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STRUCTURE AND TEMPORAL DYNAMICS OF A MACROALGAL ASSEMBLAGE ASSOCIATED WITH A RHODOLITH BED OF THE TUSCAN ARCHIPELAGO (TYRRHENIAN SEA)

Abstract - In this study a macroalgal community associated with a rhodolith bed of the north western Mediterranean Sea was studied through one-year period. The study site was located around the Island of Gorgona (Tuscan Archipelago), at a depth of 52-55 meters. A total of 74 macroalgal species was identified: 53 Rhodophyta, 2 Chlorophyta and 19 Fucophyceae. The assemblage showed a stratified structure with epiphytes of first degree, divided in erect, turf and encrusting species, and epiphytes of second degree colonizing erect algae. The total percent cover and the number of species showed higher values in June and September and lower values in March and December. Encrusting and turf species appeared steady throughout the year, while the erect layer exhibited a temporal variation, principally linked to the growth cycle of leathery Fucophyceae. Concerning phytogeographical affinities, Atlantic species were the most abundant (40.8%). The present work gives a preliminary description of epiphyte assemblage colonizing a rhodolith bed of the Tuscan Archipelago, but further investigations are necessary to understand some structural and functional aspects of these interesting assemblages.

Key words - Rhodoliths, macroalgal assemblage, temporal variation, Gorgona Island, Mediterranean Sea.

Riassunto - *Struttura e dinamica temporale di un popolamento macroalgale associato ad un letto di rodoliti dell'Arcipelago Toscano.* Con il presente lavoro sono state studiate, durante il periodo di un anno, le macroalghe epifite di corallinacee libere presenti nell'Arcipelago Toscano (Mediterraneo nord occidentale). Lo studio è stato condotto in un'area situata nella parte nord occidentale dell'Isola di Gorgona, ad una profondità tra i 50 ed i 55 metri. In totale sono state identificate 74 specie di macroalghe, di cui 53 Rhodophyta, 2 Chlorophyta e 19 Fucophyceae. Il popolamento epifita delle rodoliti era strutturato in strati costituiti da epifiti di primo grado ovvero specie a portamento eretto, specie formanti feltri, specie incrostanti ed alghe epifite delle specie erette (epifite di secondo grado). Il numero di specie ed il ricoprimento algale totale erano più elevati in giugno e settembre rispetto a marzo e dicembre. Le specie formanti feltro ed incrostanti erano qualitativamente e quantitativamente stabili durante l'anno, mentre lo strato eretto presentava ampie variazioni temporali, legate principalmente al ciclo di crescita delle Fucophyceae. Per quanto riguarda le affinità fitogeografiche, le specie atlantiche erano le più rappresentate (40,8%). Il presente studio ha fornito una prima descrizione delle macroalghe epifite delle rodoliti presenti nei fondali dell'Isola di Gorgona (Arcipelago Toscano); ulteriori studi sono necessari per approfondire la conoscenza di alcuni aspetti strutturali e funzionali di questi popolamenti algali.

Parole chiave - Rodoliti, macroalghe epifite, variazioni temporali, Isola di Gorgona, Mar Mediterraneo.

INTRODUCTION

Calcareous seaweeds belonging to the Rhodophyta represent important building organisms in coastal systems (Laborel, 1961, 1987; Sarà, 1969; Denizot *et al.*, 1981), where edified structures that normally cover hard substrate both in shallow and deep water (Augier *et al.*, 1971; Laubier, 1966; Hong, 1982). On soft bottoms, in presence of regular and unidirectional currents, the calcified thallus of these algae may develop around some kind of support (Giaccone, 1970). These structures named rhodoliths or maerl have been described in many parts of the world (Cabioch, 1969; 1974; Hily *et al.*, 1992; Riosmena-Rodriguez *et al.*, 1999; Littler *et al.*, 1991).

In the Mediterranean Sea, beds constituting by these calcareous Rhodophyta develop on deep sand bottoms (Jacquotte, 1962; Boudouresque & Denizot, 1972; Ballesteros, 1994). Pérès & Picard (1964) considered rhodolith beds as facies of coastal detritic assemblage. Giaccone *et al.* (1994) grouped these beds in an association, named *Phymatholitho-Lithothamnietum corallioidis* Giaccone (1965). Augier & Boudouresque (1978) considered rhodolith beds as a combination of species belonging to the ecological groups sciaphilous-rheophilous and sciaphilous of moving substrate. Recently Basso (1992) identified facies of *Peyssonnelia rosa-marina*, *Lithophyllum racemosum*, *Lithothamnion valens* and *Neogonolithon brassica-florida*.

Rhodoliths represent a suitable substrate for settlement of algal spores and larvae of sessile invertebrates, constituting assemblages that attract herbivorous and carnivorous vagile fauna. Thus, rhodolith assemblages support a higher biodiversity than communities colonizing soft bottoms with the same granulometry (Cabioch, 1970). Rhodolith beds are the most complex communities of deep subtidal soft bottoms of the Mediterranean Sea and are considered to represent a similar ecological role as seagrass meadows in shallow subtidal (Giaccone *et al.*, 1994).

In the Mediterranean Sea, the ecology of rhodoliths and the interaction between growth shapes and physical factors have been little investigated (Huvé, 1955; Jacquotte, 1961, 1962; Cinelli *et al.*, 1977; Di Geronimo & Giaccone, 1994; Di Geronimo, 1996; Basso, 1992; Bordehore *et al.*, 2000b). However macroalgal epiphytes of rhodolith have been less studied (Augier & Boudouresque, 1978; Ballesteros, 1989; Soto, 1990)

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and little is know about their temporal dynamic and spatial distribution. In the Mediterranean Sea, samplings of rhodolith have been mostly obtained by dredging. SCUBA diving has been utilised only recently to investigate these bottoms (Ballesteros, 1989; Soto, 1990; Bordehore *et al.*, 2000b), offering new possibilities to investigate important ecological aspects.
The aims of this work are to contribute to the knowledge of rhodolith beds of the Mediterranean Sea, studying macroalgal epiphytes of calcareous algae present on a deep soft bottom in the Tuscan Archipelago. Floristic composition was assessed and temporal dynamics were evaluated through a one-year period.

MATERIAL AND METHODS

Gorgona Island is located in the northernmost part of Tuscan Archipelago (north-western Mediterranean Sea). It has a surface of 2.25 km^2 and is situated 34 km offshore from the continental coast (Fig. 1). A rhodolith bed was found in the western part of the island by side scan sonar survey during a *Posidonia oceanica* (L.) Delile mapping project (Cinelli *et al.*, 1995). The bed was mostly constituted by *Lithothamnion corallioides* (P.L. Crouan *et* H.M. Crouan) P.L. Crouan *et* H.M. Crouan and other species corresponding to warty and lumpy growth-forms (Woelkerling *et al.*, 1993). Rhodoliths cover the sand bottom below seagrass meadows or rocky cliffs, at a depth ranging between 40 and 100 meters. The study was carried out in the south-western part of the Island at 52-55 meters of depth (43°25'26" N, 9°53'30" E) (Fig. 1). Three samplings of 1000 cm^2 were undertaken in March, June, September and December 1995 by SCUBA diving. The samples were preserved in 4% formalin seawater and observed under microscope for macroalgal determination. Taxonomic nomenclature followed Guiry and Nic Dhonncha (2001). Cover of each epiphyte species was expressed as percentage of rhodolith surface of each sample covered in vertical projection by the species (Boudouresque, 1971). To describe epiphyte macroalgal assemblage, cover percentage of encrusting, turf and erect layers was calculated. Additionally, the phytogeographical affinity of the assemblage was considered (Furnari, 1984; Cinelli, 1985).

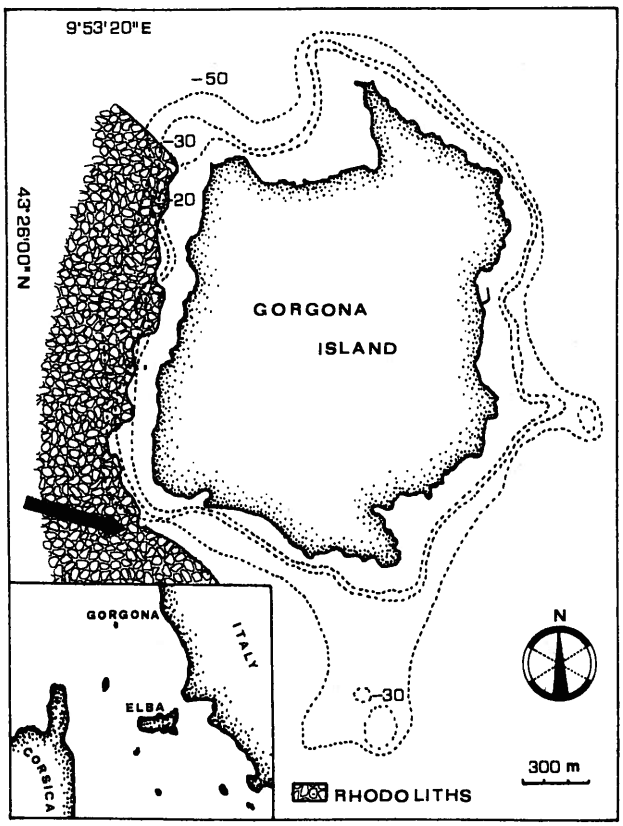

Fig. 1 - Gorgona Island with the distribution of the rhodolith bed. Arrow indicates the study area.

RESULTS

A total of 74 macroalgal species was identified: 53 Rhodophyta, 2 Chlorophyta and 19 Fucophyceae (Tab. 1). The assemblage colonizing the rhodoliths showed a stratified structure with epiphytes of first degree, divided in erect, turf and encrusting species and epiphytes of second degree of the erect algae.
The erect layer was constituted throughout the year by leathery Fucophyceae as *Cystoseira spinosa*, *C. zosteroides* and by the Rhodophyta *Osmundaria volubilis* and *Osmundea pelagosae*. In June were also present *Phyllariopsis brevipes*, *Sargassum hornschuchii*, *Sporochnus pedunculatus*, *Sebdenia dichotoma* and *Phyllophora crispa*.
The encrusting layer was characterized by *Valonia macrophysa*, *Zanardinia typus* and *Peyssonnelia* spp.
In the turf layer, *Acrothamnion preissii*, *Polysiphonia subulifera*, *Botryocladia botryoides* and *Womersleyella setacea* were common throughout the year; while *Balliella cladoderma* and *Eupogodon* spp. were abundant only in some periods.
The most part of turf species were also found as epiphytes on erect algae; among the epiphytes of second degree there were *Elachista intermedia*, *Ptilothamnion pluma*, *Stylonema alsidii*, *Wrangelia penicillata* and some species of *Ceramium*.
The number of species showed higher values in June and September (31 ± 4.2 and 39.5 ± 3.5 respectively) and lower values in March and December (17 ± 2.8 and 12.5 ± 2.1) (Fig. 2).
The total cover percentage increased between June and September (47.9 ± 1 and 28.4 ± 2.84 respectively) and decreased in March and December (12.8 ± 4.5 and 15.3 ± 1). The cover percentage of encrusting and turf layers remained low and constant through the year, while the erect layer strongly increased in June and September (38.9 ± 1.6 and 19 ± 0.7); epiphytes of second degree showed higher values in June (2.5 ± 0.4), when erect species were more developed (Fig. 3).

Tab. 1 - Floristic list of epiphytic macroalgal assemblage of Gorgona rhodolith bed.

Taxa	erect layer	turf layer	encrusting layer	epiphyte II degree
	MJSD	MJSD	MJSD	MJSD
CHLOROPHYTA				
Palmophyllum crassum (Naccari) Robenhorst	----	----	--+-	----
Valonia macrophysa Kützing	----	----	+++-	----
FUCOPHYCEAE				
"*Aglaozonia chilosa* Falkenberg" *stadium* sporophyte of *Cutleria chilosa* (Falkenberg) P.C. Silva	----	----	---+	----
Arthrocladia villosa (Hudson) Duby	-++-	----	----	----
Asperococcus bullosus J.V. Lamouroux	-++-	----	----	----
Cystoseira spinosa Sauvageau	++++	----	----	----
Cystoseira zosteroides C. Agardh	++++	----	----	----
Dictyota linearis (C. Agardh) Greville	----	-++-	----	-++-
Dictyopteris polypodioides (A.P. De Candolle) J.V.Lamouroux	--+-	----	----	----
Elachista intermedia P.L. *et* H.M. Crouan	----	----	----	-+--
Halopteris filicina (Grateloup) Kützing	----	-++-	----	----
Nemacystus flexuosus (C. Agardh) Kylin	----	----	----	-+--
Nereia filiformis (J. Agardh) Zanardini	--+-	----	----	----
Phyllariopsis brevipes (C. Agardh) Henry *et* South	-+--	----	----	----
Sargassum hornschuchii C. Agardh	-+--	----	----	----
Sphacelaria cirrosa (Roth) C. Agardh	----	--+-	----	-++-
Sphacelaria plumula Zanardini	----	++++	----	----
Spermatochnus paradoxus (Roth) Kützing	--+-	----	----	----
Sporochnus pedunculatus (Hudson) C. Agardh	-++-	----	----	----
Stilophora tenella (Esper) P.C. Silva	-++-	----	----	----
Zanardinia typus (Nardo) G. Furnari	----	----	++++	----
RHODOPHYTA				
Acrothamnion preissii (Sonder) Wollaston	----	++++	----	++++
Apoglossum ruscifolium (Turner) J. Agardh	----	-+++	----	----
Balliella cladoderma (Zanardini) Athanadiasis	----	--+-	----	----
Botryocladia boergesenii Feldmann	----	--+-	----	----
Botryocladia botryoides (Wulfen) Feldmann	----	+--+	----	----
Ceramium bertholdii Funk	----	----	----	--+-
Ceramium codii (H. Richards) Feldmann-Mazoyer	----	----	----	--+-
Ceramium diaphanum (Lightfoot) Roth	----	----	----	--+-
Ceramium siliquosum (Kutzing) Maggs *et* Hommersand	----	----	----	--+-
Champia parvula (C. Agardh) Harvey	----	-+--	----	----
Chrysymenia ventricosa (J.V. Lamouroux) J. Agardh	-+--	----	----	----
Contarinia squamariae (Meneghini) Denizot	----	----	----	--+-
Cryptonemia lomation (Bertolini) J. Agardh	----	-+--	----	----
Dasya baillouviana (S.G. Gmelin) Montagne	-+--	----	----	----
Dasya rigidula (Kutzing) Ardissone	----	++++	----	----
Dudresnaya verticillata (Withering) Le jolis	-++-	----	----	----
Eupogodon planus (C. Agardh) Kützing	----	+---	----	----
Eupogodon spinellus (C. Agardh) Kützing	----	-+--	----	----
Gloiocladia furcata (C. Agardh) J. Agardh	----	--+-	----	----
Gracilaria bursa-pastoris (S.G. Gmelin) P.C. Silva	----	-+--	----	----
Gracilaria dura (C. Agardh) J. Agardh	----	--+-	----	----
Haraldia lenormandii (Derbès *et* Solier) Feldmann	----	+---	----	----
Hydrolithon cruciatum (Bressan) Y.M. Chamberlain	----	----	----	--+-
Hypoglossum hypoglossoides (Stackhouse) Collins *et* Hervey	----	--+-	----	----
Jania rubens (Linnaeus) J.V. Lamourux	----	+--+	----	----
Kallymenia feldmannii Codomier	--+-	----	----	----
Meredithia microphylla (J. Agardh) J. Agardh	----	-+-+	----	----
Neurocaulon foliosum (Meneghini) Zanardini	----	-+--	----	----
Nitophyllum punctatum (Stackhouse) Greville	----	--+-	----	----
Osmundaria volubilis (Linnaeus) Norris	++++	----	----	----
Osmundea pelagosae (Schiffner) Nam	+++-	----	----	----
Peyssonnelia bornetii Boudouresque *et* Denizot	----	----	--++	----
Peyssonnelia rubra (Greville) J. Agardh	----	----	--++	----
Peyssonnelia squamaria (S.G. Gmelin) Dècaisne	----	----	+++-	----

Tab. 1 - Floristic list of epiphytic macroalgal assemblage of Gorgona rhodolith bed *(continued)*.

Taxa	erect layer	turf layer	encrusting layer	epiphyte II degree
	MJSD	MJSD	MJSD	MJSD
Phyllophora crispa (Hudson) P.S. Dixon	-+-+	----	----	----
Plocamium cartilagineum (Linnaeus) P.S. Dixon	----	-++-	----	----
Pneophyllum fragile Kützing	----	----	----	++--
Polysiphonia elongata (Hudson) Sprengel	----	--+-	----	----
Polysiphonia subulifera (C. Agardh) Harvey	----	++++	----	----
Pterothamnion plumula (J. Ellis) Nägeli	----	-+-+	----	----
Ptilocladiopsis horrida Berthold	----	--+-	----	----
Ptilothamnion pluma (Dillwyn) Thuret	----	----	----	--+-
Radicilingua reptans (Kylin) Papenfuss	----	--+-	----	----
Rhodophyllis divaricata (Stackhouse) Papenfuss	----	+---	----	----
Rhodymenia ardissonei Feldmann	----	+---	----	----
Rytiphloea tinctoria (Clemente) C. Agardh	----	--+-	----	----
Scinaia complanata (Collins) Cotton	--+-	----	----	----
Sebdenia dichotoma Berthold	-++-	----	----	----
Seirospora interrupta (J.E. Smith) F. Schmitz	----	----	----	--+-
Sphaerococcus coronopifolius Stackhouse	-++-	----	----	----
Stylonema alsidii (Zanardini) K.M. Drew	----	----	----	++++
Womersleyella setacea (Hollenberg) R.E. Norris	----	++++	----	++++
Wrangelia penicillata (C. Agardh) C. Agardh	----	----	----	--+-

M: March; J: June; S: September; D: December.

Concerning phytogeographical affinities, 40.8% of the studied epiphytes were represented by Atlantic species, 22.4% by Mediterranean species, 17.1% by Cosmopolitan species, 7.8% by Indo-Atlantic species, 6.6% by Atlanto-Pacific species, 5.3% by Pantropical species.

Discussion and conclusions

Rhodolith beds have been previously found in the Tuscan Archipelago (Basso, 1992), but the epiphytic flora has not been described. The epiphyte assemblage of Gorgona Island appeared dominated by Fucophyceae, such as *Phyllariopsis brevipes*, *Sargassum hornshuchii*, *C. zosteroides* and *C. spinosa*.

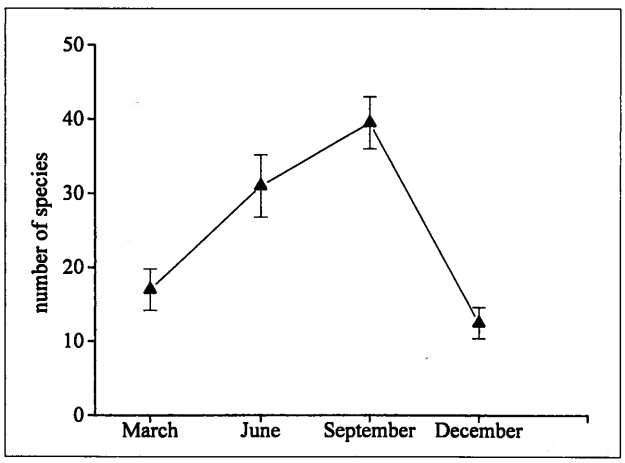

Fig. 2 - Temporal variations of the number of species of the algal assemblage associated to rhodolith bed of Gorgona Island (means ± ES, n = 3).

The studied assemblage showed a stratified structure as described for other Mediterranean rhodolith communities (Soto, 1990). Vegetation layers showed different temporal patterns: encrusting and turf species appeared steady through the year, while the erect layer exhibited a temporal variation principally linked to the growth cycle of leathery Fucophyceae. Temporal data are not available for other Mediterranean epiphyte assemblages of rhodolith, but a similar pattern was observed in a shallow bed of eastern Atlantic Ocean (Hily *et al.*, 1992).

Concerning phytogeographical aspect, in the studied assemblage, Mediterranean species showed a percentage comparable to the whole Gorgona flora (Pardi *et al.*, 1993), while Atlantic species were more abundant. The Rhodophyta *Balliella cladoderma*, *Hydrolithon cruciatum*, *Scinaia complanata* and *Sebdenia dichotoma* were not previous signalled along the insular and continental coast of the Tuscany (Rindi *et al.*, 2002).

Floristic affinities have been found with other coastal detritic assemblages of the western part of the basin: 64% of Gorgona species are common with Port-Cros (Augier & Boudouresque, 1978) and 62.7% with Spain (Soto, 1990). Assemblages of coastal detritic seemed to show structural characteristics and floristic compositions similar among them, independently of the geographical distribution and appeared quite different by macroalgal communities of the same region colonizing other habitats of the same depth.

According to Cabioch (1970), the structure, phenology and ecology of epiphytes algae resulted affected by the dynamic of rhodoliths that represent their substrate.

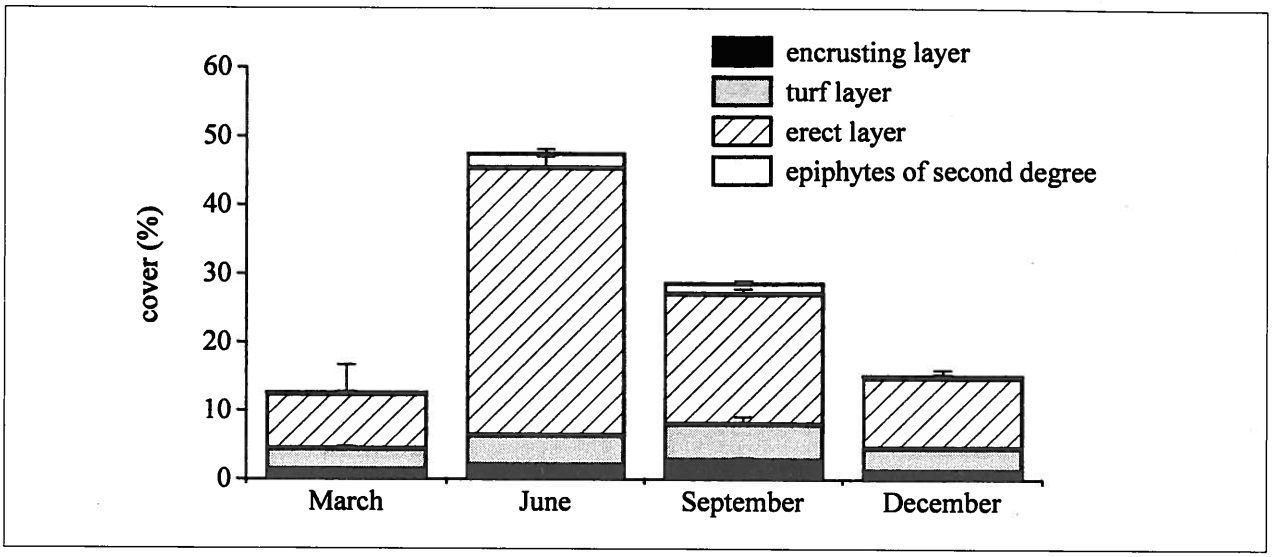

Fig. 3 - Temporal variations of percent cover of encrusting, turf, erect and second degree epiphytes of the algal assemblage associated to rhodolith bed of Gorgona Island (means ± ES, n = 3).

The growth and death of calcareous algal structures are related to characteristics of environment and to biological interactions, in fact rhodoliths are the result of a very slow building and they are subjected to an unstable equilibrium linked to currents and destructive action of boring organisms.

The importance of these communities is related to their ecological role, creating a higher spatial heterogeneity on sand bottoms and increasing biodiversity (Bordehore *et al.*, 2000a). In the last decades, in many parts of the Mediterranean Sea, rhodolith beds are menaced and sometimes destroyed by human impact mostly linked to sediment increasing (Bourcier, 1986) and to trawling fishing (Bordehore *et al.*, 2000a). These communities risk disappearing in wide zone of the basin before to have been known. This work gives a preliminary description of the temporal dynamics of one of these assemblages present on the soft bottoms of Gorgona Island; however, further studies are necessary to carefully investigate several interesting ecological aspects of these deep mediterranean communities, such as interactions among dominant organisms and their distribution at different spatial scales.

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