Algal flora associated with a *Halophila stipulacea* (Forsskål) Ascherson (Hydrocharitaceae, Helobiae) stand in the western Mediterranean

Fabio RINDI [a]*, Ferruccio MALTAGLIATI [b], Francesca ROSSI [c], Stefano ACUNTO [a], Francesco CINELLI [a]

[a] Dipartimento di Scienze dell' Uomo e dell' Ambiente, Università di Pisa, Via A. Volta 6, 56126 Pisa, Italy
[b] Dipartimento di Zoologia ed Antropologia Biologica, Via Margherita di Savoia 15, 07100 Sassari, Italy
[c] Dipartimento di Biologia Animale, Università di Modena, Via dell' Università 6, 41100 Modena, Italy
* fabio.rindi@discat.unipi.it

(Received 22 October 1998, revised 21 January 1999, accepted 25 January 1999)

Abstract – *Halophila stipulacea*, a seagrass introduced into the Mediterranean Sea as a Lessepsian immigrant, is nowadays common in the eastern Mediterranean, and it was recently recorded in the western Mediterranean; very little information is available about the algal flora associated with this species. During a survey of a *Halophila stipulacea* stand at Vulcano Island (Eolian Islands, western Mediterranean), samples were collected at three depths (5 m,15 m and 25 m) for identification of algal epiphytes. Thirty-six species of macroalgae were found. The epiflora of the leaves consisted of 20 species, the others being mixed with or entangled in the rhizomes. On the leaves, *Ceramium tenerrimum*, *Dasya corymbifera*, *Polysiphonia* cfr. *tenerrima*, *Spyridia filamentosa*, *Chondria pygmaea* and *Laurencia* sp. were the most common species; between the rhizomes, *Dictyota linearis* was abundant. A differentiation of the epiphytic assemblage between 5 m and the other depths was observed; the 5 m samples were characterized by the abundance of *Ceramium tenerrimum*, *Chondria pygmaea* and *Polysiphonia* cfr. *tenerrima*, while at 15 m and 25 m *Laurencia* sp., *Dasya corymbifera* and *Spyridia filamentosa* were the most common species. Epiphytic cover was generally very low. No rare species were found among the epiphytes. In comparison with other Mediterranean seagrasses, *Halophila stipulacea* has a qualitatively and quantitatively poor epiphytic flora. In particular, the virtual absence of encrusting corallines is noteworthy. A fast turnover rate of the leaves is hypothesized to be the main reason for this scarcity. Differences between this and other studies on epiphytes of *Halophila stipulacea* stands are discussed. © Elsevier, Paris / Ifremer / CNRS / IRD

***Halophila stipulacea* / seagrass epiphytes / epiphytism / marine algae / western Mediterranean**

Résumé – Flore algale associée à une prairie d'*Halophila stipulacea* (Forsskål) Ascherson (Hydrocharitaceae, Helobiae) de la Méditerranée occidentale. *Halophila stipulacea* est une phanérogame marine tropicale qui s'est installée en Méditerranée à la suite de l'ouverture du canal de Suez ; à présent, elle est commune en Méditerranée orientale et a été récemment signalée en Méditerranée occidentale. La végétation algale épiphyte de cette espèce est peu connue. Pendant l'étude d'un herbier à *Halophila stipulacea* de l'île de Vulcano (les Éoliennes, Méditerranée occidentale) des échantillons ont été prélevés à trois profondeurs différentes (5 m, 15 m et 25 m) pour étudier les épiphytes algaux. Parmi les 36 espèces d'algues macroscopiques identifiées dans les relevés, 20 constituent l'épiflore des feuilles ; les autres sont entremêlées entre les rhizomes. *Ceramium tenerrimum*, *Dasya corymbifera*, *Polysiphonia* cfr. *tenerrima*, *Spyridia filamentosa*, *Chondria pygmaea* et *Laurencia* sp. sont les algues les plus communes sur les feuilles ; *Dictyota linearis* est très abondant entre les rhizomes. Le peuplement épiphyte varie avec la profondeur : les relevés effectués à 5 m sont caractérisés par l'abondance de *Ceramium tenerrimum*, *Chondria pygmaea* et *Polysiphonia* cfr. *tenerrima* ; à 15 et 25 m, *Laurencia* sp., *Dasya corymbifera* et *Spyridia filamentosa* sont les espèces les mieux représentées. Le recouvrement par les épiphytes est très faible. La flore épiphyte d' *Halophila stipulacea*, qui ne compte aucune espèce rare, apparaît quantitativement et qualitativement pauvre par rapport à celle des autres phanérogames méditerranéennes ; cette pauvreté est peut-être due au renouvellement très rapide des feuilles. Les différences avec les données relatives aux épiphytes d'autres herbiers à *Halophila stipulacea* sont discutées.

***Halophila stipulacea* / épiphytes algaux / épiphytisme / algues marines / Méditerranée occidentale**

1. INTRODUCTION

The seagrass *Halophila stipulacea* (Forsskål) Ascherson, originally described from the Red Sea [13], is distributed along the Asiatic and African shores of the western Indian Ocean, occurring from the northern Red Sea to Madagascar [20]. After the opening of the Suez Canal, this species migrated into the Mediterranean, where it was first recorded by Fritsch [15]; subsequently it gradually extended its distribution westwards, becoming common in the eastern Mediterranean [4, 14, 31, 32, 42]. Recently *Halophila stipulacea* reached the Ionian shores of Sicily [47, 8], and subsequently the western Mediterranean [2; Giacobbe, pers. comm].

Studies on *Halophila stipulacea* have mainly concerned its distribution, ecology and physiology [32, and references therein; 24, 33, 34, 36, 43, 48–50]. Less attention has been paid to the epiphytic macroalgal flora associated with *Halophila stipulacea* and its congeners. The ecological importance of epiphytes in seagrass ecosystems has been stressed several times (see [9] for a review). In fact, it is generally recognised that the epiphytic algae are important contributors to the overall productivity of seagrass communities, being responsible for a significant part of the primary production [26, 37]. At the same time, by reducing light and CO_2 uptake, they may decrease the photosynthetic rate (and consequently the production) of their hosts [45]. Since many epiphytic algae are a food source for fish, sea urchins and other grazers, they also represent important nodes in trophic webs: in fact, several animals that graze on seagrasses get nutrition from epiphytes rather than seagrass tissues [9]. Furthermore, species of epiphytic algae with calcified cell walls (e.g. encrusting corallines) are a source of $CaCO_3$ for sediments [30]. For these reasons, such a scarcity of information on both the taxonomic composition and spatio-temporal dynamics of *Halophila stipulacea* epiphytes is striking. In particular, for the Mediterranean only a few papers report short lists of epiphytic macroalgae [5, 28].

The Vulcano Island (Eolian Islands, Sicily) is the first locality in the western Mediterranean where a *Halophila stipulacea* stand has been found; the original record, [2] reported details on the extent and the bathymetric range of the bed. In a subsequent survey, collection of samples was carried out in order to get information on several aspects of the biology of this species. Data on plant phenology and associated macrozoobenthic communities were reported in a previous paper [3]; in the present paper data on the composition and bathymetric distribution of the macroalgal assemblages associated with the bed are presented and analysed.

2. MATERIALS AND METHODS

The study site is located in the Levante Bay, along the northeastern shore of Vulcano Island (*figure 1*), where the *Halophila stipulacea* bed covers about two hectares of sandy substratum ranging from 3 to 27 m depth. Its upper limit is irregular, repeatedly interrupted by sandy areas devoid of vegetation. From the upper limit to 10–15 m depth, *Halophila stipulacea* is mixed with the seagrass *Cymodocea nodosa* (Ucria) Ascherson and some algal species, of which *Caulerpa prolifera* (Fosskål) Lamouroux is the most abundant. At greater depths the *Halophila* stand is almost monospecific and covers the bottom uniformly until the lower limit is reached [2].

In July 1995 samples of *Halophila stipulacea* were collected by removing all plants from randomly chosen quadrats (0.1 m^2 in area) at three depths (5 m, 15 m and 25 m; the depths were chosen as representative of the upper limit, an intermediate depth and the lower limit); for each depth three replicates were taken. The samples were stored in 4 % formalin in seawater and examined in the laboratory, where the macroalgal species were determined, and their reproductive condition assessed. Specimens of the most common epiphytic macroalgae were preserved as permanent slides (mounted in 80 % corn syrup) and deposited in the personal herbarium Fabio Rindi (*Dipartimento di Scienze dell'Uomo e dell'Ambiente, Università di Pisa*).

For epiphytes of leaves, cover (in mm^2) was calculated by recording the area covered by the plants of each species as vertical projection on the surface of the leaves; then it

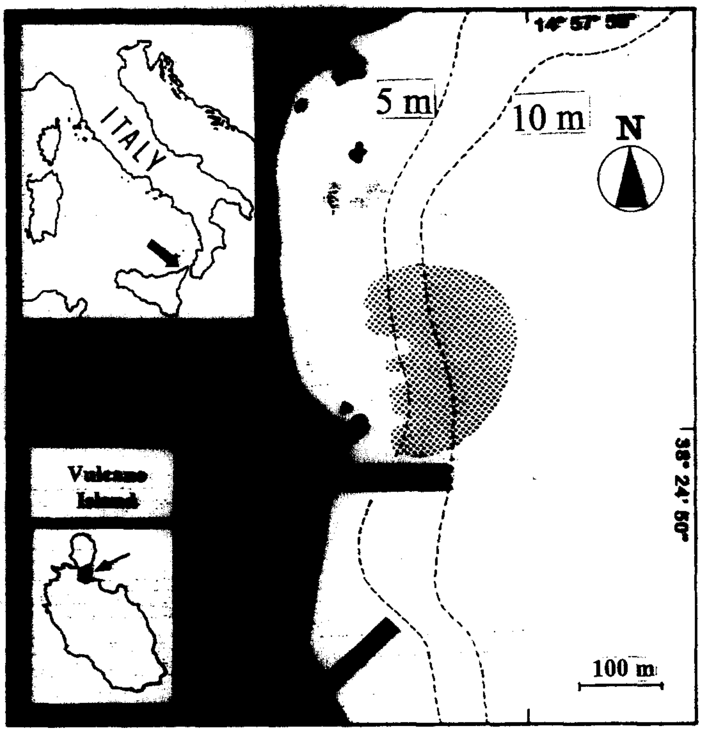

Figure 1. Study site. Shaded area represents the *Halophila stipulacea* bed.

was expressed as percentage of the total leaf surface in each sample. Percentage covers were ranked following a semi-quantitative scale (1 = up to 0.02 %; 2 = from 0.02 to 0.04 %; 3 = from 0.04 to 0.06 %; 4 = from 0.06 to 0.08 %) and reported in a species-sample matrix. In order to detect differences between the epiphytic flora at different depths, non-metric Multi-Dimensional Scaling (nMDS) was performed on a Bray-Curtis similarity matrix. Stress value was used as an index of accuracy in the representation of the similarity matrix on a two-dimensional ordination model; a stress value < 0.1 is generally regarded as an indication of a good representation [10]. The procedure was run using the PRIMER 4.0 program [10].

3. RESULTS

On the whole, 36 species of macroalgae (five Chlorophyta, five Heterokontophyta and 26 Rhodophyta) were found associated with *Halophila stipulacea*. Among them the most common were *Dictyota linearis* (C. Agardh) Greville, *Ceramium tenerrimum* (Martens) Okamura, *Chondria pygmaea* Garbary *et* Vandermeulen, *Dasya corymbifera* J. Agardh and *Laurencia* sp., which were found in all samples; *Wrangelia penicillata* C. Agardh occurred in eight samples (*table I*).

The epiflora of the leaves was formed by 20 species, six of which occurred exclusively on that part of the plant. Red algae were the most represented group; filamentous (*Ceramium tenerrimum*, *Dasya corymbifera*, *Polysiphonia* cfr. *tenerrima* Kützing, *Spyridia filamentosa* (Wulfen) Harvey, *Wrangelia penicillata*) and coarsely branched species (*Chondria pygmaea*, *Laurencia* sp.) were common, while encrusting forms were virtually absent. All these species were usually represented by small juvenile plants, no more than a few millimeters tall; in some cases this made their identification difficult. No zonation of epiphytes was evident on the leaves and their total percentage cover was very low in all samples, reaching a maximum value of 0.23 % in a sample collected at 5 m. Only *Ceramium tenerrimum*, *Chondria pygmaea*, *Dasya corymbifera*, *Polysiphonia* cfr. *tenerrima* and *Spyridia filamentosa* showed a cover > 1 cm^2 in at least one sample; the highest percentage cover recorded for a single species was 0.08 % (for *Chondria pygmaea*, in a

Table I. Bathymetric distribution and precise substratum of macroalgae species associated with *Halophila stipulacea*.

	5 m			15 m			25 m		
	A	B	C	A	B	C	A	B	C
CLOROPHYTA									
Chaetomorpha aerea (Dillwyn) Kützing			L					R	R
Chaetomorpha sp.		R							
Cladophora cfr. *vagabunda* (Linnaeus) Van den Hoek						R			
Cladophora coelothrix Kützing				R	R	R,S			R,S
Cladophora prolifera (Roth) Kützing	R					R			
HETEROKONTOPHYTA (PHAEOPHYCEAE)									
cfr. *Asperococcus fistulosus* (Hudson) Hooker						R			
Dictyota linearis (C. Agardh) Greville	R	R	R	R	R	R	R	R	R,S
Halopteris scoparia (Linnaeus) Sauvageau						R			
Sphacelaria cirrosa (Roth) C. Agardh				R	R	R,S	R	R	R,S
Stilophora tenella (Esper) Silva juv.							L		
RHODOPHYTA									
Antithamnion cruciatum (C. Agardh) Nägeli v. *profundum* G. Feldmann				R	R	R	L	R	R
Bornetia secundiflora (J. Agardh) Thuret									R
cfr. *Callithamnion corymbosum* (Smith) Lyngbye						R			
Ceramium diaphanum (Lightfoot) Roth			L		L	L			
Ceramium flaccidum (Kützing) Ardissone						L			
Ceramium tenerrimum (Martens) Okamura	L	L	L	L,S	L	L,S	L	L,S	L,R,S
Chondria cfr. *dasyphylla* (Woodward) C. Agardh juv.						L			L
Chondria pygmaea Garbary *et* Vandermeulen	L	L	L	L	L	L	L,S	L,S	L,S
Chylocladia verticillata (Lightfoot) Bliding			L						
Crouania sp.	S						L		
Dasya corymbifera J. Agardh	L	L	L	L	L	L	L	L,S	L,S
Griffithsia sp. juv.					L		L	R	
Herposiphonia secunda (C. Agardh) Ambronn						R			
Herposiphonia tenella (C. Agardh) Kützing			L						
Heterosiphonia crispella (C. Agardh) Wynne						R			
Hydrolithon farinosum (Lamouroux) Penrose *et* Chamberlain			R		R	R	R	L	R,S
Laurencia sp.	L,S	L	L	L,S	L	L,S	L	L	L,R
Lomentaria chylocladiella Funk		L	L	L	L,S	L,R,S		L	L,R
Lophosiphonia cristata Falkenberg						R			R
Pneophyllum fragile Kützing						R			
Polysiphonia scopulorum Harvey				R		R		R	R
Polysiphonia setacea Hollenberg									R
Polysiphonia cfr. *tenerrima* Kützing	L	L	L	R,L	L	R		L	
Spermothamnion cfr. *strictum* (C. Agardh) Ardissone					L		L	L,S	
Spyridia filamentosa (Wulfen) Harvey				L,S	L	L	L,S		R,S
Wrangelia penicillata C. Agardh	L	L	L	L	L		L	L	R

A, B and C indicate the three samples collected at each depth. L = epiphytic on leaves; S = epiphytic on scales; R = occuring on rhizomes.

5 m sample). Despite the quantitative scarcity of the epiphytic flora, bathymetric variation was observed. This was clearly shown by the MDS ordination, which separated the samples into two groups along the horizontal axis (*figure 2*). In the first group, situated on the left hand side of the plot and formed by the samples collected at 5 m, *Ceramium tenerrimum, Chondria pygmaea* and *Polysiphonia* cfr. *tenerrima* were quantitatively dominant species. In the second group, situated on the right hand side of the plot and including the 15 m and 25 m samples, *Dasya corymbifera, Laurencia* sp. and *Spyridia filamentosa* were the most abundant species (*table II*).

No macroalgae epiphytized the rhizomes, but 21 species were found mixed with or entangled in the rhizomes. Twelve of them only occurred there, while the others

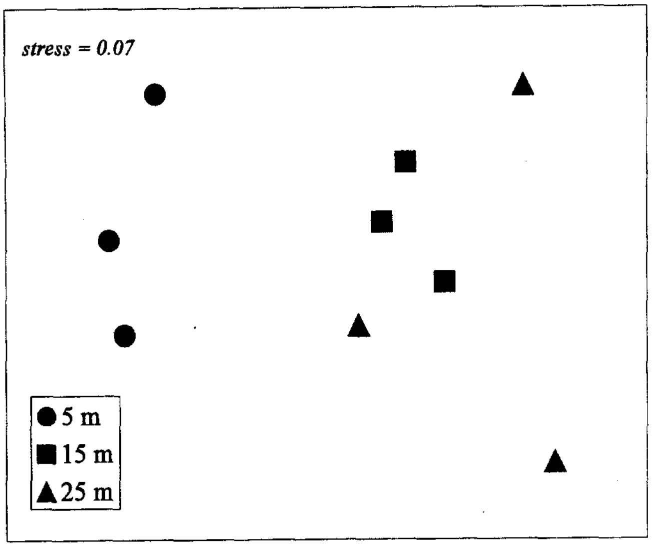

Figure 2. Two-dimensional nMDS ordination model of samples, performed on Bray-Curtis similarity matrix.

Table II. Percentage cover of epyphytic species on leaves, ranked following a semiquantitative scale: 0 = 0 %; 1 = up to 0.02 %; 2 = from 0.02 to 0.04 %; 3 = from 0.04 to 0.06 %; 4 = from 0.06 to 0.08 %.

	5 m			15 m			25 m		
	A	B	C	A	B	C	A	B	C
Chaetomorpha aerea	0	0	1	0	0	0	0	0	0
Stylophora tenella juv.	0	0	0	0	0	0	1	0	0
Antithamnion cruciatum v. *profundum*	0	0	0	0	0	0	1	0	0
Ceramium diaphanum	0	0	2	0	1	1	0	0	0
Ceramium flaccidum	0	0	0	0	0	1	0	0	0
Ceramium tenerrimum	3	3	1	1	1	1	1	1	1
Chondria cfr. *dasyphylla* juv.	0	0	0	0	0	1	0	0	1
Chondria pygmaea	3	4	2	1	1	1	1	1	1
Chylocladia verticillata	0	0	1	0	0	0	0	0	0
Crouania sp.	0	0	0	0	0	0	1	0	0
Dasya corymbifera	1	1	1	1	2	1	1	1	2
Griffithsia sp. juv.	0	0	0	0	1	0	1	0	0
Herposiphonia tenella	0	0	1	0	0	0	0	0	0
Hydrolithon farinosum	0	0	0	0	0	0	0	1	0
Laurencia sp.	1	1	1	1	1	1	2	1	2
Lomentaria chylocladiella	0	1	1	1	2	1	0	1	1
Polysiphonia cfr. *tenerrima*	4	4	2	1	1	1	0	1	0
Spermothamnion cfr. *strictum*	0	0	0	0	1	0	1	1	0
Spyridia filamentosa	0	0	0	1	2	2	1	0	0
Wrangelia penicillata	1	1	1	1	1	0	1	1	0

A, B and C as in *table I*.

were also observed on leaves and/or scales. Among them, the brown alga *Dictyota linearis* was the most abundant; *Antithamnion cruciatum* (C. Agardh) Nägeli, *Cladophora coelothrix* Kützing, *Polysiphonia scopulorum* Harvey and *Sphacelaria cirrosa* (Roth) C. Agardh were also observed in many samples. In many cases these species were represented by drift specimens; in others they were epiphytes on detached leaves, as in the case of the encrusting corallines *Hydrolithon farinosum* (Lamouroux) Penrose *et* Chamberlain and *Pneophyllum fragile* Kützing, which were either rarely observed or not observed on living leaves.

The highest mean number of species (18.00, SD = 6.25) was observed for the samples collected at 15 m, the lowest (10.33, SD = 2.30) being recorded for the 5 m samples; at 25 m a mean number of 15.67 species per sample was found (SD = 2.08). The most common species (*Dictyota linearis*, *Ceramium tenerrimum*, *Chondria pygmaea*, *Dasya corymbifera*, *Laurencia* sp. *Polysiphonia* cfr. *tenerrima* and *Wrangelia penicillata*) and another two species were collected at all depths. Among the other species, three were found only at 5 m, seven only at 15 m and three only at 25 m; two species occurred either at 5 and 15 m, eight species either at 15 m and 25 m, two species either at 5 m and 25 m (*table I*). Even considering only species occurring on leaves, the highest mean number (9.33, SD = 1.52) was recorded at 15 m; but in this case the difference between 15 m and the other depths (a mean number of 8.00 and 8.67 species was found respectively at 5 m and 25 m, SD = 2.65 and 2.51) was weaker.

Reproductive structures were observed only in seven species of red algal epiphytes: *Ceramium diaphanum* (Lightfoot) Roth, *Chondria pygmaea*, *Dasya corymbifera*, *Laurencia* sp., *Polysiphonia* cfr. *tenerrima*, *Spermothamnion* cfr. *strictum* (C. Agardh) Ardissone, *Wrangelia penicillata* (*table III*). In the case of *Laurencia* sp. and *Polysiphonia* cfr. *tenerrima* all phases of the life history were found reproductive (tetrasporangial plants, spermatangial plants and female gametophytes with cystocarps were observed). No fertile macroalgal species were found between the rhizomes.

Table III. Reproductive structures observed in macroalgal species associated with *Halophila stipulacea*.

	5 m	15 m	25 m
Ceramium diaphanum	S,T	S	
Chondria pygmaea	C,T		
Dasya corymbifera			T
Laurencia sp.			S,C,T
Polysiphonia cfr. *tenerrima*	S,C,T		
Spermothamnion cfr. *strictum*			B
Wrangelia penicillata			S

C = cystocarps; B = bisporangia; S = spermatangial branches; T = tetrasporangia.

4. DISCUSSION

All macroalgae associated with *Halophila stipulacea* have previously been reported for the algal flora of Vulcano Island or Sicily [6, 18]; no rare species were found. The record of the red alga *Chondria pygmaea* is interesting. This species was described as an epiphyte of *Halophila stipulacea* in the Gulf of Aqaba, Red Sea [16]; in the Mediterranean it was first recorded in Catania Harbour, Sicily [11] and subsequently reported for Albania [28]. Because of the constant occurrence of this species on leaves of *Halophila stipulacea*, the previous authors regarded *Chondria pygmaea* as possibly introduced in the Mediterranean together with its host. Recently specimens of *Chondria pygmaea* were found as epiphytes on other algae in the Maltese Islands, showing that its presence is not strictly linked to seagrasses [12]. This species can be easily overlooked because of its diminutive size and future surveys might show a much wider distribution than that currently reported. Moreover, we think that in some floristic reports *Chondria pygmaea* could have been confused with *Chondria mairei* G. Feldmann, another diminutive species widely distributed in the Mediterranean.

Our observations highlight some characteristics of the epiphytic community of the *Halophila stipulacea* bed of Vulcano Island. In particular, the low number of epiphytic species (20) is striking. It should be considered that in the present survey it was not possible to repeat sampling in the time available; consequently this study cannot elucidate the seasonal dynamics of the epiphytic community. It must also be mentioned that in a previous survey of the same stand [2] at least three species that were not recorded in the present study were found as leaf epiphytes: the green algae *Entocladia viridis* Reinke and *Ulvella lens* P.L. *et* H.M. Crouan, and the red *Pneophyllum fragile* Kützing. Probably the epiphytic assemblage undergoes seasonal changes of composition and the number of leaf epiphytes that we recorded underestimates the number of taxa which can actually colonize the leaves during a whole annual cycle. This seems to be confirmed by the comparison with data on other Mediterranean stands of *Halophila stipulacea*. For a bed off eastern Sicily, 30 taxa were recorded [5]; in that case samples were collected in winter months, and some differences between the epiphytic flora described in that study and the one of the Vulcano stand are evident. In that case prostrate red and green algae (that were virtually absent at Vulcano) were recorded [5]; furthermore, the erect forms were mainly represented by ectocarpoid brown algae (while in Vulcano they were red algae). Our epiphytic assemblage is apparently more similar to the one reported for Albanian shores [28], although in that case the encrusting coralline *Hydrolithon farinosum* was a common species as well. It is noticeable that the only species commonly found in all three studies is *Chondria pygmaea*.

The scarcity of the epiphytic flora of *Halophila stipulacea* is particularly remarkable if compared with the same kind of assemblage colonizing the leaves of the endemic Mediterranean seagrass *Posidonia oceanica*. Even in this case it is not easy to generalise, because often studies on *Posidonia oceanica* were performed at different depths, in different periods and with different methods; this is clearly reflected by the strong variation of the number of epiphytic species in different studies. Anyway, for beds of this last species a generally higher number of epiphytes than for *Halophila stipulacea* is reported: up to 90 [46], 81 [7] and 43 species [35] were found on leaves. In a survey, carried out in the same period of the year, on *Posidonia oceanica* beds at Elba Island (occupying more or less the same bathymetric range of the Vulcano stand) 38 taxa were recorded (Rindi, unpubl. data).

Another characteristic of the Vulcano stand is the bathymetric differentiation of the epiphytic assemblage observed between 5 m and the other depths. The 5 m samples were characterized by the abundance of *Ceramium tenerrimum*, *Chondria pygmaea* and *Polysiphonia* cfr. *tenerrima*. At 15 m and 25 m these species were still present but rarer. Quantitatively they were replaced by other species that were absent at 5 m (*Spyridia filamentosa*) or less abundant (*Laurencia* sp., *Dasya corymbifera*). Furthermore, some species were recorded at 5 m but not at greater depths (*Chylocladia verticillata* (Lightfoot) Bliding, *Herposiphonia tenella* (C. Agardh) Kützing), while others were not recorded in shallow waters (*Stilophora tenella* (Esper) Silva, *Antithamnion cruciatum*, *Chondria* cfr. *dasyphylla* (Woodward) C. Agardh, *Griffithsia* sp., *Spermothamnion* cfr. *strictum*). Factors determining such a clear difference are probably numerous and it is not possible to elucidate them on the basis of our observations alone. Besides variations of physico-chemical parameters related to depth, two characteristics of the Vulcano stand should be pointed out: i) the different composition of the stand at 5 m in comparison with the one at greater depths; ii) the proximity of the upper limit of the stand to hydrothermal springs. In the shallow parts (from the upper limit to 10–15 m depth) *Halophila stipulacea* is mixed with other seagrasses and some macroscopic algae, while at increasing depths the stand is virtually monospecific [2]. Hydrothermal springs are present in the shallow sublittoral of some parts of Levante Bay [17] and the upper part of the *Halophila* stand is intermixed with some springs. Previous observations suggest that hydrothermal activity may be a factor influencing the small-scale distribution of algal species in those areas. Sites located in the proximity of hydrothermal springs (a few meters) are occupied by a relatively poor vegetation, characterized by a low number of species; conversely, sites located at greater distance from the springs (about 200 m) host a higher number of species [1]. This seems to indicate that the presence of the springs negatively infuences at least some species, possibly due to rising temperature or alteration of the chemical composition of seawater (further studies are necessary to elucidate exactly the type and extent of influence). Thus, the possibility that these factors can also affect the epiphytic vegetation of *Halophila stipulacea* should not be dismissed.

The very low epiphytic cover observed on the leaves of the Vulcano stand is an even more striking peculiarity: no epiphytic species exhibited a total percent cover > 1 % in any sample. In particular the absence, or very reduced cover, of encrusting corallines is noteworthy. Encrusting coralline algae are amongst the most ubiquitous of seagrass epiphytes; they are pioneer colonisers with rapid development to sexual maturity and have a low profile which reduces the likelihood of detachment from their host [9]. Several factors can affect the epiphytic load of seagrasses: turnover rate of leaves, which depends on leaf morphology of the species, but also on habitat, and varies seasonally with changes in growth rate [29, 40, 41], reproduction and turnover rate of epiphytes [19] and grazing on the epiphytic biomass [38, 39]. In the study bed, no signs of grazing were evident on the leaves and on the epiphytes, and we think that the turnover rate (and consequently the life span of leaves) plays a major role.

The life span of the various portions of a seagrass affects epiphyte diversity and biomass. In general, if other conditions are equal, epiphytes have a better chance of establishing themselves on leaves with a longer life span [23]. So, a high leaf turnover rate ensures that epiphytic loads are kept low [25, 44]. Usually the older parts of leaves and the oldest leaves in any cluster, support the most mature and diverse epiphytic community [9]. Species of *Halophila* have small elliptic or lanceolate leaves and their turnover rate, compared with most seagrasses, is fast. For example, a mean turnover time of 14.7 days has been estimated for *Halophila hawaiiana* [21], 10–30 days for *Halophila decipiens* [27]; for *Halophila ovalis* leaves a life span of 11–24 days has been reported [22]. So, the epiphytic flora of *Halophila* species can be expected to be qualitatively and quantitatively poor, as was the case in this study. But this conclusion should be made with caution, as no studies on the life span of *Halophila stipulacea* leaves have been carried out in the Mediterranean Sea. It must also be mentioned that Wahbeh [49], for plants of *Halophila stipulacea* from the Red Sea, calculated a life span of 74 days, which is similar to values reported for other genera of seagrasses hosting a more abundant epiflora [9].

Acknowledgements

The research was funded by *PADI FOUNDATION*, Beverly Hills, California (Request No. 60/1996 to S.A. and F.M.).

REFERENCES

[1] Acunto S., Rindi F., Variabilità spaziale di popolamenti fitobentonici in relazione ad attività idrotermali nella Baia di Levante dell'Isola di Vulcano (Isole Eolie): studio preliminare, Biol. Mar. Medit. 4 (1997) 351–352.

[2] Acunto S., Maltagliati F., Rindi F., Rossi F., Cinelli F., Osservazioni su una prateria di *Halophila stipulacea* (Forssk.) Aschers. (Hydrocharitaceae) nel Mar Tirreno meridionale, Atti Soc. Tosc. Sci. Nat., Mem., Serie B, 102 (1995) 19–22.

[3] Acunto S., Maltagliati F., Rindi F., Rossi F., Cinelli F., Lardicci C., Indagine su una prateria di *Halophila stipulacea* (Forssk.) Aschers. (Hydrocharitaceae) dell'Isola di Vulcano, Atti XII Congresso A.I.O:L. 1 (1997) 51–60.

[4] Aleem A.A., The occurrence of the sea-grass: *Halophila stipulacea* (Forssk.) Asch. on the west coast of Egypt, Bull. Fac. Sci. Univ. Alexandria 4 (1962) 79–84.

[5] Alongi G., Cormaci M., Pizzuto F., La macroflora epifita delle foglie di *Halophila stipulacea* (Forssk.) Aschers. del Porto di Catania, Biol. Mar. Medit. 1 (1993) 287–288.

[6] Alongi G., Pizzuto F., Scammacca B., Giaccone G., La flora sommersa dell'Isola di Vulcano (Isole Eolie), Boll. Acc. Gioenia Sci. Nat. 26 (1993) 273–291.

[7] Battiato A., Cinelli F., Cormaci M., Furnari G., Mazzella L., Studio preliminare della mcroflora epifita della *Posidonia oceanica* (L.) Delile di una prateria di Ischia (Golfo di Napoli), Naturalista sicil. S. IV 1 (1982) 15–27.

[8] Biliotti M., Abdelahad N., *Halophila stipulacea* (Forssk.) Aschers. (Hydrocharitaceae): espèce nouvelle pour l'Italie, Posidonia Newslett. 3 (1990) 23–26.

[9] Borowitzka M.A., Lethbridge R.C., Seagrass epiphytes, in: Larkum A.W.D., Mc Comb A.J., Shepherd S.A. (Eds.), Biology of Seagrasses, Treatise on the biology of seagrasses with special reference to the Australian region, Elsevier, Amsterdam, 1989, pp. 458–499.

[10] Clarke K.R., Warwick R.M., Change in marine communities: an approach to statistical analysis and interpretation, NERC, U.K. 1994, 144 pp.

[11] Cormaci M., Furnari G., Alongi G., Dinaro R., Pizzuto F., On the occurrence in Sicily of three Florideophyceae new to the Mediterranean Sea, Bot. Mar. 35 (1992) 447–449.

[12] Cormaci M., Lanfranco E., Borg J.A., Buttigieg S., Furnari G., Micallef S.A., Mifsud C., Pizzuto F., Scammacca B., Serio D., Contribution to the knowledge of benthic marine algae on rocky substrata of the Maltese Islands (Mediterranean Sea), Bot. Mar. 40 (1997) 203–215.

[13] Forsskål P., Flora Aegypto-Arabica sive descriptiones plantarum quas per Aegyptum Inferiorem et Arabiam Felicem, Moeller, Copenhagen, 1775, 219 p.

[14] Forti A., La propagazione dell'*Halophila stipulacea* (Forssk.) Aschers. anche nel Mediterraneo, Nuovo G. Bot. Ital. 34 (1928) 714–716.

[15] Fritsch C., Über die Auffindung einer marinen Hydrocharidee im Mittelmeer, Verh. Zool. Bot. Ges. Wien 45 (1895) 104–106.

[16] Garbary D., Vandermeulen H., *Chondria pygmaea* sp. nov. (Rhodomelaceae, Rhodophyta) from the Gulf of Aqaba, Red Sea, Bot. Mar. 33 (1990) 311–318.

[17] Giaccone G., Associazioni algali e fenomeni secondari di vulcanismo nelle acque marine di Vulcano (Mar Tirreno), Giorn. Bot. It. 103 (1969) 353–366.

[18] Giaccone G., Colonna P., Graziano C., Mannino A.M., Tornatore E., Cormaci M., Furnari G., Scammacca B., Revisione della flora marina di Sicilia e isole minori, Boll. Acc. Gioenia Sci. Nat. 18 (1985) 537–781.

[19] Harlin M.M., Seagrass epiphytes, in: Phillips R.C., Mc Roy C.P. (Eds.), Handbook of Seagrass Biology: an ecosystem perspective, Garland STPM Press, New York, 1980, pp. 117–151.

[20] Hartog C. den, The seagrasses of the world, North Holland Publ. Co., Amsterdam, 1970, 275 p.

[21] Herbert D.A., The growth dynamics of *Halophila hawaiiana*, Aquat. Bot. 23 (1986) 351–360.

[22] Hillman K., The production ecology of the seagrass *Halophila ovalis* (R.Br.) Hook. in the Swan-Canning estuary, Western

Australia, Ph.D. Thesis, Botany Dep. Univ. Western Australia, Perth, 1985.

[23] Hillman K., Mc Comb A.J., Walker D.I., The distribution, biomass and primary production of the seagrass *Halophila ovalis* in the Swan/Canning estuary, Western Australia, Aquat. Bot. 51 (1995) 1–54.

[24] Hulings N.C., The ecology, biometry and biomass of the seagrass *Halophila stipulacea* along the Jordanian coast of the Gulf of Aqaba, Bot. Mar. 22 (1979) 425–430.

[25] Johnstone I.M., Papua New Guinea seagrasses and aspects of the biology and growth of *Enhalus acoroides* (L. f.) Royle, Aquat. Bot. 7 (1979) 197–208.

[26] Jones J.A., Primary productivity of the tropical marine turtle grass, *Thalassia testudinum* König, and its epiphytes, Ph.D. Thesis, Miami Univ. Florida (1968) 169 p.

[27] Josselyn M., Fonseca M., Niesen T., Larson R., Biomass, production and decomposition of a deep water seagrass, *Halophila decipiens* Ostenf., Aquat. Bot. 25 (1986) 47–61.

[28] Kashta L., Pizzuto F., Sulla presenza di *Halophila stipulacea* (Forsskål) Ascherson (Hydrocharitales, Hydrocharitaceae) nelle coste dell'Albania, Boll. Acc. Gioenia Sci. Nat. 28 (1995) 161–166.

[29] Kirkman H., Cook I.H., Distribution and leaf growth of *Thalassodendron pachyrhizum* den Hartog in southern Western Australia, Aquat. Bot. 27 (1987) 257–266.

[30] Land L.S., Carbonate mud: production by epibiont growth on *Thalassia testudinum*, J. Sediment. Petrol. 40 (1971) 1361–1363.

[31] Lanfranco E., The occurrence of *Halophila stipulacea* (Forsskål) Ascherson (Family: Hydrocharitaceae) in Maltese waters, Maltese Nat. 1 (1970) 16–17.

[32] Lipkin Y., *Halophila stipulacea*, a review of a successful immigration, Aquat. Bot. 1 (1975) 203–215.

[33] Lipkin Y., Quantitative aspects of seagrass communities, particularly of those dominated by *Halophila stipulacea*, in Sinai (northern Red Sea), Aquat. Bot. 7 (1979) 119–128.

[34] Malea P., Uptake of cadmium and the effect on variability of leaf cells in the seagrass *Halophila stipulacea* (Forssk.) Aschers, Bot. Mar. 37 (1994) 67–73.

[35] Mazzella L., Scipione M.B., Buia M.C., Spatio-temporal distribution of algal and animal communities in a *Posidonia oceanica* meadow, P.S.Z.N.I.: Mar. Ecol. 10 (1989) 107–129.

[36] McMillan C., Flowering and controlled conditions by *Cymodocea serrulata, Halophila stipulacea, Syringodium isoetifolium, Zostera capensis* and *Thalassia hemprichii* from Kenya, Aquat. Bot. 8 (1980) 323–336.

[37] Morgan M.D., Kitting C.L., Productivity and utilization of the seagrass *Halodule wrightii* and its attached epiphytes, Limnol. Oceanogr. 29 (1984) 1099–1176.

[38] Ogden J.C., Faunal relationships in Caribbean seagrass beds, in: R.C. Phillips R.C., Mc Roy C.P. (Eds.), Handbook of Seagrass Biology: an ecosystem perspective, Garland STPM Press, New York, 1980, pp. 173–198.

[39] Orth R.J., van Montfrans J., Epiphyte-seagrass relationships with an emphasis on micrograzing: a review, Aquat. Bot. 18 (1984) 43–69.

[40] Orth R.J., Moore K.A., Seasonal and year-to-year variations in the growth of *Zostera marina* L. (eelgrass) in the lower Chesapeake Bay, Aquat. Bot. 24 (1986) 335–341.

[41] Ott J.A., Growth and production in *Posidonia oceanica* (L.) Delile, P.S.Z.N.I.: Mar. Ecol. 1 (1980) 47–64.

[42] Politis J., De la présence de l'*Halophila stipulacea* (Forssk.) Aschers. dans les mers Grecques, Prakt. Akad. Athenon 1 (1926) 111–113.

[43] Price A.R.G., Crossland C.J., Dawson Shepherd A.R., McDowall R.J., Medley P.A.H., Stafford Smith M.G., Ormond R.F.G., Wrathall T.J., Aspects of seagrass ecology along the eastern coast of the Red Sea, Bot. Mar. 31 (1988) 83–92.

[44] Sand-Jensen K., Biomass, net production and growth dynamics in an eelgrass (*Zostera marina* L.) population in Vellerup Vig, Denmark, Ophelia 14 (1975) 185–201.

[45] Silberstein K., Chiffings A.W., McComb A.J., The loss of seagrass in Cockburn sound, Western Australia. III. The effect of epiphytes on productivity of *Posidonia australis* Hook F., Aquat. Bot. 24 (1986) 355–371.

[46] Van der Ben D., Les épiphytes des feuilles de *Posidonia oceanica* sur les côtes françaises de la Méditerranée, Proc. Int. Seaweed Symp., Madrid 6 (1969) 79–84.

[47] Villari R. *Halophila stipulacea* (Forssk.) Aschers. (Hydrocharitaceae). Genere e specie nuovi per l'Italia, Inform. Bot. Ital. 20 (1988) 672.

[48] Wahbeh M.I., Studies on the ecology and productivity of the seagrass *Halophila stipulacea*, and some associated organisms in the Gulf of Aqaba (Jordan), Ph.D. Thesis, Univ. York, UK, 1980.

[49] Wahbeh M.I., The growth and production of the leaves of the seagrass *Halophila stipulacea* (Forssk.) Aschers. from Aqaba, Jordan, Aquat. Bot. 20 (1984) 33–41.

[50] Wahbeh M.I., Mahasneh A.M., Some aspects of the composition of leaf litter of the seagrass *Halophila stipulacea* from the Gulf of Aqaba (Jordan), Aquat. Bot. 21 (1985) 237–244.