

## 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. (\*\*)

Le relazioni tra l'instabilità dei bacini sedimentari e le comunità bentoniche sono state recentemente analizzate da DI GERONIMO e ROBBA (1989). In particolare questi autori hanno fatto riferimento al significato dei Popolamenti Eterogenei (PICARD, 1975) allo scopo di valutare fenomeni d'instabilità climatica o tettonica.

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 sedimentaria 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 ri-

conducibili a tipici Popolamenti Eterogenei (PICARD, 1975) in quasi la metà delle stazioni campionate. Particolare interesse ha inoltre suscitato il frequente rinvenimento di facies a *Ditrupea*, anche in ragione della facilità di riconoscimento a mezzo osservazione diretta.

A seguito dei campionamenti sono stati dunque identificati tre ambienti-tipo su cui effettuare ricognizioni dirette mediante telecamera filoguidata (R.O.V. Hyball). Il primo dei tre casi esaminati riguarda un tratto di fondo antistante la foce della fiumara Torbido (Gioiosa Jonica), in corrispondenza della porzione sommitale di un canyon sottomarino. Il sito, che al campionamento è risultato privo di significativa macrofauna bentonica vivente, presenta caratteristiche riconducibili al terzo stadio dell'evoluzione dei Popolamenti Eterogenei, secondo DI GERONIMO e ROBBA (1989). L'ipotesi è del resto confermata dall'esame delle tanatocenosi, estremamente esigue e composte esclusivamente da elementi alloctoni. In quest'ambiente, le osservazioni visive hanno evidenziato la presenza di un substrato estremamente eterogeneo, caratterizzato dalla rapida e irregolare alternanza di tratti fangosi, sabbiosi e ciottolosi. Non sono state osservate evidenze dirette o indirette della presenza di organismi bentonici.

Per quel che concerne l'identificazione e lo studio delle facies a *Ditrupea arietina*, si è fatto riferimento ad una stazione ubicata presso l'abitato di S. Ilario dello Jonio, non lontano dalla foce della

(\*) Dipartimento Ecologia animale e Biologia marina - MESSINA.

(\*\*) Coop. Nautilus - Vibo Valentia (CZ).

fiumara Portigliola. La facies, identificata sulla base del campionamento con benna, comprende, quali elementi accessori, poche altre specie indicatrici 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 sovrainposto 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.

A completamento delle osservazioni effettuate, si è deciso inoltre di esaminare un sito caratterizzato dalla presenza di una tipica facies a *Turritella communis*. Sequenze stratigrafiche testimonianti l'evoluzione di Popolamenti Eterogenei verso la Biocenosi dei Fanghi Terrigeni Costieri sono infatti note in letteratura (DI GERONIMO & ROBBA, 1989). Inoltre, ipotesi sul ruolo di *Turritella communis* nei processi di riorganizzazione delle comunità bentoniche, a seguito di fenomeni di torbidità, sono state recentemente formulate da GIACOBBE e MONDELLO.

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 batimetrico.

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 tessiturali del sedimento, confermano la generale attendibilità delle osservazioni mediante telecamera filoguidata. Nel caso specifico, l'utilizzo di tale tecnica ha consentito di riconoscere comunità bentoniche poco appariscenti ma di rilevante significato ecologico, di evidenziarne la distribuzione batimetrica 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 orogenic phenomena responsible for the juvenile order of catchment basins and for an underwater morphology characterized by a steep slope.

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 seabottom 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 tanatocoenosis examination, extremely poor and composed exclusively by alloctonous 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 tana-tocoenosis researches, besides the sediment tessitural 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. (\*\*)

**ABSTRACT** – The hypothesis that the onset of high salinity conditions during the last glaciation caused the extinction of the Red Sea stenoeic marine biota (JANSSEN & TAVIANI, 1985, TAVIANI *et alii*, 1992) has been tested by comparing the modern and Eemian (last interglaciation, isotopic substage 5e) reef molluscan assemblages. The area selected for this study is the Egyptian coastal plain between 24°-28° Lat N. Last interglacial reefs outcropping from Ras Shukeir down to Marsa' Alam have been studied for their paleontological content. Best exposures are found in Gebel Zeit and Hurghada. Analogous data on modern counterparts have been gathered by surveying the reefs of the Hurghada area (including offshore islands) by means of SCUBA and skin diving operations. Back-reef lagoonal and reef-crest Eemian deposits consistently show the recurrent presence of a stock of species which do not belong to the present fauna of the region, i.e., *Diodora impedimentum*, *Rhinoclavis vertagus*, *Columbella turturina* (see also TAVIANI, 1982).

Other species are common last interglacial fossils but are quite rarified in the modern Red Sea basin (i.e., *Cypraea moneta*, *Oliva bulbosa*). Therefore, although the post-glacial recolonization of the Red Sea basin can be seen as a phenomenon largely restoring a coral reef ecosystem overall very similar to the last interglacial one, some conspicuous differences are evident at taxonomic level. Our results fully support the suggestion that the hydrological perturbations linked to the climatic cooling of the last glaciation were strongly resented by the reefal biota.

**RIASSUNTO** – L'ipotesi che condizioni di alta salinità durante l'ultima glaciazione abbia causato l'estinzione della fauna marina stenoecia del Mar Rosso (JANSSEN & TAVIANI, 1985, TAVIANI *et alii*, 1992) è stata analizzata attraverso la comparazione di molluschi dei reef attuale ed Eemiane (ultimo interglaciale, sottostadio isotopico 5e).

L'area scelta per questo studio è la piana costiera egiziana compresa tra i 24° e i 28° lat N. Le scogliere dell'ultimo inter-

glaciale affioranti tra Ras Shukeir e Marsa'Alam sono state studiate dal punto di vista paleontologico. Le più belle esposizioni si trovano a Gebel Zeit e Hurghada. Dati analoghi su scogliere attuali sono stati raccolti rilevando i reefs dell'area di Hurghada (comprese le isole) in immersioni subacquee. Sia i depositi lagunari di retroscogliera che quelli della cresta del reef Eemiano mostrano la presenza ricorrente di un gruppo di specie che non appartengono alla fauna attuale della regione, come *Diodora impedimentum*, *Rhinoclavis vertagus*, *Columbella turturina* (vedi anche TAVIANI, 1982). Altre specie sono comuni fossili interglaciali, ma sono abbastanza rari nel moderno bacino del Mar Rosso (*Cypraea moneta*, *Oliva bulbosa*).

Sebbene la ricolonizzazione post-glaciale del bacino del Mar Rosso possa essere vista come un fenomeno che ha ristabilito l'ecosistema del reef corallino nell'insieme molto simile a quello interglaciale, alcune differenze cospicue sono evidenti a livello tassonomico. I nostri risultati sostengono pienamente l'ipotesi che le perturbazioni idrologiche, legate al raffreddamento climatico dell'ultima glaciazione, abbiano influenzato fortemente la fauna del reef.

#### BIBLIOGRAFIA

- JANSSEN R. & TAVIANI M. (1985) - *Factors constraining the composition of the Red Sea mollusc fauna*. 4th Deep-Sea Biology Symposium, Hamburg 23-29 June 1985, Abstracts.
- TAVIANI M. (1982) - *Paleontological markers in late Pleistocene raised coral reefs in the Red Sea*. XI INQUA Congress, Moscow, 1: 307.
- TAVIANI M., JANSSEN R. & SENGUPTA B. (1992) - *The Red Sea unique deep-sea benthic biota and their significance for the basin biogenic sedimentary budget*. International Symposium on Sedimentation and Rifting in the Red Sea and Gulf of Aden, Cairo, January 10-14 1992, Abstracts.

(\*) Dipartimento di Biologia Animale, Università di Trieste.

(\*\*) Istituto per la Geologia Marina, CNR, Bologna.

# The coral *Cladocora caespitosa* (Anthozoa, Scleractinia) as a bioherm builder in the Mediterranean Sea

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

PEIRANO A. (\*), MORRI C. (\*\*), MASTRONUZZI G. (\*\*\*), NIKE BIANCHI C. N. (\*)

**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 Tyrrhenian 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 costruttrice, vivente nel Mediterraneo. In letteratura sono noti cospicui bioermi di questa specie, sia viventi sia fossili: questo lavoro fornisce una breve rassegna della loro distribuzione. I fossili sono di età pleistocenica; la maggior parte dei rinvenimenti sono riferibili al Tirreniano o sono comunque associati a faune temperato-calde. Attualmente, *C. caespitosa* si rinviene, quando abbondante, o in campi (numerosi piccole colonie subsferiche in popolazioni dense) o in banchi (ampie formazioni alte qualche decimetro ed estese per diversi metri quadrati). Entrambe 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 biocostruttore; 2) comprendere l'influenza dei fattori ambientali sull'accrescimento dei bioermi; 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 polipi, possono facilitare il consolidamento dei bioermi. Per il loro sviluppo sembrano essere cruciali le strategie modulari di crescita, quali la fusione di colonie adiacenti, la «colata» per gravità della massa biocostruita, e l'inclusione di colonie satelliti. Misure preliminari, effettuate con radiografia-X, sull'accrescimento dei coralliti hanno fornito valori di 2.5 mm-anno<sup>-1</sup> in media.

**PAROLE-CHIAVE:** Coralli, Terrazzi marini, Pleistocene, Età radiometrica, Bioermi, 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. arbuscula* (Lesueur), *C. debilis* Milne Edwards & Haime, and *C. caespitosa* (L.).

*C. arbuscula* is a western Atlantic species, ranging from Florida to the Caribbean. *Cladocora debilis*

(\*) Centro Ricerche Ambiente Marino, ENEA S.Teresa, CP 316, I-19100 La Spezia (Italia).

(\*\*) Istituto di Zoologia, Università di Genova, Via Balbi 5, I-16126 Genova (Italia)

(\*\*\*) Dipartimento di Geologia e Geofisica, Università di Bari, Via E. Orabona 4, I-70125 Bari (Italia).

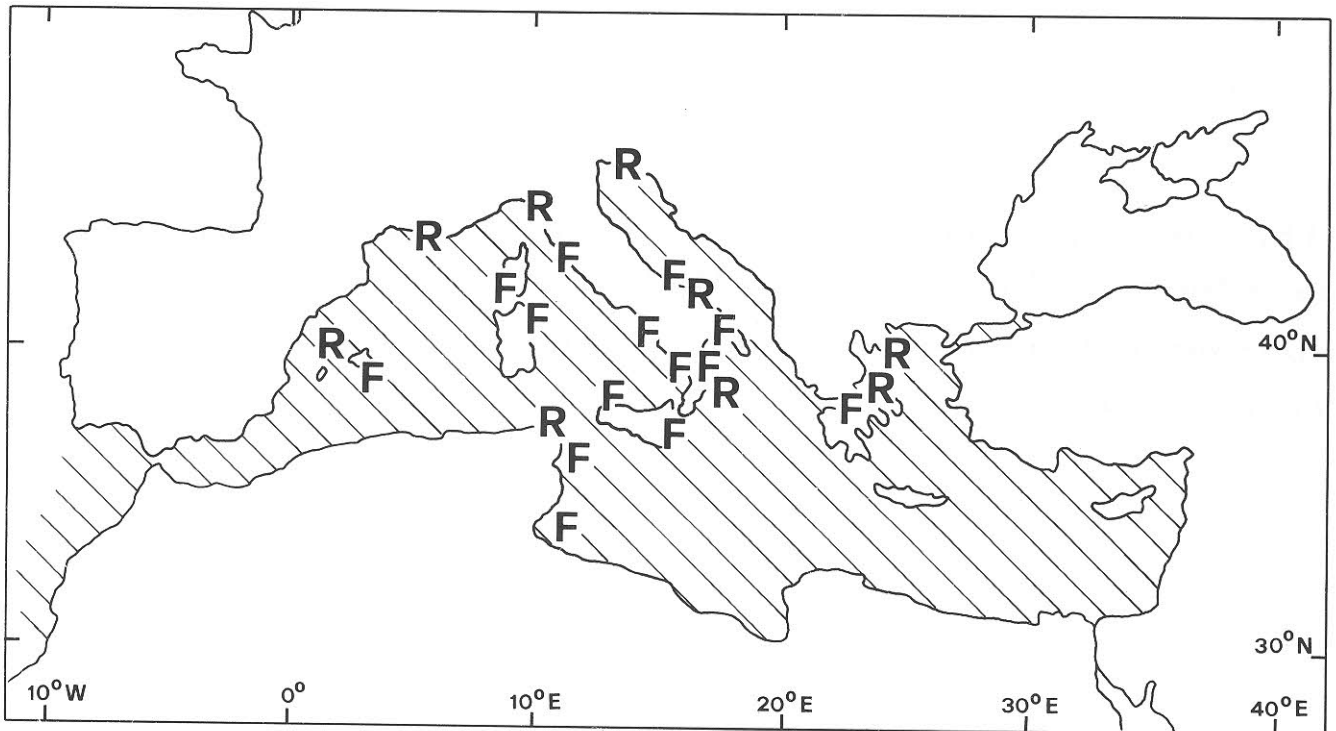


Fig. 1 – Present geographical distribution of *Cladocora caespitosa* (dashed) (Atlantic records need confirmation) and main records of recent (R) and fossil or subfossil (F) formations in the Mediterranean Sea (see text).

Attuale distribuzione geografica di *Cladocora caespitosa* (tratteggiato) (le segnalazioni in Atlantico necessitano conferma) e principali rinvenimenti di formazioni attuali (R) e fossili o subfossili (F) nel mar Mediterraneo (vedi testo).

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. arbuscola*, but unlike to *C. debilis*, *C. caespitosa* harbours symbiotic zooxanthellae (DUCLAUX & LAFARGUE, 1973). It can be locally abundant and colonies occasionally grow to large sizes (LABOREL, 1987). Important formations or even buildups 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 distinguish-

shed 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 simtavy 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 *Polycyathus muelleriae* (Abel), distinct azooxanthellate species. His diagram was reproduced elsewhere, for example in the highly influential paper of PÉRÈS & 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 (CUERDA, 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. PIRAZZOLI, pers. comm., 1994); and many sites in southern Italy.

Pleistocene shorelines are recognisable at different levels and are represented by both abrasion tavatforms 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 Val di Chiana (central Italy), both successions being refer-

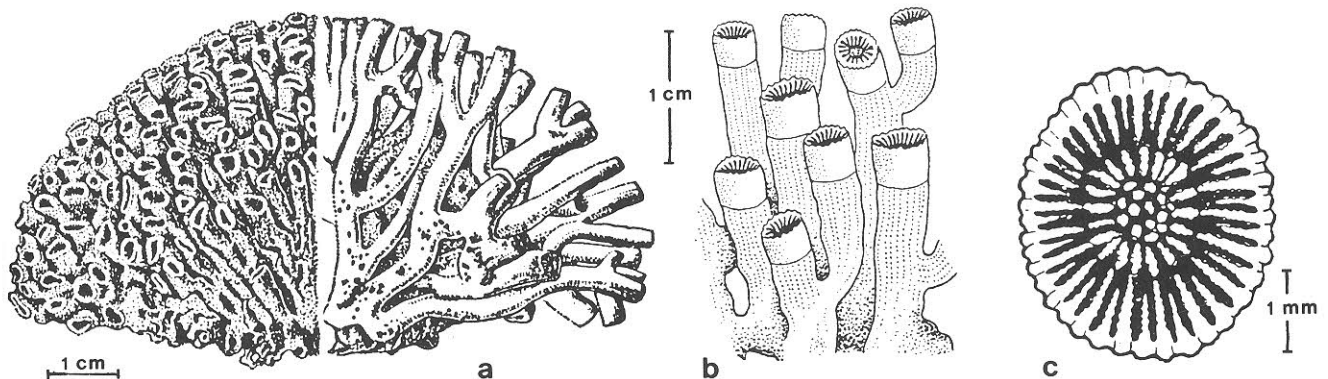


Fig. 2 – Morphology of *Cladocora caespitosa*. a: colony (after RIEDL, 1963, modified); b: corallites (after ROSSI, 1971, modified); c: calice, showing septal arrangement and columella (after ROSSI, 1971, modified).

Morfologia di *Cladocora caespitosa*. a: colonia (da RIEDL, 1963, modificato); b: coralliti (da ROSSI, 1971, modificato); c: calice, in cui si vedono la disposizione dei setti e la columella (da ROSSI, 1971, modificato).

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*

Absolute age (10 <sup>3</sup> yr)	Dating technique	<i>Strombus bubonius</i> presence	Isotopic stage	Aninogrup	Sites	References
200	230Th/234U	Y	7	F	S. Teresiola (Taranto)	Cotecchia et alii (1971)
205 ± 20	230Th/234U	Y	7	F	S. Teresiola (Taranto)	Dai Pra & Stearns (1977)
87 ± 30	230Th/234U	Y	5a/5c	C	Il Fronte (Taranto)	
130 ± 10	230Th/234U	Y	5e	E		
106 ± 8	230Th/234U	Y	5a/5c	C		
154 ± 13	230Th/234U	Y	5e	E		
142 ± 4	230Th/234U	Y	5e	E		
146 ± 12	230Th/234U	Y	5e	E		
138 ± 14	230Th/234U	Y	5e	E	Carelli (Taranto)	
290 + 60-40	230Th/234U	N	7	F?		
>300	230Th/234U	N	9	G?	Torre Castelluccia (Taranto)	
>350	230Th/234U	N	9/11	G/H?	Torre Castiglione (Taranto)	
>350	230Th/234U	N	9/11	G/H?		
142 ± 14	230Th/234U	N	5e	E	Massere S. Giovanni (Taranto)	
128 ± 5	230Th/234U	N	5e	E	Capo di Conca (Napoli)	Brancaccio et alii (1978)
131 ± 6	230Th/234U	N	5e	E	Cala di Ieranto (Napoli)	
133 ± 6	230Th/234U	N	5e	E		
123 ± 8	230Th/234U	N	5e	E		
30	14C	N			P.ta Cirello (Cosenza)	Copat Marconi et alii (1982)
28	14C	N			P.ta di Diamante (Cosenza)	
117 ± 7	230Th/234U	Y	5e	E	Il Fronte (Taranto)	Hearty & Dai Pra (1985)
128 ± 7	230Th/234U	Y	5e	E		Hearty et alii (1986a)
121 ± 7	230Th/234U	Y	5e	E		
138 ± 7	230Th/234U	Y	5e	E	Calamosca (Cagliari)	Hearty et alii (1986b)
>350	230Th/234U	N	9/11	G/H	P.ta India (Cosenza)	Carobene et alii (1986)
>350	230Th/234U	N	9/11	G/H	Grotta del Prete (Cosenza)	
>300	230Th/234U	N	9	G	P.ta Cirello (Cosenza)	
>306	230Th/234U	N	9	G	P.ta di Diamante (Cosenza)	
252 + 70-40	230Th/234U	N	7	F	Torre Talao (Cosenza)	
162 + 23-18	230Th/234U	Y	5e	E	S. Teresiola (Taranto)	Dai Pra & Hearty (1988)
125 ± 8	230Th/234U	Y	5e	E		
134 ± 16	230Th/234U	N	5e	E	Massere Bagnara (Taranto)	
86/106	230Th/234U		5a/5c	C	Il Fronte (Taranto)	
87 ± 10	230Th/234U		5c/5a	E	Le Castella (Crotone)	Belluomini et alii (1988)
329 + 196-64	230Th/234U	N	9/11	G/H	Grotta del Prete (Cosenza)	Carobene & Dai Pra (1990)
172 + 26-20	230Th/234U	N	7	F	P.ta della Matrella (Potenza)	Carobene & Dai Pra (1991)
208 + 44-29	230Th/234U	N	7	F	Marina di Maratea (Potenza)	
159 + 23-17	230Th/234U	N	7	F	Cersuta Capo La Nave (Potenza)	
122 ± 7	230Th/234U	Y	5e	E	Vibo Valentia	Dai Pra et alii (1993)
119 ± 6	230Th/234U	Y	5e	E		
132 ± 6	230Th/234U	N	5e	E	Ustica (Palermo)	De Vita et alii (1994)
138 ± 10	230Th/234U	N	5e	E	S. Marcellino (Caserta)	Romano et alii (1994)
137 ± 11	230Th/234U	N	5c	E		



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), *Cerastoderma 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 Castellana, near Taranto, by CALDARA (1986); in this case, the buildups colonised a basal conglomerate characterised by sandstone blocks and were referred to the Tyrrhenian, because of the occurrence of *S. bubonius* and other warm-water fauna. At Crotona, PALMENTOLA *et alii* (1990) found deposits including *C. caespitosa* and belonging to 3 main terraces dated 330,000 years B.P. (Crotonian, stage 9), 125,000 years B.P. (Tyrrhenian I, stage 5e), and 100,000 years B.P. (Tyrrhenian II, stage 5c). The occurrence of *C. caespitosa* in Tyrrhenian 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 & OPDYKE (1973) and SHACKLETON *et alii* (1990).

In the Mar Piccolo of Taranto, a bank extends for several hundred meters, 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 (tav. 1) and Santa Teresiola. To the East, near Punta Penne, it

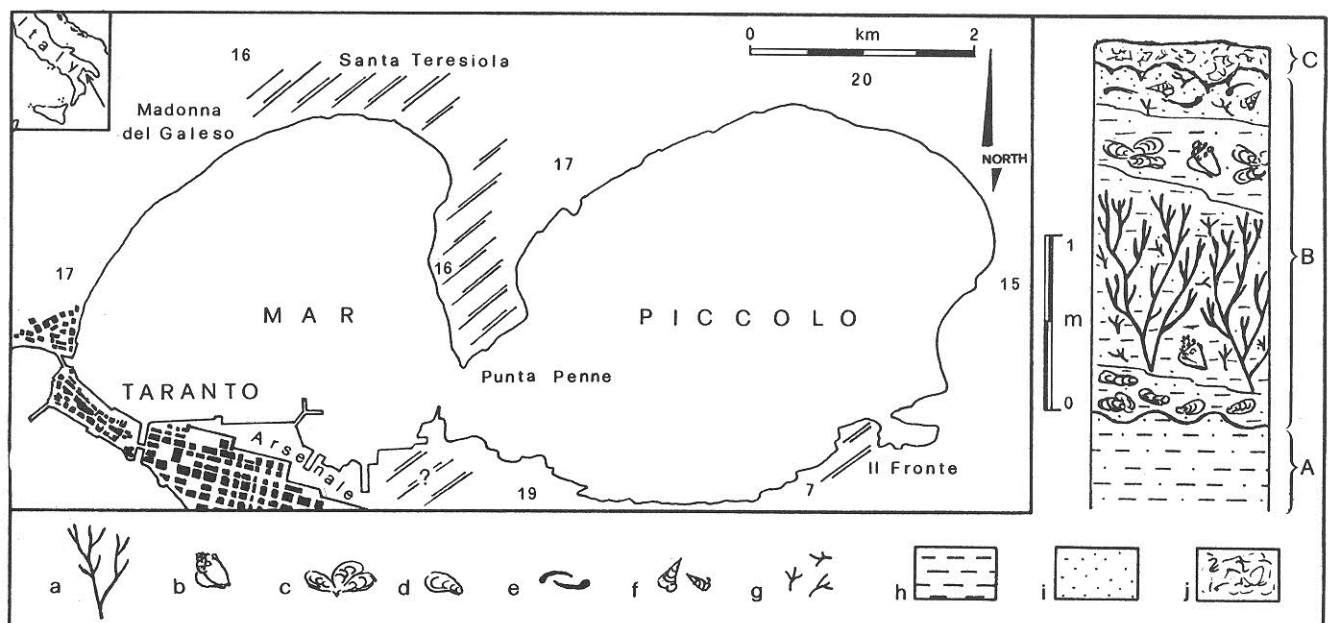


Fig. 3 – Stratigraphic sequence and extent of Tyrrhenian deposit of *Cladocora caespitosa* near the Mar Piccolo, Taranto (125,000 years B.P.; stage 5e).

**A:** Plio-Lower Pleistocene unit; **B:** Tyrrhenian 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.

Sequenza stratigrafica ed estensione dei depositi tirreniani di *Cladocora caespitosa* nei dintorni del Mar Piccolo, Taranto (125,000 anni fa; stadio 5e).

**A:** unità plio-pleistocenica inferiore; **B:** unità tirreniana; **C:** suolo. **a:** *Cladocora caespitosa* in posizione fisiologica; **b:** *Strombus bubonius*; **c:** *Ostrea edulis* L. in posizione fisiologica; **d:** valve di *Ostrea edulis*; **e:** altri bivalvi; **f:** altri gasteropodi; **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. bubonius* and by articulated valves of *Pinna nobilis* L. and *Panopea glycymeris* (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  $^{230}\text{Th}/^{234}\text{U}$  age of about 200,000 years B.P. (COTECCHIA *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 thanatofacies of *C. caespitosa* bioclasts in a muddy matrix was described by GIACOBBE & RINELLI (1994) from Augusta Bay (Sicily) 11 to 16 m deep. P. ORRÙ (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 amphoras of Punic age; the banks were subsequently covered by encrusting coralline 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  $^{14}\text{C}$  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. caespitosa* 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 (ZIBROWIUS, 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. caespitosa* was abundant at the end of the last century

(GRAEFFE, 1884) and remains so at present (SCHILLER, 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 subspherical 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 & JABLONSKI, 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 & LABOREL-DEGUEN, 1978), Villefranche (A. MEINESZ, pers. comm., 1995), the northern Adriatic (DUCLAUX & LAFARGUE, 1973; TINS, 1978; HERNDL & VELIMIROV, 1986; SCHILLER, 1993a,b), and the Ionian coast (LUMARE, 1966). LUMARE (1966) at Crotona (Ionian Sea) and SCHILLER (1993a) at Piran (northern Adriatic Sea) studied distribution, biometry, and the associated fauna in some detail.

At Crotona, and especially in the locality known as Capo Donato, *C. caespitosa* occurs within a belt approximately 8000 m<sup>2</sup> 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 brittle star *Ophiothrix fragilis* (Abildgaard) was particularly constant.

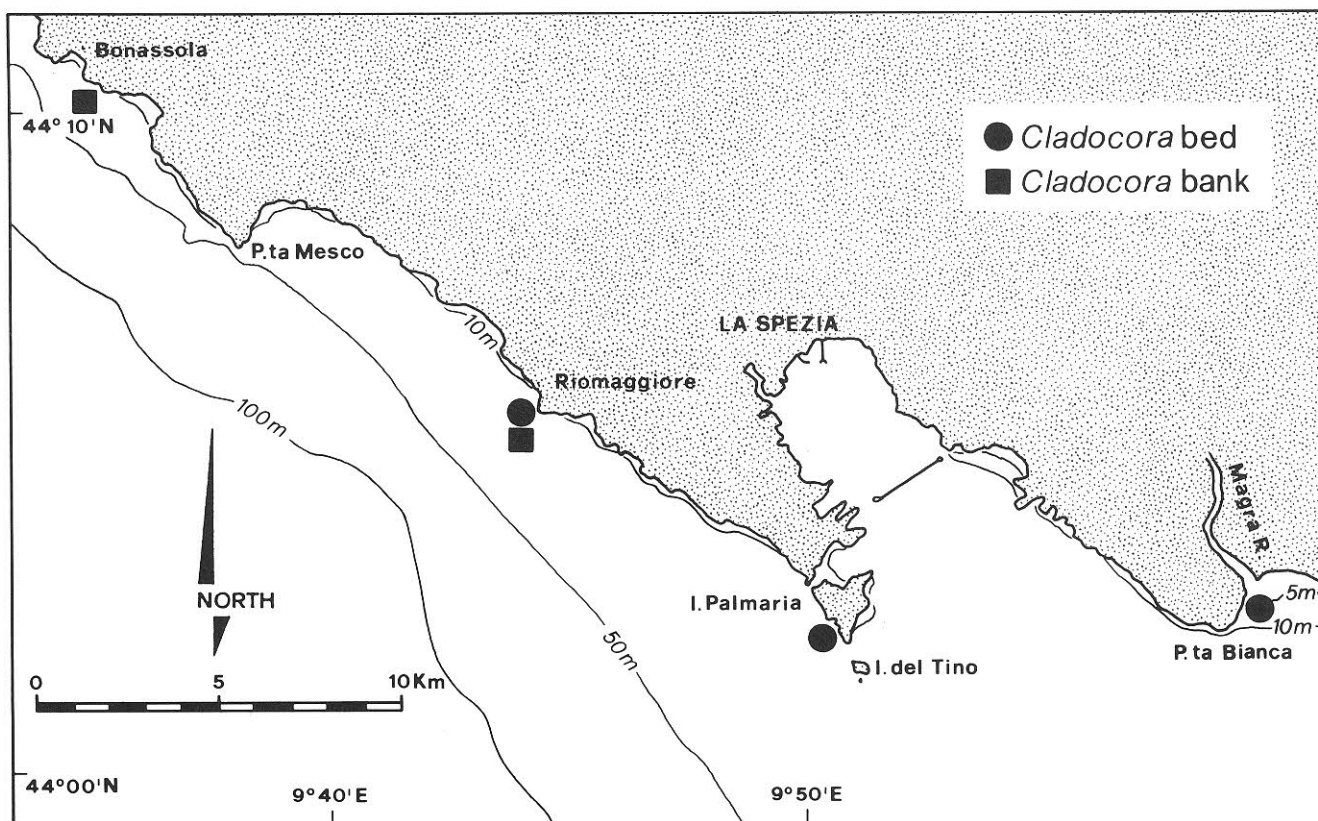


Fig. 4 – The coastal region around La Spezia, with major known formations of *Cladocora caespitosa*.  
La regione costiera della Spezia, con indicate le principali formazioni di *Cladocora caespitosa* conosciute.

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.

Living banks of *C. caespitosa* are known especially from Tunisian coast (ZIBROWIUS 1974, 1980), southern Adriatic (COLANTONI & GALLIGNANI, 1974, 1975), and Aegean Sea (LABOREL, 1961, 1987; KOUKOURAS & KÜHLMANN, 1991; KÜHLMANN *et alii*, 1991).

LABOREL (1961) gave an accurate description of such banks in the Gulf of Atalanta (Vórios Evvoikós 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 example, 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.

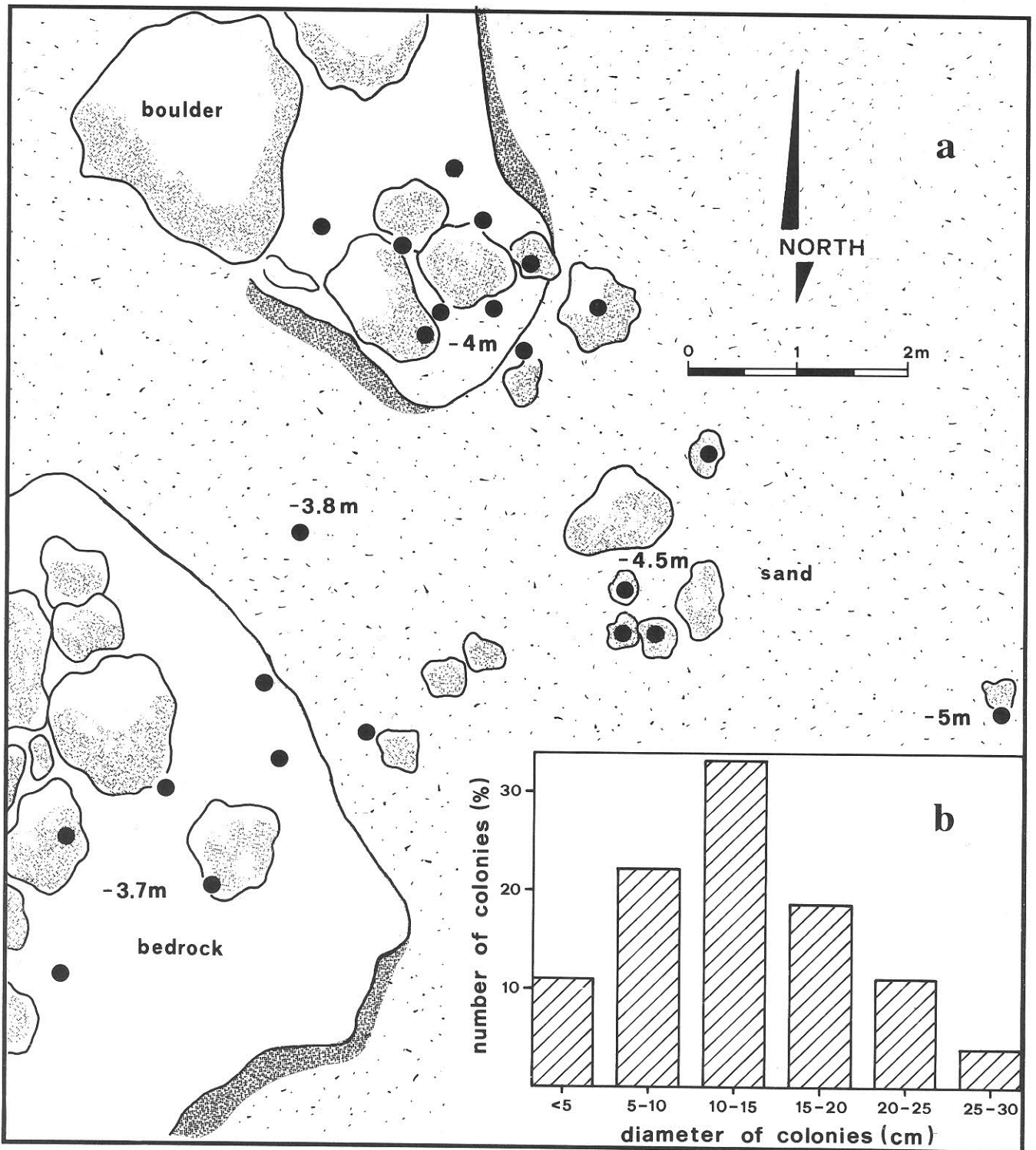


Fig. 5 – The *Cladocora caespitosa* bed at Bocca di Magra. **a**: underwater survey map (each black dot represents a single colony); **b**: frequency distribution of colony sizes.

*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 (ANSELMINI *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. LITTLER & LITTLER (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 "Rodophycées 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 tavancton ingestion, gives *C. caespitosa* an advantage over algae in deeper locations (*i.e.*, near the compensation depth for photophilic algae) or in turbid water: this may extavain

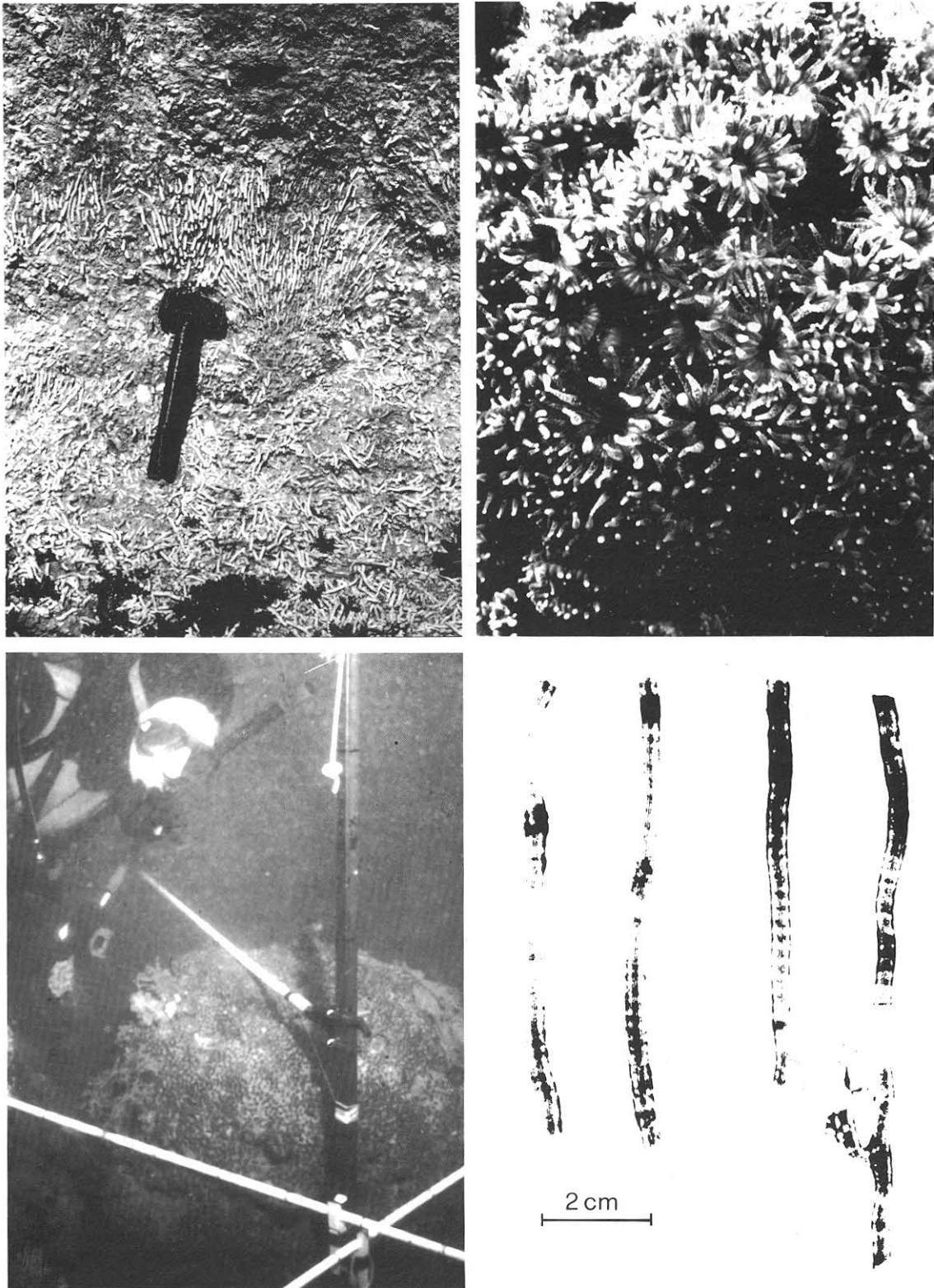
occurrence of beds and banks at depths below 20 m or in front of the mouth of the Magra River.

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 (BUDD *et 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 VALLS, 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).

*Aspetto dei depositi di Cladocora caespitosa presso Madonna del Galeo (Mar Piccolo, Taranto) (in alto a sinistra). Cladocora caespitosa viventi, con polipi espansi (in alto a destra). Tecnica di rilevamento con fotomosaico dei banchi viventi di Cladocora caespitosa (in basso a sinistra). Positivo X-radiografico di coralliti dal banco di Cladocora caespitosa di Bonassola, mostrante le bande di densità (in basso a destra).*

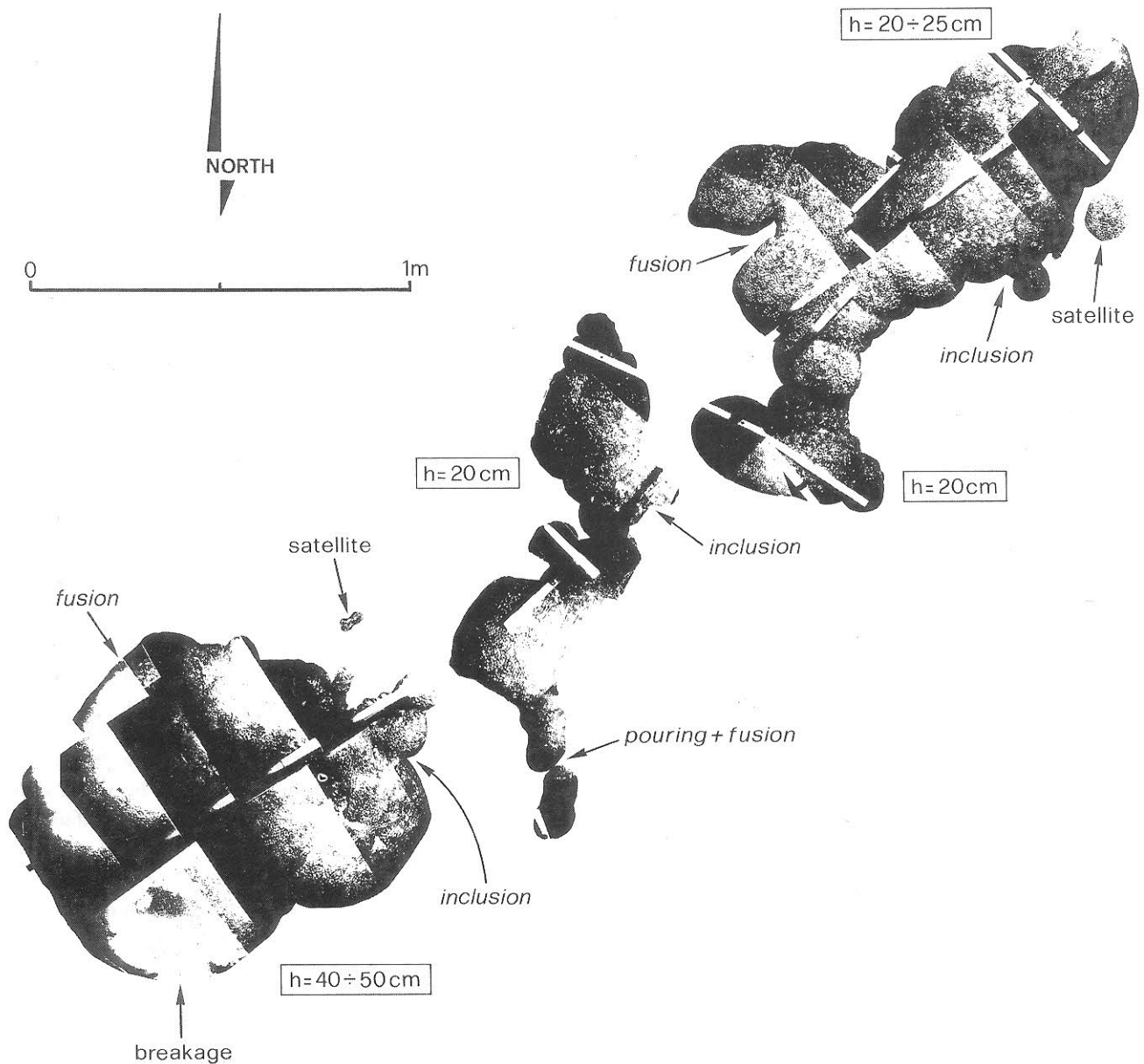


Fig. 6 – Photomosaic map of the *Cladocora caespitosa* bank of Bonassola, with main accretionary mechanisms indicated (see text).  
 Fotomosaico del banco di *Cladocora caespitosa* di Bonassola, con indicati i principali meccanismi di accrescimento (vedi testo).

(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 place. After a breakage is generated, by accident (*e.g.*, an an-

chor, 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 gro-

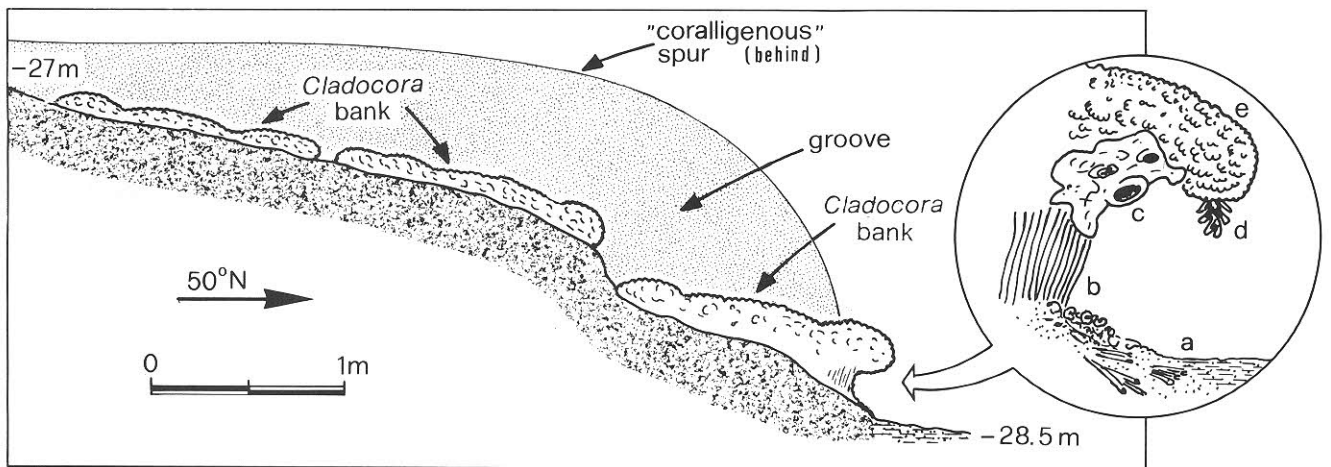


Fig. 7 – Topography and schematic profile of the *Cladocora caespitosa* bank of Bonassola. a: sediment with corallite fragments; b: basal corallites; c: boring sponge, *Cliona viridis* (Schmidt); d: erect bryozoan, *Myriapora truncata* (Pallas); e: living part of the bank.

Situazione topografica e profilo schematico del banco di *Cladocora caespitosa* di Bonassola. a: sedimenti con frammenti di coralliti; b: coralliti basali; c: spugne perforanti, *Cliona viridis* (Schmidt); d: briozoi eretti, *Myriapora truncata* (Pallas); e: parte vivente del banco.

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<sup>-1</sup> 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<sup>-1</sup>. 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<sup>-1</sup>.

Taking into account a growth rate of 2.5 mm-year<sup>-1</sup> 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 example, 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.



## ACKNOWLEDGEMENTS

M. SASSARINI (Monterosso al Mare) and F. SPARANI (Deiva Marina) participated to the field work. P. ORRÙ (Cagliari), P. PIRAZZOLI (Paris), and A. MEINESZ (Nice) provided useful information on *Cladocora* occurrences, while discussions with P. COLANTONI (Urbino) and S. GIACOBBE (Messina) helped us to clarify our ideas. H. ZIBROWIUS (Marseille) critically read an early version of the manuscript and A. D'ALESSANDRO (Bari) gave advice on the geological part. A. LOGAN (Saint John) kindly revised the text. The study of *Cladocora caespitosa* falls within the scope of the research project CLIM-BIOCCA («influence of CLIMatic change on the activity of BIOConstructional organisms and on their role in the CARbon cycle of the marine environment») of the ENEA Marine Environment Research Centre of La Spezia.

## REFERENCES

- ABEL E.F. (1959) - *Zur Kenntnis der marinen Höhlenfauna unter besonderer Berücksichtigung der Anthozoen*. Pubbl. Staz. zool. Napoli, **30**, suptav.: 1-94, 22 figg, 4 tabb, Napoli.
- ANSELMI B., BRONDI A., FERRETTI O. & FELLETTI A. (1983) - *Studio granulometrico e mineralogico dei sedimenti della piattaforma costiera compresa tra Punta Mesco e Viareggio*. Atti 4 Congr. Ass. it. Oceanol. Limnol., **36**: 1-22, 12 figg, 4 tabb, Genova.
- AUGIER H. (1982) - *Inventory and classification of marine benthic biocenoses of the Mediterranean*. Council of Europe, Strasbourg, Nature and Environment Series, **25**: 1-57, 5 figg, France.
- BALDUZZI A., BIANCHI C.N., BURLANDO B., CATTANEO-VIETTI R., MANGONI R., MORRI C., PANSINI M., PRONZATO R. & SARÀ M. (1994) - *Zoobenthos di substrato duro delle isole di Capraia e del Giglio (Arcipelago Toscano)*. Atti Soc. toscana Sci. nat. Mem., Pisa (*in press*).
- BARNES D.J. & LOUGH J.M. (1993) - *On the nature and causes of density banding in massive coral skeletons*. J. exp. mar. Biol. Ecol., **167**: 91-108, 5 figg, 1 tab., Amsterdam.
- BARSOTTI G., FEDERICI P.R., GIANNELLI L., MAZZANTI R. & SALVATORINI G. (1974) - *Studio del Quaternario livornese, con particolare riferimento alla stratigrafia ed alle faune delle formazioni del bacino di carenaggio della Torre del Fanale*. Mem. Soc. geol. ital., **13**: 425-495, 10 figg, 2 tabb, Roma.
- BELLUOMINI G., GLIOZZI E., RUGGERI G., BRANCA M. & DELITALA L. (1988) - *First dates on the terraces of the Crotona peninsula (Calabria, Southern Italy)*. Boll. Soc. geol. ital., **107**: 249-254, 1 fig., 2 tabb, Roma.
- BIANCHI C.N. & MORRI C. (1994) - *Southern species in the Ligurian Sea (northern Mediterranean): new records and a review*. Boll. Ist. Mus. biol. Univ. Genova, **58-59** (1992-1993): 181-197, 3 figg, Genova.
- BIANCHI C.N. & PEIRANO A. (1990) - *Mappatura delle praterie di Posidonia oceanica in Mar Ligure*. ENEA-CRAM S. Teresa, Rapporto tecnico interno: 1-372, 12 tavv, La Spezia.
- BRANCACCIO L., CAPALDI G., CINQUE A., PECE R. & SGROSSO I. (1978) -  *$^{230}\text{Th}/^{234}\text{U}$  dating of corals from a Tyrrhenian beach in the Sorrentine Peninsula*. Quaternaria, **20**: 175-183, 3 figg, 2 tabb, Roma.
- BRANCACCIO L. & VALLARIO A. (1968) - *Osservazioni geomorfologiche nel tratto di costa compreso tra le foci dei fiumi Noce-Castrocucco e Lao*. Boll. Soc. Nat. Napoli, **77**: 303-325, 3 figg, 2 tabb, Napoli.
- BUDD A.F., MANN K.O., GUZMAN H.M. (1993) - *Environmental interpretation using insoluble residues within reef coral skeletons: problems, pitfalls, and preliminary results*. Coral Reefs, **12**: 31-42, 7 figg, 8 tabb, Berlin.
- BUDDEMEIER R.W. (1978) - *Coral growth: retrospective analysis*. In: D.R. STODDART & R.E. JOHANNES (eds), *Coral reefs: research methods*. UNESCO: 551-571, Paris.
- CAIRNS S.D. (1991) - *A revision of the aberrant Scleractinia of the Galapagos and Cocos Island*. Smithsonian contributions to zoology, **504**: 1-44, 12 tavv, Washington.
- CALDARA M. (1986) - *La sezione tirreniana di Ponte del Re (Castellana Marina, Taranto): analisi paleoecologica*. Atti Soc. toscana Sci. nat. Mem., **93**: 129-163, 5 figg, 4 tabb, 2 tavv, Pisa.
- CAROBENE L. & DAI PRA G. (1990) - *Genesis, chronology and tectonics of the Quaternary marine terraces of the Tyrrhenian coast of Northern Calabria (Italy). Their correlation with climatic variations*. Il Quaternario, **3** (2), 75-94, 16 fig., 1 tab., 1 tav., Napoli.
- CAROBENE L. & DAI PRA G. (1991) - *Middle and Upper Taveistocene sea level highstands along the Tyrrhenian coast of Basilicata (Southern Italy)*. Il Quaternario, **4** (1a): 173-202, 34 figg, 2 tabb, Napoli.
- CAROBENE L., DAI PRA G. & GEWELT M. (1986) - *Niveaux marins du Taveistocene moyen-supérieur de la côte tyrrhénienne de la Calabrie (Italie méridionale). Datations  $^{230}\text{Th}/^{234}\text{U}$  et tectonique récente*. Z. Geom. N. F., **62**, suptav.: 141-158, 8 figg, 1 tab., Berlin.
- CAROBENE L. & PASINI G. (1982) - *Contributo alla conoscenza del Taveistocene superiore e dell'Olocene del Golfo di Orosei (Sardegna orientale)*. Boll. Soc. adriatica Sci., **64**(14): 5-36, 23 figg, 2 tabb, Trieste.
- COLANTONI P. & GALLIGNANI P. (1974) - *Osservazioni subacquee sui fondali del Golfo di Manfredonia*. Atti I° Simp. Naz. Com. it. Ricerche Studi Subacquee: 103-108, 2 figg, Roma.
- COLANTONI P. & GALLIGNANI P. (1975) - *Sea floor types and recent sedimentation on the continental shelf between Manfredonia and Trani (Southern Adriatic Sea)*. 8th Symp. Underwater Association: 115-132, 6 figg, London.
- COPAT MARCONI G., LENA G. & ZEZZA F. (1982) - *Segnalazione del ritrovamento e della datazione di Cladocora caespitosa nel livello dei due-quattro metri nel tratto di costa calabro-lucana tra Maratea e Belvedere Marittimo*. Rend. Soc. geol. ital., **4**: 373-374, 2 figg, 1 tab., Roma.
- COTECCHIA V., DAI PRA G. & MAGRI G. (1971) - *Sul Tirreniano della costa ionica salentina (Puglia). Datazione di un campione di coralli col metodo del  $^{230}\text{Th}/^{234}\text{U}$* . Geol. aptavic. Idrogeol., **6**: 106-112, 4 figg, Bari.
- CUERDA B.J. (1975) - *Los tiempos cuaternarios en Baleares*. pp. 471, Instituto de Estudios Baleáricos, Palma de Mallorca.
- DAI PRA G. & HEARTY P.J. (1988) - *I livelli marini taveistocenici del Golfo di Taranto. Sintesi geocronostratigrafica e tettonica*. Mem. Soc. geol. ital., **41**: 637-644, 2 figg, Roma.

- DAI PRA G., MIYAUCHI T., ANSELMI B., GALLETTI M. & PAGANIN G. (1993) - *Età dei depositi a Strombus bubonius di Vibo Valentia Marina (Italia meridionale)*. Il *Quaternario*, **6** (1): 139-144, 5 figg, 1 tab., Napoli.
- DAI PRA G. & STEARNS C.E. (1977) - *Sul Tirreniano di Taranto: datazioni su coralli con il metodo del  $^{230}\text{Th}/^{234}\text{U}$* . Geologica Romana, **16**: 231-242, 5 figg, 1 tab., Roma.
- D'ALESSANDRO A. & BROMLEY R.G. (1994) - *A new Ichnospecies of Spongeliomorpha from the Taveistocene of Sicily*. J. Paleont., Lawrence, Kansas (in press).
- DELLA CROCE N., COVAZZI A. & BONOMI A. (1994) - *Valori di trasparenza nei mari Ligure e Tirreno*. Atti 10° Congr. Ass. it. Oceanol. Limnol. (1992): 125-133, 5 figg, 3 tabb, Genova.
- DE VITA S., LAURENZI M.A., ORSI G. & VOLTAGGIO M. (1994) - *Aptavication of  $^{230}\text{Th}$  and  $^{40}\text{Ar}/^{39}\text{Ar}$  dating methods to the chronostratigraphy of Quaternary basaltic volcanic areas: the Ustica island case history*. Quat. Int., Oxford (submitted).
- DODGE R.E., ALLER R.C. & THOMSON J. (1974) - *Coral growth related to resuspension of bottom sediments*. Nature, **247**: 574-576, 4 figg, 1 tab., London.
- DONE T.J. & POTTS D.C. (1992) - *Influences of habitat and natural disturbances on contributions of massive Porites corals to reef communities*. Marine Biology, **114**: 479-493, 11 figg, 5 tabb, Berlin.
- DUCLAUX G. & LAFARGUE F. (1973) - *Madréporaires de Méditerranée occidentale. Recherches des zooxanthelles symbiotiques. Comportements morphologiques et écologiques*. Vie Milieu, sér. A, **23** (1) (1972): 45-63, 6 tavv, Paris.
- FAGERSTROM J.A. (1987) - *The evolution of reef communities*. pp. 600, John Wiley & Sons, New York.
- FUCHS T. (1874) - *Die Tertiär bildungen von Taranto*. Sitz. ber. K. Akad. Wien, **70**: 193-197, Wien.
- GEISTER J. (1983) - *Holoäne westindische Korallenriffe: Geomorphologie, Ökologie und Fazies*. Facies, **9**: 173-284, 57 figg, 8 tabb, 11 tavv, Erlangen.
- GIACOBBE S. & RINELLI P. (1994) - *Tanatofacies a Cladocora caespitosa ed evoluzione dell'assetto ecologico della Rada di Augusta (SR)*. Biol. mar. mediterr., **1** (1): 237-241, 2 figg, Genova.
- GIGNOUX M. (1913) - *Les formations marines Taviocènes et Quaternaires de l'Italie du sud et de la Sicilie*. Ann. Univ. Lyon, **1**, **36**: i-xxiv, 1-693, 42 figg, 21 tabb, Lyon.
- GRAEFFE E. (1884) - *Uebersicht der Seethierfauna des Golfes von Triest nebst Notizen über Vorkommen, Lebensweise, Erscheinungs- und Fortpflanzungszeit der einzelnen Arten. 3. Coelenteraten*. Arb. zool. Inst. Univ. Wien zool. Stat. Triest, **5** (3): 333-362, Wien.
- HEARTY P.J. & DAI PRA G. (1985) - *Aminostratigraphy and  $^{230}\text{Th}/^{234}\text{U}$  dating of Quaternary shoreline in the Puglia region of southern Italy*. Proc. 5th int. Coral Reef Congr., **3**: 163-169, 4 figg, 2 tabb, Tahiti.
- HEARTY P.J. & DAI PRA G. (1986) - *Aminostratigraphy of Quaternary marine deposits in the Lazio Region of Central Italy*. Z. Geom. N.F., **62**, suprav.: 131-140, 3 figg, 1 tab., Berlin.
- HEARTY P.J. & DAI PRA G. (1992) - *The age and stratigraphy of middle Taveistocene and younger deposits along the Gulf of Taranto (Southeast Italy)*. J. coast. Res., **8** (4): 882-905, 12 figg, 3 tabb, Fort Lauderdale.
- HEARTY P.J., BONFIGLIO L., VIOLANTI D. & SZABO B.J. (1986a) - *Age of late Quaternary marine deposits of southern Italy determined by aminostratigraphy faunal correlation, and uranium-series dating*. Riv. ital. Paleontol. Stratigr., **92** (1): 149-164, 1 fig., 5 tabb, Milano.
- HEARTY P.J., MILLER G.H., STEARNS C.E. & SZABO B.J. (1986b) - *Aminostratigraphy of Quaternary shoreline around the Mediterranean basin*. Bull. geol. Soc. America, **97**: 850-858, 5 figg, 3 tabb, Boulder.
- HECKEL P.H. & JABLONSKI D. (1979) - *Reefs and other carbonate buildups*. In: R.W. FAIRBRIDGE & D. JABLONSKI (Eds.): "The Encyclopedia of Paleontology". Dowden, Hutchinson & Ross: 691-705, Penna.
- HERNDL G.J. & VELIMIROV B. (1986) - *Microheterotrophic utilization of mucus released by the Mediterranean coral Cladocora caespitosa*. Marine Biology, **90**: 363-369, 2 figg, 1 tab., Berlin.
- HUGUES M.K., KELLY P.M., PILCHER J.R. & LAMARCHE V.C. (1982) - *Climate from tree rings*. pp. 223, Cambridge University Press, London.
- KNUTSON D.W., BUDDEMEIER R.W. & SMITH S.V. (1972) - *Coral chronometers: seasonal growth bands in reef corals*. Science, **177**: 270-272, 1 fig., 1 tab., Washington.
- KOBELT W. (1874) - *Verzeichniss der von mir bei Tarent gesammelten fossilen Conchylien*. Jahr. Deutsch. malak. Ges., **1**: 1-65, Wien.
- KOUKOURAS A. & KÜHLMANN D.H.H. (1991) - *Rasenkoralen als Biotope in der Ägäis*. Naturwissenschaftliche Rundschau, **44** (11): 444-445, Berlin.
- KÜHLMANN D.H.H., CHINTIROGLOU H., KOUTSOUBAS D. & KOUKOURAS A. (1991) - *Korallenriffe in Mittelmeer?* Naturwissenschaftliche Rundschau, **44** (8): 316, Berlin.
- LABOREL J. (1961) - *Sur un cas particulier de concrétionnement animal. Concrétionnement à Cladocora caespitosa L. dans le Golfe de Talante*. Rapp. P.-V. Reun. CIESM, **16** (2): 429-432, 3 figg, Monaco.
- LABOREL J. (1987) - *Marine biogenic constructions in the Mediterranean: a review*. Sci. Rep. Port-Cros natl. Park, Fr, **13**: 97-126, 20 figg, Port-Cros.
- LABOREL J. & LABOREL-DEGUEN F. (1978) - *Abondance du madréporaire Cladocora caespitosa (Linné 1767) dans les herbiers de posidonies de la baie de Port-Cros*. Trav. sci. Parc natl. Port-Cros, **4**: 273-274, Port-Cros.
- LE TISSIER M. D'A.A., CLAYTON B., BROWN B.E. & SPENCER DAVIS P. (1994) - *Skeletal correlates of coral density banding and an evaluation of radiography as used in sclerochronology*. Mar. Ecol. Prog. Ser., **110**: 29-44, 11 figg, Berlin.
- LITTLER M.M. & LITTLER D.S. (1985) - *Factors controlling relative dominance of primary producers on biotic reefs*. Proc. 5th int. Coral Reef Congr., **4**: 35-39, 2 figg, Tahiti.
- LOGAN A. & TOMASCIK T. (1991) - *Extension growth rates in two coral species from high-latitude reefs of Bermuda*. Coral Reefs, **10**: 155-160, 3 figg, 5 tabb, Berlin.
- LOUGH J.M. & BARNES D.J. (1992) - *Comparisons of skeletal density variations in Porites from the central Great Barrier Reef*. J. exp. mar. Biol. Ecol., **155**: 1-25, 2 figg, 6 tabb, Amsterdam.
- LUMARE F. (1966) - *Sulla scogliera a Cladocora di Crotona e le sue biocenosi*. Rend. Acc. naz. XL, ser. 4, **17-17** (1965-1966): 101-131, 11 figg, 9 tabb, 3 tavv, Roma.
- MORRI C., PEIRANO A., BIANCHI C.N. & SASSARINI M. (1994) - *Present-day bioconstructions of the hard coral, Cladocora caespitosa (L.) (Anthozoa, Scleractinia), in the Eastern Ligurian Sea (NW Mediterranean)*. Biol. mar. mediterr., **1** (1), 371-372, 1 figg, Genova.

- OLIVER VALLS J.A. (1989) - *Développement de Cladocora caespitosa (Linné 1767) en aquarium*. Bull. Inst. océanogr. Monaco, n° spécial, **5**: 205-209, 3 figg, Monaco.
- PALLAS P.S. (1766) - *Elenchus zoophytorum sistens generum adurbationes generaliores et specierum cognitarum succinctas descriptiones cum selectis auctorum synonymis*. pp. i-xvi, 28-451, P. van Cleef, Hagae Comitum.
- PALMENTOLA G., CAROBENE L., MASTRONUZZI G. & SANSÒ P. (1990) - *I terrazzi marini taveistoceni della penisola di Crotone (Calabria)*. Geogr. fis. Dinam. quat., **13** (1): 75-80, 3 figg, Bari.
- PERÈS J.M. & PICARD J. (1964) - *Nouveau manuel de bionomie benthique de la Mer Méditerranée*. Rec. Trav. Stat. mar. Endoume, **31** (Bull. 47): 1-137, 7 figg, Marseille.
- PICCO P. (1990) - *Climatological atlas of the Western Mediterranean*. pp. 224, ENEA, Santa Teresa Centre, La Spezia.
- POIZAT C. (1970) - *Hydrodynamisme et sédimentation dans le Golfe de Gabès (Tunisie)*. Tethys, **2** (1): 267-296, 11 tabb, 7 tavv, Marseille.
- RICCHETTI G. (1967) - *Osservazioni preliminari sulla geologia e morfologia dei depositi quaternari nei dintorni del Mar Piccolo (Taranto)*. Atti Acc. Gioena Sci. nat. Catania, **6** (18): 123-130, 1 tav., Catania.
- RIEDL R. (1963) - *Fauna und Flora der Adria*. pp. 640, Verlag Paul Parey, Hamburg.
- ROCA I. & MORENO I. (1987) - *Pocilloporidae, Faviidae y Dendrophylliidae (Anthozoa: Scleractinia) de las aguas costeras de Mallorca*. Boll. Soc. Hist. nat. Balears, **31**: 105-114, 6 figg, Palma de Mallorca.
- ROGERS C.S. (1990) - *Responses of coral reefs and reef organisms to sedimentation*. Mar. Ecol. Progr. Ser., **62**, 185-202, 1 fig., 3 tabb, Berlin.
- ROMANO P., SANTO A. & VOLTAGGIO M. (1994) - *L'evoluzione geomorfologica della pianura del fiume Volturno (Campania) durante il tardo Quaternario (Taveistocene medio superiore - Olocene)*. Il Quaternario, **7** (1): 41-56, 9 figg, 1 tab., 5 tavv, Napoli.
- ROSSI L. (1971) - *Guida a Cnidari e Ctenofori della fauna italiana*. Quad. civ. Staz. idrobiol. Milano, **2**: 5-101, 36 figg, Milano.
- SCHILLER C. (1993a) - *Ecology of the symbiotic coral Cladocora caespitosa (L.) (Faviidae, Scleractinia) in the Bay of Piran (Adriatic Sea): I. Distribution and biometry*. P.S.Z.N. I: Mar. Ecol., **14** (3): 205-219, 10 figg, 3 tabb, Berlin.
- SCHILLER C. (1993b) - *Ecology of the symbiotic coral Cladocora caespitosa (L.) (Faviidae, Scleractinia) in the Bay of Piran (Adriatic Sea): II. Energy budget*. P.S.Z.N. I: Mar. Ecol., **14** (3): 221-238, 7 figg, 9 tabb, Berlin.
- SCHUHMACHER H. & ZIBROWIUS H. (1985) - *What is hermatypic? A redefinition of ecological groups in corals and other organisms*. Coral Reefs, **4**: 1-9, 1 tab., Berlin.
- SEGUENZA G. (1864) - *Disquisizioni paleontologiche intorno ai Corallarii fossili delle rocce terziarie del distretto di Messina*. Mem. R. Accad. Sci. Torino, Cl. Sci. fis. mat., ser. 2, **21**: 399-560, 15 tavv, Torino.
- SEGUENZA G. (1880) - *Le formazioni terziarie nella provincia di Reggio (Calabria)*. Atti R. Accad. Lincei, Mem. Cl. Sci. fis., mat. nat., ser. 3, **6**: 1-466, 2 figg, 17 tavv, Roma.
- SHACKLETON N.J. & OPDYKE J.N. (1973) - *Oxygen isotope and paleomagnetic stratigraphy of equatorial Pacific core V28-238: oxygen isotope temperatures and ice volumes on a 10<sup>5</sup> and 10<sup>6</sup> year time scale*. Quaternary Res., **3**: 39-45, 8 figg, 4 tabb, Orlando.
- SHACKLETON N.J., BERGER A. & PEILTIER W.R. (1990) - *An alternative astronomical calibration on the Lower Taveistocene time scale based on ODP Site 677*. Trans. Royal Soc. Edinburgh, Earth Sci., **81**: 251-261, 3 tabb, Edinburgh.
- SOROKIN Y.I. (1993) - *Coral reef ecology*. pp.465, Springer-Verlag, Ecological Studies 102, Berlin.
- TINS W. (1978) - *Biotische und abiotische limitierung bei die Koralle Cladocora caespitosa (Madreporaria)*. Verh. Ges. Ökol., **7** (1977): 79-87, Kiel.
- TUR J.M. & PERE GODALL (1982) - *Consideraciones preliminares sobre la ecología de los antozoos del litoral sur de la Costa Brava*. Oecol. aquat., **6**: 175-183, 3 figg, 1 tab., Barcelona.
- ULZEGA A. & HEARTY P.J. (1986) - *Geomorphology, stratigraphy and geochronology of Late Quaternary marine deposits in Sardinia*. Z. Geomorph. N. F., **62**, suptav.: 119-129, 6 figg, Berlin.
- VERON J.E.N. (1993) - *A biogeographic database of hermatypic corals*. Austr. Inst. mar. Sci., Monogr. Ser., **10**: 1-433, 112 figg, 2 tabb, Cape Ferguson.
- VERRI A. & DE ANGELIS D'OSSAT G. (1899) - *Cenni sulla geologia di Taranto*. Boll. Soc. geol. ital., **18** (2): 179-210, 2 tabb, Roma.
- WELLS J.W. (1956) - *Scleractinia*. In: R.C. MOORE (Ed.) "Treatise on invertebrate paleontology. Part F: Coelenterata". Geological Society of America, University of Kansas Press: 328-444, 117 figg, Lawrence.
- WELLS J.W. (1967) - *Corals as bathometers*. In: A. HALLAM (Ed.) "Depth indicators in marine sedimentary environments". Mar. Geol. **5** (5-6): 349-365, 11 figg, Amsterdam.
- WOOD E.M. (1983) - *Corals of the World*. pp. 256, T.F.H. Publications, Neptune City.
- ZEI M. (1993) - *I depositi tirreniani dell'area pontina: un giacimento sottomarino a Strombus su un fondale a est del Promontorio Circeo*. G. Geol., ser. 3, **54** (1992), (2): 127-141, Bologna.
- ZIBROWIUS H. (1974) - *Oculina patagonica, Scleractiniaire hermatypique introduit en Méditerranée*. Helgoländer wiss. Meeresunters., **26**: 153-173, 2 figg, Hamburg.
- ZIBROWIUS H. (1979) - *Campagne de la Calypso en Méditerranée nord-orientale (1955, 1956, 1960, 1964)*. 7. Scleractiniaires. Ann. Inst. océanogr. Paris, **55**, suptav.: 7-28, 2 tavv, 1 map, Paris.
- ZIBROWIUS H. (1980) - *Les Scleractiniaires de la Méditerranée et de l'Atlantique nord-oriental*. Mém. Inst. océanogr., **11**: 1-284, 3 tabb, 107 tavv, Monaco.
- ZIBROWIUS H. (1983) - *Nouvelles données sur la distribution de quelques Scleractiniaires "méditerranéens" à l'est et à l'ouest du détroit de Gibraltar*. Rapp. Comm. int. Mer. Médit., **28** (3), 307-309, Monaco.
- ZIBROWIUS H. (1984) - *Taxonomy in abermatypic scleractinian corals*. Paleontogr. amer., **54**: 80-85, Washington.
- ZIBROWIUS H. (1989) - *Mise au point sur les Scleractiniaires comme indicateurs de profondeur (Cnidaria: Anthozoa)*. Géol. médit., **15** (1988), (1), 27-47, 3 tab., 1 tav., Marseille.