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Species composition and morphological groups of macroalgal assemblages around Gorgona Island (north-western Mediterranean Sea)

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Abstract – Macroalgal communities of Gorgona, the smallest island of the Tuscan Archipelago National Park (north-western Mediterranean Sea), were described by using both species and morphological groups. A floristic list was obtained for the main benthic habitats of the island and temporal fluctuations in macroalgal assemblages were studied during a one-year period on rocky substrata at 1, 10 and 35 m depth, on leaves and on rhizomes of *Posidonia oceanica* at 10 m depth and in a rhodolith assemblage on a soft bottom at 50 m depth. A total of 230 macroalgal species were identified (30 Chlorophyta, 46 Fucophyceae and 154 Rhodophyta). On rocky substrata, filamentous and crustose species were abundant in shallow water, corticated-terete and foliose species dominated the intermediate assemblage and crustose, foliose and articulated algae characterized the deep assemblage. In *P. oceanica* meadows, crustose species dominated on leaves and filamentous species on rhizomes. On rhodoliths, leathery macrophytes dominated in June and September. The loss of information by using of morphological groups was comparable to that shown in similar studies of other biogeographical regions. The main patterns of temporal variability in the studied assemblages, however, were maintained by using this approach.

Gorgona Island / macroalgal assemblages / Mediterranean Sea / morphologicals groups.

Résumé – La composition spécifique et les groupes morphologiques des communautés de macroalgues autour de l'île de Gorgona (nord-ouest de la mer Méditerranée). Les communautés macroalgales de l'Ile de Gorgona, la plus petite île du Parc National de l'Archipel Toscan (Méditerranée nord occidentale), ont été décrites par les espèces et les groupes morphologiques. Une liste floristique a été obtenue pour les principaux habitats benthiques de l'île et les fluctuations temporelles des communautés algales ont été étudiées pendant un an sur le substrat rocheux à 1, 10 et 35 mètres de profondeur, dans les herbiers à *Posidonia oceanica* à 10 mètres et sur les Corallinacées libres sur un substrat sableux à 50 mètres. Au total, 230 espèces de macroalgues ont été identifiées : 30 Chlorophyta, 46 Fucophyceae et 154 Rhodophyta. Sur le substrat rocheux, les espèces filamenteuses et encroûtantes étaient abondantes dans les eaux superficielles, les espèces cylindriques-cortiquées et foliacées dominaient le peuplement intermédiaire et les espèces encroûtantes, articulées et foliacées caractérisaient le peuplement profond. Dans les herbiers à *P. oceanica,* les espèces encroûtantes dominaient sur les feuilles et les filamenteuses sur les rhizomes. Sur les Corallinacées libres, les Fucophyceae dressées dominaient de juillet à septembre. La perte d'informations par l'utilisation des groupes morphologiques a été comparable à celle montrée par des études dans d'autres régions biogéographiques, cependant, les modèles principaux de variabilité temporelle des peuplements algaux sont maintenus en utilisant cette méthode.

Île de Gorgona / groupes morphologiques / Mer Méditerranée / peuplements macroalgaux.

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INTRODUCTION

Littoral systems around small islands show peculiar characteristics, both biotic and abiotic, if compared to those of continental regions (Whittaker, 1998). The causes of these peculiarities are linked to the isolation of the islands and to differences in environmental factors, such as currents, water transparency, sedimentation rate and interactions with pelagic systems (Rindi & Cinelli, 1995). These differences are becoming more evident because of the increased anthropogenic impact on littoral habitats along many continental coasts. Small, little-impacted islands allow conservation of habitats and ecosystems deteriorated and sometimes destroyed elsewhere, represent a refuge for threatened species and are considered good field laboratories for ecological studies (Benedetti-Cecchi *et al.,* 2003). On the other hand, small islands are characterized by a delicate equilibrium and are highly sensitive to human impact or introduction of allochthonous organisms (Vitousek *et al.,* 1997; Francour et al., 2001). The management of these important areas is closely related to the knowledge of the structural composition and dynamics of terrestrial and marine ecosystems. Macroalgal communities are an important part of benthic ecosystems and have been widely utilised in environmental monitoring and impact studies (Verlaque & Fritayre, 1994; Rodríguez-Prieto & Polo, 1996; Eriksson *et al.,* 1998; Cormaci & Furnari, 1999; Forster & Vanblaricom, 2001; Piazzi *et al.,* 2001; Schils *et al.,* 2001; Soltan *et al.,* 2001; Rindi & Guiry, 2004).

Benthic communities can be described by using several levels of taxonomic resolution (Chapman, 1998). Although analyses of species assemblages are considered the most precise method for description of communities, the grouping of species in coarser levels of taxonomic resolution may be advantageous for many reasons. Refined taxon identification requires much time and taxonomic expertise; furthermore, a precise identification at species-level is often not possible for all collected specimens. Moreover, many species cannot be identified by non-destructive sampling methods. In order to reduce the time of sorting, the use of methods with lower taxonomic resolution allows the analysis of larger numbers of replicates, which is particularly important when the aim of the investigation is to quantify the spatial and temporal variability in natural communities (Underwood, 1997). However, the grouping of species in community analyses needs to be evaluated, to check if the same patterns of community structure revealed by a common analysis based on species are obtained.

Methods for reducing the taxonomic resolution include the use of morphological groups, which have been widely used to study macroalgal assemblages (Littler, 1980; Littler & Littler, 1980; 1984; Hay, 1994; Steneck & Dethier, 1994). Morphological groups have been regarded as good descriptors of benthic communities in ecological studies (Vadas & Steneck, 1988; Viejo, 1997 ; Lirman & Biber, 2000), although their use leads to a loss of information if compared with analyses at the species level (Lavery & Vanderklift, 2000). Phillips *et al.* (1997) showed the effectiveness of the morphological groups model to detect shift in dominant algal forms along a disturbance gradient, but not as a measure of diversity. In the Mediterranean Sea, a morphological groups approach has been used to describe *Posidonia oceanica* (L.) Delile epiphytes (Mazzella *et al.,* 1989) and epilithic macroalgal assemblages (Sala & Boudouresque, 1997; Benedetti-Cecchi 2001; Benedetti-Cecchi *et al.*, 2001; Piazzi *et al.*, 2002b). As this method may prove to be fast and inexpensive for ecological studies, it is appropriate to investigate its results for marine plant communities of the Mediterranean Sea.

We here present a study of the main macroalgal communities (shallow and deep assemblages on rocky bottom, rhizome and leaf epiphytes of seagrasses and sandy bottom assemblages) around Gorgona, the smallest island of the Tuscan Archipelago National Park (north western Mediterranean Sea), by using both species and morphological groups.

The presence of a prison since 1864 and the distance from the continental coast have preserved the island from high anthropogenic impact. The study of marine benthic communities around the island started in the early 1990s. Macroalgal assemblages have been partially investigated (Sartoni & Boddi, 1992; Pardi *et al.*, 1993; Piazzi *et al.*, 1995; 1996; 1999) and seagrass meadows of *Posidonia oceanica* have been mapped (Cinelli *et al.*, 1995).

The aims of the present work were: i) the description of the structure and species composition of the marine vegetation around Gorgona Island, ii) a characterization of the main macroalgal assemblages through the abundance of morphological forms and iii) a comparison of species and morphological groups approaches to examine temporal variability in the assemblages. To achieve these objectives, a floristic list was obtained for the main benthic habitats of the island and temporal fluctuations in macroalgal assemblages were studied during a one-year period at different depths on rocky bottoms, on *Posidonia oceanica* meadows and on a rhodolith assemblage.

MATERIAL AND METHODS

Study site

Gorgona, the northernmost island of the Tuscan Archipelago (43°26' N, 9°54' E), has a land area of 2.25 km^2 and is situated 34 km from the continental coast of North-western Italy (Fig. 1). It is mostly bordered by rocky cliffs that drop down to a depth of about 45-50 meters to a sand plain that slopes down. A rhodolith assemblage colonizes the deep sand plain in the south-western part of the island. Two rocky banks are situated off the eastern and southern coasts. *Posidonia oceanica* meadows are distributed all around the island and occur mostly on rock (Cinelli *et al.*, 1995). The most extensive meadows occur along the south-eastern coast, where the substrate slope is more gradual (Fig. 1).

Floristic study

A floristic list of Gorgona Island was obtained. The list is based on a total of 70 samples collected at the different seasons between 1994 and 1997. Forty samples were collected on rocky shores: 8 in the intertidal zone (that in Gorgona Island occupies a vertical range of about 30 cm), 20 in the shallow subtidal (1-15 m), 16 in the deep subtidal (30-45 m) and 4 on the rocky banks; 14 samples were collected in *Posidonia oceanica* beds (10-15 m) and 12 in rhodolith assemblages on soft sediments (45-50 m). Species on hard substrata were sampled by scraping off 400 cm^2 surfaces (Boudouresque, 1971), while in *P. oceanica* beds five rhizomes were collected in each sampling station (Mazzella *et al.*, 1989; Piazzi *et al.*, 2002a). All organisms within quadrats of 1000 cm^2 were collected in rhodolith beds; this sampling surface is smaller than the surface normally used for these assemblages (Ballesteros, 1989; Soto, 1990), but it was chosen for the high density of rhodoliths.

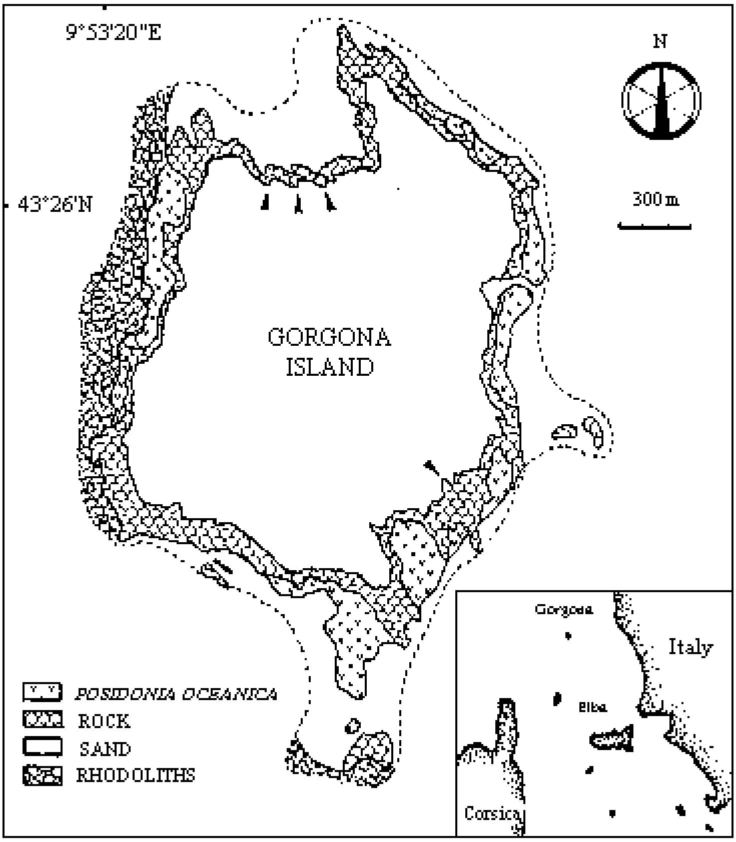

Fig. 1. Gorgona Island: localization and mapping of the principal benthic assemblages. Arrows indicate *Lithophyllum byssoides* ledges.

The samples were preserved in 4 % formalin in seawater and observed under microscope for macroalgal identification. Taxonomic nomenclature follows Guiry & Nic Dhonncha (2003).

Temporal fluctuations and morphological groups

The study was carried out in the south-western part of Gorgona Island, where all the main benthic communities of the island were present. We studied six different communities: three on rocky substrata at 1, 10 and 35 m depth, two at 10 m depth on leaves and on rhizomes of *Posidonia oceanica* respectively, and one in a rhodolith bed on a soft bottom at 50 m depth.

Two samples were randomly collected in each community at four different times in one year (March, June, September and December 1995) using the methods described above.

Cover of each species was estimated as vertical projection of the species and expressed as the percentage of sampling area (Boudouresque, 1971). Sampling areas was 400 cm^2 on rock (Boudouresque, 1971), calcareous algae surface in rhodolith beds (estimated as vertical projection) and the surface of rhizomes and leaves in *Posidonia oceanica* meadows (Mazzella *et al.*, 1989; Piazzi *et al.*, 2002a). Rhodoliths represented 100 % of the samples and their cover was not taken into account for the calculation of the cover percentage that referred only to the epiphytic algae. Total percent cover was calculated for each sample by summing the percent cover of all the algae of the sample.

Macroalgal species were divided into morphological groups according to Steneck & Dethier (1994) (foliose, filamentous, corticated-terete, crustose, articulated and leathery macrophytes) and the cover percentage of each group was calculated as the sum of the percent cover of all the algae belonging to the group.

The similarity in macroalgal composition based on species and morphological group data and their abundance among sampling periods was analysed by calculating the Bray-Curtis similarity coefficient. Data were square root transformed before calculating the coefficient (Clarke & Warwick, 1994). One-way ANOSIM (analysis of similarity) was performed to quantify differences among sampling periods in each habitat. The RELATE procedure was used to compare the two similarity matrices, obtained by species and morphological groups for each community; this test allowed to measure, through R values, how closely related the two matrices were.

RESULTS

Floristic study

A total of 230 macroalgal species were identified (30 Chlorophyta, 46 Fucophyceae and 154 Rhodophyta; Tab. 1). The intertidal zone was characterised by the development of *Rissoella verruculosa* and *Nemalion helminthoides* from late winter to early summer. Well-developed *Lithophyllum byssoides* ledges were present in the northern and eastern shores (Fig. 1).

The shallow subtidal zone (0-30 m) was colonised in the most exposed areas by a macroalgal assemblage dominated by brown algae such as *Cystoseira amentacea* var *stricta, C. compressa, Stypocaulon scoparium, Dictyota dichotoma* and *Padina pavonica*. Assemblages of shaded sites were characterised by *Corallina elongata, Valonia utricularis, Bryopsis cupressina* and *Ceramium* spp.

On *Posidonia oceanica* rhizomes, the filamentous introduced red algae *Acrothamnion preissii* and *Womersleyella setacea* were abundant, whereas algal assemblages on leaves were characterised by encrusting corallines (*Hydrolithon farinosum* and *Pneophyllum fragile*) and small erect species such as *Cladosiphon cylindricus, Giraudia sphacelarioides* and *Sphacelaria cirrosa*.

The deep subtidal zone (30-50 m) was characterised by a coralligenous assemblage constituted by a layer of encrusting coralline algae that were colonised by shade-living species such as *Palmophyllum crassum, Flabellia petiolata, Halimeda tuna* and *Peyssonnelia* spp. Seasonal Rhodophyta such as *Chrysymenia ventricosa, Sebdenia dichotoma* and *Kallymenia feldmannii* were present in summer.

The macroalgal assemblages graving on rhodoliths were mostly characterised by the brown algae *Cystoseira spinosa, C. zosteroides, Phyllariopsis brevipes, Sargassum hornschuchii* and *Sporochnus pedunculatus* and by the red algae *Osmundaria volubilis* and *Phyllophora crispa*.

Table 1. Floristic list. I = intertidal, Pl = *Posidonia oceanica* leaves, Pr = *P. oceanica* rhizomes, SS = shallow rocky subtidal, DS = deep rocky subtidal, R = rhodoliths.

Taxa	*I*	*Pl*	*Pr*	*SS*	*DS*	*R*
CHLOROPHYTA						
Acetabularia acetabulum (Linnaeus) P.C. Silva	-	-	-	+	-	-
Anadyomene stellata (Wulfen) C. Agardh	-	-	-	+	-	-
Bryopsis cupressina J.V. Lamouroux	+	-	-	+	-	-
Bryopsis duplex De Notaris	+	-	-	+	-	-
Bryopsis plumosa (Hudson) C. Agardh	-	-	-	+	-	-
Chaetomorpha linum (O.F. Müller) Kützing	-	+	-	+	-	-
Cladophora coelothrix Kützing	-	-	-	+	-	-
Cladophora dalmatica Kützing	-	-	-	+	-	-
Cladophora echinus (Biasoletto) Kützing	-	-	-	+	-	-
Cladophora hutchinsiae (Dillwyn) Kützing	-	-	-	+	-	-
Cladophora pellucida (Hudson) Kützing	+	-	-	+	-	-
Cladophora prolifera (Roth) Kützing	-	-	+	+	+	-
Cladophora rupestris (Linnaeus) Kützing	+	-	-	-	-	-
Cladophora socialis Kützing	-	-	-	+	-	-
Cladophora vagabunda (Linnaeus) Van den Hoek	-	-	-	+	-	-
Codium bursa (Linnaeus) C. Agardh	-	-	-	+	-	-
Codium effusum (Rafinesque) Delle Chiaje	-	-	-	+	-	-
Codium fragile (Suringar) Hariot subsp. *tomentosoides* (Van Goor) P.C. Silva	-	-	-	+	-	-
Derbesia tenuissima (Moris *et* De Notaris) P.L. *et* H.M. Crouan	+	-	-	+	-	-
Flabellia petiolata (Turra) Nizamuddin	-	-	+	+	+	-
Halimeda tuna (J. Ellis *et* Solander) J.V. Lamouroux	-	-	-	+	+	-
Microdictyon tenuius Decaisne *ex* J.E. Gray	-	-	-	+	+	-
Palmophyllum crassum (Naccari) Rabenhorst	-	-	-	-	-	+
Pedobesia simplex (Meneghini *ex* Kützing) M.J. Wynne *et* Leliart	+	-	-	-	-	-
Phaeophila dendroides (P.L. *et* H.M. Crouan) Batters	-	-	-	+	-	-
Pseudochlorodesmis furcellata (Zanardini) Børgesen	+	-	+	+	+	+
Rhizoclonium tortuosum (Dillwyn) Kützing	-	-	-	+	+	-
Ulva compressa Linnaeus	+	-	-	-	-	-
Ulva laetevirens Areschoug	-	-	-	+	-	-
Valonia macrophysa Kützing	-	-	+	+	+	+
Valonia utricularis (Roth) C. Agardh	+	-	-	+	-	-
FUCOPHYCEAE						
Arthrocladia villosa (Hudson) Duby	-	-	-	-	-	+
Asperococcus bullosus J.V. Lamouroux	-	-	-	+	-	-
Carpomitra costata (Stackhouse) Batters	-	-	-	-	+	-
Cladosiphon cylindricus (Sauvageau) Kylin	-	+	-	+	-	-
Cladostephus spongiosus (Hudson) C. Agardh	-	-	-	+	-	-
Colpomenia sinuosa (Mertens) Derbès *et* Solier	-	-	-	+	-	-
Cutleria chilosa (Falkenberg) P.C. Silva (sporophyte "*Aglaozonia*")	-	-	-	+	-	-
Cutleria multifida (J.E. Smith) Greville (sporophyte "*Aglaozonia*")	-	-	+	+	+	-
Cystoseira amentacea (C. Agardh) Bory var. *stricta* Montagne	+	-	-	+	-	-

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Taxa	*I*	*Pl*	*Pr*	*SS*	*DS*	*R*
Cystoseira brachycarpa J. Agardh var. *balearica* (Sauvageau) Giaccone	-	-	-	+	-	-
Cystoseira compressa (Esper) Gerloff *et* Nizamuddin	-	-	-	+	-	-
Cystoseira spinosa Sauvageau	-	-	-	-	-	+
Cystoseira zosteroides C. Agardh	-	-	-	-	-	+
Dictyopteris polypodioides (A.P. De Candolle) J.V. Lamouroux	-	-	-	+	+	+
Dictyota dichotoma (Hudson) J.V. Lamouroux	-	-	-	+	-	-
Dictyota fasciola (Roth) J.V. Lamouroux	-	-	+	+	+	-
Dictyota linearis (C. Agardh) Greville	-	+	+	+	+	-
Dictyota mediterranea (Schiffner) G. Furnari	-	-	-	+	+	-
Dictyota spiralis Montagne	-	-	-	+	-	-
Discosporangium mesarthrocarpum (Meneghini) Hauck	-	-	-	+	-	-
Ectocarpus siliculosus (Dillwyn) Lyngbye	-	+	-	+	-	-
Elachista intermedia P.L. *et* H.M. Crouan	-	+	-	-	-	+
Giraudia sphacelarioides Derbès *et* Solier	-	+	-	-	-	-
Halopteris filicina (Grateloup) Kützing	-	-	+	+	+	+
Mesospora macrocarpa (Feldmann) Den Hartog	-	-	-	+	-	-
Myrionema liechtensternii Hauck	-	-	-	+	-	-
Nemacystus flexuosus (C. Agardh) Kylin	-	-	-	+	-	-
Nereia filiformis (J. Agardh) Zanardini	-	-	-	+	+	+
Padina pavonica (Linnaeus) Thivy	-	-	-	+	-	-
Phyllariopsis brevipes (C. Agardh) Henry *et* South	-	-	-	-	+	+
Ralfsia verrucosa (Areschoug) Areschoug	+	-	-	-	-	-
Sargassum hornschuchii C. Agardh	-	-	-	-	+	+
Sargassum vulgare C. Agardh	-	-	-	+	-	-
Scytosiphon lomentaria (Lyngbye) Link	-	-	-	+	-	-
Spatoglossum solieri (Chauvin) Kützing	-	-	-	-	+	-
Spermatochnus paradoxus (P.H. Roth) Kützing	-	-	-	-	+	+
Sphacelaria cirrosa (P.H. Roth) C. Agardh	-	+	+	+	+	+
Sphacelaria fusca (Hudson) S.F. Gray	-	-	+	+	-	-
Sphacelaria plumula Zanardini	-	-	+	+	-	-
Sphacelaria tribuloides Meneghini	-	-	-	+	-	-
Sporochnus pedunculatus (Hudson) C. Agardh	-	-	-	-	-	+
Stilophora tenella (Esper) P.C. Silva	-	-	-	+	+	+
Stypocaulon scoparium (Linnaeus) Kützing	-	-	+	+	-	-
Taonia atomaria (Woodward) J. Agardh	-	-	-	+	-	-
Zanardinia typus (Nardo) G. Furnari	-	-	-	-	+	+
Zonaria turnefortii (J.V. Lamouroux) Montagne	-	-	-	+	-	-
RHODOPHYCEAE						
Acrodiscus vidovichii (Meneghini) Zanardini	-	-	-	+	+	-
Acrosorium venulosum (Zanardini) Kylin	-	-	+	+	+	-
Acrosymphyton purpuriferum (J. Agardh) G. Sjöstedt	-	-	-	+	-	-
Acrothamnion preissii (Sonder) Wollaston	+	+	+	+	+	+
Aglaothamnion tenuissimum (Bonnemaison) Feldmann-Mazoyer	-	-	-	+	+	-

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Taxa	*I*	*Pl*	*Pr*	*SS*	*DS*	*R*
Aglaothamnion tripinnatum (C. Agardh) Feldmann-Mazoyer	-	-	+	+	-	-
Amphiroa rigida J.V. Lamouroux	-	-	-	+	-	-
Amphiroa rubra (Philippi) Woelkerling	-	-	-	+	-	-
Anotrichium barbatum (C. Agardh) Nägeli	-	-	-	+	-	-
Anotrichium tenue (C. Agardh) Nägeli	+	-	-	+	-	-
Antithamnion cruciatum (C. Agardh) Nägeli	-	+	+	+	+	-
Antithamnion heterocladum Funk	-	-	-	+	-	-
Antithamnion tenuissimum (Hauck) Schiffner	-	-	-	+	-	-
Antithamnionella elegans (Berthold) J.H. Price *et* D.M. John	+	-	-	-	-	-
Apoglossum ruscifolium (Turner) J. Agardh	-	+	+	+	+	+
Asparagopsis armata Harvey (sporophyte "*Falkenbergia*")	+	+	+	+	+	-
Balliella cladoderma (Zanardini) Athanasiadis	-	-	-	-	-	+
Botryocladia boergesenii Feldmann	-	-	+	+	+	+
Botryocladia botryoides (Wulfen) Feldmann	-	-	-	+	+	+
Callithamnion corymbosum (J.E. Smith) Lyngbye	-	-	-	+	-	-
Callithamnion granulatum (Ducluzeau) C. Agardh	+	-	-	-	-	-
Caulacanthus ustulatus (Turner) Kützing	-	-	-	+	-	-
Ceramium bertholdii Funk	-	-	+	-	+	+
Ceramium ciliatum (J. Ellis) Ducluzeau	+	-	-	-	-	-
Ceramium cimbricum H.E. Petersen	-	-	-	+	+	-
Ceramium circinatum (Kützing) J. Agardh	+	-	-	+	-	-
Ceramium codii (H. Richards) Feldmann-Mazoyer	-	+	+	+	+	-
Ceramium diaphanum (Lightfoot) P.H. Roth	-	+	+	+	+	-
Ceramium echionotum J. Agardh	-	-	-	+	-	-
Ceramium flaccidum (Kützing) Ardissone	+	+	+	+	+	-
Ceramium giacconei Cormaci *et* Furnari	-	-	-	+	-	-
Ceramium rubrum C. Agardh	+	-	-	-	-	-
Ceramium siliquosum (Kützing) Maggs *et* Hommersand	-	+	+	+	-	-
Ceramium tenerrimum (G. Martens) Okamura	-	+	+	+	+	-
Champia parvula (C. Agardh) Harvey	+	+	+	+	-	-
Chondria capillaris (Hudson) M.J. Wynne	-	-	+	-	+	-
Chondria dasyphylla (Woodward) C. Agardh	-	+	-	+	-	-
Chondria mairei Feldmann-Mazoyer	-	-	-	+	-	-
Chrysymenia ventricosa (J.V. Lamouroux) J. Agardh	-	-	-	-	+	+
Chylocladia verticillata (Lightfoot) Bliding	-	-	-	+	-	-
Colaconema daviesii (Dillwyn) Stegenga	-	+	-	-	+	-
Contarinia squamariae (Meneghini) Denizot	-	-	-	+	+	+
Corallina elongata J. Ellis *et* Solander	-	-	-	+	-	-
Corallina officinalis Linnaeus	-	-	-	+	-	-
Corallophila cinnabarina (Grateloup) R.E Norris	+	-	-	-	-	-
Crouania attenuata (C. Agardh) J. Agardh	-	+	-	+	+	-
Cruoria cruoriaeformis (P.L. *et* H.M. Crouan) Denizot	-	-	-	+	-	-
Cryptonemia lomation (Bertolini) J. Agardh	-	-	-	-	-	+
Dasya baillouviana (S.G. Gmelin) Montagne	-	-	-	+	-	+

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Dasya corymbifera J. Agardh	-	-	-	+	+	-
Dasya ocellata (Grateloup) Harvey	+	-	-	+	+	-
Dasya rigidula (Kützing) Ardissone	+	+	+	+	+	-
Dipterosiphonia rigens (Schousboe) Falkenberg	-	-	-	+	+	-
Dudresnaya verticillata (Withering) Le Jolis	-	-	-	-	-	+
Erythroglossum sandrianum (Kützing) Kylin	-	-	-	-	+	-
Erythrotrichia carnea (Dillwyn) J. Agardh	+	-	-	-	-	-
Eupogodon planus (C. Agardh) Kützing	-	-	+	-	+	+
Eupogodon spinellus (C. Agardh) Kützing	-	-	-	-	+	+
Feldmannophycus rayssiae (Feldmann *et* Feldmann-Mazoyer) Augier *et* Boudouresque	-	-	-	+	-	-
Gelidiella lubrica (Kützing) Feldmann *et* Hamel	+	-	-	+	-	-
Gelidiella nigrescens (Feldmann) Feldmann *et* Hamel	+	-	-	-	-	-
Gelidiella pannosa (Feldmann) Feldmann *et* Hamel	+	-	-	-	-	-
Gelidium bipectinatum G. Furnari	-	-	-	+	-	-
Gelidium pusillum (Stackhouse) Le Jolis	+	-	-	-	-	-
Gelidium spathulatum (Kützing) Bornet	-	-	-	+	-	-
Gelidium spinosum (S.G. Gmelin) P.C. Silva	-	-	-	+	-	-
Gloiocladia furcata (C. Agardh) J. Agardh	-	-	-	+	-	+
Gracilaria bursa-pastoris (S.G. Gmelin) P.C. Silva	-	-	-	-	-	+
Gracilaria dura (C. Agardh) J. Agardh	-	-	-	-	+	+
Grateloupia filicina (J.V. Lamouroux) C. Agardh	-	-	-	+	-	-
Griffithsia schousboei Montagne	-	+	-	+	-	-
Haliptilon virgatum (Zanardini) Garbary *et* H.W. Johansen	+	-	-	+	-	-
Halopithys incurvus (Hudson) Batters	-	-	-	+	-	-
Halydyction mirabile Zanardini	-	-	-	+	-	-
Haraldia lenormandii (Derbès *et* Solier) J. Feldmann	-	-	-	-	+	+
Herposiphonia secunda (C. Agardh) Ambronn	-	+	+	+	-	-
Heterosiphonia crispella (C. Agardh) M.J. Wynne	-	-	+	+	-	-
Hildenbrandia crouanii C. Agardh	-	-	-	+	-	-
Hydrolithon farinosum (J.V. Lamouroux) Penrose *et* Y.M. Chamberlain	-	+	-	+	-	-
Hypnea musciformis (Wulfen) J.V. Lamouroux	+	-	-	-	-	-
Hypnea spinella (C. Agardh) Kützing	-	-	-	+	-	-
Hypoglossum hypoglossoides (Stackhouse) Collins et Harvey	-	-	-	+	+	+
Jania rubens (Linnaeus) J.V. Lamouroux	-	-	+	+	+	+
Kallymenia feldmannii Codomier	-	-	-	-	-	+
Laurencia obtusa (Hudson) J.V. Lamouroux	-	-	+	+	-	-
Lejolisia mediterranea Bornet	-	-	-	+	-	-
Liagora viscida (Forsskål) C. Agardh	-	-	-	+	-	-
Lithophyllum byssoides (Lamarck) Foslie	+	-	-	-	-	-
Lithophyllum frondosum (Dufour) Furnari, Cormaci *et* Alongi	-	-	-	+	+	-
Lithophyllum pustulatum (J.V. Lamouroux) Foslie	-	-	-	-	+	-
Lithothamnion corallioides (P.L. *et* H.M. Crouan) P.L. *et* H.M. Crouan	-	-	-	-	-	+

Table 1. Floristic list. I = intertidal, Pl = *Posidonia oceanica* leaves, Pr = *P. oceanica* rhizomes, SS = shallow rocky subtidal, DS = deep rocky subtidal, R = rhodoliths *(suite)*.

Taxa	*I*	*Pl*	*Pr*	*SS*	*DS*	*R*
Lomentaria chylocladiella Funk	-	-	-	+	-	-
Lomentaria clavaeformis Ercegovic	-	+	+	+	-	-
Lomentaria ercegovicii Verlaque, Boudouresque, Meinesz, Giraud *et* Marcot-Coqueugniot	-	-	-	+	-	-
Lomentaria verticillata Funk	-	-	-	+	-	-
Lophosiphonia cristata Falkenberg	-	-	-	+	-	-
Lophosiphonia obscura (C. Agardh) Falkenberg	-	-	-	+	-	-
Meredithia microphylla (J. Agardh) J. Agardh	-	-	-	+	+	+
Monosporus pedicellatus (J.E. Smith) Solier	+	-	-	+	+	-
Nemalion helminthoides (Valley) Batters	+	-	-	-	-	-
Neurocaulon foliosum (Meneghini) Zanardini	-	-	-	-	-	+
Nitophyllum punctatum (Stackhouse) Greville	+	+	+	+	+	-
Osmundaria volubilis (Linnaeus) R.E. Norris	-	-	-	-	+	+
Osmundea pelagosae (Schiffner) F.W. Nam	-	-	-	-	+	+
Osmundea truncata (Kützing) F.W. Nam *et* Maggs	-	-	-	+	-	-
Peyssonnelia armorica (P.L. *et* H.M. Crouan) Weber van Bosse	-	-	-	-	+	-
Peyssonnelia bornetii Boudouresque *et* Denizot	-	-	+	+	+	+
Peyssonnelia dubyi P.L. *et* H.M. Crouan	-	-	-	-	+	-
Peyssonnelia rubra (Greville) J. Agardh	-	-	+	+	+	+
Peyssonnelia squamaria (S.G. Gmelin) Decaisne	-	-	+	+	+	+
Peyssonnelia stoechas Boudouresque *et* Denizot	-	-	-	+	+	-
Phyllophora crispa (Hudson) P.S. Dixon	-	-	-	+	-	+
Plocamium cartilagineum (Linnaeus) P.S. Dixon	-	-	+	+	+	+
Pneophyllum coronatum (Rosanoff) Penrose	-	+	-	-	-	-
Pneophyllum fragile Kützing	-	+	-	+	-	-
Polysiphonia banyulensis Coppejans	-	-	-	+	-	-
Polysiphonia dichotoma Kützing	-	-	-	+	-	-
Polysiphonia elongata (Hudson) Sprengel	-	-	-	+	-	-
Polysiphonia furcellata (C. Agardh) Harvey	-	-	-	+	-	-
Polysiphonia opaca (C. Agardh) Moris *et* De Notaris	-	-	-	+	-	-
Polysiphonia polyspora (C. Agardh) Montagne	-	-	-	+	-	-
Polysiphonia sanguinea (C. Agardh) Zanardini	-	-	-	+	-	-
Polysiphonia scopulorum Harvey	-	-	-	+	-	-
Polysiphonia subulata (Ducluzeau) J. Agardh	-	-	-	+	-	-
Polysiphonia subulifera (C. Agardh) Harvey	-	+	+	+	+	+
Polysiphonia tripinnata J. Agardh	-	-	-	+	-	-
Porphyra leucosticta Thuret	+	-	-	-	-	-
Pterocladiella capillacea (S.G. Gmelin) Santelice *et* Hommersand	-	-	-	+	-	-
Pterosiphonia pennata (C. Agardh) Sauvageau	-	-	-	+	-	-
Pterothamnion plumula (J. Ellis) Nägeli	-	+	-	+	+	+
Ptilocladiopsis horrida Berthold	-	-	-	-	-	+
Ptilothamnion pluma (Dillwyn) Thuret	-	+	-	+	+	+
Radicilingua reptans (Kylin) Papenfuss	-	-	-	-	+	+
Rhodophyllis divaricata (Stackhouse) Papenfuss	-	-	+	+	+	+
Rhodymenia ardissonei Feldmann	-	-	-	-	-	+

Table 1. Floristic list. I = intertidal, Pl = *Posidonia oceanica* leaves, Pr = *P. oceanica* rhizomes, SS = shallow rocky subtidal, DS = deep rocky subtidal, R = rhodoliths *(suite)*.

Taxa	*I*	*Pl*	*Pr*	*SS*	*DS*	*R*
Rhodymenia delicatula P.J.L. Dangeard	+	-	-	-	-	-
Rissoella verruculosa (Bertoloni) J. Agardh	+	-	-	-	-	-
Rytiphlaea tinctoria (Clemente) C. Agardh	-	-	-	-	+	+
Scinaia furcellata (Turner) J. Agardh	-	-	-	-	-	+
Schottera nicaeënsis (J.V. Lamouroux) Guiry *et* Hollenberg	-	-	-	+	-	-
Sebdenia dichotoma Berthold	-	-	-	-	+	+
Seirospora apiculata (Meneghini) Feldmann-Mazoyer	-	-	-	+	-	-
Seirospora interrupta (J.E. Smith) F. Schmitz	-	-	-	-	-	+
Seirospora sphaerospora Feldmann	-	-	-	+	+	-
Spermothamnion flabellatum Bornet	-	+	-	+	-	-
Spermothamnion repens (Dillwyn) Rosenvinge	-	+	+	+	-	-
Sphaerococcus coronopifolius Stackhouse	-	-	-	+	-	+
Spyridia filamentosa (Wulfen) Harvey	-	-	-	+	-	-
Stylonema alsidii (Zanardini) K.M. Drew	+	+	-	+	+	+
Stylonema cornu-cervi Reinsch	-	-	-	+	-	-
Vickersia baccata (J. Agardh) Karsakoff	-	-	-	+	-	-
Womersleyella setacea (Hollenberg) R.E. Norris	-	-	+	+	+	+
Wrangelia penicillata (C. Agardh) C. Agardh	+	+	-	+	-	+

An assemblage adapted to strong current colonized the upper part of the rocky banks in the East and in the South of the island: the erect layer was dominated by *Cystoseira spinosa, Phyllariopsis brevipes, Sargassum hornschuchii* and *Dictyopteris polypodioides*.

Temporal fluctuations of macroalgal assemblages

The number of species on rocky substrata was relatively high, with the highest recorded number for the assemblages around 10 meters depth (from 48.5 ± 2.5 in December to 40.5 ± 1.5 in June; means ± SE, n = 2). Relatively few species were recorded on *Posidonia oceanica* rhizomes (from 11.0±2.0 in June to 15.5 ± 1.5 in March) and leaves (from 7.0 ± 1.0 in December to 15.3 ± 1.2 in March). Epiphytes of the rhodoliths showed a higher species richness in June and September (25.0 ± 2.0 and 29.5 ± 0.5 respectively) and a low species richness in March and December (11.5 ± 0.5 and 9.5 ± 0.5 respectively).

Temporal fluctuations in the total percent cover of macroalgal assemblages are shown in Fig. 2. Macroalgal cover on rocky bottom ranged between 115.3 ± 3.5 % at 1 m in March and 196.9 ± 10 % at 35 m in June. The highest values were found at 35 m depth for the entire year. At 10 m, the percent cover was higher in June and September than in March and December. In *Posidonia oceanica* beds, the highest percent cover of algae was found in June on leaves (27.7 ± 3.2) and in March on rhizomes (78.8 ± 7). The algal cover on leaves declined from June to December (0.7 ± 0.1). The macroalgal assemblages on rhodoliths showed higher values of percent cover in June and September (88.5 ± 5.0 and 45.5 ± 2.5 respectively), due to the growth of erect Fucophyceae.

On rocky bottoms, the assemblage in shallow water showed a high abundance of filamentous and crustose species throughout the year; in June, the number of corticated-terete and foliose species increased (Fig. 2A). At 10 meters, we observed large differences between samples of December and March and those of June and September, when the abundance of foliose species increased (Fig. 2B). The assemblage at 35 meters was characterised by the dominance of crustose algae, but foliose, articulated and filamentous species were also well represented throughout the year (Fig. 2C).

In *Posidonia oceanica* meadows, crustose species dominated on leaves, with an addition of filamentous species for June (Fig. 2D). On rhizomes, filamentous species were the most abundant during the entire study period (Fig. 2E).

On rhodoliths, the macroalgal assemblages showed a low cover of filamentous and foliose species present during the entire year, and an increase in the cover of leathery macrophytes and corticated-terete species in June and September (Fig. 2F).

Species and morphological groups analyses

For rocky substrata, the cluster analysis and the ANOSIM procedure (Tab. 2) of the sample site-species matrices detected temporal fluctuations mostly

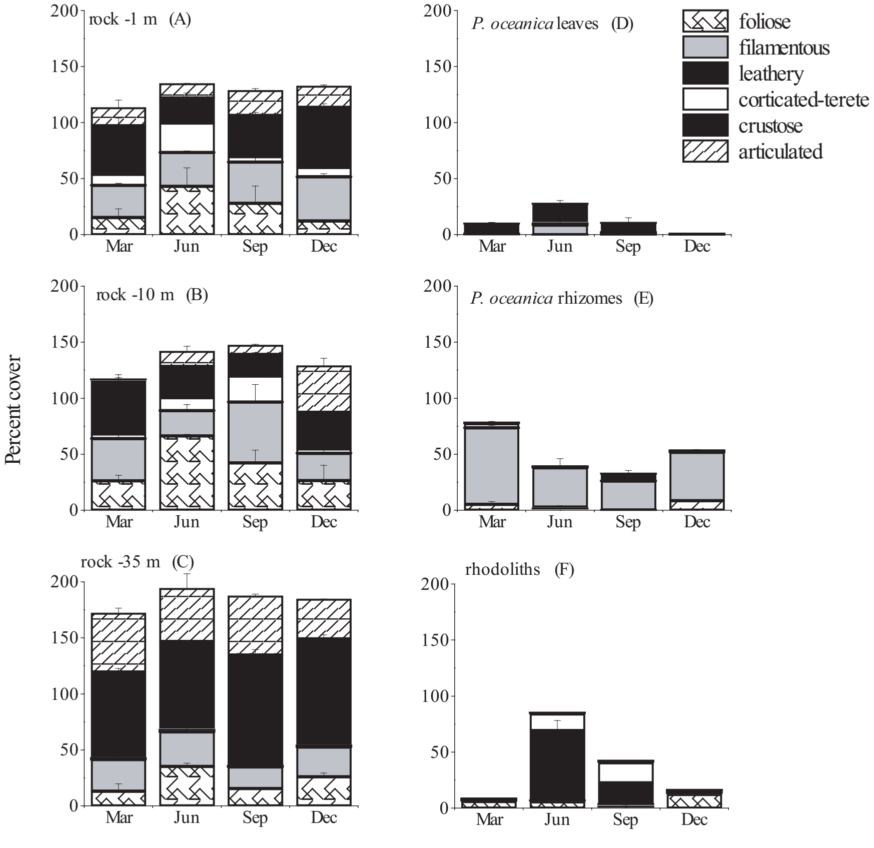

Fig. 2. Temporal variations of percent cover of morphological groups in the studied habitats of Gorgona Island (means ± SE, n=2).

Tab. 2. Results of ANOSIM tests examining differences among dates in the studied communities. The number of permutations is 105.

	Species		*Morphological group*	
Habitat	*Global R*	*Significance*	*Global R*	*Significance*
Rock –1 m	0.41	<0.1	0	ns
Rock –10 m	0.75	<0.01	0.5	<0.05
Rock –35 m	0.45	<0.05	0.1	ns
P. oceanica leaves	0.56	<0.05	0.54	<0.1
P. oceanica rhizomes	0.31	<0.1	0.31	<0.1
Rhodoliths	1.0	<0.01	1.0	<0.01

in the intermediate assemblages (-10 m), where March and December samples were separated from those of June and September (Fig. 3B). The same dates were also separated in the shallow (-1 m) and deep (-35 m) assemblages (Fig. 3A and 3C), but with lower significance levels (Tab. 2). For *Posidonia oceanica* leaves, June and September samples were grouped together while December and March were separated (Fig. 3D). For *P. oceanica* rhizomes, June and December samples clustered together and March and September were separated (Fig. 3E), even if the R value was low (Tab. 2). Rhodolith assemblages consisted of two groups, the March and December samples being separated from those of June and September (Fig. 3F).

The cluster analysis of the sample sites-morphological groups matrices detected patterns of temporal fluctuations similar to those of the sample sites-species matrices on *Posidonia oceanica* meadows and rhodolith beds; on rock, shallow and deep assemblages showed different patterns in the two analyses (Fig. 4). The ANOSIM showed similar results for *P. oceanica* and rhodolith communities between the two matrices, whereas for rocky substrata the global R values of morphological groups analysis were lower (Tab. 2).

RELATE procedure obtained for rocky assemblage global R values of 0.44 at 1 m, 0.63 at 10 m and 0.59 at 35 m; in the other habitats, values were higher: 0.77 for *Posidonia oceanica* leaves, 0.83 for *P. oceanica* rhizomes and 0.71 for rhodoliths.

DISCUSSION

Gorgona macroalgal assemblages showed a relatively high species diversity in relation to the dimensions of the island (230 species for about 8 km of coasts), when compared to the whole Tuscan Archipelago (382 taxa in Rindi *et al*., 2002) and other Mediterranean insular areas, such as Tremiti Islands (301 taxa in Cormaci & Furnari, 1999) and Maltese Islands (223 in Cormaci *et al*., 1997).

Rocky assemblages showed a structure similar to those described for other macroalgal communities of the same biogeographical region (Cinelli, 1969; Boudouresque & Perret, 1977; Boudouresque, 1984; Ribera Siguán & Gómez

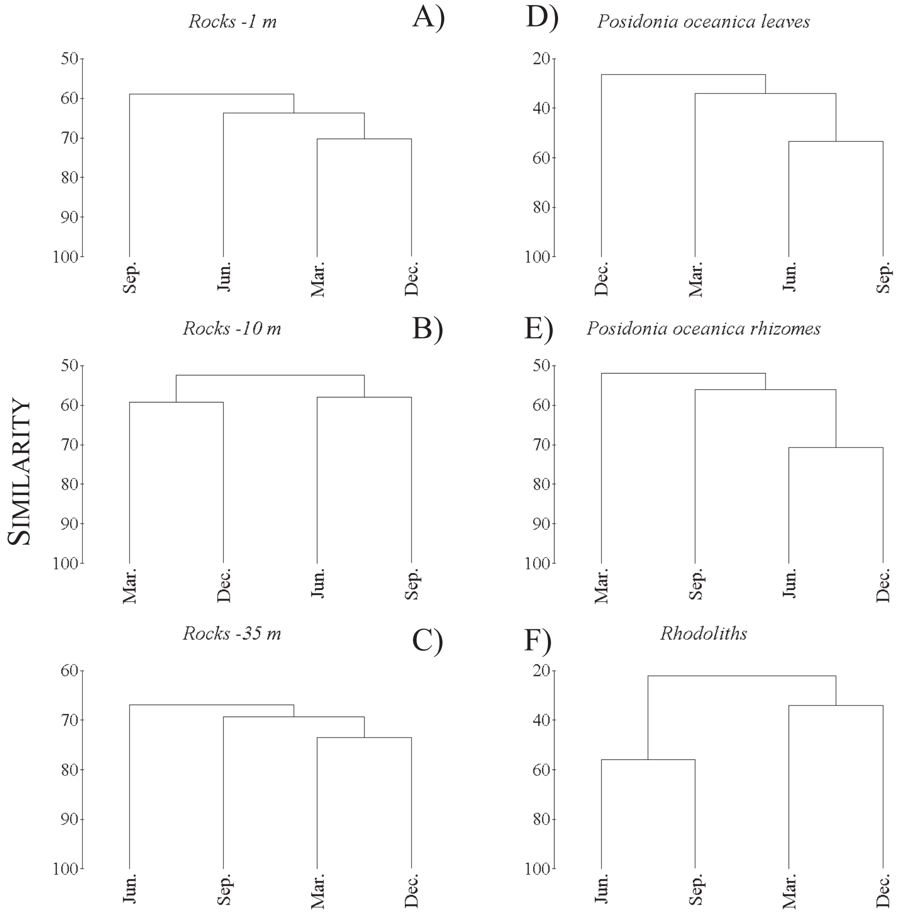

Fig. 3. Clusters ordination based on Bray-Curtis similarity coefficient applied to sample site-species matrices.

Garreta, 1984; 1985; Giaccone *et al.*, 1993; 1994a; 1994b). The most interesting assemblages in shallow water were *Lithophyllum byssoides* ledge and *Cystoseira* beds: both these organisms are very sensitive to pollution (Laborel, 1987; Benedetti-Cecchi *et al.*, 2001) and well-developed populations are rare along the continental coasts of Tuscany.

Introduced filamentous Rhodophyta (*Womersleyella setacea* and mostly *Acrothamnion preissii*) dominated assemblages of *Posidonia oceanica* rhizomes. This phenomenon has previously been described for other localities of northern Tuscany and the western Mediterranean basin (Piazzi & Cinelli, 2000). The abundance of these introduced and invasive algae on *P. oceanica* rhizomes might be the cause of the low species richness in this habitat (Airoldi *et al.*, 1995; Piazzi & Cinelli, 2001).

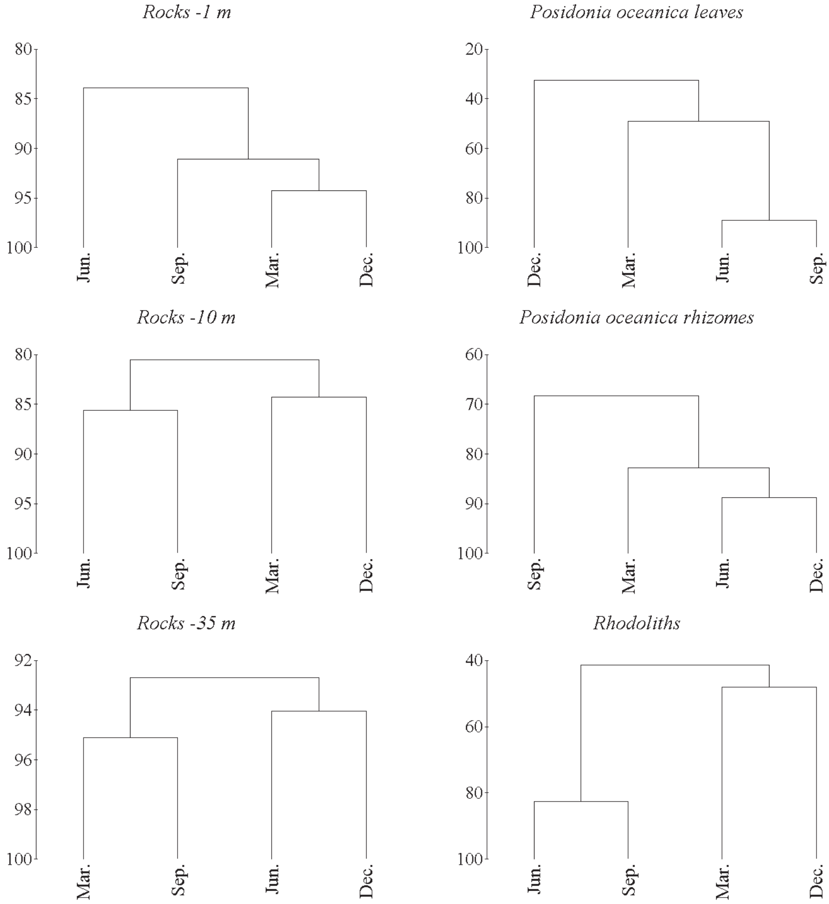

Fig. 4. Clusters ordination based on Bray-Curtis similarity coefficient applied to sample site-morphological groups matrices.

The presence of extensive rhodolith beds on sand platforms at 45-50 meters depth is a very interesting aspect of the benthic subtidal vegetation around the island. These communities are uncommon and little is known about their ecology in the Mediterranean Sea (Jacquotte, 1962; Augier & Boudouresque, 1978). Rhodolith beds have previously been found in the Tuscan Archipelago (Basso, 1995a; 1995b), but they have not been described floristically. Both rhodoliths and rocky shoals communities represent assemblages adapted to strong currents, seasonally dominated by Fucophyceae such as *Phyllariopsis brevipes*, *Sargassum hornschuchii, Cystoseira zosteroides* and *C. spinosa*.

This study represents a first attempt to describe the main Mediterranean macroalgal communities through the abundance of morphological forms and to compare the suitability of species and morphological groups to detect temporal patterns in macroalgal assemblages. Results must be considered with caution and further investigations are necessary to evaluate the use of morphological groups for Mediterranean phytobenthic communities. The low number of replicates (two replicated samples for each habitat and date) may influence the similarity among dates, especially in assemblages characterized by a high spatial heterogeneity. Moreover, this study refers only to habitats of the north-western basin and other Mediterranean areas have to be studied.

In this study, patterns of temporal variability in macroalgal assemblages obtained by species and morphological groups approach were similar in the investigated habitats, except in shallow and deep rocky assemblages. The temporal fluctuations on rocky bottoms were less obvious at the deeper assemblages (- 35 m) compared to the shallow assemblages, where the presence of seasonal species was higher (in particular foliose algae belonging to Dictyotales, that grow in June and September). Temporal fluctuations were detected on *Posidonia oceanica* leaves and on rhodoliths. In the first habitat, fluctuations are linked to seagrass seasonal cycle: the fall of leaves causes a strong decrease of macroalgal abundance in December and March. On rhodoliths, the seasonal growth of leathery Fucophyceae was the most important difference between samples of June and September and those of December and March. The macroalgal cover on *P. oceanica* rhizomes did not differ significantly throughout the year, as shown by low R values; however, in December and March, the macroalgal cover increased slightly, probably due to the decrease of seagrass canopy that allowed a higher light penetration in rhizome layer.

The R values of the ANOSIM test of the sample sites-morphological groups matrices were very low on rocky substrata. RELATE procedure showed that the similarity level between the sample sites-species matrices and the sample sites-morphological groups matrices varied among habitats but remained high, except in the shallow rocky assemblage. Results of this study suggest that the use of morphological groups causes a loss of information in detecting temporal variability mostly in high complexity assemblages, where the number of species is high. This is in agreement with the results obtained by similar studies for other biogeographical regions (Phillips *et al.*, 1997 ; Lavery & Vanderklift, 2000). Both in these studies and in the present investigation, the main patterns of variability were maintained by the use of morphological groups, but the levels of significance of the ANOSIM test were smaller than those obtained by the analyses at species level.

Results seem to support the effectiveness of the use of macroalgal morphological groups in descriptive ecological studies of Mediterranean macroalgal communities. Although this approach cannot completely replace the analysis at species level, it may provide interesting information about the structure of macroalgal assemblages and may be used with species analysis to obtain more accurate descriptions of phytobenthic communities.

In the present study, we investigated only the possibility to use morphological groups in descriptive studies, while their potentiality to detect community functioning (Littler & Littler, 1984) was not considered. This aspect has not been studied in Mediterranean ecosystems and it may prove to be an interesting topic for further investigations.

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