Osservazione diretta, mediante telecamera filoguidata, di comunità bentoniche correlate ad instabilità sedimentaria

A direct observation with a remote operated vehicle of benthic communities related to sedimentary instability

GIACOBBE S. (*), PARISI R. (**)


Così come è stato possibile valutare l’evoluzione dei Popolamenti Eterogenei attraverso tre fasi caratteristiche, allo stesso modo è possibile valutare il grado di instabilità sedimentaria di un bacino per mezzo dello studio della composizione delle comunità bentoniche. Al tempo stesso è possibile seguire l’andamento spaziale di gradienti di torbidità all’interno di un unico bacino sedimentario.

Evidenze di instabilità sedimentarie sono state riscontrate in gran parte dei fondi costieri della Calabria, indagati nell’ambito di un programma di interventi per la valutazione delle condizioni ambientali. Questa Regione è interessata infatti da fenomeni orogenetici ancora attivi, responsabili dell’assetto giovanile dei bacini imbriferi e di una morfologia subacquea caratterizzata da forte pendenza.

Il notevole numero di campionamenti (oltre 500), effettuati mediante benna, ha consentito di mettere in evidenza, fra 5 e 50 m di profondità, una vasta gamma di situazioni riconducibili a fenomeni di instabilità sedimentaria. In particolare, per quel che attiene la composizione e struttura delle comunità bentoniche, queste erano chiaramente riconducibili a tipici Popolamenti Eterogenei (Picard, 1975) in quasi la metà delle stazioni campionate. Particolare interesse ha inoltre suscitato il frequente rinvenimento di facies a Ditrupa, anche in raggione della facilità di riconoscimento a mezzo osservazione diretta.


Per quel che concerne l’identificazione e lo studio delle facies a Ditrupa arctica, si è fatto riferimento ad una stazione ubicata presso l’abitato di S. Ilario dello Jonio, non lontano dalla foce della
La facies, identificata sulla base del campionamento con benna, comprende, quali elementi accessori, poche altre specie indicative di instabilità sedimentaria (ad es. *Tellina distorta*) o a larga ripartizione ecologica. All'osservazione diretta il fondo appariva fangoso, in ragione dello strato di fango fluido sovrapposto al substrato sabbioso compatto.

L'identificazione della facies a *Ditrupa* risultava invece immediata, data l'elevatissima densità di esemplari viventi. La facies, che si estende in modo pressoché continuo da circa 40 a 50 m di profondità, si estingue gradatamente alle quote minori. Intorno ai 50 m diminuisce gradatamente la frequenza degli esemplari osservati in posizione di vita.


Le osservazioni dirette, effettuate nei pressi di Roccella Jonica, intorno ai 40 m di profondità, hanno evidenziato la presenza di una facies ben caratterizzata, nettamente delimitata in senso bathimetrico.

I tre casi presentati in questa sede, in cui i risultati dell'osservazione diretta vengono confrontati con quanto emerso dallo studio dei popolamenti bentonici e delle tanatocenosi, oltre che delle caratteristiche tessurali del sedimento, confermano la generale attendibilità delle osservazioni mediante telecomando filoguidata. Nel caso specifico, l'utilizzo di tale tecnica ha consentito di riconoscere comunità bentoniche poco apparscenti ma di rilevante significato ecologico, di evidenziare la distribuzione bathimetrica e, in definitiva, di collocare in un ben preciso contesto ambientale i dati resi disponibili dalle tecniche consuete di campionamento.

Sedimentary basins instability and benthic communities relationships had been recently discussed by Di Geronimo & Robba (1989). In particular these authors referred on the «heterogeneous community» PE (Picard, 1975) significance to evaluate climatic or tectonic instability phenomena.

At the same time it is possible to follow the spatial course of turbidity gradient within a single sedimentary basin.

Sedimentary instability occurrences have been found in most of the Calabrian coastal seabottoms, investigated in the ambit of an intervention plan for the assessment of the environmental conditions. This Region is involved in still active orogenetic phenomena responsible for the juvenile order of catchment basins and for an underwater morpho-

The remarkable number of samplings (over 500) performed with a grab, have enabled to point out, in a depth of 5 to 50 m, a vast range of situations linked to sedimentary instability phenomena. In particular, as regard to the composition and structure of benthic communities, they were clearly linked to typical heterogeneous communities PE (Picard, 1975) in almost half of the stations sampled. Moreover, the frequent recovery of facies at *Ditrupa arietina* aroused particular interest, even for the easiness in identification by a direct observation.

After the samplings, three environments-pattern have been identified on which to perform direct recognitions with a remote operated vehicle (ROV Hyball).

The first of the three events studied, concerns a stretch of seafloor opposite to the mouth of Torbido river (Gioiosa Jonica), connected with the upper section of an underwater canyon. The place, that was without significative living benthic macrofauna during the sampling, shows characteristics linked to the third stage of the heterogeneous populations evolution, according to Di Geronimo and Robba (1989).

Moreover, the hypothesis is confirmed by the tanatocenosis examination, extremely poor and composed exclusively by allochtonous elements. In this environment, the visual observations have pointed out the presence of a substratum extremely heterogeneous, characterized by the irregular and fast rotation of muddy, sandy and pebbly parts. There have not been observed direct or indirect evidences of benthic organisms.

As regard to the identification and study of facies at *Ditrupa arietina*, we referred to a station located by the town of S. Ilario dello Jonio, not far from the mouth of Portigliola river. The facies identified, using the grab sampling, includes, as optional elements, some other species indicative of sedimentary instability (for example *Tellina distorta*) or at large ecologic division.
On a direct observation, the seabottom appeared muddy, owing to a stratum of fluid mud superimposed upon a dense sandy stratum. On the contrary the facies at Ditrupa was immediate because of a very high density of living specimens. The facies, that spreads almost in a regular manner at a depth of about 40 to 50 m, at smaller depths fades away gradually. At about 50 m, the frequency of the living specimens observed diminishes gradually.

To complete the studies performed, in addition, we investigated a site characterized by the presence of typical facies at *Turritella communis*.

Stratigraphic sequences proving the evolution of heterogeneous communities towards coastal terrigenous muds biocoenosis (VTC), are known in literature (Di Geronimo & Robba, 1989). Moreover, hypotheses on *Turritella communis* role in the reorganization processes of benthic communities, due to turbidity phenomena, have been recently expressed by Giacobbe and Mondello.

Direct observations, performed near Roccella Jonica, at a depth of 40 m, have stressed the presence of a well characterized facies, clearly defined in the bathimetric sense.

The three cases here shown, where the outcomes of a direct observation are compared with what comes out from the benthic communities and tanaocoenosis researches, besides the sediment tessital features, confirm the general reliability of the studies with a remote operated vehicle. In this case, the method utilized has allowed to identify little known benthic communities but of important ecologic meaning, to point out the bathimetric distribution and, in conclusion, to place in a well definite environmental context, the outcomes, made available by the usual sampling methods.
Biological modification of coral reef molluscan assemblages during a glacial-interglacial cycle (Red Sea, Egypt)

Modificazioni biologiche di molluschi di scogliera corallina durante un ciclo glaciale-interglaciale (Mar Rosso, Egitto)

MARCHESAN M. (*), TAVIANI M. (**)
The coral *Cladocora caespitosa* (*Anthozoa, Scleractinia*) as a bioherm builder in the Mediterranean Sea

**Bioermi di Cladocora caespitosa (Anthozoa, Scleractinia) in Mediterraneo**

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**ABSTRACT** — *Cladocora caespitosa* (L.) is a zooxanthellate and constructional colonial coral, living in the Mediterranean Sea. Sizeable bioherms of this species, both living and fossil, are known in the literature, and their distribution is here briefly reviewed. Fossils are Pleistocene in age; largest formations date from the Tertiary and are associated with warm-temperate faunas. Living *C. caespitosa* colonies occur, when abundant, in either “beds” (numerous small subspherical colonies in dense populations) or “banks” (large formations reaching some decimetres in height and covering several square meters in surface area). Both occurrences have been found in the region around La Spezia (eastern Ligurian Sea) and are presently being studied under the hypothesis that *C. caespitosa* may be a bio-indicator of warm-temperate climate, as fossil records seem to indicate.

**KEY-WORDS**: Stony corals, Marine terraces, Pleistocene, Radiometric age, Bioherms, Growth, Climate, Density banding, Mediterranean Sea.

**RIASSUNTO** — *Cladocora caespitosa* (L.) è una madrepora coloniale, zooxantellata e costruttiva, vivente nel Mediterraneo. In letteratura sono noti cospicui bioeremi di questa specie, sia viventi sia fossil: questo lavoro fornisce una breve rassegna della loro distribuzione. I fossili sono di età pleistocene; la maggior parte dei rinvenimenti sono riferibili al Tortoniano o sono comunque associati a faune temperate-calde. Attualmente, *C. caespitosa* si rinvie, quando abbondante, o in campi (numerosi piccoli colonie sferiche in popolazioni dense) o in banchi (ampie formazioni alte qualche decimetro ed estese per diversi metri quadrati). Entrambi le tipologie sono state rinvenute nei pressi della Spezia (Mar Ligure orientale) e sono attualmente studiate nell'ipotesi che *C. caespitosa* possa essere un bio-indicatore di clima temperato caldo, come sembrano indicare i rinvenimenti fossili. In particolare, gli obiettivi dello studio in corso sono: 1) quantificare l’attuale importanza della specie come biocostrettore; 2) comprendere l’influenza dei fattori ambientali sull’accrescimento dei bioeremi; 3) correlare la crescita della specie alla temperatura. I primi risultati sembrano evidenziare che la distribuzione delle formazioni di *C. caespitosa* sia controllata dalla competizione con le alghe frondose. Tassi di sedimentazione elevati, ma non tali da soffocare i polpi, possono facilitare il consolidamento dei bioeremi. Per il loro sviluppo sembrano essere cruciali le strategie modulari di crescita, quali la fusione di colonie adiacenti, la confezione per gravità della massa biocostrettore, e l’inclusione di colonie satellite. Misure preliminari, effettuate con radiografia-X, sull’accrescimento dei coralli hanno fornito valori di 2.5 mm-anno-1 in media.

**PAROLE-CLEAVE**: Coralli, Terrazzi marini, Pleistocene, Età radiometrica, Bioeremi, Accrescimento, Clima, Sclerocronologia, Mar Mediterraneo.

**INTRODUCTION**

*Cladocora caespitosa* is a colonial scleractinian coral belonging to the family Faviidae; although this family is fourth in importance (after Acroporidae, Pocilloporidae, and Poritidae) among coral reef communities (Sorokin, 1993), species of *Cladocora* are not considered among the major reef builders (Wood, 1983). The genus *Cladocora* occurs in warm waters of the Atlantic and the Eastern Pacific (Cairns, 1991; Veron, 1993). According to Zibrowius (1980), there are three Recent species in the Atlantic Ocean: *C. arbucula* (Lesueur), *C. debilis* Milne Edwards & Haime, and *C. caespitosa* (L.).

*C. arbucula* is a western Atlantic species, ranging from Florida to the Caribbean. *Cladocora debilis*
is widely distributed in the Atlantic: from Florida to Brazil, oceanic islands (Madeira, Cape Verde, Ascension and St. Helena), and along the West African coasts from Morocco to the Gulf of Guinea. It is also present in the western Mediterranean. *C. caespitosa* occurs throughout the Mediterranean. There are only few records from the neighbouring eastern Atlantic, from southern Portugal (Algarve) and Morocco (Agadir) (Zibrowius, 1983). It does not seem to occur in the Black Sea (Zibrowius, 1979).

Like *C. arbuscula*, but unlike *C. debilis*, *C. caespitosa* harbours symbiotic zooxanthellae (Dulcaux & Lafargue, 1973). It can be locally abundant and colonies occasionally grow to large sizes (Laborel, 1987). Important formations or even builds of *Cladocora caespitosa*, both living and fossil or sub-fossil, have been reported from several sites in the Mediterranean Sea (fig. 1).

Being zooxanthellate, colonial, and often large-sized, *C. caespitosa* has been regarded as hermatypic by several authors (e.g., Zibrowius, 1974, 1980; Laborel, 1987; Kühlmann et alii, 1991). However, Schuhmacher & Zibrowius (1985) critically analysed the use of the term hermatypic and distinguished between constructional (i.e., forming a bioherm, that is an elevated durable carbonate structure) and hermatypic (i.e., significantly contributing to the framework of reefs, reefs being defined as persistent, biogenic structures with positive topography, rising up to the sea surface and being resistant to hydrodynamic stress). According to these definitions, *C. caespitosa* should not be considered hermatypic, but simtvay constructional (see also Zibrowius, 1989).

The biology and systematics of *C. caespitosa* have been adequately summarised by Zibrowius (1980, 1984), while Tins (1978) has described major aspects of its ecology. Further information was added by Oliver Valls (1989) and Schiller (1993a,b). *C. caespitosa* (tav. 1) is never found without zooxanthellae and is thus confined to the euphotic zone, from a few meters below sea surface to around 50 m depth, although it is rarely found below 30 m. Deeper records in the literature resulted from misidentifications. Colonies of this species occur in a great variety of habitats, from rocky to sandy bottoms, and from calm water to sites exposed to strong currents and wave action. Consequently, colony morphology varies considerably accor-
ding to sedimentation rates and mechanical requirements. Extreme forms range from encrusting, phaceloid colonies with short corallites to loosely branched, dendroid colonies with long slender corallites. The most “typical” colonies are globose or hemispherical in shape; corallites are cylindrical and may give rise, by budding, to lateral branches that subsequently will grow parallel to the parent corallite (fig. 2).

The great morphological variability led early authors to describe different varieties (or even distinct species) within C. caespitosa. Abel (1959) tried to correlate the polymorphism of the colonies with gradients of light and water movement, but erroneously included in his diagram C. debilis and Polygyathus muelleri (Abel), distinct azoosanthellate species. His diagram was reproduced elsewhere, for example in the highly influential paper of Peres & Picard (1964).

The recent finding of two C. caespitosa bioherms in the eastern Ligurian Sea (Morri et alii, 1994) gave the Scientific Divers’ Team of the Marine Environment Research Centre (La Spezia) the opportunity of developing a research project on ecological aspects and growth of Cladocora caespitosa bioherms. In this paper we present a short review of the occurrences of fossil and living formations of C. caespitosa in the Mediterranean Sea, together with the scope and first results of the research project.

1. — FOSSIL RECORDS

The genus Cladocora is believed to have first appeared in the Late Cretaceous (Wells, 1956). Cladocora caespitosa is known from the Pleistocene, when it built very large banks; its occurrence during the Pleistocene is uncertain (A. D’Alessandro, pers. comm., 1994). In the Mediterranean area, Pleistocene records are numerous: south and east coast of Majorca (Guerra, 1975); east coast of Cape Bon (Tunisia), north of Nabeul (Zibrowius, 1980); Gulf of Corinth (Greece), 5-15 m above present sea level near Maura Litharia (P. Pi Razzoli, pers. comm., 1994); and many sites in southern Italy.

Pleistocene shorelines are recognisable at different levels and are represented by both abrasion pavements and marine calcarenite deposits, known as “panchina” in the geological literature. Fossil remains within the panchina frequently included C. caespitosa. Seguenza (1864, 1880), Fuchs (1874) and Kobelt (1874) assigned the faunal association to an inner-shelf environment during periods of warm-temperate climate.

Verri & De Angelis D’Ossat (1899) found a C. caespitosa bank, more than 1 m high, in the Taranto area. They compared the bank and the associated stratigraphic sequence to a similar sequence observed near Città della Pieve in Valdichiana (central Italy), both successions being refer-

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**Fig. 2** — Morphology of Cladocora caespitosa. **a**: colony (after Ruzh., 1963, modified); **b**: corallites (after Rossi, 1971, modified); **c**: calice, showing septal arrangement and columna (after Rossi, 1971, modified).

*Morfologia di Cladocora caespitosa*. **a**: colonia (da Ruzh., 1963, modificata); **b**: coralliti (da Rossi, 1971, modificato); **c**: calice, in cui si vedono la disposizione dei setti e la columna (da Rossi, 1971, modificata).
### Tab. 1 – Radiometric datings performed on fossil *Cladocora caespitosa* from Pleistocene deposits of Italy

**Datazioni radiometriche su reperti fossili di *Cladocora caespitosa* provenienti da depositi pleistocenici italiani**

<table>
<thead>
<tr>
<th>Absolute age (10⁶ yr)</th>
<th>Dating technique</th>
<th>Strenuous fraction presence</th>
<th>Isotopic stage</th>
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red to the Pleistocene. Similarly, GIGNOUX (1913), referred marine Plio-Pleistocene deposits of southern Italy to post-Sicilian successive transgressions. These deposits were calcareous sands and marly clay with remains of Strombus bubonius (Lamarck), Ceratoderma edule (L.) and Cladocora caespitosa. At Scordia (near Catania), D’ALESSANDRO & BROMLEY (1994) found C. caespitosa buildups about 10 m wide and up to 40 cm high on a basal conglomerate with basaltic pebbles; this sequence was referred to the Lower Pleistocene. Similar formations were observed at Castellaneta, near Taranto, by CALDARA (1986); in this case, the buildups colonised a basal conglomerate characterised by sandstone blocks and were referred to the Tyrrenian, because of the occurrence of S. bubonius and other warm-water fauna. At Crotone, PALMONTOLA et alii (1990) found deposits including C. caespitosa and belonging to 3 main terraces dated 330,000 years B.P. (Crotorian, stage 9), 125,000 years B.P. (Tyrrenian I, stage 5c), and 100,000 years B.P. (Tyrrenian II, stage 5c). The occurrence of C. caespitosa in Tyrrenian deposits and its association with S. bubonius was underlined also by ZEI (1993) at Cape Circeo (Central Italy).

In summary, C. caespitosa is present in shallow water fossil associations of the Mediterranean area throughout the Quaternary, and is particularly frequent in terraced deposits of Middle to Late Pleistocene age. Fragments are often abundant in bioclastic deposits, and occurrence in life position has been reported frequently (RICCHETTI, 1967; WELLS, 1967; BRANCACCIO & VALLARIO, 1968; BARSOTTI et alii, 1974; CAROBENE & PASINI, 1982; CALDARA, 1986; HEARTY & DAI PRA, 1986; ULZEGA & HEARTY, 1986; etc.). Small globose colonies 10 to 30 cm in diameter are often recognisable on and among boulders. Being generally linked to warm-temperate faunas, C. caespitosa represents a good climatic indicator.

Being aragonitic as all scleractinian corals, C. caespitosa has frequently been used for geochronological studies (tab. 1). Radiometric datings correlate with the isotopic stages 5, 7, 9 and (possibly) 11 of the curve of sea level change proposed by SHACKLETON & ODPYKE (1973) and SHACKLETON et alii (1990).

In the Mar Piccolo of Taranto, a bank extends for several hundred metres, showing well-developed colonies of C. caespitosa in life position, in a marly-sandy matrix (fig. 3). The sequence reaches about 1 m high between Madonna del Galeso (tab. 1) and Santa Teresiola. To the East, near Punta Penne, it

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Fig. 3 - Stratigraphic sequence and extent of Tyrrenian deposit of Cladocora caespitosa near the Mar Piccolo, Taranto (125,000 years B.P.; stage 5c).

A: Plio-Lower Pleistocene unit; B: Tyrrenian unit; C: soil. a: Cladocora caespitosa in life position; b: Strombus bubonius; c: Ostrea edulis L. in life position; d: valves of Ostrea edulis; e: other bivalves; f: other gastropods; g: Cladocora caespitosa fragments; h: clay; i: sand; j: soil.

Sfereoscia stratigrafica e estensione dei depositi sirenici di Cladocora caespitosa nei dintorni del Mar Piccolo, Taranto (125,000 anni fa; stadio 5c).
A: unità plio-plisostenica inferiore; B: unità tyrreniana; C: suolo. a: Cladocora caespitosa in posizione fisiologica; b: Strombus bubonius; c: Ostrea edulis L. in posizione fisiologica; d: valvole di Ostrea edulis; e: altri bivalvi; f: altri gastropodi; g: frammenti di Cladocora caespitosa; h: argilla; i: sabbia; j: suolo.
exceeds 1.5 m and exhibits an associated fauna characterised by bioeroded shell fragments of *S. bufo-
nius* and by articulated valves of *Pinna nobilis* L. and *Pamphela gicrymeris* (von Born) in life position. To the Southeast, towards Il Fronte, the colonies of *C. caespitosa* are smaller. The first dating of the Mar Piccolo deposit provided a 230Th/234U age of about 200,000 years B.P. (COTTECCHIA et alii, 1971), whereas more recent datings suggest an age of about 125,000 years B.P. (DAI PRA & STEARNS, 1977; HEARTY & DAI PRA, 1985; HEARTY et alii, 1986a; HEARTY & DAI PRA, 1992).

*Cladocora caespitosa* has been reported also as a ‘subfossil’ in a number of localities. POIZAT (1970) described wide domes in shallow waters of the Gulf of Gabès, Tunisia. A thanatozones of *C. caespitosa* bioclasts in a muddy matrix was described by GRA-COBLE & RINELLI (1994) from Augusta Bay (Sicily) 11 to 16 m deep. P. ORRÜ (pers. comm., 1994) found wide subfossil banks at about 1.5 m depth in the Ria of Olbia (north-east Sardinia). These banks developed on sediments that can be dated by archaeological deposits including amphorae of Punic age; the banks were subsequently covered by encrusting coraline algae, and then small *C. caespitosa* colonies settled on the top: these living colonies do not seem to aggregate. Similar banks, with a diameter of several meters, were observed in Corsica by LABOREL (1987), who obtained an age of 600 to 2400 years B.P. by 14C dating; encrustation by calcareous algae also preserved the banks from erosion in this case.

### 2. PRESENT OCCURRENCE

According to LABOREL (1987), the present geographical range of *Cladocora caespitosa* bioherms in the Mediterranean has decreased with respect to their fossil distribution. Reasons for this impoverishment are not known but might be related to climatic change.

There are also clues that such a reduction is still in progress. AUGIER (1982) included *C. caespiti-
tosa* in a list of marine species declining or in danger of disappearance. The large colonies of the Gulf of Marseilles, reported by PALLAS (1766) and still present at the end of the 19th century, are not longer found nowadays (ZIBROWSKI, 1980). One of the causes of the disappearance has been thought to be increased pollution in the Marseilles region. However, in the equally polluted Gulf of Trieste *C. cae-
spitosa* was abundant at the end of the last century (GRAEFFE, 1884) and remains so at present (SCHIL-
LER, 1993a); it has even been seen to dramatically increase in abundance in the late 1970s (HERNDL & VELIMIROV, 1986). Thus, pollution may not be the major cause of the reduction of *C. caespitosa* in some areas.

Although common in the whole Mediterranean, *Cladocora caespitosa* is abundant only locally (fig. 1). Whether its distribution was similarly patchy in the past, or was more homogeneous, is not known.

Where abundant, *C. caespitosa* occurs in two ways, either as: 1) a great number of distinct sub-
spherical colonies (10 to 30 cm in diameter); or 2) large formations reaching some decimetres in height and covering several square metres in surface area. The difficulty of establishing an adequate terminology for such kinds of bioconstructions, especially with respect to minimum size and topography, has been underlined by various authors (HECKEL & JABLOŃSKI, 1979; FAGERSTROM, 1987; etc.). For the first type of occurrence (i.e. the large formations) we shall use the term “bank” throughout this paper. The second type of occurrence (i.e. numerous small colonies) could qualify as a “coral community” in the sense of GEISTER (1983): to the biologist, however, the word community is reminiscent of a multispecies assemblage, whereas in this case only one species is involved: thus, we shall prefer the rather general and inclusive term “bed”.

Such beds of *C. caespitosa* are known from several sites in the Mediterranean: Majorca (ROCA & MORENO, 1987), Port-Cros (LABOREL & LABO-
REL-DEGUEN, 1978), Villefranche (A. MEINESZ, pers. comm., 1995), the northern Adriatic (DUCLAUX & LAFARGUE, 1973; TINS, 1978; HERNDL & VEL-
IMIROV, 1986; SCHILER, 1993a,b), and the Ionian coast (LUMARE, 1966). LUMARE (1966) at Crotone (Ionian Sea) and SCHILER (1993a) at Piran (northern Adriatic Sea) studied distribution, biometry, and the associated fauna in some detail.

At Crotone, and especially in the locality known as Capo Donato, *C. caespitosa* occurs within a belt approximately 8000 m² wide and 4 to 10 m deep, on rocks at the lower limit of a meadow of the seagrass *Posidonia oceanica* (L.) Delile. Colonies typically reach 30 cm height, but they may coalesce in larger blocks (up to about 60 x 40 cm). Colony growth is said to be influenced by light intensity, water movement, substrate inclination, and water turbidity. LUMARE (1966) listed more than 30 invertebrate species he found strictly associated with *C. caespitosa* colonies: among these, the bristle star *Ophiobrix fragilis* (ABIL-
dgaard) was particularly constant.
In the Bay of Piran, *C. caespitosa* is common on boulders 2 to 5 m deep and on fine sand 8 to 16 m deep; it reaches a maximum cover of 31%. The largest colonies are over 30 cm in diameter, but most are smaller than 10 cm. Schiller (1993a) found evidence that colony size was limited by storm disturbances and boring organisms; he also inferred from the cleaning activity of polyps that this coral is well adapted to high sedimentation rates. *C. caespitosa* colonies attract both sessile and vagile organisms, resulting in a rich associated cryptofauna, whose biomass is directly proportional to colony size.


Laboreil (1961) gave an accurate description of such banks in the Gulf of Atalanta (Vórios Eftvóikós Kolpós on maps of modern Greece), western Aegean Sea. He reported formations of *C. caespitosa* 1 to 3 m high covering up to 100% of the bottom, from 5 to 18 m depth according to specific sites; maximum development was observed where turbid waters and strong currents were present. The associated fauna was rich and diverse, with large numbers of *O. fragilis* also in this case.

The only living banks of *C. caespitosa* presently known in the north-western Mediterranean seem to be those discovered in 1992 in the Ligurian Sea that were mapped and briefly described by Morri et alii (1994).

3. RESEARCH IN PROGRESS

*Cladocora caespitosa* is particularly common in the coastal region around La Spezia (fig. 4). Both types of occurrences are found. Beds are known, for examtave, on boulders and sand at 3-5 m depth at Bocca di Magra, in front of the mouth of the Magra River (fig. 5), on rock at 20 m depth off Palmaria Island, and on rock at about 10 m depth near Riomaggiore. Banks exist at Riomaggiore at 26 m, and Bonassola, between 27 to 29 m depth: in both localities, the banks occur on coralligenous bottoms, in small grooves conveying sediments and currents.
Fig. 5 – The Cladocora caespitosa bed at Bocca di Magra. 
a: underwater survey map (each black dot represents a single colony); 
b: frequency distribution of colony sizes.

Il campo di Cladocora caespitosa di Bocca di Magra. 
a: pianta da rilevamento subacqueo (ogni cerchietto nero rappresenta una singola colonia); 
b: distribuzione di frequenza delle taglie delle colonie.
The coastal waters of eastern Ligurian Sea are characterised by poor transparency (DELLA CROCE et alii, 1994), possibly related to the sediment load carried by the Magra River (ANSELMI et alii, 1983). Therefore the great abundance of _C. caespitosa_ formations, both as beds and banks, in the La Spezia region is consistent with the fact that the species is known to reach maximum development in turbid waters (LABOREL, 1961; TUR & PERE GODALL, 1982).

The on-going study of _C. caespitosa_ in the La Spezia region has the following goals: 1) to quantify the importance of the species as a bioherm builder during the present time; 2) to understand the influence of major environmental factors upon the bioherm's accretion; 3) to correlate the growth of the species with temperature data.

To answer the first question, we started to map the two banks of Bonassola and Riomaggiore using underwater photomosaic techniques (tav. 1). Analysis of the photographic maps allowed us to estimate the surface area, volume and carbonate mass of the banks, and to infer their developmental patterns (MORRI et alii, 1994). The two banks differ greatly in their morphology: that of Bonassola is oblong in shape and reaches a total length of over 3.5 m, whereas that of Riomaggiore is smaller and looks like a stout pillar about 0.6 m high.

Mapping of Bocca di Magra bed, through a compass traverse and a 50 m long tape marked off in centimetres, is still in progress; the bed is composed by hemispherical or slightly dome-shaped colonies of not more than 30 cm in diameter (fig. 5).

Regarding the second goal, the distribution observed in the La Spezia region suggests the hypothesis that the abundance of _C. caespitosa_ is mainly controlled by competition with soft, frondose algae. LITTLE & LITTLE (1985) presented a relative-dominance paradigm for coral reef areas: in such a model, zooxanthellate corals gain primacy upon algae under intense herbivory. The shallow _C. caespitosa_ bed of Riomaggiore develops on rock made nearly bare by sea-urchin grazing; the biotic assemblage found in such a situation is evocatively called R.C.E.O. (acronym of the French expression “Rodophyces Calcaires Encroutantes et Oursins”) in the Mediterranean bionomical literature (see BALDUZZI et alii, 1994, for a recent reference). The capability of combining autotrophy (thanks to the symbiotic algae) with tawnkton ingestion, gives _C. caespitosa_ an advantage over algae in deeper locations (i.e., near the compensation depth for photothilic algae) or in turbid water: this may extain occurrence of beds and banks at depths below 20 m or in front of the mouth of the Magra River.

The formation of large banks in shallow water is probably prevented by physical disturbance by storms, as observed by SCHILLER (1993a) in the Bay of Piran. On the contrary, building in deeper or sheltered water might be enhanced by higher sedimentation: fine sediments fill interstices among corallites, giving the buildup more strength and compactness. The Ligurian coast experienced heavy anthropogenic siltation during the 1960s (causing the regression of _Posidonia oceanica_ meadows: BIANCHI & PEIRANO, 1990), which could have resulted in enhanced development of the banks at that time. It must be recalled, however, that the response of corals to sedimentation is not yet fully understood (ROGERS, 1990). Massive corals are known to decrease their upward extension rate in response to siltation stress (BUD & alii, 1993) and TINS (1978) considered excessive sedimentation as a limiting factor for _C. caespitosa_. Clearly, there must be a balance in the sedimentation rate (DODGE et alii, 1974): within a certain limit it might favour bank’s accretion, either through inhibition of the algal competitors or by the cementing actions of fine sediments filling interstices among corallites; beyond that limit, suffocation of polyps will occur.

_In situ_ underwater observations during dives and examination of the photomosaic of the Bonassola bank (fig. 6), the largest of the two mapped by MORRI et alii (1994), showed the importance of modular growth strategies for the bioherm’s accretion. Three main mechanisms were recognised: i) fusion of adjacent colonies (as observed in aquarium by OLIVER VAHLE, 1989), ii) “pouring” of the mass due to gravity, and iii) inclusion of satellite colonies.

If it is assumed that the Bonassola bank started as a bed, then as neighbouring colonies grow up, they come into contact with each other, eventually merging into larger masses. In the absence of physical disturbance by storms, due to depth, these masses keep on growing. They progress chiefly in a horizontal way, “pouring” by gravity down the groove in which they are developing: maximum accretion is thus observed at the lower end of the groove (fig. 7). During this process, other portions of the bank may be met and then added by fusion; or the bank may incorporate smaller, satellite colonies present nearby.

Satellite colonies derive from larvae or originate asexually, by fragmentation. According to SCHILLER...
Tav. 1 – View of Cladocora caespitosa deposits near Madonna del Galeo (Mar Piccolo, Taranto) (upper left). Living Cladocora caespitosa, with expanded polyps (upper right). Photomosaic technique to map living banks of Cladocora caespitosa (lower left). X-radiograph positives of corallites from the Cladocora caespitosa bank of Bonassola, showing banding (lower right).

(1993a), boring sponges erode the corallites close to the living tissue until they break off the colony. Fragments remain in the vicinity of the "parent-colony" and may even grow to form a new colony.

The fusion of initially distinct colonies results in sutures and depressions being formed where sediments accumulate, thus causing the death of the polyps by suffocation. If a depression is large enough and if the colony is more than 50 cm high, an erosional process may take taveae. After a breakage is generated, by accident (e.g., an anchor, as hypothesised for the breakage shown in fig. 6) or by boring organisms (e.g., the sponge Cliona viridis), currents may pass across and, through a chimney-effect, wash away the cementing sediments, so causing the collapse of the portion. A similar process has been described by Rogers (1990) for multi-lobed, knobby corals, and may serve to colonise areas beneath, as observed for Porites species by Done & Potts (1992), or enrich the sediments in calcium carbonate. At Bonassola, C. caespitosa bioclasts constitute a major fraction of the sediments at the base of the groo-
ve, but no further colonies were found in the surrounding soft bottoms.

Finally, to meet the third goal we are measuring *C. caespitosa* growth through X-radiography (tav 1), a technique widely used on corals (Knutson et alii, 1972; Buddemeier, 1978; Lough & Barnes, 1992). X-radiographs clearly show the well-known deposition pattern of alternate light and dark bands: based on the width of the bands, an average growth rate of 2.5 mm-year\(^{-1}\) can be estimated. This figure is slightly lower than data from Schiller (1993a) who, using Alizarin Red S, calculated 2.9-5.2 mm-year\(^{-1}\). In an aquarium, with a water temperature of 18-20°C all year round, Oliver Valls (1989) observed a growth rate of about 5 mm-year\(^{-1}\).

Taking into account a growth rate of 2.5 mm-year\(^{-1}\) and a maximum height of 50 cm, the age of the bank may be estimated at 200 years. Year-to-year variations in band width are obvious on X-radiographs (tav 1), and we are presently trying to correlate band width with temperature data: the Meteorological Observatory of Genoa has temperature records since 1833, thus covering most of the life of the Bonassola bank, and climatic fluctuations are evident, with warmer years alternating with colder ones (Bianchi & Morri, 1994).

The use of annual density bands in corals as a tool to understand past climatic variations is well known. There is general agreement that growth over one year is represented by the above-mentioned adjacent light and dark bands, but there is still debate about whether temperature and/or light is the chief causative factor (Logan & Tomascik, 1991); other environmental parameters may be contributing factors. This has led Barnes & Lough (1993) to state that despite a steady increase in the sophistication of techniques for extracting and processing data, twenty years of research into density banding has failed to provide a clear, unequivocal link between density banding and environmental variables (see also Le Tissier et alii, 1994).

Barnes & Lough (1993), however, mainly worked with Porites, a massive coral in which growth may be accompanied by some form of skeletal reworking; we hope that Cladocora, being a tavocoid coral and thus having distinct and separate corallites, may provide less equivocal results. Another advantage of *C. caespitosa* is that in the Mediterranean Sea, seasonality is strong; shallow water temperatures in the region of La Spezia, for examtave, range from winter values of slightly less than 13°C to summer values of about 23°C (Picco, 1990). Dendrochronology and dendroclimatology — which are frequently cited as the closest analogues to the study of annual banding in corals — have provided a wealth of information about past environmental variations, especially in temperate regions (Hugues et alii, 1982).

If band width proves to be related to mean annual temperature, the comparison of living and fossil growth rates will help to reconstruct the conditions under which major Cladocora banks were built in the past, and it will be possible to predict the response of *C. caespitosa* formations to climatic change.
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