the Revellata Bay, the *Corallinaceae* are mainly represented by two dominant species: *Hydrolithon farinosum* (J. V. Lamouroux) D. Penrose & Y. M. Chamberlain and *Pneophyllum fragile* Kützing. These taxa are current all the year at all depths and always have reproductive structures such as gametangia or sporangia. Another small red alga belonging to the family *Acrochaetiaceae*: *Acrochaetium daviesii* (Dillwyn) Nägeli is also common. This tufts forming red alga develops, from spring to summer, mainly on the leaves margins where it can form a continuous belt from near the basal to the apical part of the leaves. There, it can be found in association with other small tufts forming red algae of the genus *Acrochaetium* which however are rarer. The remaining epiphytic red algae belong to the orders *Bonnemaisoniales* (DQ: 2 %), *Gigartinales* (DQ: 2 %), and *Rhodymeniales* (DQ: 3 %). They are weakly represented qualitatively and quantitatively in the Revellata Bay. *"Falkenbergia rufolanosa"* (Harvey) F. Schmitz, the tetrasporophyte phase of *Asparagopsis armata* Harvey, known to have a epiphytic behaviour, occurs rather occasionally all year round, but is most obvious in October-March. Dark-red, well branched, filamentous, it is easy to recognise but still anecdotic. It is also the case of the translucent, membranous, dichotomously and irregularly divided fronds of *Rhodophyllis divaricata* (Stackhouse) Papenfuss which has been observed regularly but does not seem to play a key role in the epiphytic community of *Posidonia oceanica* leaves in the Revellata Bay. The *Rhodymeniales* are represented by two species: *Lomentaria* cf. *chylocladiella* Funk and *Champia parvula* (C. Agardh) Harvey. The epiphytic *Lomentaria* and *Champia* thallus are erect or partly prostrate, terete or compressed and have variable branching. An important discriminative character is the absence of monostromatic septa

constricting the cortex into regular segments for *Lomentaria*. It is however not always clearly expressed and the two species are sometimes difficult to separate. Finally, we must also cite the presence of two species of *Bangiophyceae*: *Erythrotrichia carnea* (Dillwyn) J. Agardh and *Stylonema alsidii* (Zanardini) K. M. Drew. These two taxa are common as secondary epiphytes (growing on a first order epiphyte, usually on *Ceramiales*) but may also be found growing on leaves blades of the host plant. *Bangiophyceae* thus represent a small part of the total epiphytic macroflora spectra (DQ: 3 %). Note that other *Bangiophyceae* like *Erythrocladia* spp. are probably present but too small to be detected in our observation conditions. *Bangiophyceae* could be revealed as more abundant by considering the microscopic assemblages together with diatoms and small blue-greens.

The *Phaeophyceae* totalise 13 species and thus represent 22 % of the algal community (Fig. 2). Within this taxonomical group, the *Ectocarpales* are the most diversified with 10 species (DQ: 17 %). *Sphacelariales* and *Dictyotales* account respectively for 3 % and 2 % of the total macroflora. The *Chordariaceae Myrionema orbiculare* J. Agardh is dominant and shows the highest cover values. Like the *Corallinaceae*, this species is a pioneer. It can already develop on young tissues of the leaves and still be present at all seasons. A massive development of this species occurs in early spring and is immediately followed by the growth of the other important members of the *Chordariaceae* family: *Castagnea cylindrica* Sauvageau, *Castagnea irregularis* Sauvageau, *Castagnea mediterranea* (Kützing) Hauck and *Giraudya sphacelarioides* Derbès & Solier. These species are very common during spring in shallow *Posidonia oceanica* meadows of Revellata Bay. They persist in late spring and summer in association with the other *Phaeophyceae* very frequent at this period: *Sphacelaria cirrosa* (Roth) C. Agardh and *Dictyota dichotoma* (Hudson) J. V. Lamouroux. Other *Phaeophyceae* are rarer in the Revellata Bay but may nevertheless be observed regularly during spring and summer: *Ectocarpus siliculosus* (Dillwyn) Lyngbye, *Kuckuckia spinosa* (Kützing) Kornmann and *Feldmannia* cf. *paradoxa* (Montagne) G. Hamel. Finally, we must also cite two species which have only been observed twice: *Myriactula stellulata* (Harvey) Levring and *Sphacelaria tribuloides* Meneghini.

The *Chlorophyceae* are poorly represented in the *Posidonia oceanica* epiphytic macroflora of the Revellata Bay. They account for 7 % of the total flora and are only represented by four species: *Enteromorpha* cf. *flexuosa* (Wulfen) J. Agardh, *Pringsheimiella scutata* (Reinke) Marchewianka, *Cladophora* cf. *dalmatica* Kützing and *Bryopsis* sp. Their presence as epiphytes in the Revellata Bay appear to be exceptional and their cover values are insignificant except for *Pringsheimiella scutata* which appears in several samples.

Finally, we must cite the frequent occurrence of epiphytic *Cyanophyceae* on *Posidonia oceanica* leaves in the Revellata Bay. The recorded species are two Oscillatoriales: *Lyngbya gracilis* (Meneghini ex Gomont) Rabenhorst ex Gomont and *Lyngbya sordida* (Zanardini ex) Gomont and two Nostocales: *Calothrix aeruginea* (Kützing ex Bornet & Flahaut) Thuret ex Bornet & Flahaut and *Calothrix confervicola* (Roth ex Bornet & Flahaut) C. Agardh ex Bornet & Flahault. Together, they account for 7 % of the total flora (Fig. 2). Most of the time, their cover is minor but they can occasionally proliferate to form a near continuous layer on a few cm² of leave blade. *Lynbya* species were only observed during the summer months (from June to September), they appeared as tuffs of several trichomes linked together by the basal part. The *Calothrix* colonies, even if mainly aestival, may occasionally be found during early spring (March). As for the *Bangiophyceae* and diatoms, summer blue-greens may be an important constituent of microscopic epiphytic flora.

Comparison between meadows at the species level. - Table 1 summarizes the available floristic inventories of epiphytic taxa published for *Posidonia oceanica* meadows located in the Western Mediterranean (Fig. 3 & Table 1). Given the fact that almost all species reported by Buia & al. occurring in the Island of Correnti have also been found by these authors near the Island of Capo Passero and given the close proximity of these meadows, we have considered the two has a whole under the generic name of "Capo Passero". Several taxonomical considerations must be taken into account when considering Table 1: 1°) *Acrochaetium daviesii* (Dillwyn) Nägeli is now regarded as *Colaconema daviesii* (Dillwyn) Stegenga (Nielsen & al. 1995). The order Colaconematales has been recently created by Harper & Saunders (2002) but given the absence of morphological characters allowing to distinguish it clearly from *Acrochaetiales*, we preferred to keep here a large *Acrochaetiales* order. 2°) given the problems concerning the status of *Dictyota dichotoma* (Hudson) J. V. Lamouroux, *Dictyota dichotoma* var. *intricata* (C. Agardh) Greville and *Dictyota linearis* (C. Agardh) Greville in the Mediterranean (De Clerck 2003), we choose to consider here these taxa as synonymous. So, the last two one (recorded by Panayotidis) have been recorded in Table 1 under the name of *Dictyota dichotoma* (Hudson) J. V. Lamouroux. 3°) Soto Moreno (1992) recorded *Myrionema magnusii* (Sauvageau) Loiseaux. We however followed John & al. (2004) in considering it a synonym of *Ascocyclus orbicularis* (J. Agardh) Magnus and *Myrionema orbiculare* (J. Agardh). 4°) Blundo & al. (1999) and Soto Moreno (1992) recorded both *Ulvella lens* P. L. Crouan & H. M. Crouan and *Pringsheimiella scutata* (Reinke) Marchewianka. Given the taxonomic problems concerning those algae we preferred to include only *Pringsheimiella scutata* into the table. 5°) *Chaetomorpha aerea* (Dillwyn) Kützing and *Chaetomorpha linum* (O. F. Müller) Kützing have been here regarded as conspecific (Burrows 1991).

One must also note that *Cyanophyceae* have only been considered by Blundo & al. (1999) and Soto Moreno (1992), in consequence, they have been excluded from this comparison. Nevertheless it appears that this group of algae is represented by a small number of taxa. Blundo & al. (1999) reported 7 *Cyanophyceae* (3 *Nostocales*, 2 *Oscillatoriales* and 2 *Chroococcales*) contributing for 9 % of the total epiphytic flora. Soto Moreno (1992) only reported 2 taxa belonging to this group: *Lyngbya sordida* and *Calothrix confervicola*. These results thus appear consistent with those obtained in the Revellata Bay (see above).

Furthermore, it is important to note that sampling has not always been performed during the same periods (Table 2). The Revellata Bay, Banyuls-sur-Mer, Villefranche-sur-Mer, the Gulf of Marseille and Murcia meadows benefit of a sampling spread over the year which surely allows a nearly complete floristic inventory. However, in Galeria, Capo Passero, Lacco Ameno, Vendicari Island and, especially, in Port-Cros, the seasonal sampling is reduced suggesting that some taxa (e.g. strict summer species) may be lacking.

A total of 199 taxa has been identified to species (i.e. exclusion of *Acrochaetium* sp.; *Antithamnion* sp.*; Ceramium* sp.; *Dasya* sp.; *Laurencia* sp.; *Polysiphonia* sp.; *Seirospora* sp.; *Spermothamnion* sp.; *Titanoderma* sp.; *Rhodophyllis* sp.; *Lomentaria* sp.; *Asperococcus* sp.; *Castagnea* sp.; *Sphacelaria* sp.; *Cladophora* sp.; *Bryopsis* sp.) forming the "potential flora" of *Posidonia oceanica* leaves epiphytic algae in the Western Mediterranean (Table 1). Thus, a great diversity of algae seems to find in *Posidonia oceanica* leaves a good substrate for their development. Nevertheless, even if one considers studies with a good seasonal sampling, the diversity in each meadow is much lower: between

Table 1. List of epiphytes species found on *Posidonia oceanica* leaves in diverse meadows (**B:** Banyuls-sur-Mer, France; **C. P.:** Capo Passero, south Sicily; **G:** Galeria, west Corsica; **L. A.:** Lacco Ameno, Gulf of Naples; **M:** Gulf of Marseille, France; **MU:** Murcia, S-E of the Iberian Peninsula; **P-C:** Port-Cros Bay, France; **R. B.:** Revellata Bay, N-W Corsica; **V:** Villefranche-sur-Mer, France; **V. I.:** Vendicari Island, S-E Sicily). Tagged species are those found in nearly all considered meadows.

	Van der Ben (1971)	Panayot. (1980)	Buia, Cormaci, Furnari & Mazzella (1989)	Cinelli, Buia, Cormaci, Furnari Scipione & Mazzella (1984-89)	Soto Moreno (1992)	Blundo, DiMartino & Giaccone (1999)	Jacqu. & Demoulin (2007)
BANGIOPHYCEAE							
ERYTHROPELTIDALES							
Erythrotrichia carnea	B/V	M/P-C/G	C. P.	L. A.	MU	V. I.	R. B.
Erythrocladia subintegra			C. P.				
STYLONEMATALES							
Chroodactylon ornatum						V. I.	
Stylonema alsidii	B/V	M/P-C/G	C. P.	L. A.	MU	V. I.	R. B.
Stylonema cornu-cervi					MU		
BANGIALES							
Porphyra sp.		M					
FLORIDEOPHYCEAE							
ACROCHAETIALES							
Acrochaetium daviesii	B/V	M/P-C/G		L. A.	MU	V. I.	R. B.
Acrochaetium humile						V. I.	
Acrochaetium lenormandii						V. I.	
Acrochaetium leptonema						V. I.	
Acrochaetium secundatum		P-C			MU	V. I.	
Acrochaetium virgatulum	B	M/P-C/G			MU		
Acrochaetium sp. (spp.)		M	C. P. (2)	L. A. (3)			R. B.
BONNEMAISONIALES							
Bonnemaisonia asparagoides	B/V						
« Falkenbergia rufolanosa »	B/V	M/P-C/G	C. P.		MU		R. B.
« Trailliella intricata »		M					
CERAMIALES							
Acrosorium ciliolatum					MU		
Aglaothamnion caudatum	B						
Aglaothamnion cordatum	B				MU	V. I.	
Aglaothamnion tenuissimum	B	G	C. P.			V. I.	R. B.
Aglaothamnion tripinnatum	B	M					
Anotrichium barbatum		G	C. P.			V. I.	R. B.
Anotrichium tenue						V. I.	
Antithamnion cruciatum	B/V	M/P-C		L. A.			R. B.
Antithamnion heterocladum		M	C. P.				
Antithamnion plumula var. [plumula				L. A.			
Antithamnion tenuissimum	B/V	M	C. P.	L. A.			R. B.
Antithamnion sp. (spp.)		G	C. P. (2)	L. A.			
Aphanocladia stichidiosa		M					
Apoglossum ruscifolium	B/V; cf.		C. P.				
Callithamnion corymbosum	V	G	C. P.		MU	V. I.	R. B.
Callithamnion sp.			C. P.				
Ceramium bertholdii	V		C. P.				
Ceramium ciliatum	B	M					
Ceramium cingulatum		M/G					
Ceramium codii			C. P.			V. I.	R. B.
Ceramium comptum	B/V			L. A.		V. I.	
Ceramium deslongchampsii	B/V	G					
Ceramium diaphanum		G; cf.	C. P.	L. A.			
Ceramium fastigiatum f. [flaccidum		M/P-C/G					
Ceramium flaccidum	B	M/G	C. P.			V. I.	R. B.
Ceramium siliquosum var. [lophophorum	B/V	M/P-C/G	C. P.				R. B.

Table 1. Continued.

	Van der Ben (1971)	Panayot. (1980)	Buia, Cormaci, Furnari & Mazzella (1989)	Cinelli, Buia, Cormaci, Furnari Scipione & Mazzella (1984-89)	Soto Moreno (1992)	Blundo, DiMartino & Giaccone (1999)	Jacqu. & Demoulin (2007)
Ceramium siliquosum var. [*zostericola*		G					
Ceramium tenerrimum			C. P.				
Ceramium tenerrimum var. [*brevizonatum*						V. I.	
Ceramium tenuicorne					MU	V. I.	
Ceramium tenuissimum	V	M/P-C/G	C. P.				
Ceramium virgatum	B	M					
Ceramium sp.			C. P.	L. A.			
Chondria capillaris		M	C. P.				
Chondria dasyphylla		M	C. P.				
Chondria mairei	B/V; cf.		C. P.			V. I.	R. B.
Chondria sp.			C. P.				R. B.
Compsothamnion thuyoides		M					
Cottoniella filamentosa var. [*algeriensis*			C. P.				
Crouania attenuata		M/G	C. P.				R. B.
Crouania attenuata f. *bispora*	B/V		C. P.			V. I.	
Dasya baillouviana		M				V. I.	
Dasya corymbifera		M					
Dasya hutchinsiae					MU		
Dasya ocellata	B; cf.						
Dasya rigidula	B	M			MU	V. I.	R. B.; cf.
Dasya sp.	V						
Dipterosiphonia rigens						V. I.	
Eupogodon planus	B		C. P.				
Eupogodon sp.		M	C. P.				
Herposiphonia secunda	B/V	M	C. P.		MU	V. I.	
Herposiphonia secunda f. [*tenella*		M/G	C. P.				R. B.
Heterosiphonia crispella			C. P.				
Hypoglossum hypoglossoides	B; cf.	M			MU		R. B.
Janczewskia verrucaeformis			C. P.				
Laurencia glandulifera						V. I.	
Laurencia microcladia		M; cf.	C. P.				
Laurencia obtusa	B/V	M/G	C. P.				R. B.
Laurencia pyramidalis							R. B.; cf.
Laurencia truncata							R. B.; cf.
Laurencia sp.			C. P.	L. A.			
Lejolisia mediterranea		G; cf.	C. P.			V. I.	R. B.
Lophocladia lallemandii			C. P.				
Lophosiphonia cristata						V. I.	
Monosporus pedicellatus			C. P.		MU		
Nitophyllum albidum					MU		
Nitophyllum micropunctatum			C. P.				
Nitophyllum punctatum		M/P-C					R. B.
Pleonosporium borreri						V. I.	
Polysiphonia adriatica			C. P.			V. I.	
Polysiphonia atra			C. P.; cf.			V. I.	
Polysiphonia breviarticulata						V. I.	
Polysiphonia dichotoma			C. P.			V. I.	
Polysiphonia elongata	B						
Polysiphonia furcellata		M; cf.	C. P.	L. A.			
Polysiphonia scopulorum		M/G				V. I.	
Polysiphonia sertularioides		M; cf.					
Polysiphonia subulata		M/G; cf.				V. I.	
Polysiphonia subulifera	V		C. P.				
Polysiphonia tenerrima			C. P.			V. I.	
Polysiphonia sp. (spp.)	B/V (3)		C. P. (3)	L. A. (2)	MU		R. B.
Pseudocrouania ischiana							R. B.
Pterothamnion crispum	B/V						R. B.
Pterothamnion plumula		M	C. P.				
Ptilothamnion pluma	B/V	M/G	C. P.	L. A.			R. B.
Radicilingua reptans	B						

Table 1. Continued.

	Van der Ben (1971)	Panayot. (1980)	Buia, Cormaci, Furnari & Mazzella (1989)	Cinelli, Buia, Cormaci, Furnari Scipione & Mazzella (1984-89)	Soto Moreno (1992)	Blundo, DiMartino & Giaccone (1999)	Jacqu. & Demoulin (2007)
Rodriguezella sp.			C. P.				
Seirospora apiculata		M; cf.					
Seirospora interrupta	B/V	M; cf.					
Seirospora sphaerospora	B						
Seirospora sp.		M					R. B.
Spermothamnion flabellatum			C. P.	L. A.			R. B.
Spermothamnion flabellatum f. *[disporum*	B		C. P.	L. A.			R. B.
Spermothamnion johannis	B	M/G	C. P.			V. I.	
Spermothamnion repens	V	M/G				V. I.	
Spermothamnion repens var. *[flagelliferum*							R. B.
Spermothamnion sp.		P-C/G		L. A.			
Spyridia filamentosa	V		C. P.				
Womersleyella setacea						V. I.	
Wrangelia penicillata	B/V	M/G					R. B.; cf.
CORALLINALES							
Fosliella sp.				L. A.			
Haliptilon virgatum						V. I.	
Hydrolithon boreale				L. A.			R. B.; cf.
Hydrolithon cruciatum			C. P.	L. A.		V. I.	
Hydrolithon farinosum	B/V	M/P-C/G	C. P.	L. A.	MU	V. I.	R. B.
Jania adhaerens						V. I.	
Jania rubens	B	M/P-C			MU	V. I.	
Lithophyllum sp.			C. P.				
Melobesia membranacea				L. A.			
Pneophyllum confervicola			C. P.	L. A.			
Pneophyllum fragile	B/V	M/P-C/G	C. P.	L. A.	MU	V. I.	R. B.
Pneophyllum zonale				L. A.		V. I.	
Titanoderma litorale			C. P.				
Dermatolithon litorale	B/V; cf.	M/P-C/G		L. A.			
Titanoderma sp.			C. P.	L. A.			
GELIDIALES							
Gelidiella nigrescens						V. I.	
GIGARTINALES							
Dudresnaya verticillata	B		C. P.				
Rhodophyllis divaricata		M/P-C/G		L. A.	MU		R. B.
Rhodophyllis strafforelloi			C. P.				
Rhodophyllis sp.			C. P.				
PLOCAMIALES							
Plocamium cartilagineum		M					
RHODYMENIALES							
Botryocladia microphysa			C. P.				
Champia parvula	B/V		C. P.		MU	V. I.	R. B.
Chylocladia verticillata var. *[unistratosa*		M/P-C/G					
Lomentaria chylocladiella			C. P.				R. B.; cf.
Lomentaria ercegovicii		M					
Lomentaria verticillata		M					
Lomentaria sp.				L. A.			
PHAEOPHYCEAE							
CUTLERIALES							
Aglaozonia sp.		M					
Zanardinia prototypus	B						
DICTYOTALES							
Dictyota dichotoma	B/V	M/G	C. P.	L. A.		V. I.	R. B.

Table 1. Continued.

	Van der Ben (1971)	Panayot. (1980)	Buia, Cormaci, Furnari & Mazzella (1989)	Cinelli, Buia, Cormaci, Furnari Scipione & Mazzella (1984-89)	Soto Moreno (1992)	Blundo, DiMartino & Giaccone (1999)	Jacqu. & Demoulin (2007)
Padina pavonica	B					V. I.	
Taonia atomaria	B						
ECTOCARPALES							
Asperococcus bullosus		M					
Asperococcus bullosus f. *[profundus*	V						
Asperococcus sp.			C. P.				
Castagnea cylindrica	B/V	M/P-C/G	C. P.	L. A.	MU	V. I.	R. B.
Castagnea irregularis	B/V	M/P-C/G				V. I.	R. B.
Castagnea mediterranea	B/V						R. B.
Castagnea zosterae			C. P.	L. A.			
Castagnea sp.			C. P.	L. A.			
Colpomenia sinuosa		P-C					
Ectocarpus siliculosus	B/V	M	C. P.	L. A.	MU	V. I.	R. B.
Ectocarpus siliculosus var. *[pygmaeus*			C. P.				
Ectocarpus sp.		G	C. P.				
Elachista intermedia	B/V						
Elachista stellaris			C. P.				
Feldmannia irregularis	B	M				V. I.	
Feldmannia lebelii						V. I.	
Feldmannia paradoxa		M			MU	V. I.	R. B.; cf.
Giffordia sp.		M					
Giraudya sphacelarioides	B/V	M/P-C/G	C. P.	L. A.	MU	V. I.	R. B.
Hincksia granulosa	B						
Hincksia sandriana	B						
Kuckuckia kylinii		M					
Kuckuckia spinosa		M/P-C/G	C. P.; cf.				R. B.
Liebmannia leveillei	B						
Myriactula arabica				L. A.			
Myriactula gracilis	B/V	M				V. I.	
Myriactula rigida		M					
Myriactula rivulariae			C. P.				
Myriactula stellulata	B; cf.				MU		R. B.
Myrionema liechtensternii						V. I.	
Myrionema orbiculare	B/V	M/P-C/G	C. P.	L. A.	MU	V. I.	R. B.
Myrionema strangulans						V. I.	R. B.; cf.
Scytosiphon lomentaria		M/P-C			MU		
Stictyosiphon adriaticus			C. P.				
SPHACELARIALES							
Cladostephus spongiosus f. *[verticillatus*	B						
Halopteris filicina	B		C. P.				
Halopteris scoparia				L. A.			
Sphacelaria cirrosa	B/V	M/P-C/G	C. P.	L. A.		V. I.	R. B.
Sphacelaria fusca			C. P.	L. A.		V. I.	
Sphacelaria plumula		M					
Sphacelaria rigidula		P-C/G					
Sphacelaria tribuloides		G				V. I.	R. B.
Sphacelaria sp. (spp.)		M	C. P.	L. A. (2)			
CHLOROPHYCEAE							
ULOTRICHALES							
Acrochaete flustrae					MU		
Acrochaete geniculata						V. I.	
Acrochaete inflata		P-C					
Enteromorpha flexuosa							R. B.; cf.
Enteromorpha intestinalis		M; cf.					
Enteromorpha prolifera		M; cf.				V. I.	
Entocladia viridis		M	C. P.	L. A.	MU	V. I.	
Gongrosira malardii					MU		

Table 1. Continued.

|	Van der Ben (1971)	Panayot. (1980)	Buia, Cormaci, Furnari & Mazzella (1989)	Cinelli, Buia, Cormaci, Furnari Scipione & Mazzella (1984-89)	Soto Moreno (1992)	Blundo, DiMartino & Giaccone (1999)	Jacqu. & Demoulin (2007)
Phaeophila dendroides			C. P.		MU	V. I.	
Pilinia rimosa					MU		
Pringsheimiella scutata	B		C. P.	L. A.	MU	V. I.	R. B.
Ulva rigida		M; cf.					
CLADOPHORALES							
Chaetomorpha aerea		M; cf.				V. I.	
Cladophora aegagropila						V. I.	
Cladophora albida		M; cf.					
Cladophora dalmatica		M; cf.					R. B.; cf.
Cladophora retroflexa					MU		
Cladophora sp.		P-C/G	C. P.		MU		
Rhizoclonium riparium	V				MU		
CODIALES							
Bryopsis hypnoides			C. P.				
Bryopsis plumosa	B; cf.						R. B.
Bryopsis sp.			C. P.				
Codium sp.			C. P.				
Derbesia tenuissima	B						
Total number of species: **199**	**B: 68 V: 45**	**M: 81 P-C: 29 G: 44**	**C. P.: 97**	**L. A. : 48**	**MU : 39**	**V. I.: 69**	**R. B.: 56**
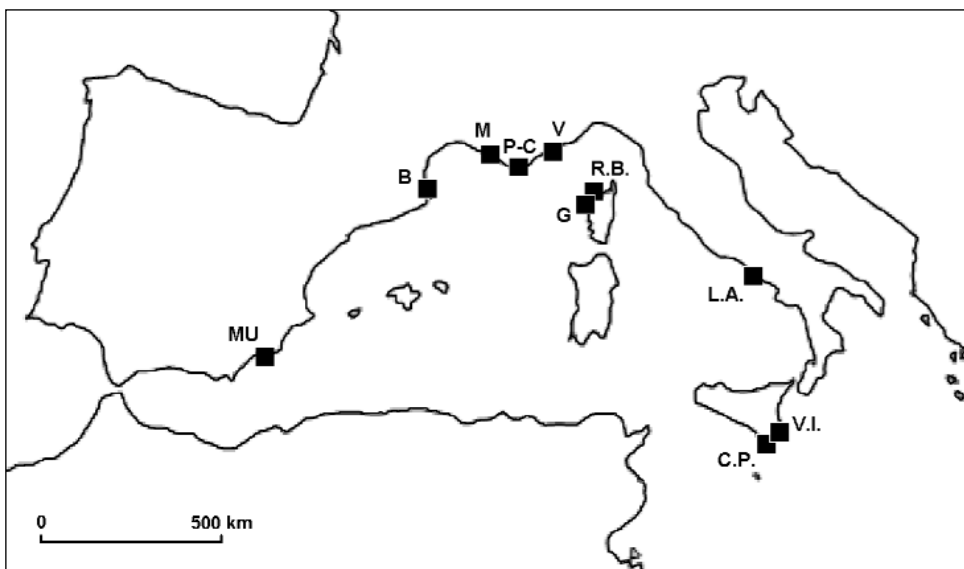
Fig. 3. Location of the different meadows in the Western Mediterranean (**B**: Banyuls-sur-Mer, France; **C. P.**: Capo Passero, south Sicily; **G**: Galeria, west Corsica; **L. A.**: Lacco Ameno, Gulf of Naples; **M**: Gulf of Marseille, France; **MU**: Murcia, S-E of the Iberian Peninsula; **P-C**: Port-Cros Bay, France; **R. B.**: Revellata Bay, N-W Corsica; **V**: Villefranche-sur-Mer, France; **V. I.**: Vendicari Island, S-E Sicily).

39 species, in Murcia, and 97 species, in Capo Passero. Furthermore, only 11 species have been found in almost every meadow considered. These species are those tagged in Table 1. Most of them (i.e. *Hydrolithon farinosum* (J. V. Lamouroux) D. Penrose & Y. M. Chamberlin, *Pneophyllum fragile* Kützing, *Myrionema orbiculare* J. Agardh, *Giraudya sphacelarioides* Derbès & Solier, *Castagnea cylindrica* Sauvageau and *Sphacelaria cirrosa* (Roth) C. Agardh) belong to the dominant and/or characteristic species of the HP "Herbier de posidonies" ecological group (Van der Ben 1971). The absence of *Sphacelaria cirrosa* and *Dictyota dichotoma* (Hudson) J. V. Lamouroux from the meadow of Murcia is remarkable and, if confirmed, could represent a particularity of this meadow or of the SW Mediterranean. Four other taxa (i.e. *Erythrotrichia carnea* (Dillwyn) J. Agardh, *Stylonema alsidii* (Zanardini) K. M. Drew, *Acrochaetium daviesii* (Dillwyn) Nägeli and *Ectocarpus siliculosus* (Dillwyn) Lyngbye) appear to be widespread in all meadows considered but are not dominant or characteristic. A few species (e.g. « *Falkenbergia rufolanosa* » (Harvey) F. Schmitz; *Laurencia obtusa* (Hudson) J. V. Lamouroux) must be added to this list given the fact that their absence in some meadow could probably be explained by the lack of seasonal sampling. One can note that some species considered as characteristic of the *Posidona oceanica* leaves flora by Van der Ben have not been recorded in every meadow. It is the case of *Castagnea irregularis* Sauvageau (absent in Capo Passero, Lacco Ameno and Murcia). Nevertheless, this species could have been reported in Capo Passero and Lacco Ameno under the name of *Cladosiphon* sp. and *Castagnea* sp. respectively). It is also the case of *Myriactula gracilis* Van der Ben (absent in Port-Cros, Galeria, Capo Passero, Lacco Ameno, Murcia and Revellata Bay), *Chondria mairei* G. Feldmann (absent in Marseille, Port-Cros, Galeria, Lacco Ameno, and Murcia meadows) and *Spermothamnion flabellatum* f. *disporum* Feldmann-Mazoyer (absent in Marseille, Port-Cros, Galeria, Murcia and Vendicari Island meadows). Two other species presented as dominant but not characteristic by Van der Ben did not occur in every meadow: *Dermatolithon litorale* (Lamouroux) Foslie (absent in Capo Passero, Murcia, Vendicari Island and Revellata Bay) and *Laurencia obtusa* Lamouroux (absent in Lacco Ameno, Murcia and Vendicari Island). Again, Murcia meadow appears as the most divergent.

Figure 4 shows the dendrogram obtained by group-average clustering performed on the whole species-meadow data (Table 1) except for Port-Cros Bay which has been excluded because of its limited temporal sampling. This dendrogram is characterised by long branches revealing a rather great dissimilarity in species composition between meadows (Fig. 4). Nevertheless, some groups appear consistent: Villefranche-sur-Mer and Banyuls-sur-Mer groups together with more than 60 % similarity in species composition. As well, the two Corsican meadows, Galeria and Revellata Bay are grouped together with more than 50 % similarity. Those results suggest a geographical correlation in species composition, but one should remember that Banyuls and Villefranche records have been both made by the same author (Van der Ben) suggesting also a possible "observer effect". A geographical correlation is however contradicted by the non-grouping of the two Sicilian meadows which only shares 35 % similarity. The multidimensional scaling ordination of meadows confirms the pattern of similarities showed by the dendrogram (Fig. 5). Stress value is low (= 0,1) revealing a good ordination with no real risk of false inferences (Clarke 1993). Furthermore, it reveals a consistent group formed by French and Corsican meadows which appear clearly much similar in species composition. Surprisingly, it shows

that the two Sicilian meadows are as much dissimilar as Spanish and Italian ones. Moreover, as already revealed by the dendrogram, the floristic composition in Vendicari Island is much similar with Murcia while Capo Passero appears close to Lacco Ameno.

The fact that only 11 species are widespread in nearly all meadows considered explains the low levels of similarity observed between meadows at the species level. Nevertheless, this is an unexpected result which can probably be explained by different reasons. First of all, the epiphytic organisms are very small, often juvenile and difficult to identify to species. Thus, we cannot dismiss the idea that a significant part of the dissimilarities in species composition between meadows could be due to identification "errors" that could have increased artificially the "total flora" diversity. This problem is particularly relevant for critical groups (e.g. *Acrochaetium*, *Ceramium*, *Polysiphonia* and *Corallinaceae*). Furthermore, the examination of Table 1 suggests that authors have not necessarily concentrated their identification efforts on the same groups of algae (e.g. Blundo & al. identified a great diversity of *Acrochaetium* and *Polysiphonia* species while others only record *Acrochaetium* and *Polysiphonia* spp.; Mazzella and collaborators relate the presence of more *Corallinaceae* than other authors).

Another important consideration that could explain a part of the dissimilarity observed between the specific compositions of the different meadows is the occurrence of occasional or "accidental" taxa. These taxa are represented only by one or a low number of individuals and never reach high cover values. It is obvious that occurrence of such taxa is related to sampling strategies (number of replicates, number of shoots observed, parts of the leaves examined) which could be very different between studies. On the basis of Van der Ben descriptions and the analysis of Panayotidis sub-samples as well as our own experience, we may say that at least 32 taxa may be considered as occasional (Table 3).

Another feature that could explain the observed pattern is the differences in sampling period and sampling depths. Sampling period could be responsible of the dissimilarities observed between the two Sicilian meadows that have been studied in different months and did not benefit of a large temporal sampling. This feature could also partly explain the grouping observed between Vendicari Island and Murcia on one hand, between Capo Passero and Lacco Ameno on the other hand. Indeed, these two pairs of meadows present more concurrent sampling periods (Table 2). Sampling depths probably also play an important role. Mazzella and collaborators investigated a huge depth range in Capo Passero (between 6 and 25 m deep) and in Lacco Ameno (between 1 m and 30 m deep) whereas Soto Moreno and Blundo & al. have harvested shallow *Posidonia oceanica* meadows (4 m deep in Murcia; between 0,5 m and 3 m deep in Vendicari Island). In the same manner as for "occasional taxa", we identified twelve other species that are strictly limited by depth and did not appear as epiphytes in shallow meadows (Table 3). Another limitation is the geographical one. This effect on observed dissimilarities is probably weak but three species reported by Blundo & al. (1999) in Vendicari Island and Buia & al. (1989) in Capo Passero would be limited to Sicily and Adriatic (Table 3).

Finally, to explain dissimilarities between meadows, one must consider the size of the observed algae. Six other taxa which could be present in all meadows considered have not been reported by most authors probably because of their small size and/or their preferential secondary epiphyte behaviour (Table 3).

Table 2. Sampling periods in the different meadows.

	Sampling periods											
	J	F	M	A	M	J	J	A	S	O	N	D
Banyuls-sur-Mer, France (Van der Ben 1971)	■	■	■	■	■	■	■	■	■			
Villefranche-sur-Mer, France (Van der Ben 1971)	■	■	■	■	■	■	■	■	■			
Gulf of Marseille, France (Panayotidis 1980)				■	■	■	■	■	■			■
Port-Cros Bay, France (Panayotidis 1980)			■									
Galeria, Corsica (Panayotidis 1980)								■			■	■
Capo Passero, Sicily (Buia & al. 1989)	■						■	■		■		
Lacco Ameno, Italy (Mazzella & al.; Cinelli & al. 84-89)				■	■	■	■	■	■	■		
Murcia, Spain (Soto Moreno 1992)		■		■	■				■	■	■	
Vendicari Island, Sicily (Blundo & al. 1999)				■	■					■		
Revellata Bay, Corsica (Jacquemart & Demoulin 2006)			■	■			■		■		■	

Table 3. List of taxa excluded from table 1 to form the constrained species-meadow data set.

Occasional taxa
Porphyra sp.
Bonnemaisonia asparagoides
« Trailliella intricata »
Aglaothamnion caudatum
Aglaothamnion tripinnatum
Antithamnion plumula var. *plumula*
Ceramium siliquosum var. *zostericola*
Dasya corymbifera
Pseudocrouania ischiana
Radicilingua reptans
Rodriguezella sp.
Seirospora sphaerospora
Haliptilon virgatum
Hydrolithon boreale
Myriactula rivulariae
Jania adhaerens
Dudresnaya verticillata
Lomentaria ercegovicii
Aglaozonia sp.
Zanardinia prototypus
Padina pavonica
Taonia atomaria
Asperococcus bullosus
Colpomenia sinuosa
Giffordia sp.
Hincksia granulosa
Cladostephus spongiosus f. *verticillatus*
Sphacelaria plumula
Gongrosira malardii
Rhizoclonium riparium
Bryopsis plumosa
Codium sp.

Taxa of limited distribution
Acrochaetium lenormandii (SE Sicily)
Laurencia glandulifera (SE Sicily)
Polysiphonia adriatica (SE Sicily)

Taxa only found in deep meadows
Antithamnion tenuissimum
Janczewskia verrucaeformis
Polysiphonia furcellata
Polysiphonia subulifera
Spyridia filamentosa
Rhodophyllis strafforelloi
Botryocladia microphysa
Asperococcus bullosus f. *profundus*
Elachista intermedia
Elachista stellaris
Bryopsis hypnoides
Derbesia tenuissima

Small and/or secondary epiphyte taxa
Erythrocladia subintegra
Chroodactylon ornatum
Stylonema cornu-cervi
Acrochaete flustrae
Acrochaete geniculata
Acrochaete inflata

Uncertain taxa

Acrochaetium spp. *(*)*	*Seirospora* sp.
Antithamnion sp.	*Spermothamnion* sp.
Callithamnion sp.	*Lithophyllum* sp.
Ceramium sp.	*Titanoderma* sp.
Chondria sp.	*Rhodophyllis* sp.
Dasya cf. *ocellata*	*Lomentaria* sp.
Dasya sp.	*Asperococcus* sp.
Eupogodon sp.	*Castagnea* sp.
Laurencia cf. *pyramidalis*	*Ectocarpus* sp.
Laurencia cf. *truncata*	*Sphacelaria* sp.
Laurencia sp.	*Ulva* cf. *rigida*
Polysiphonia spp. *(*)*	*Cladophora* sp.
Seirospora cf. *apiculata*	*Bryopsis* sp.

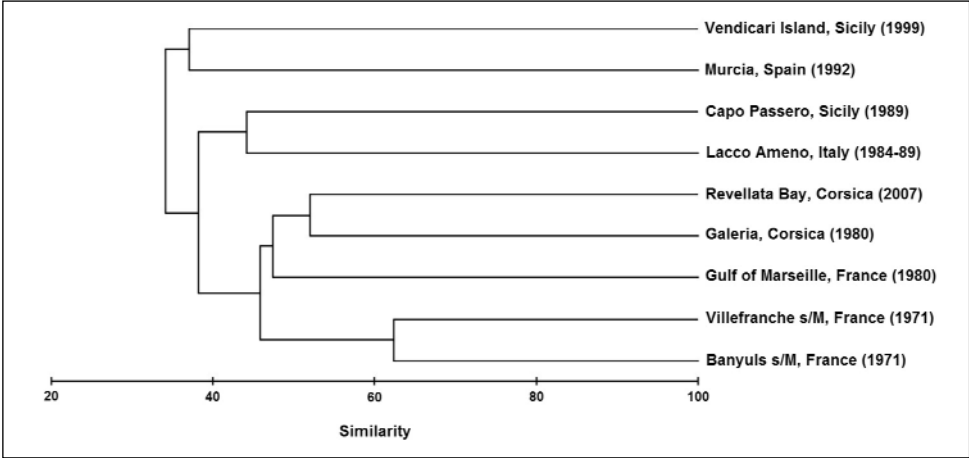(*) Species not excluded but reunited under their generic name.

Fig. 4. Group-average clustering based on Bray-Curtis similarities calculated on presence/absence data using the whole species by meadow dataset.
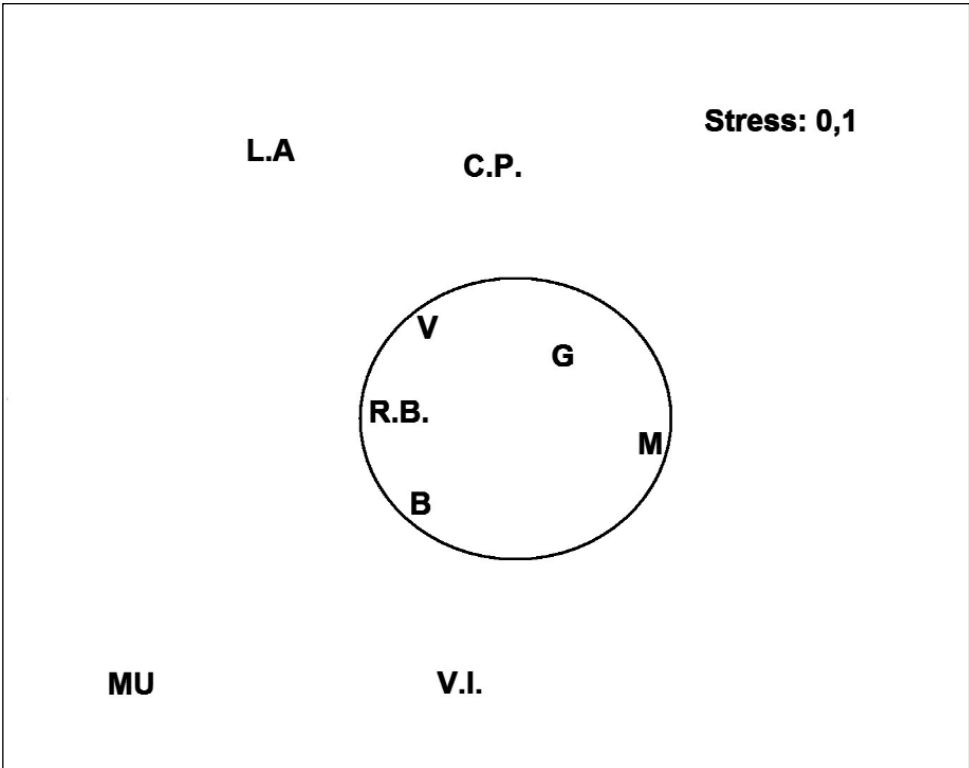

Fig. 5. Multidimensional scaling ordination of meadows constructed in 2 dimensions from Bray-Curtis similarities calculated on presence/absence data using the whole species by meadow dataset.

Comparison at the species level using a constrained data set. - In order to test the influence of occasional taxa, sampling depths and identification methodology on observed patterns of similarity, we constructed a constrained data set of species in which potential problematic taxa were excluded (Table 3). Figures 6 & 7 respectively show the dendrogram and MDS ordination plot resulting of this data manipulation. Stress value is lower (= 0,07) giving an almost excellent two dimensional representation of the similarities between meadows (Clarke 1993).

Once more, Villefranche-sur-Mer, Banuyls-sur-Mer, Galeria and Revellata Bay form a well defined cluster revealing a stronger similarity in species composition (Fig. 6). The case of Marseille is more ambiguous on the MDS plot (Fig. 7) but the clustering shows that this meadow is close to the formers (Fig. 6). The other four meadows appear to be much more dissimilar and do not form groups in the dendogram nor in the MDS ordination. One can observe that the two Sicilian meadows are now closer even if dissimilarities remain huge. Finally, Lacco Ameno and Murcia remain the two most dissimilar meadows. Thus, these results seem to confirm a geographical correlation between floristic compositions of meadows which seems independent of determination imprecision as well as the occurrence of occasional taxa. Effectively, if we except the two Sicilian meadows for which the dissimilarities observed could probably be related to the differences in sampling periods and sampling depth (see above), some geographical pattern of similarity appears.

Comparison at a higher taxonomical level. - It appeared that the specific compositions of the epiphytic algae growing on *Posidonia oceanica* leaves can be very different between meadows. But one can also compare these compositions at a higher taxonomical level by pooling all species which belong to the same order, so that differences due to the methods of different authors are minimalized.

Fig. 8 shows the relative contribution of the orders composing the "potential" epiphytic macroflora if all taxa from all meadows are considered. This floristic spectra shows that at least 18 different orders of algae could be represented in the *Posidonia oceanica* leaves macroflora community of the Western Mediterranean (Fig. 8). It also shows that the relative contribution of these orders is very different. The order *Ceramiales* appear to be the most important; almost half of the total number of "potential" species belonging to this order. The *Ectocarpales* order also appears to be of prime importance and represents 16,5 % of the total diversity. Three other important orders are the *Corallinales*, *Ulotrichales* and *Sphacelariales* which respectively represents 6,5 %, 6 % and 4 % of the total "potential" diversity. Just after come the *Acrochaetiales*, *Rhodymeniales* and *Cladophorales* which each represent 3 % of the diversity. Other orders (i.e. *Stylonematales*, *Erythropeltidales*, *Bonnemaisoniales*, *Gigartinales* and *Dictyotales*) even if represented by few species are important given the fact that they were present in nearly every meadow (see Fig. 9) and Table 1). Remaining orders (i.e. *Bangiales*, *Gelidiales*, *Plocamiales*, *Cutleriales* and *Codiales*) are each represented by one or two species which are mostly occasional on *Posidonia oceanica* leaves and do not occur in every meadow.

The comparison of the floristic spectra obtained for the different meadows considered (Fig. 9) shows that the above described pattern is consistent. In fact, only three meadows (i.e. Port-Cros Bay, Murcia and Lacco Ameno) present divergent spectra. The multivariate analysis based on Bray-Curtis similarities performed on standardised and untransformed
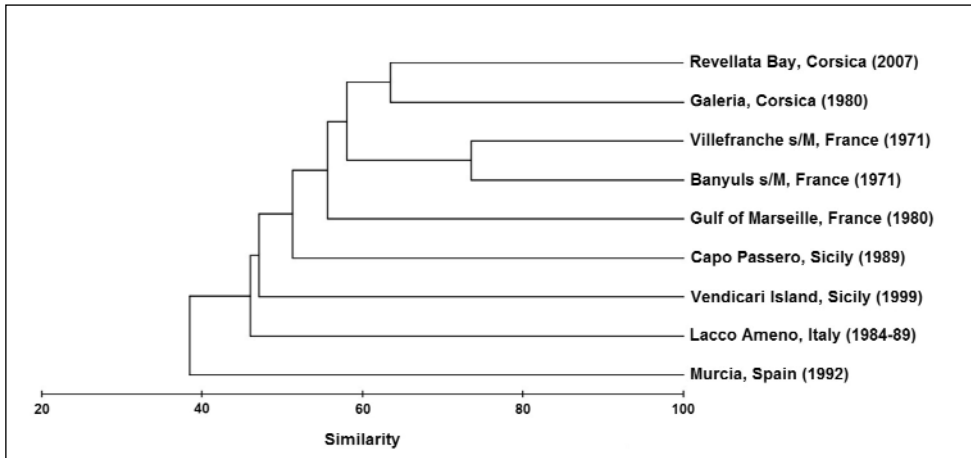
Fig. 6. Group-average clustering based on Bray-Curtis similarities calculated on presence/absence data using the constrained species by meadow dataset.
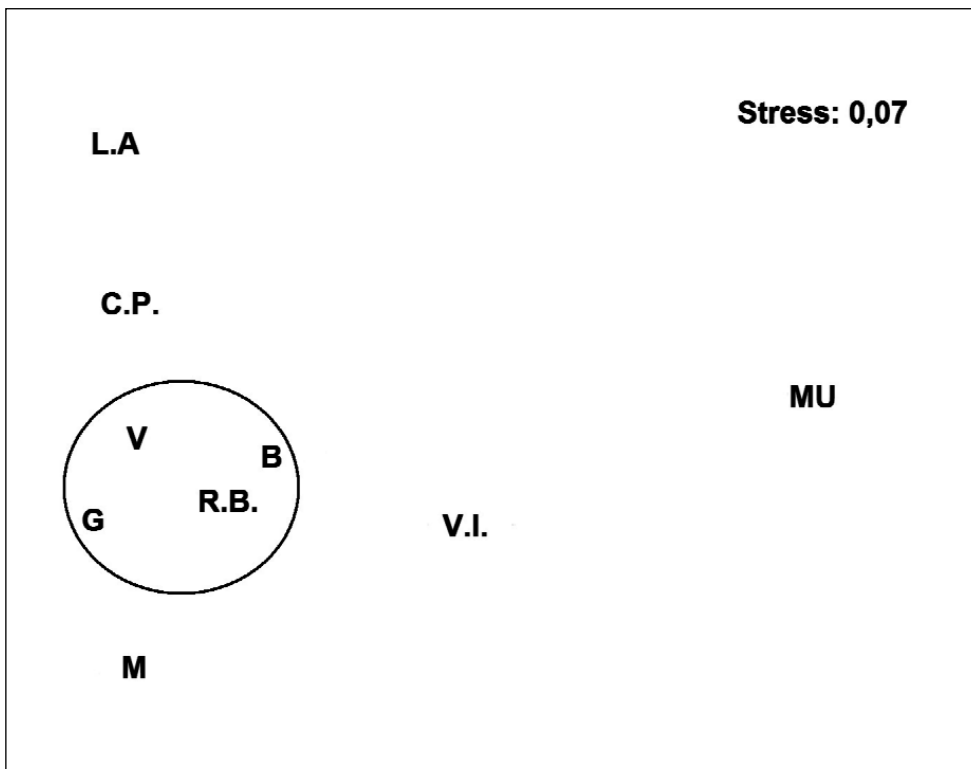

Fig. 7. Multidimensional scaling ordination of meadows constructed in 2 dimensions from Bray-Curtis similarities calculated on presence/absence data using the constrained species by meadow dataset.

orders data (number of species included in each order) clearly confirms this observation. The group-average clustering (Fig. 10) shows two distinct clusters. The first one groups Lacco Ameno, Port-Cros and Murcia meadows which only shares 68 % similarity with the others. Moreover, within this cluster, the three meadows appear rather dissimilar. Within the second cluster, one reliable group is formed by six meadows (i.e. Revellata Bay, Marseille, Banyuls-sur-Mer, Villefranche-sur-Mer, Galeria and Capo Passero) which shares more than 87 % similarity at this taxonomical level and appears close to the "potential" flora pattern. Vendicari Island meadow is included in this second cluster but appears much dissimilar by only sharing 81 % similarity with the other six meadows. The MDS plot (Fig. 11) present a very low stress value (= 0,04) that guarantees an excellent two-dimensional representation of the similarities between meadows at this taxonomical level. It clearly confirms the groups revealed by clustering and shows that, Lacco Ameno, Port-Cros and, especially, Murcia meadows are fairly dissimilar from the others. Moreover, those three meadows do not exhibit a common pattern.

As revealed by the examination of floral spectra and multivariate analysis, the difference among meadows at the order level is low. So, if meadows separated by hundred of
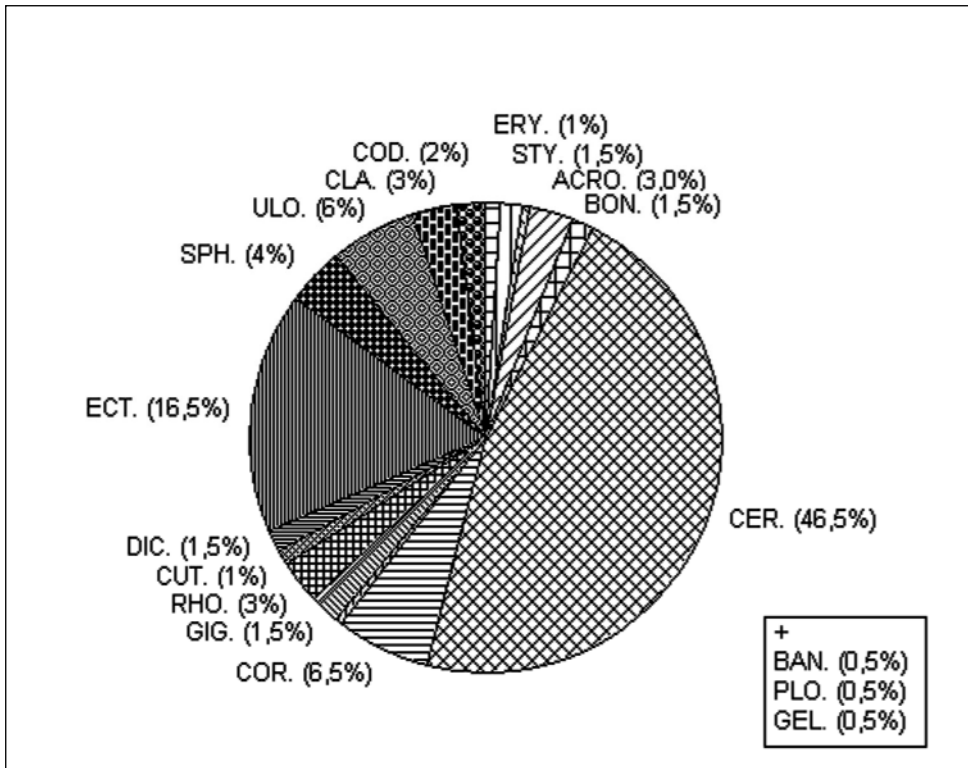

Fig. 8. The "Potential Flora": relative contribution of the orders composing the epiphytic macroflora if all meadows are considered together.
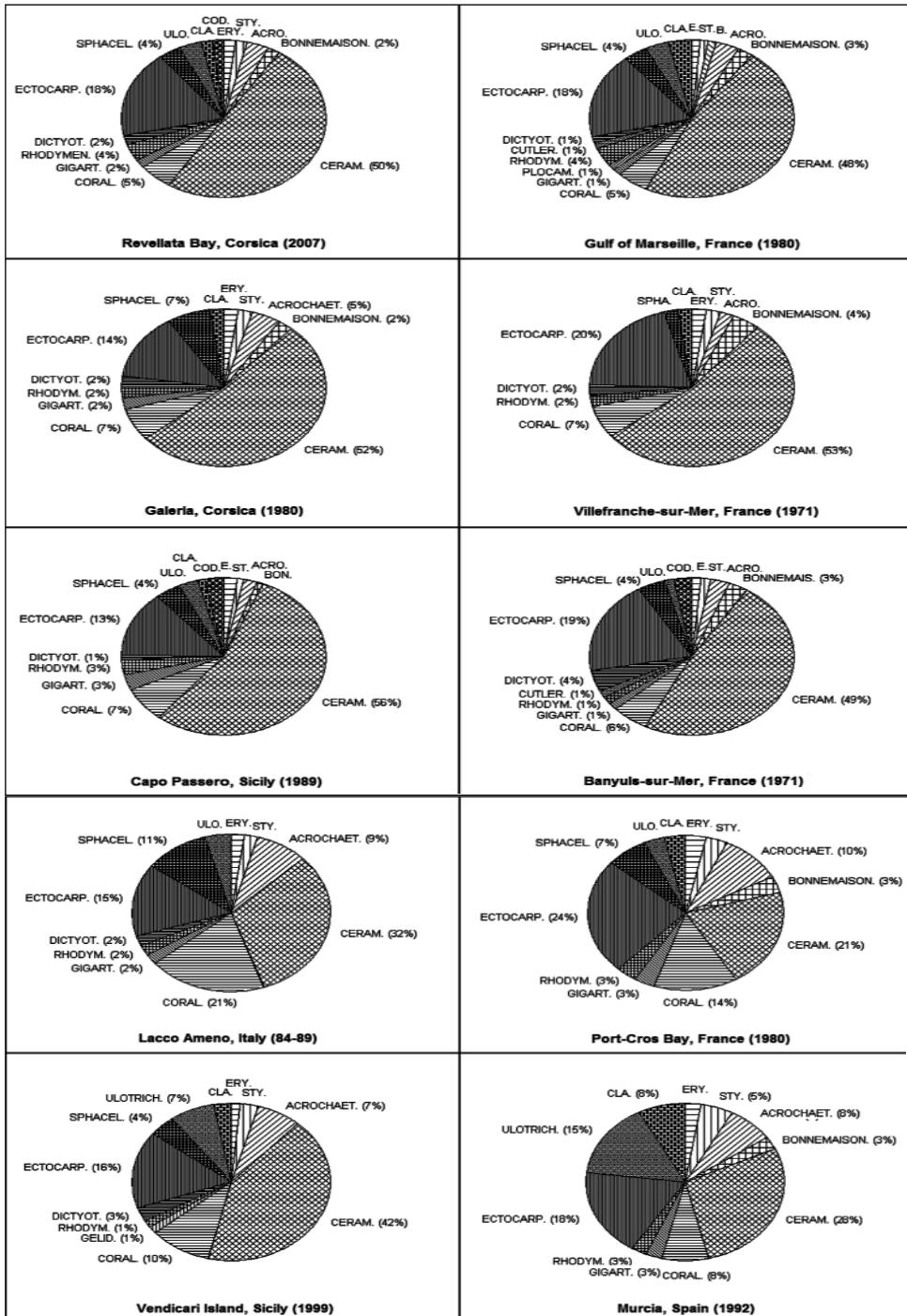
Fig. 9. The relative contribution of the orders composing the epiphytic macroflora of each meadow.
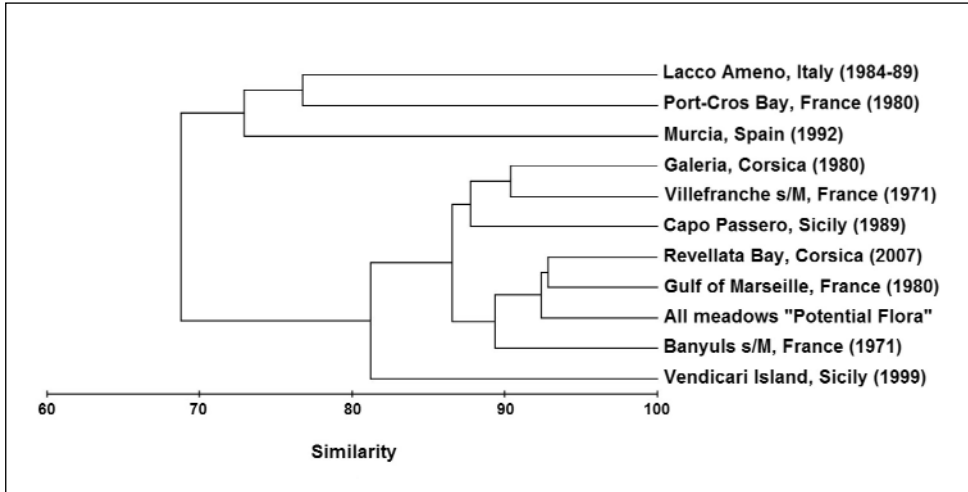
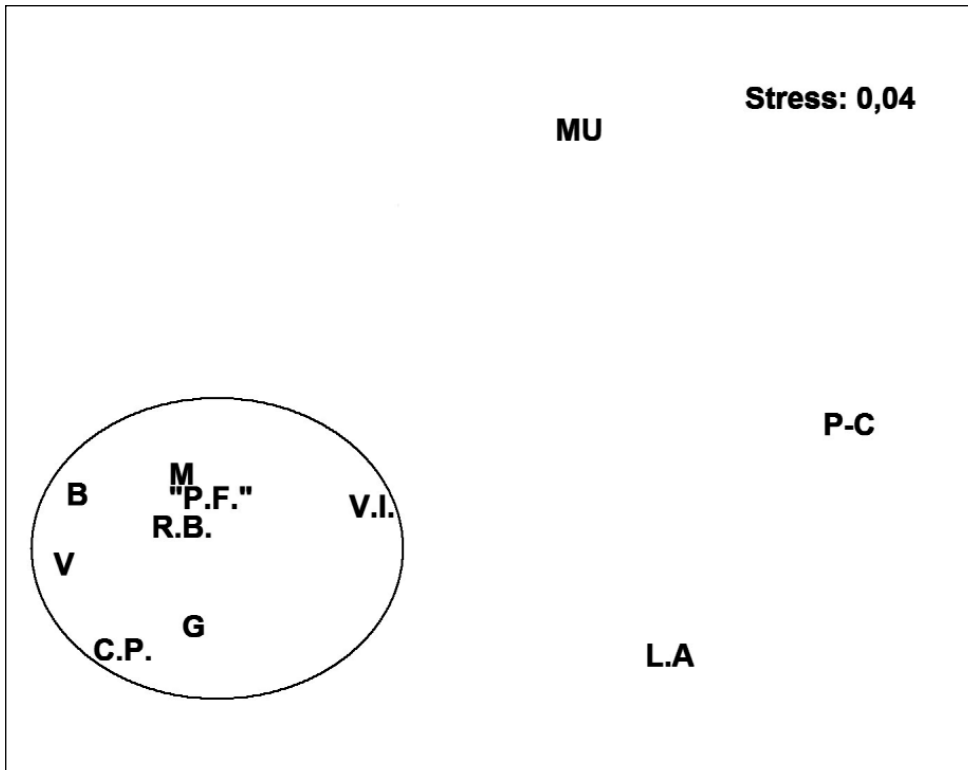Fig. 10. Group-average clustering based on Bray-Curtis similarities calculated on order data.

Fig. 11. Multidimensional scaling ordination of meadows constructed in 2 dimensions from Bray-Curtis similarities calculated on order data. **"P.F."** = "Potential Flora" (all meadows gathered).

kilometres may be rather dissimilar in species composition, it appears that the flora struc-
ture at a higher taxonomical level is generally preserved. This is true except for three
meadows: Port-Cros, Lacco Ameno and Murcia.

The Port-Cros spectra is characterised by a low representation of *Ceramiales* and a sig-
nificant higher proportion of *Acrochaetiales*, *Corallinales*, *Ectocarpales* and
Sphacelariales (Fig. 9). This is surely an effect of the lack of sampling during late spring
and summer, periods during which most of the *Ceramiales* develop. The examination of
Table 1 shows that Port-Cros meadow does not presents specific taxa but a typical early
spring pattern characterised by a low number of species and a relatively low
Rodophyceae/Phaeophyceae ratio (Table 4). It seems plausible that Port-Cros spectra
would have been much closer to the others if summer samplings had been performed. The
same remark is partly true to explain the divergent spectra of Lacco Ameno. The lack of
samplings between June and October almost certainly led to depreciation of the
Rhodophycean upright layer. Nevertheless, the sampling period does not explain the sig-
nificant higher diversity of *Corallinales* which clearly characterise this meadow (Fig. 9).
Ten frequent and abundant species of the family *Corallinaceae* composing the encrusting
epiphytic layer were identified in Lacco Ameno by Mazzella & al. (1989). It is much more
diversified than for most of the other meadows considered here (see Table 1). Given the
difficulties to correctly identify these species, it is obvious that Mazzella and collaborators
have produced a particular determination effort on this group and that the specificity of the
Lacco Ameno meadow could therefore be explained by an "observer effect". This seems
to be confirmed by the fact that a great diversity of *Corallinaceae* has also been encoun-
tered in Capo Passero and Vendicari Island, two other meadows investigated by the same
school of researchers (Università di Catania and Stazione Zoologica di Napoli).
Nevertheless, this *Corallinaceae* richness may also reveal a real biological specificity of
these meadows linked to particular ecological conditions in this geographical area (e.g.
light intensity, temperatures, recruitment).

Murcia appears clearly as the most divergent meadow. Despite a rather good seasonal
sampling, it is characterized by a low number of species (low diversity), a lower propor-
tion of *Ceramiales*, an absence of *Dictyotales* and *Sphacelariales* and a significant higher
proportion of *Chlorophyceae* (*Cladophorales* and, especially, *Ulotrichales*). A higher pro-
portion of *Ulotrichales* is also observed for Vendicari Island and could therefore be relat-
ed to shallow meadows together with a greater diversity of *Acrochaetiales* (also described
as frequent and abundant in the shallower stations by Mazzella & al. 1989). Nevertheless,
Murcia is very different of the other meadows as revealed by the examination of the floris-
tic spectra and by the multivariate analysis performed on specific and order compositions.

Table 4. *Rhodophyceae/Phaeophyceae* ratio values of epiphytic flora of the different meadows con-
sidered (**B:** Banyuls-sur-Mer; **C. P.:** Capo Passero; **G:** Galeria; **L. A.:** Lacco Ameno; **M:** Gulf of
Marseille; **MU:** Murcia; **P-C:** Port-Cros Bay; **R. B.:** Revellata Bay; **V:** Villefranche-sur-Mer; **V. I.:**
Vendicari Island).

Meadow	P-C	B	L.A.	M	V.I.	R.B.	V	G	MU	C.P.
R/P	2.0	2.4	2.5	2.9	2.9	3.0	3.0	3.3	3.3	3.9

As pointed out by Soto Moreno (1992), Murcia meadow is especially characterised by a low specific diversity and the absence of tall erect species in favour of small, encrusting or prostrate taxa (e.g. *Erythrotrichia carnea* (Dillwyn) J. Agardh*, Acrochaetium* spp.*, Acrochaete flustrae* (Reinke) O'Kelly*, Entocladia viridis* Reinke*, Phaeophila dendroides* (P. L. Crouan & H. M. Crouan) Batters*, Pilinia rimosa* Kützing*, Pringsheimiella scutata* (Reinke) Marchewianka*, Rhizoclonium riparium* (Roth) Harvey). Soto Moreno explains the low number of species encountered by the fact that his work was conducted only over young *Posidonia oceanica* leaves. He also explained the relative importance of prostrate species by the important hydrodynamic forces occurring in the investigated area. It thus appears that the strong divergence of the Murcia meadow could be explained by the fact that it is a shallow meadow under high hydrodynamic influence. Nevertheless, spatial isolation from the others is to be taken into consideration and makes it desirable to study the epiphytes of *Posidonia oceanica* leaves in other areas of the Spanish coast, between Murcia and Banyuls as well as in the Balearic Islands.

Conclusions

Comparison of floristic inventories of *Posidonia oceanica* leaves algal epiphytes made by different authors is not an easy goal to achieve. Before assessing the biological differences and driving factors associated, the influence of several methodological features must be considered. Sampling characteristics (sampling periods and sampling depths, number of shoots harvested, number of replicates) and observational conditions (scales of observation, taxonomical groups and parts of the leaves considered) are important. The problem is also complicated by the occurrence of occasional taxa which are not relevant for the general structure and characteristics of the association. Nevertheless, this study brings some perspectives on the spatial variability of the *Posidonia oceanica* leaves community in the Western Mediterranean as well as several stable characteristics of the association.

First, the overall diversity is huge: at least 199 different algae may occur on *Posidonia oceanica* leaves in the whole Western Mediterranean. However, for each meadow, the species richness is much lower. Among the whole pool of "potential species", only a small part (11 species) is constantly represented and thus really characterises the association at the species level. Most of these taxa belong to the HP "herbier de posidonies" ecological group of Van der Ben (1971) and are dominant and/or characteristic of the association. On the other hand, some species generally considered as characteristic of the *Posidona oceanica* leaves flora have not been necessarily recorded in all meadows.

Finally, it appears that the specific composition of *Posidonia oceanica* epiflora is, for the biggest part, very variable among meadows. This variability is mostly due to the Rhodophyceae and, in particular, to the *Ceramiales* which represent more than 50 % of the total diversity. These algae mostly develop during summer on *Posidonia oceanica* leaves and also include a lot of "occasional taxa". This signifies that the most important dissimilarities between meadows must occur during summer. The occurrence of *Chlorophyceae* may also play an important role in the dissimilarities which can be encountered, the role of eutrophication in explaining their presence being worthwhile investigating.

In opposition to the high variability at the species level one can note that general structure of the flora is generally preserved, as revealed by the high similarity of order spectra observed for most meadows. In fact, if the specificity and dominance of the members of the HP ("Herbier de Posidonies") ecological group is confirmed for almost all meadows; other members of the flora (named "compagnes et diverses" by Van der Ben) also constitute a consistent association at a higher taxonomical level. The epiphytic compartment could therefore be occupied by a large number of species but, in a given geographical area, only a few are competitive and able to develop on leaves. Indeed, the similarities at the species level observed between French and Corsican meadows on one hand, between Lacco Ameno and Capo Passero meadow on the other hand as well as the apparent isolation of the Spanish meadow allow to think that a geographical correlation in species composition exist. Nevertheless, this assumption can be contradicted if the compared meadows are characterised by very different depth ranges. Indeed, it appears that shallow meadows present rather similar patterns in species composition (Murcia and Vendicari Island) which superimpose to the geographical one. Moreover, it appears that a relatively greater importance of *Chlorophyceae* (especially in *Ulotrichales*) and encrusting/prostrate species could be a characteristic of the shallow meadows.

Hydrodynamic regimes are often presented as important in influencing the settlement and structure of the epiphyte community. Nevertheless, given the fact that Banyuls-sur-Mer and Villefranche-sur-Mer present relatively high similarities in species composition and, as reported by Van der Ben, a great difference in hydrodynamics regimes, it is probable that this factor have mostly an effect on species composition in shallow meadows.

It is also interesting to note that spatial variations of species composition (even at the scale of hundreds kilometres) remain low against seasonal variations as revealed by the fact that incomplete seasonal sampling (case of Port-Cros and Lacco Ameno) cause strong deviations in the similarity patterns. This also means that seasonal features (temperature, light intensity) are the most important factors driving the settlement of the studied epiphytic taxa. Therefore, seasonally representative sampling appears as the most important feature to take into consideration when trying to describe the epiphytic *Posidonia oceanica* leaves macroflora in the Western Mediterranean.

Concerning the Revellata Bay, our results show that the specific composition and seasonal variation of *Posidonia oceanica* epiphytic macroflora does not diverge from other close localities of the Western Mediterranean. The general trends of seasonal variations as well as the presence of the characteristic and/or dominant algae belonging to the "HP" ecological group are respected. If compared to other meadows, the epiphytic species richness encountered in the Revellata Bay appears intermediate. Revellata Bay epiphytic macroflora inventory made in 2004 appeared very similar to those made by Panayotidis in Galeria in 1980 and by Van der Ben in Banyuls-sur-Mer and Villefranche-sur-Mer in 1970. This could signify that the Revellata Bay epiphytic macroflora has not shown important modifications in composition during the last four decades. Unfortunately, this assumption cannot be demonstrated given the fact that no inventories of epiphytic flora of *Posidonia oceanica* leaves have been done in the Revellata Bay in the past. Nevertheless, it could be very interesting to investigate the current floristic composition of *Posidonia oceanica* leaves epiphytes of the French Mediterranean coast were regression of seagrasses were observed. Important modifications (e.g. strong shifts in orders

spectra) could reveal the existence of external disturbing factors and could therefore be used as a diagnostic tool for assessing *Posidonia oceanica* meadow quality in other regions of the Western Mediterranean.

Acknowledgements

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