

Bollettino Malacologico

INTERNATIONAL JOURNAL OF MALACOLOGY

XXXIII 1997



First Workshop on marine mollusc communities of the Mediterranean

Gibilmanna, 7-9 Ottobre 1994

R. Chemello & G.F. Russo (eds)

con il patrocinio della Provincia Regionale di Palermo

Autorizzazione Tribunale di Milano n. 479 del 15 Ottobre 1983
Spedizione in A.P. Art. 2 comma 20/C Legge 662/96 - filiale di Milano
25 Maggio 1998 spedizione n. 2 - 1998

ISSN 5678 8976



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First workshop on marine mollusc communities of the Mediterranean: introduction and concluding remarks

Primo workshop sulle comunità dei molluschi marini del Mediterraneo: una premessa ed alcune considerazioni conclusive

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INTRODUCTION

The idea of organizing a workshop on mollusc communities was the result of critical observations made on the malacological literature. The growing "reductionist trend" in the biological and natural sciences (MACINTOSH, 1985) has had a great influence on the direction of malacofauna research. In particular, an increasingly marked divergence has been observed during the last decade between the research lines of systematics and taxonomy on the one hand, and those of physiology and, to a lesser extent, autecology on the other. In a recent article by PONDER (1995) on the state of the art in malacology, the clear predominance of studies of systematics and taxonomy with respect to the other disciplines was highlighted. The "quotation index" syndrome of the last few years has given the definitive blow to research of a synecological nature, inasmuch as it is considered a current version of "antiquated" faunistic studies.

Information on malacological associations has always been considered to be of prevalently local interest and thus not worthy of appearing in journals, the depositories of knowledge of "global interest". Yet, just such studies of communities are the basis of the holistic analysis of ecological systems, allowing the characterization of a particular area through an analysis of the biological typologies present (for example, bionomic studies). Moreover, there are important implications for the application of this approach to feasibility studies of protected areas (CHEMELLO, 1991; RUSSO & SGROSSO, 1997). In this context, marine molluscs hold a role of primary importance due to their wide adaptive range which makes them effective descriptors of environmental typologies (GAMBI *et al.*, 1982). Nevertheless, at present molluscs constitute a rather neglected group in synecological analysis compared, for example, to Amphipod Crustaceans.

There is a risk that synecological culture (intended as a convergence and a synthesis of taxonomic, autecological and bionomic knowledge, as well as the development of conceptual and analytical techniques capable of confronting high levels of complexity (cf. for example BOCCHI & CERUTI, 1985), if neglected too long, could experience an impoverishment from which it is

LA PREMESSA

L'idea di organizzare un workshop sulle comunità a molluschi nasce dall'osservazione critica di quanto prodotto nella letteratura malacologica. La sempre maggiore "tendenza riduzionista" nel campo delle scienze biologiche e naturali (MACINTOSH, 1985) ha pesantemente influenzato anche l'orientamento delle ricerche sulla malacofauna. In particolare, nell'ultimo decennio si è assistito ad una divaricazione sempre più spinta tra le linee di ricerca di sistematica e di tassonomia da un lato e quelle di fisiologia e, al più, di autoecologia, dall'altro. Nella recente sintesi di PONDER (1995) sullo stato dell'arte delle ricerche in malacologia, si sottolinea la netta prevalenza degli studi di sistematica e tassonomia rispetto alle altre discipline della malacologia. La "sindrome da *quotation index*" degli ultimi anni, poi, ha dato il colpo definitivo alle ricerche di carattere sinecologico, in quanto considerate una versione attuale degli 'antiquati' studi faunistici.

L'informazione sulle associazioni malacologiche è stata sempre più spesso considerata di interesse prevalentemente locale e, quindi, non degna di apparire su riviste depositarie di una conoscenza 'di interesse globale'. Eppure, proprio gli studi di comunità sono il fondamento delle analisi olistiche dei sistemi ecologici, che consentono la caratterizzazione di un determinato territorio attraverso l'analisi dell'assortimento delle tipologie biologiche presenti (ad es. studi bionomici). Peraltro, un tale tipo di approccio ha un risvolto applicativo di particolare rilevanza negli studi di fattibilità di aree protette (CHEMELLO, 1991; RUSSO & SGROSSO, 1997). In quest'ambito, i molluschi marini rivestono un ruolo di primaria importanza per la loro ampia radiazione adattativa, che li rende descrittori molto efficaci delle tipologie ambientali (GAMBI *et al.*, 1982). Tuttavia, attualmente i molluschi costituiscono un gruppo poco considerato nell'ambito delle analisi sinecologiche, rispetto, ad esempio, ai Crostacei Anfipodi.

Il rischio è che la cultura sinecologica, intesa come ambito di convergenza e di sintesi dell'esperienza tassonomica, autoecologica e bionomica, nonché di sviluppo di tecniche concettuali ed analitiche adeguate ad affrontare un tale livello di complessità (cfr. ad es. BOCCHI & CERUTI, 1985), se trascurata troppo a lungo potrebbe portare ad un impoverimento delle conoscenze tale da non consen-



impossible to return. This is especially true if one considers that the level of complexity of the littoral marine systems of the Mediterranean is incomparably greater than that of the systems studied by the reigning Anglo-Saxon school of ecology, which renders an uncritical transfer of the models developed by the latter to the Mediterranean context impossible. It is no coincidence that studies of simple systems (i.e. with few components) such as those of the northern Atlantic or northern Pacific (cf. review of all the landmark studies in PAINE, 1994) have allowed the development of an *experimentalist school* which favours the analysis of interactions, while studies of complex systems (i.e. with many components) such as those of the Mediterranean, have contributed to the development of the French-Canadian *holistic school* which favours structural and functional analyses of its components (cf. for all PIELOU, 1984; LEGENDRE & LEGENDRE, 1979).

The former school, which selects relatively few control variables, operates in the context of a "paradigm of simplification" (*sensu* MORIN, 1983), to which are adapted the classic methods of experimental ecology which are often associated with the analytical techniques of *mathematical ecology*. The latter school, on the other hand, demands a different approach which operates in a "paradigm of complexity" (*sensu* MORIN, 1983), making use of a large number of variables and the techniques of *numerical ecology* (cf. on this point also ALLEN & STARR, 1982).

This workshop is the product of the need to regain our ancient faunistic patrimony, which draws on the classic taxonomic and bionomic studies, and the attempt to interpret it in synecological terms using modern analytical methods.

SOME CONCLUDING OBSERVATIONS

During the three days of the workshop, the scientific contributions and the long and articulate discussions involving all the researchers present offered several lines of future study which will prove useful and interesting.

Analytical methodology

In the three categories of benthos examined in the workshop (soft bottoms, hard bottoms and seagrass bottoms), the conceptual evolution towards considering, more realistically, coenotic *continua* (or coenoclines) rather than coenotic "units" (or communities) calls for an adjustment in sampling methodology and a different sampling strategy. A better understanding of the efficiency of the sampling systems currently used can thus be gained.

As far as soft bottoms are concerned, rather than employing the standard sampling volume of 50 litres (PICARD, 1965), it would be useful to establish experimentally the optimal sampling volumes for the principal sedimentary environments and their associated malacofauna. The importance of carrying out more replicas of each sample must also be considered. Such studies would prove useful, above all, in the optimisation of sampling effort and data quality in studies of populations which are rather dispersed (for example, those of detritic or unstable soft bottoms) or particularly aggregated (such as those of lagoons).

tirne il recupero. Ciò è tanto più vero se si considera che il livello di complessità dei sistemi marini litorali del Mediterraneo è incomparabilmente superiore a quello dei sistemi oggetto di studio da parte dell'imperante scuola di ecologia anglo-sassone, per cui non è possibile il trasferimento acritico dei modelli sviluppati da questa scuola in ambito mediterraneo. Non è un caso, infatti, che da un lato sistemi semplici (cioè a poche componenti), quali quelli del Pacifico Settentrionale (cfr. per tutti gli studi riassunti in PAINE, 1994), abbiano consentito lo sviluppo di una scuola sperimentalista che privilegia l'analisi delle interazioni, mentre, dall'altro, sistemi complessi (cioè a molte componenti), quali quelli del Mar Mediterraneo, abbiano contribuito allo sviluppo della scuola olista franco-canadese che privilegia l'analisi strutturale e funzionale delle componenti (cfr. per tutti PIELOU, 1984 e LEGENDRE & LEGENDRE, 1979). La prima, muovendosi nell'ambito di un 'paradigma di semplificazione' (*sensu* MORIN, 1983), utilizza i metodi classici dell'ecologia matematica, mentre la seconda si avvale delle tecniche di ecologia numerica (ad esempio, analisi multivariata), poichè necessita di un approccio diverso che si muova nell'ambito di un 'paradigma di complessità' (cfr. ALLEN & STARR, 1982). Il workshop nasce dall'esigenza di recuperare l'antico patrimonio di cultura faunistica (che attinge dai classici studi tassonomici e bionomici) e dal tentativo di interpretarlo in chiave sinecologica con i moderni metodi analitici.

ALCUNE CONSIDERAZIONI CONCLUSIVE

Dai contributi scientifici e dalle lunghe ed articolate discussioni che hanno animato i tre giorni del Workshop e che hanno coinvolto tutti i ricercatori presenti, sono stati individuati alcuni indirizzi di studio e di lavoro che potrebbe essere particolarmente utile ed interessante seguire nel futuro.

Metodologie di analisi

Nei tre compartimenti del benthos considerati durante il workshop (fondi molli, fondi duri e fondi a fanerogame), l'evoluzione concettuale indirizzata a considerare più realisticamente *continua* cenotici (o cenoclini), invece di 'individualità' cenotiche (o comunità), comporta un adeguamento delle metodologie di prelievo ed una differente strutturazione dei piani di campionamento. È stata, quindi, rilevata l'opportunità di approfondire le analisi sull'efficienza dei sistemi di campionamento attualmente in uso.

Per i fondi mobili, invece dei classici 50 litri (PICARD, 1965), sarebbe utile stabilire sperimentalmente volumetrie di campionamento ottimali per i principali ambiti sedimentari e per le associate malacofaune, prendendo in considerazione anche la necessità di effettuare più repliche dello stesso campione. Queste analisi potrebbero essere utili soprattutto per ottimizzare lo sforzo di campionamento e la qualità dei dati durante lo studio di popolamenti che si presentano alquanto dispersi (ad esempio, quelli dei fondi molli detritici o instabili) o particolarmente aggregati (ad esempio, quelli lagunari).

Per i fondi a fanerogame, ulteriori ricerche dovrebbero essere condotte per verificare l'efficienza delle tecniche attualmente adottate (retino e sorbona), soprattutto confrontando praterie con caratteristiche strutturali diverse (cfr. RUSSO *et al.*, 1985; RUSSO & VINCI, 1991).



As regards seagrass bottoms, further research needs to be carried out to verify the efficiency of the techniques in current use (hand-towed net and suction pump), especially by comparing prairies with different structural characteristics (cfr RUSSO *et al.*, 1985; RUSSO & VINCI, 1991).

As regards hard bottoms, research is still at the planning stage, *sic et simpliciter*. The "suction-scraping-suction" technique recently adopted (CHEMELLO, 1991) seems an efficient one, but too few synecological studies have been carried out so far to allow useful comparisons to be made.

Functional Organization

The necessity of characterizing malacological communities better, not only in terms of their taxonomic organization but also as regards their organization on a morphological-functional basis, was highlighted. Taxonomy must, however, still be considered the essential tool of any ecological investigation.

Taking taxonomic data as the starting point, research should be carried out by identifying descriptors which are homogeneous with respect to the functional aspects to be considered in the community analysis (see for example RUSSO, 1986; 1989), something which often does not happen. To this end, information derived from the biology of the species is important, in particular that regarding diet, reproduction and population; it is regrettably true that very little is known about almost all the species of mollusc in the Mediterranean that are not of commercial interest.

To improve links between studies of the various levels in the organisation of living systems (*sensu* ALLEN & STARR, 1982), it is necessary to begin to study the biology of the species of importance to synecological analysis. It would therefore be appropriate to begin from structural "images" of communities so as to individuate the "structuring" species which can then be submitted to population and autecological analyses according to a *top-down* hierarchical approach.

The importance of integration between research groups

Given the high degree of integration between the above themes and the large number of study perspectives, opportunities to link the activities of the various groups studying the ecology of malacological communities of the Mediterranean must be taken. What has also emerged is the importance of developing research on populations which belong to both present and earlier time scales. More integration with palaeontology, palaeoecology and palaeoclimatology is essential for an understanding of the real life history of species which is reflected in the life history of communities.

Per i fondi duri la ricerca è tutta da impostare, *sic et simpliciter*. Infatti, nonostante la tecnica 'sorbona-grattaggio-sorbona' utilizzata di recente (CHEMELLO, 1991) sembri essere efficiente, sono ancora troppo scarsi gli studi sinecologici sino ad oggi pubblicati per consentire confronti utili.

Organizzazione funzionale

È risultato necessario caratterizzare meglio le comunità malacologiche non solo per la loro organizzazione tassonomica, ma anche per la loro organizzazione su base morfologico-funzionale, sebbene la tassonomia debba sempre considerarsi lo strumento essenziale per qualsiasi indagine di tipo ecologico.

Partendo sempre e comunque da dati tassonomici, la ricerca dovrebbe essere condotta individuando descrittori omogenei rispetto agli aspetti funzionali da considerare nell'analisi di comunità (ad esempio, RUSSO, 1986; 1989), cosa che spesso non avviene. A tal fine risultano importanti le informazioni che derivano dalla biologia delle specie, in particolar modo quella alimentare, riproduttiva e di popolazione: è purtroppo un fatto noto che, in Mediterraneo, nulla o poco si conosce di quasi tutte le specie di molluschi che non siano d'interesse commerciale.

Per migliorare il collegamento tra gli studi condotti sui vari livelli dell'organizzazione gerarchica dei sistemi viventi (*sensu* ALLEN & STARR, 1982), diventa necessario iniziare a studiare la biologia di specie che risultano essere importanti nelle analisi sinecologiche. Sarebbe, quindi, opportuno partire dalle 'immagini' strutturali delle comunità per poi individuare le 'specie-strutturanti' da sottoporre ad analisi di popolazione e ad analisi autoecologiche, secondo un approccio gerarchico di tipo *top-down*.

Necessità d'integrazione tra i gruppi di ricerca

Data la forte integrazione fra le tematiche suddette ed il gran numero di prospettive di studio, per razionalizzare lo sforzo di ricerca, è emersa l'opportunità di collegare il più possibile l'attività dei gruppi che operano nel settore dell'ecologia delle comunità malacologiche del Mediterraneo. È emersa anche la necessità di un maggiore sviluppo delle ricerche mirate sia sui popolamenti appartenenti all'attuale che a scale temporali diverse, con una maggiore integrazione con paleontologia, paleoecologia e paleoclimatologia, essenziali per comprendere la reale *storia delle specie* che si riflette poi nella *storia delle comunità*.

RINGRAZIAMENTI

Questo volume non avrebbe mai visto le stampe se alcuni cari amici e colleghi non ci avessero dato una mano d'aiuto. Tra questi è doveroso ringraziare Ignazio Ciuna e Gianfranco Scotti che hanno provveduto alla noiosa stesura ed alla revisione di tutti i testi. La dott.ssa Helen Main per l'indispensabile revisione e per l'uniformazione della lingua inglese di tutti i lavori. L'ex-Presidente Piero Piani e l'attuale Presidente della Società Italiana di Malacologia Riccardo Giannuzzi-Savelli, assieme al Direttore Scientifico Daniele Bedulli ed al Direttore Editoriale Carlo Smriglio, per aver consentito la stampa degli atti sul "rinato" *Bollettino Malacologico*.



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Soft bottom mollusc biocoenoses and thanatocoenoses in the Island of Lipari (Aeolian Islands)

Salvatore Giacobbe & Nunziacarla Spanò

KEY WORDS: Biocoenoses, Thanatocoenoses, Soft bottoms, Aeolian Islands.

ABSTRACT Preliminary data on mollusc biocoenoses and thanatocoenoses sampled along the western side of the island of Lipari are discussed. The circalittoral soft bottoms are characterized by coarse sediments, terrigenous inputs and a high level of water movement. The biocoenosis of coarse sand and fine gravel under bottom currents (SGCF of PÉRÈS & PICARD, 1964) was identified in two stations. Some evidence of sedimentary instability was found in the other stations. The qualitative and quantitative composition of the mollusc thanatocoenoses was related to the occurrence of the various biocoenotic stocks: very high dominance values were found in the stock of species characteristic of the detritic biocoenoses complex. The observed differences between biocoenoses and thanatocoenoses are probably not related to the gradual modification of the biotope, but are the result of irregular variations in the sedimentary rate.

RIASSUNTO I fondi mobili circalitorali dell'Isola di Lipari sono stati indagati nel corso del programma 40% M.P.I. "Colonna d'acqua e fondo marino; relazioni tra le componenti del sistema nei mari siciliani". In particolare è stato effettuato uno studio comparativo su composizione e struttura dei popolamenti e delle tanatocenosi a molluschi su quattro campioni volumetrici, rappresentativi di altrettante stazioni. L'ambiente indagato è caratterizzato da sedimenti grossolani, prevalente sedimentazione terrigena e intenso idrodinamismo. Evidenze di destrutturazione sono state osservate in tutti i popolamenti a molluschi, anche quando riferibili a ben definite biocenosi (SGCF di PÉRÈS & PICARD, 1964), probabilmente in relazione ad instabilità del substrato. La composizione delle tanatocenosi a molluschi ha evidenziato, rispetto ai popolamenti, differenze di ordine qualitativo e quantitativo, soprattutto in ragione degli altissimi valori di dominanza dello stock dei fondi biodetritici. Si ritiene che le differenze riscontrate nell'organizzazione delle comunità attuali e pregresse siano principalmente da attribuire a irregolari variazioni nel regime sedimentario, piuttosto che ad una graduale modificazione del biotopo.

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INTRODUCTION

Biologists and palaeontologists have become increasingly interested in the relationships between biocoenosis and thanatocoenosis. With regard to this subject, a specific research project (TSM) has recently investigated detritic circalittoral biocoenoses of the Tuscan Archipelago and Pontine Islands (BASSO *et al.*, 1990). In these environments the scarce terrigenous input and high water movement produce feedback processes between organisms and the substratum; insular areas with volcanic activity, such as the Eolian Islands, have not been extensively studied.

In this paper, preliminary data on mollusc biocoenoses and thanatocoenoses investigated along the western coast of the island of Lipari, are shown and discussed. The results are a contribution to knowledge of soft-bottom communities in volcanic insular environments, with regard to biotic stability.

MATERIALS AND METHODS

Samples were taken using a modified Van Veen grab, which allows the collection of 70 dm³ (BASSO *et al.*, 1990) of sediment from a surface of 0.4 m².

Benthic malacofauna and the associated mollusc thanatocoenoses were studied on a volume of 50 dm³, retained on 1 mm mesh sieves (PÉRÈS & PICARD, 1964), according to the method described by DI GERONIMO & ROBBA (1976). The complete lists of the living macrobenthic species, and of those of the mollusc thanatocoenoses, are given in a separate data report (AA. VV.,

in press). All biocoenoses were identified and named according to PÉRÈS & PICARD (1964).

The textural features of the sediments were obtained by dry-sieving the fraction greater than 63 mm and using a sedimentation column for pelitic fractions (BUCHANAN & KAIN, 1971). As suggested by FOLK & WARD (1957) the most important statistical parameters (Mz, sk, s and Kg) were also examined. Calcium carbonate content was evaluated by NaOH titration after etching (BARNES, 1959).

Sampling location

Samples of benthos and sediment were collected on October 20 1989, in two different areas along the western coast of the island of Lipari (Fig. 1). The southern area (area A on the map), abeam of Punta Le Grotticelle, faces a steep and indented coast which is markedly hollowed by small torrents. From the shore to a depth of 30 m, rocky bottoms are common and partially covered by *Posidonia* seagrass; at 30-60 m depth, sandy and gravelly soft bottoms are prevalent. Two quantitative samples were taken at depths of 39 m (station 1A) and 47 m (station 2A). The northern area (area B in Fig. 1) is located near Punta Palmeto, a stretch of coast characterized by a high, sheer cliff, with a sharply sloping bottom. From the shore to a depth of 40 m, rough hard bottoms are prevalent, whereas coarse sediments are common at greater depths. Quantitative sampling was carried out at two stations at 56 m (st. 1B) and 59 m (st. 3B).



Geographic and bathymetric data of the sampling stations are reported in Table 1.

Station	Depth m	Geographic	Co-ordinates
1A	39	38°27.53 N	14°54.86 E
2A	47	38°27.49 N	14°54.81 E
1B	56	38°29.81 N	14°53.47 E
3B	59	38°29.89 N	14°53.72 E

Table 1. Sampling stations data.

RESULTS

The main granulometric features of the samples are shown in table 2. Sand is the prevailing class, with a maximum rate of 100% in station 1B. A small percentage of silt (14-16%) is present in sediment samples 1A and 2A; a quantity of gravel (16%) was found in the sediments of station 3B. Sediments of samples 1A and 2A show the same grain size average ($Mz = 2.8 F$), similar to the value of sample 1B (2.26 F), but very different from that of 3B, which has a coarser texture (0.72 F). There are no marked differences in sk and kg values, showing symmetric and mesocurtic grain size distributions. Sediments are moderately sorted in stations 1A, 2A and 3B; only in station 1B are they mildly sorted, according to the highest textural homogeneity. Calcium carbonate content, entirely biogenic, is very low (>3,5%).

Thirty-one macrobenthic species of living molluscs (twenty-four Bivalves and seven Gastropods) were found in the samples (Tab. 3). Three species only were found in station 1B, 12-15 were found in the remaining stations. A high number of species (twenty-four) was found only once, twenty-two of them with one specimen only. *Abra prismatica* is the only species found throughout, although with a low number of specimens. The highest abundance values were observed in station 1A, due to the bivalve *Pteromeris minuta* and to the gastropod *Natica rizzae* (13 and 12 individuals respectively).

Species were given a bionomic attribute according to the literature data; six biocoenotic stocks were identified, excluding the eurytopic species with large ecological distributions (Lre). Dominance values of the stocks are shown in Table 4.

Divaricella divaricata is the sole species found which is characteristic of the fine, well-sorted sand biocoenosis (SFBC); the presence of this infralittoral species only in station 2A is accidental. The species of the coarse sand and fine gravel under bottom currents biocoenosis (SGCF) form the greatest part of the benthic mollusc assemblages in stations 1A and 3B; this is related to high hydrodynamism. The coastal detritic biocoenosis (DC) is well represented in all the stations (12-24% of dominance values); the very high value of dominance (80%) attained in the unstructured populations of station 1B is clearly not to be considered. Another species, *Timoclea ovata*, characteristic of

the detritic biocoenoses complex (DC-DE-DL) was found in samples 2A and 3B; the higher frequency in station 2A (16% of dominance value) is justified by the presence of a percentage of silt in the sediment as *T. ovata* is a typical mixtophile species. In sample 3B (3%) it is probably an accidental species.

The record of characteristic preferential species of the terrigenous mud biocoenosis (VTC) in the 1A and 2A samples is also related to the silt fraction of the sediment. The dominance value of this stock is very low in both the stations (2% and 8% respectively).

Besides the stock of species which come from well-defined benthic biocoenoses, mollusc assemblages include some species which are "indicators" of sedimentary instability, and which have an important role in the make-up of the so-called Heterogenous Community (PE: PICARD, 1965). These species are present in all four stations, but particularly in station 2A in which they make up almost half of the whole mollusc fauna.

The most significant species in this stock is *Corbula gibba*, recorded with 8 specimens in station 2A (32% dominance).

Natica rizzae was found in station 1A with 12 specimens, and was also included in this stock, although its role in the composition of the heterogenous community is still not well known.

As far as *habitus* and trophic roles, are concerned it was observed that the communities are almost entirely made up of infaunal species; filter feeders are prevalent, but there are also a low number of deposit and detritus feeders; carnivorous species are very rare, but twelve specimens (28.57% dominance value) of *Natica rizzae* were found in sample 1A. These observations do not concern station 1B, whose benthic populations are quite unstructured.

The mollusc thanatocoenoses presented 205 species (105 Gastropods, 3 Scaphopods and 97 Bivalves). The complete list of molluscs, with their respective abundances and dominance values, is published in the data report mentioned above (AA.VV., in press). The highest number of species (166) was found in station 1A, the lowest in station 1B (49), the same applies for the number of specimens (2590 and 233 respectively).

As regards the biocoenoses, a bionomic significance was also attributed to the single species of the mollusc thanatocoenoses, in accordance with the literature. The various stocks identified were put into 8 groups, including the stock of the species without any specific ecological role (Lre). For example, the characteristic exclusive and preferential species of the *Posidonia* meadows (HP) were united with those of the photophilic algae biocoenosis (AP) due to the much higher incidence of the former and to the high number of species which live in both biocoenoses. In the same way, species characteristic of terrigenous mud (VTC), species of the circalittoral-bathyal transition and those typical of the upper horizon of the bathyal zone were merged. Furthermore, a stock including all midlittoral and infralittoral species of the soft bottom was created.

The numerical relationships between the various stocks identified in the four samples are shown in Figure 2. We observed that station 1A is mainly characterized by the high incidence of the AP-HP stock (13.49%), which was present as a minimum percentage (0.14% in 2A) in other samples. This



entirely allochthonous stock originates from the seagrass meadow of area A. Another allochthonous stock composed of various midlittoral and infralittoral species is present in all stations (max 21.37% in 1A). The autochthonous component is dominated by species characteristic of detritic biocoenoses. Two stocks were identified. The first involves species characteristic of the coastal detritic biocoenosis (DC), which include the few coralligenous species found; the highest values are to be found in the two deeper stations. The second stock includes characteristic preferential species of the coastal detritic (DC) and muddy detritic bottom (DE) biocoenoses. Except in station 1A, in which the dominance is only 14.59%, this stock is by far the most important, and in the deeper stations (3B and 2A) it alone constitutes more than half the thanatocoenoses (59.5% approx). It must also be emphasized that the high incidence of this stock is almost entirely due to *Timoclea ovata*, present with high dominance values, above all in the two deepest stations (43-45%). Another group of species related to environments with a high level of hydrodynamism was found in all stations with dominance values ranging from 5.6% (station 1B) to 13.5% (station 1A). The stock attributed to the biocoenosis of coarse sand and fine gravel under bottom currents, is entirely autochthonous only in the two deepest thanatocoenoses (2A and 3B). On the other hand, a notable allochthonous component is present in the two more superficial samples, especially in sample 1 where the relationship between soft bottoms and *Posidonia* meadows (channels of "intermatte") seems to be important.

Finally, a small group of species characteristic of the terrigenous mud biocoenosis, together with a few others with bathyal affinities, is present in the four stations. Its incidence is generally very modest, with dominance values lower than 1%, except in station 1B where it exceeds 9%. In station 1B the entirely autochthonous stock is to be considered with the presence of a significant fine sediment fraction.

The species indicating bottom turbidity, which are not very numerous, have higher dominance values in the shallowest stations (5.7-10%) than in the deepest ones (about 3.5%).

All the stocks described here include a high number of species, the majority of which are present as a limited number of specimens. Excluding the autochthonous stocks, only 20 species have dominance values higher than 1% in at least one sample (Table 5). Moreover a clear difference is noted between the high dominance values of *Timoclea ovata* and *Cerithidium submammillatum* the much lower values of all the other species.

DISCUSSION AND CONCLUSION

The granulometric and faunistic data of this study have allowed the identification in stations 1A and 3B of molluscan assemblages which belong to the biocoenoses of coarse sand and fine gravel under bottom currents (SGCF). In both stations, it can be hypothesized that there are conditions of relative sedimentary instability due to the presence of specific secondary stocks (PE) related to the poor trophic structure of the community. On the other hand, differences in the specific composition of the two stations are to be attributed to their bathymetric locations and different relationships to the adjacent biotopes. The instability factor noted in these two stations seems to be even more marked in station 2A, the populations of which are made up of a small number of characteristic species of different biocoenoses (SFBC, DC, DC-DE-DL and VTC), numerically subordinate to the opportunist species stock (PE). Finally in

station 1B, the limited number of species and individuals show a marked involution of the community.

The quali-quantitative composition of the mollusc thanatocoenoses show, with respect to the biocoenoses, a different occurrence of the various biocoenotic stocks considered. These differences are only partly explained by the presence of a large allochthonous component in the thanatocoenoses, which is easily identifiable on both a deductive basis (the autoecological characteristics of the species) and an objective one (the state of conservation of the specimens). All this leads us to suppose that the present benthic communities were preceded, in a recent past, by different ones whose salient appearance was lent, to a different extent, by species characteristic of detritic environments. The exact temporal distance between the two types of community cannot be quantified here, although it certainly comes within the evolution times of benthic marine mesoe-

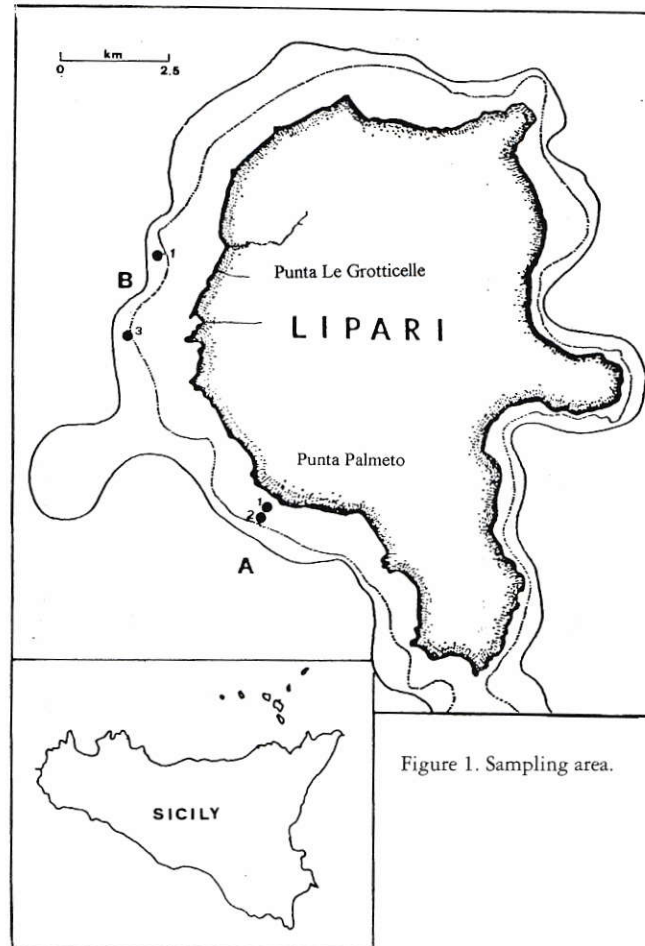


Figure 1. Sampling area.



cosystems (PICARD, 1985), but on a smaller scale. This hypothesis is also supported by the sedimentary characteristics of the site, which is fed intensively by easily-eroded piroclastic deposits while the high acclivity of the bottom, the low specific weight of the sediments and the intensive hydrodynamism all contribute to determining a more or less marked condition of sedimentary instability.

Thus, in our opinion, the observed differences between the biocoenoses and thanatocoenoses should not be interpreted in terms of a gradual modification of the biotope but as different manifestations of a single phenomenon. Once again, with reference to the composition of the mixed detritic stock, we observe that its dominant role within the thanatocoenoses is almost entirely due to only two species, *Timoclea ovata* and *Cerithidium submammillatum*, whose dominance is much greater than that of any other species present in the thanatocoenoses. As the stock is entirely autochthonous, these species must obviously at some time have had the possibility of forming luxuriant populations. An alternative hypothesis is that these species were the only ones among all those found to have populated the biotope in a significant and continuous way. We find the latter hypothesis less plausible, given that the species with the highest dominance values in the biocoenoses (including *Timoclea ovata*) are also well represented in the thanatocoenoses, while *Cerithidium submammillatum* is absent from the biocoenoses, even though it is extremely abundant in the thanatocoenoses. Moreover, what is known about the autoecology of the two mixtophile species suggests that both might have profited from a phase characterized by a higher rate of fine sedimentation.

In conclusion, these data contribute to characterizing an environment with a high level of hydrodynamism, a more or less marked sedimentary instability and, consequently, a variability in the benthic communities in short and medium time periods. This variability, which can be hypothesized on the basis of the poor structure of the mollusc assemblages, is also documented in the qualitative and quantitative composition of the thanatocoenoses, despite the rather non-conservative sedimentary environment. Recent investigations on deep benthic assemblages (ALBERTELLI *et al.*, 1995; DI GERONIMO *et al.*, 1995) also show a very scanty presence of living organisms, notwithstanding a much more diversified thanatocoenosis. In this way we believe that environmental instability could be relatively common in the insular biotope of the Eolian Islands.

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Station	Gravel %	Sand %	Silt %	Mz Φ	Sk	σ	Kg
1A	0.73	83.23	16.04	2.87	-0.26	1.19	0.96
2A	1.79	83.32	14.88	2.82	-0.43	1.30	1.12
1B	0	100	0	2.26	0.12	0.92	0.95
3B	16.01	83.9	0	0.72	0.28	1.77	0.86

Table 2. Main granulometric data.

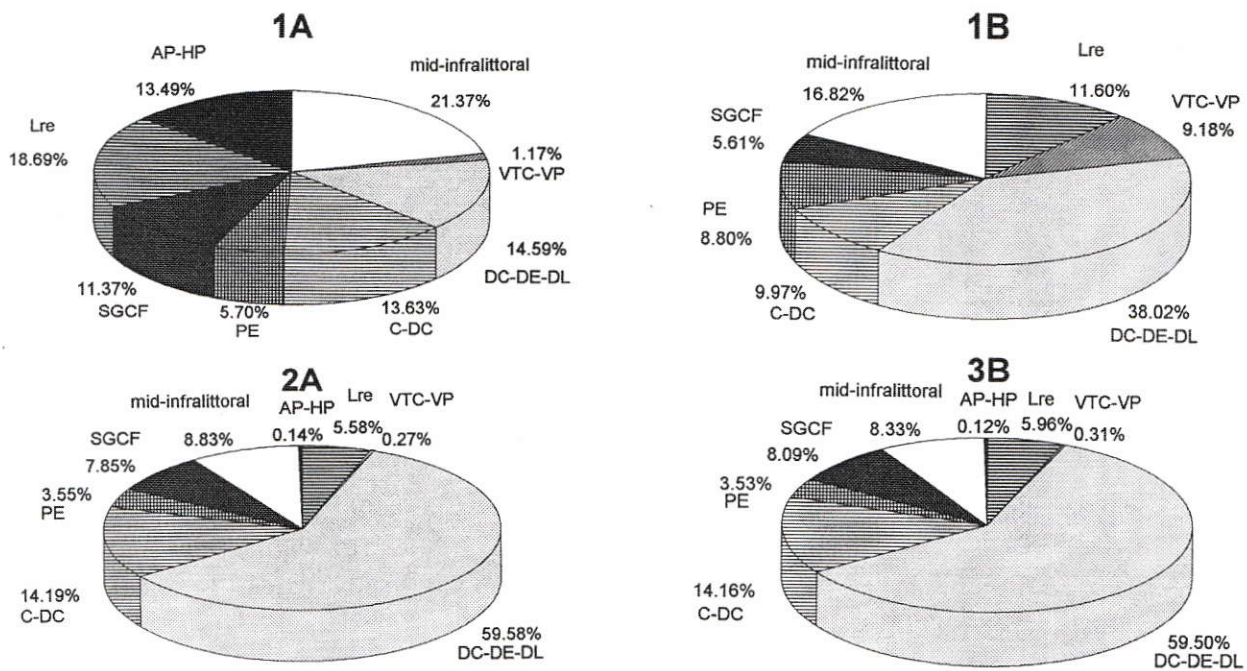


Figure 2. Diagrams of biocoenotic stocks in mollusc taxocoenoses.

Station	1A		2A		1B		3B	
	Abb	Dom	Abb	Dom	Abb	Dom	Abb	Dom
<i>Turritella communis</i> RISSO					1	4		
<i>Caecum trachea</i> (MONTAGU)							1	3:23
<i>Bittium reticulatum</i> (DA COSTA)							1	3:23
<i>Calyptrea chinensis</i> (L.)							5	16.13
<i>Natica (Tectonatica) filosa</i> PHILIPPI	12	28.57						
<i>Cylichna cylindracea</i> (PENNANT)	1	2:38						
<i>Roxania utriculus</i> (BROCCHI)			1	4				
<i>Nuculana (Lembulus) pella</i> (L.)			3	12	1	20	2	6:45
<i>Glycymeris glycymeris</i> (L.)							1	3:23
<i>Neopycnodonte cochlear</i> (POLI)							1	3:23
<i>Lucinella divaricata</i> (L.)			1	4				
<i>Myrtea (M.) spinifera</i> (MONTAGU)							1	3:23
<i>Laptaxinus subovatus</i> (JEFFREYS)	1	2:38						
<i>Diplodonta rotundata</i> (MONTAGU)			1	4				
<i>Pteromeris (Coripia) minuta</i> (SCACCHI)	13	30.95					7	22.58
<i>Digitaria digitata</i> (L.)	2	4.76						
<i>Astarte fusca</i> (POLI)			1	4			1	3:23
<i>Gonilia calliglypta</i> (DALL)							4	13
<i>Goodallia triangularis</i> (MONTAGU)	3	7.14				1	20	
<i>Parvicardium minimum</i> (PHILIPPI)			1	4				
<i>Tellina (Moerella) donacina</i> L.			1	4				
<i>Tellina (Moerella) pygmaea</i> LOVEN	4		9.52				3	9.68
<i>Psammobia (P.) fervensis</i> (GMELIN)	1	2:38	1	4				
<i>Abra (A.) prismatica</i> (MONTAGU)	1	2:38	1	4	3	60	1	3:23
<i>Clausinella fasciata</i> (DA COSTA)							1	3:23
<i>Timoclea ovata</i> (PENNANT)			4	16			1	3:23
<i>Gouldia minima</i> (MONTAGU)			1	4				
<i>Callista chione</i> (L.)	1	2:38						
<i>Corbula (Varicorbula) gibba</i> (OLIVI)			8	32			1	3:23
<i>Thracia (T.) villosiuscula</i> (MC GILLIWRAY)	2	4.76						
<i>Lyonsia (L.) norvegica</i> (GMELIN)	1	2:38						

Table 3. Mollusc taxocoenoses abundance and dominance values.



Station	SFBC	SGCF	PE	DC	DC-DE-DL	VTC	Lre
1A	0	49.99	28.57	12	0.00	2:38	7.14
2A	4	0	44	24	16	8	4
1B	0	0	20	80	0	0	0
3B	0	45.17	9.68	16.14	3:23	0	22.59

Table 4. Biocoenotic stocks in mollusc taxocoenoses.

Station	1A		2A		1B		3B	
	Abb	Dom	Abb	Dom	Abb	Dom	Abb	Dom
Species and related biocoenotic stocks								
SGCF								
<i>Gonilia calliglypta</i> (DALL)	3	0.12	63	4.16	5	2:16	68	4.02
<i>Tellina (Moerella) pygmaea</i> LOVEN	167	6.45	30	1.98	-	-	31	1.83
<i>Psammobia (Psammobella) costulata</i> TURTON	38	1.47	14	0.93	-	-	16	0.95
<i>Pteromeris (Coripia) minuta</i> (SCACCHI)	19	0.73	-	-	-	-	48	2.84
PE								
<i>Corbula (Varicorbula) gibba</i> (OLIVI)	96	3.71	17	1.12	8	3:45	20	1.18
<i>Nuculana (Lembulus) pella</i> (L.)	18	0.69	25	1.65	7	3:02	26	1.54
<i>Tellina (Tellinella) distorta</i> POLI	11	0.42	-	-	3	1:29	1	0.06
DC								
<i>Tellina (Moerella) donacina</i> L.	160	6.18	30	1.98	9	3:88	31	1.83
<i>Goodallia triangularis</i> (MONTAGU)	218	8.42	48	3.17	2	0:86	25	1:48
<i>Limatula subauriculata</i> (MONTAGU)	48	1.85	99	6.54	-	-	105	6.20
<i>Limatula gwyni</i> (SYKES)	10	0.39	6	0.04	6	2:56	15	0.89
<i>Plagiocardium (Papillocardium) papillosum</i> (POLI)	12	0.46	5	0.33	3	1:29	5	0.30
DC-DE-DL								
<i>Jujubinus montagui</i> (W. WOOD)	-	-	22	1.45	2	0:86	24	1:42
<i>Timoclea ovata</i> (PENNANT)	101	4	681	45.01	87	37.5	729	43.06
<i>Cerithidium submammillatum</i> (DE RAYNEVAL & PONZI)	137	5.29	185	12.23	5	2:16	225	13.29
<i>Hyalopecten (Similpecten) similis</i> (LASKEY)	35	1.35	22	1.45	3	1:29	23	1.36
<i>Glans (Centrocardita) aculeata</i> (POLI)	71	2.74	2	0.13	-	-	3	0.18
VTC-VP								
<i>Yoldiella philippiana</i> (NYST)	1	0.04	-	-	3	1:29	-	-
<i>Kelliella abyssicola</i> (FORBES)	-	-	-	-	4	1:72	-	-
<i>Alvania (A.) testae</i> (ARADAS e MAGGIORE)	-	-	-	-	3	1:29	-	-

Table 5. Main species of mollusc thanatocoenoses (abundance and dominance values).



The Molluscan assemblage of the leaf stratum in a *Cymodocea nodosa* bed of a marine coastal lagoon

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KEY WORDS: Mollusc, *Cymodocea nodosa*, Marine lagoon, Mediterranean.

ABSTRACT The malacofauna of the leaf stratum in a *Cymodocea nodosa* bed in the "Stagnone di Marsala" lagoon (Western Sicily) has been used as an ecological descriptor of this coastal system. The results indicate a relative temporal homogeneity in the assemblage, with a few differences due to the demographic explosions of Rissoids during the spring. The distribution of the species in the basin is related to a particular hydrodynamic gradient caused by surface currents.

RIASSUNTO La malacofauna di strato foliare di una prateria di *Cymodocea nodosa* in una laguna mediterranea. Viene descritta la distribuzione del popolamento a molluschi di strato foliare di una prateria a *Cymodocea nodosa* dello Stagnone di Marsala (Sicilia occidentale). Questo studio si inserisce nel tentativo di inquadrare il popolamento a molluschi dello Stagnone nell'ambito di uno schema zonale, individuando i fattori che ne governano la strutturazione. Dai risultati emerge che il popolamento a molluschi rimane piuttosto stabile nel tempo, anche se la stagionalità sembra influenzare le abbondanze di alcune specie di Rissoidi. La malacofauna mostra, infine, una buona correlazione con il modello idrodinamico dell'area studiata, senza apprezzabili differenze tra le diverse stazioni legate a fenomeni di confinamento.

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INTRODUCTION

Numerous studies have been carried out on the malacofauna of the foliar stratum of *Posidonia oceanica* beds (e.g. RUSSO *et al.*, 1984a, 1984b, 1991a, 1991b) with the aim of describing the structure of the assemblages during the annual cycle or during their diel variations, while less is known about the molluscs associated with the other Mediterranean phanerogam, *Cymodocea nodosa* (Ucria) Aschers (SCOTTI *et al.*, 1995).

This small marine plant lives on sandy and sandy-muddy bottoms both in lagoon and open-sea habitats. Bionomically it belongs to the SVMC biocoenosis (muddy bottoms in calm waters) of the PÉRÈS & PICARD (1964) system and can form dense plots called "turf" (BUIA *et al.*, 1985), of wover rhizomes and sediment. In the "Stagnone di Marsala", a shallow marine lagoon along the western coast of Sicily, *Cymodocea nodosa* prairies cover about 70% of the sea bottom (CALVO *et al.*, 1980; 1982), either in a pure facies or in a mixed assemblage with *Caulerpa prolifera* or *Zostera noltii*.

Regarding the malacofauna of this basin, a number of studies have recently been carried out describing the taxonomic composition of this *taxon* (CATTANEO-VIETTI & CHEMELLO, 1992; CHEMELLO & RIGGIO, 1991a, 1991b). The relationships between molluscan communities and nature conservation have also been examined (TUMBILOLO *et al.*, 1992).

MATERIALS AND METHODS

Study area

The "Stagnone di Marsala" is a large marine lagoon (*sensu* MOLINIER & PICARD, 1953) which extends for 7 Km along a north-south axis off the western coast of Sicily (Fig. 1). It can be divided into two different basins: the first, more southerly,

basin has a large exchange of water with the open sea, and the second, more northerly, one has more marked lagoon characteristics and, with its shallow bottom, presents three islets and a number of superficial bioformations which regulate the hydrodynamic pattern.

The bottoms of the northern basin are mainly sandy and sandy-muddy (AGNESI *et al.*, 1993) and are covered by dense meadows of *Cymodocea nodosa*. Hard calcarenitic bottoms are relatively scarce. *Posidonia oceanica* meadows also appear in the southern part of the basin with singular "recif" and "atoll" formations (CALVO & FRADÀ-ORESTANO, 1984).

Hydrological exchange with the open sea occurs through two mouths of different widths which produce a particular current scheme characterized by oscillating and whirling motions. According to a theoretical model (DI PISA & RIGGIO, 1982), water circulation can be linked to a laminar flux regulated by the tides and winds, above all those coming from the north and north-west (Fig. 2).

Sampling techniques

Sampling was performed during one year in 6 stations (Fig. 1), along a hypothetical N-S and E-W hydrodynamic gradient. The samples were collected seasonally on *Cymodocea nodosa* meadows with a percent age cover of about 100% of the total surface, using a standard hand-towed net (RUSSO *et al.*, 1986; RUSSO & VINCI, 1991) on a 20m length transect. This distance was obtained from the rarefaction curve of the area/species ratio (Fig. 3).

Data analysis

The raw data were inserted in a sample/species matrix. Descriptive analysis was performed by considering the quantitative dominance of species (1-D), the Shannon index of diversity (H')

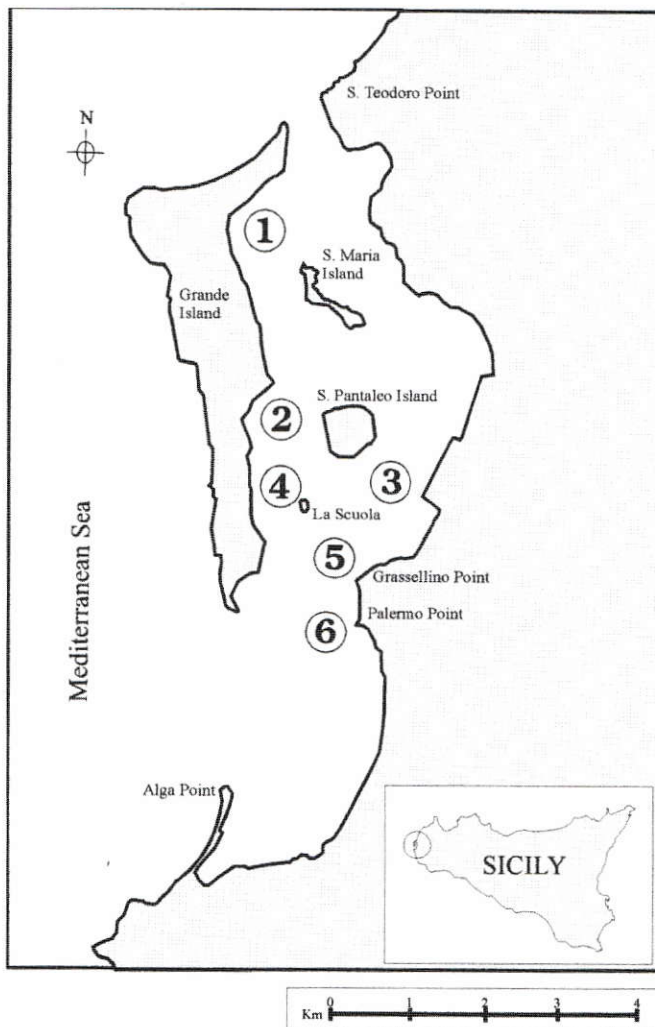


Figure 1. The Stagnone di Marsala lagoon with the stations of sampling (1-6).

and the evenness (J) for each sample; the Dajoz index of frequency ($Fr\%$) and the Glemarec index of total dominance ($Dt\%$) were calculated for each species. The first index (DAJOZ, 1971) separates the species into frequency classes: the *taxa* with a frequency of occurrence $100 > Fr\% > 76$ are defined as "constant"; the species with $75 > Fr\% > 51$ are considered "very common"; with $50 > Fr\% > 26$ area "common" and with $25 > Fr\% > 12$ "less common". Finally, the species with $Fr\% < 12$ are defined as "rare".

Prior to carrying out the structural analyses, the "rare" species were excluded from the matrix. "Rare species" were considered those present only once with one individual. *Pusillina* spp. juv and *Rissoa* spp. juv were also excluded as these *taxa* were composed of species which in practice were undistinguishable from each other.

Structural analysis, based on the time series of samples, was performed by cluster analysis using the Jaccard index on a presence/absence matrix while the χ^2 index was applied on the semi-quantitative data matrix (PIELOU, 1984). Both matrices were clustered using the UPGMA technique. Multivariate correspondence analysis (BENZECRÌ, 1973; LEGENDRE & LEGENDRE,

1971) was carried out to determine structure, and the significance of the axes was tested using the method of FRONTIER (1976).

RESULTS AND DISCUSSION

A total of 17466 individuals belonging to 53 species of foliar stratum were found. The dominant *taxa* were the Gastropods, with 52 species, and the Bivalves, which were present with only one species, *Parvicardium exiguum*, associated with the lower part of *Cymodocea nodosa* leaves. Among the gastropods, Naerotaenioglossa was the dominant order, with the 35.8% of the total number of species, followed by Neogastropoda (24.5%), Heterostropha (13.2%) and Vetigastropoda with 11.3%. All the other orders together reached only 15.1% (Fig. 4).

Using the constancy index of Dajoz (Tab. 1a), only 13 species were considered "constant", with a high frequency of occurrence in the assemblage: *Tricolia speciosa*, *Granulina occulta*, *Pusillina dolium*, *Columbella rustica*, *Pusillina marginata*, *Vexillum tricolor*, *Ocenebrina aciculata*, *Retusa truncatula*, *Rissoa paradoxa*, *Nassarius costulatus*, *Haminoea hydatis* and *Parvicardium exiguum*. A second group was composed of *Conus mediterraneus*, *Gibbula ardens*, *Cerithium vulgatum* and *Rissoa similis*, all "very common" species in the assemblage. *Vexillum ebenus*, *Alvania cimex*, *Haminoea* sp., *Pisinnia glabrata*, *Chrysallida nanodea*, *Alvania pagodula*, *Tragula fenestrata* were "common". The other *taxa* did not reach significant constancy values and 20 were "rare" species.

The highest value of total dominance (Tab. 1b), according to

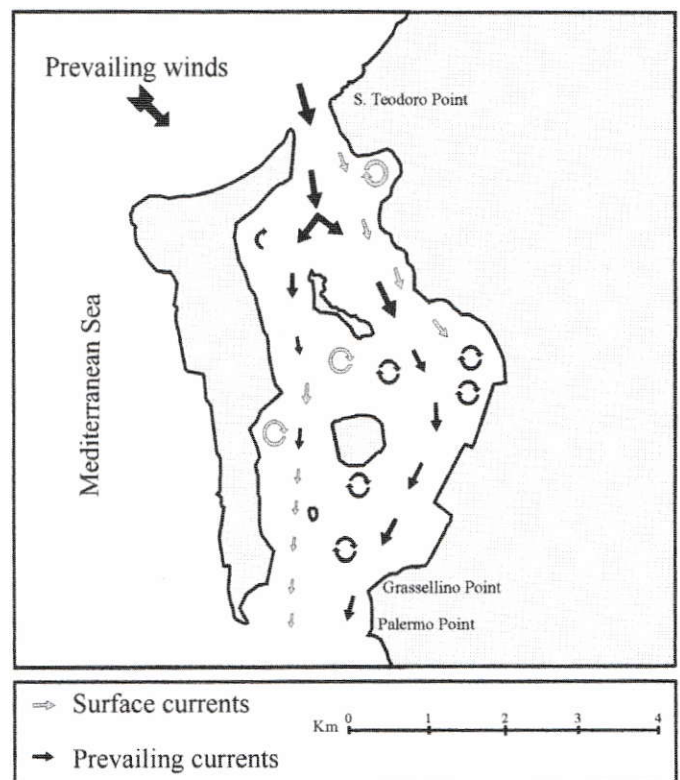


Figure 2. The hydrodynamic model of surface currents (from DI PISA & RIGGIO, 1982, slightly modified).

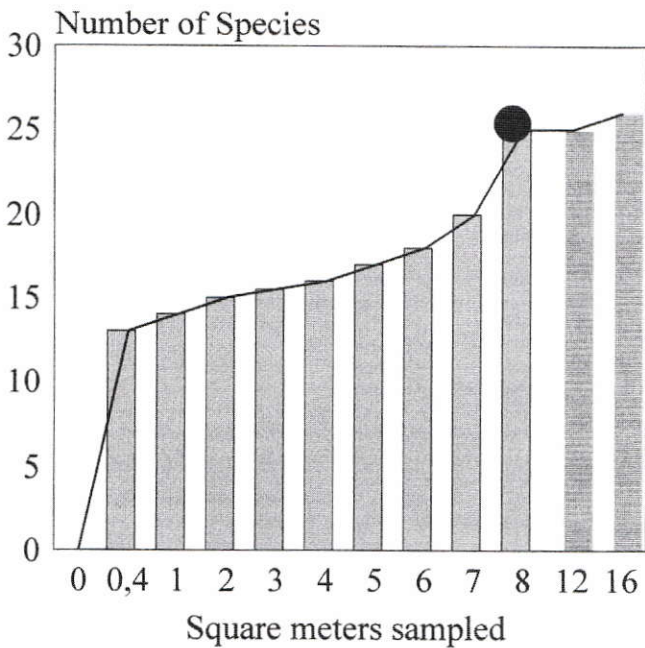


Figure 3. Rarefaction curve of sampling area/number of species ratio.

the Glemarec index, was obtained by *Pusillina marginata*, followed, with a lower value, by *Granulina occulta*, *Pusillina dolium* and *Tricolia speciosa*.

Seasonality biased the relative abundances of some species, above all *Pusillina marginata* and *P. dolium*, which were the dominant species during spring and summer, *Gibbula ardens*, which was dominant in the spring and summer samples of station 1, and *Setia turriculata*, present only in the spring sample of station 1.

Plots of the seasonal values of H'-J and D-E (Fig. 5-6) indicate an overall homogeneity during the year, with a constant decrease between summer and winter in the samples in which the low diversity is due to the high specific dominance of a small number of species present with a large number of individuals.

The cluster analysis on the presence/absence matrix, carried out using the similarity index of Jaccard, shows a homogeneous

group of samples without marked differences in composition (Fig. 7). The second cluster analysis on quantitative data, using 2, separates samples of the station 1 from the other stations (Fig. 8).

The FAC on qualitative data (Fig. 9) presents only one significant axis (explained variance = 14.2% of the total). The distribution of the sample-points in the F1-F2 plane is similar to that in the graphic model called "circular cloud" proposed by FRESI & GAMBÌ (1982) and testifies to the homogeneity of the assemblage, due to the species composition.

The FAC on quantitative data (F1= 32.7%, F2= 18.8%, F3= 12.1% of the total variance) ordonates the sample-points in three separate groups in the F1-F2 plane (Fig. 10a): the first includes all the samples of station 1; the second gathers together all the spring samples (2P, 3P, 4P, 5P, 6P); the third group assembles all the remaining samples. On the F1-F3 plane (Fig. 10b) only the samples of station 1 are separated from the others, while 3I and 5I clusterize separately.

In this tridimensional system, the F1-axis can be interpreted as an open-sea-inner lagoon gradient while the F2 axis is probably a seasonal gradient due to the rearrangement of specific abundances more than to a change in the species composition of the assemblage. The F3-axis is more complex to identify.

To highlight the development of the principal gradient, the barycentres of the sample-points were projected on the F1 axis (Fig. 11 above). This arrangement indicates a marked polarization in the negative part of the first axis of the samples collected from stations 2-6. This is due to the high variance inherent to station 1 very different in composition to the others. This station can be, in fact, considered "open-sea"-like due to its position near the northern mouth, in a more vivified area. This model separates two sub-basins, the first, more northerly, and the second in the central area, distinguished by their different hydrodynamic conditions (MAZZOLA & SARÀ, 1995). The hydrodynamic pattern of the surface currents seems again to be the principal factor conditioning the distribution of the species.

In order to show these differences in species distribution or their belonging to one or more assemblages, the barycentres with the species-points were reported on the F1 axis, in comparison of

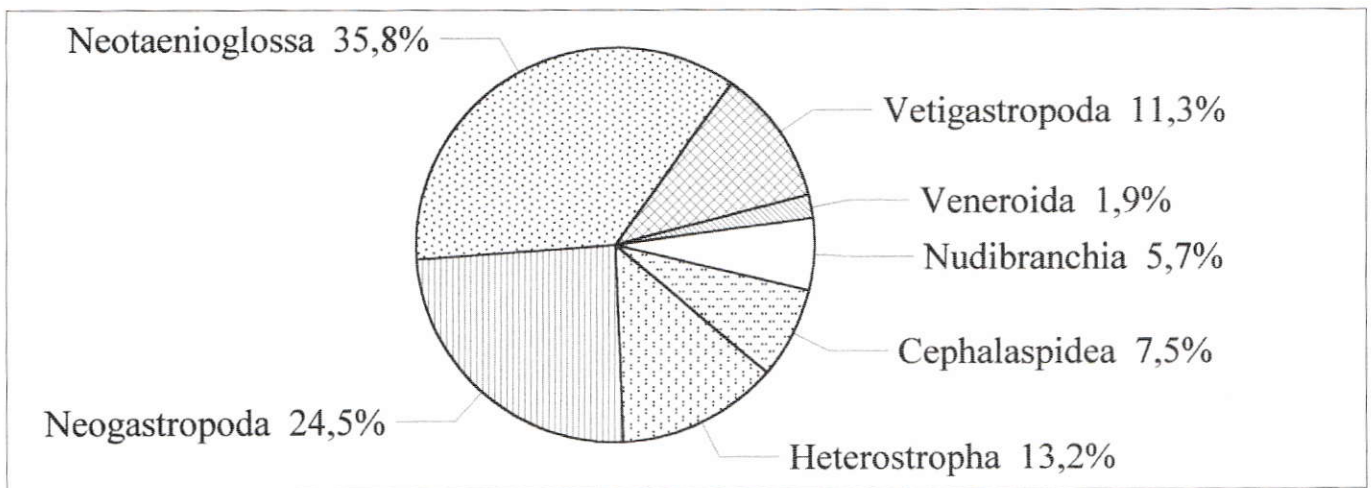


Figure 4. Distribution of the sampled species in orders.

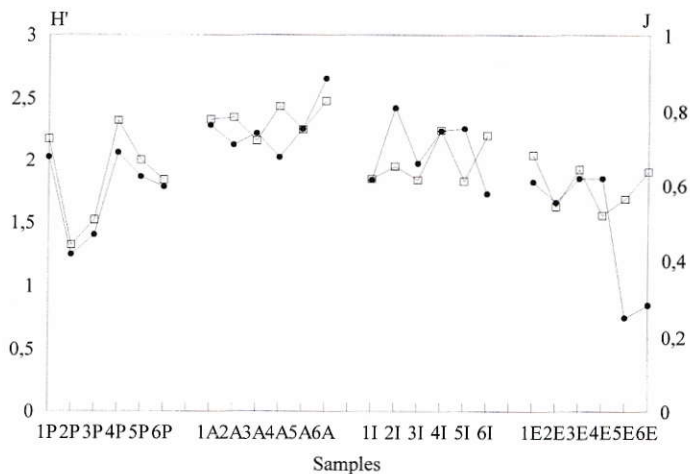


Figure 5. Shannon-Wiener diversity indices and their evenness.

The open quadrats mean the values of the Shannon index while the black dots mean the relative values of the evenness.

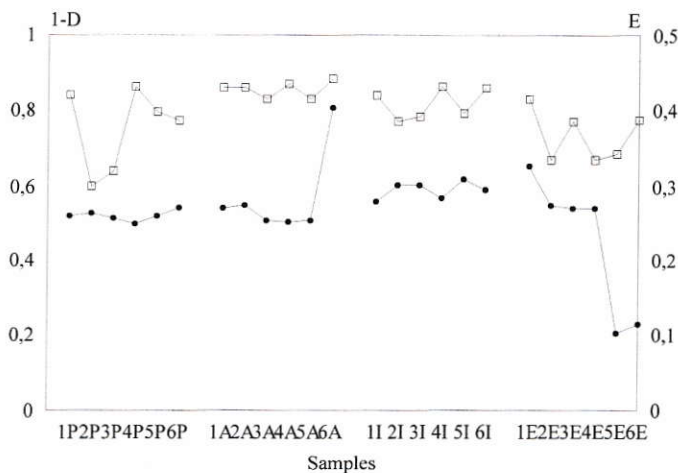


Figure 6. Simpson diversity indices and their evenness.

The open quadrats mean the values of the Simpson index while the black dots mean the relative values of the evenness.

the distribution of the sample-points (Fig. 11, below). Three different groups of species are evidenced: the first is related to the single 1P sample in which some exclusive species are present. The second cluster collects the samples 1E-1A-1I and the third cluster all the remaining samples. The strong polarization of this third group of samples is partially due to a bias in the ordination technique that gives more weight to the species- or sample-points which explain the major part of the system variance. The species further away from the origin of the axes are the exclusive or dominant species in single samples and these can be related to seasonality or, better, to the development of the predominant factor.

The species belonging to the first group are: *Setia turriculata*, *Gibbula ardens*, *Peringiella elegans*, *Dikoleps nitens* and *Barleeria unifasciata*, strictly associated with the *Cymodocea nodosa* prairie

of sample 1P. The second group is composed of: *Bittium latreillii*, *Hexaplex trunculus*, *Vexillum tricolor*, *Haminoea hydatis*, *Cerithium vulgatum*, *Nassarius costulatus*, *Ocenebrina aciculata*, *Tricolia speciosa*. All these species are present in more or less all the samples and constitute the "fundamental group" of species associated with the leaf stratum in this area. The third cluster assembles all the species living in the inner part of the Stagnone, present during the year with low abundances and without demographic explosions. The continuity among groups and the low values of scores do not allow the recognition of more than one assemblage.

CONCLUSIONS

The model of distribution obtained from the malacofauna of the *Cymodocea nodosa* leaf stratum in the Stagnone shows a species zonation mainly related to the hydrodynamic pattern (Fig. 12), hence to an inverse gradient of "vivification" (SACCHI, 1959) or "marinization" (ZAOUALI & BAETEN, 1983) from the northern mouth to the inner part. The assemblage of station 1 differs throughout from that of the other stations and presents a high number of species more akin to the open-sea assemblage, like *Gibbula ardens* e *Setia turriculata*.

The inner area of the Stagnone presents an annually-stable malacofauna, composed of marine species which are well adapted to a more lagoon-like environment (TUMBIOLO *et al.*, 1991). This assemblage, annually homogeneous in its species composition, presents a reduced temporal drift due solely to the spring demographic explosions of *Pusillina marginata* and *P. dolium*.

The faunistic coenocline presented by other lagoons, which is characterized by the progressive exclusion of marine taxa (GRAVINA *et al.*, 1988), is less evident in the Stagnone of Marsala. In particular, the peculiar morphological structure of the basin and its wide relationship with the open sea do not allow the formation of a paralic assemblage *sensu stricto* but of a malacofauna quite reophilous in the northern part and quite galenophilous in the inner part, respecting the general scheme suggested by BIANCHI (1985; 1988).

The hydrodynamic model proposed by DI PISA & RIGGIO (1982) and reviewed by MAZZOLA & SARÀ (1995) seems to be confirmed by the distribution pattern of the malacofauna of the foliar stratum.

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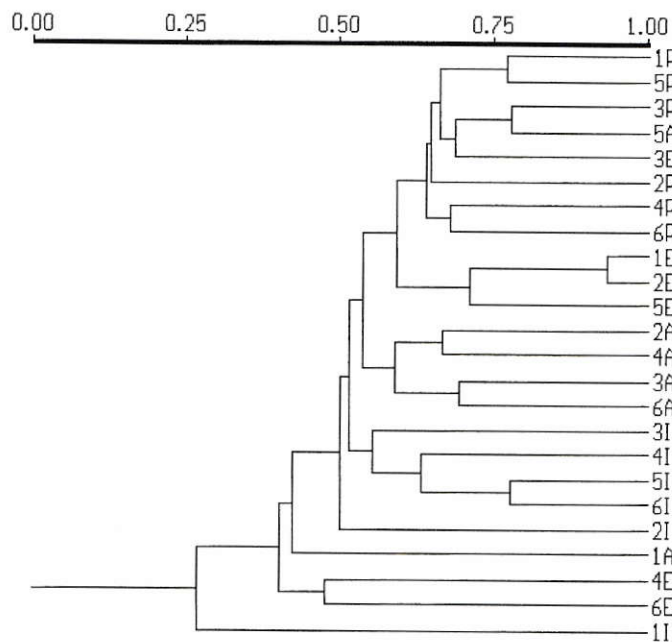


Figure 7. Dendrogram of the samplings, using Jaccard index and UPGMA clustering method.

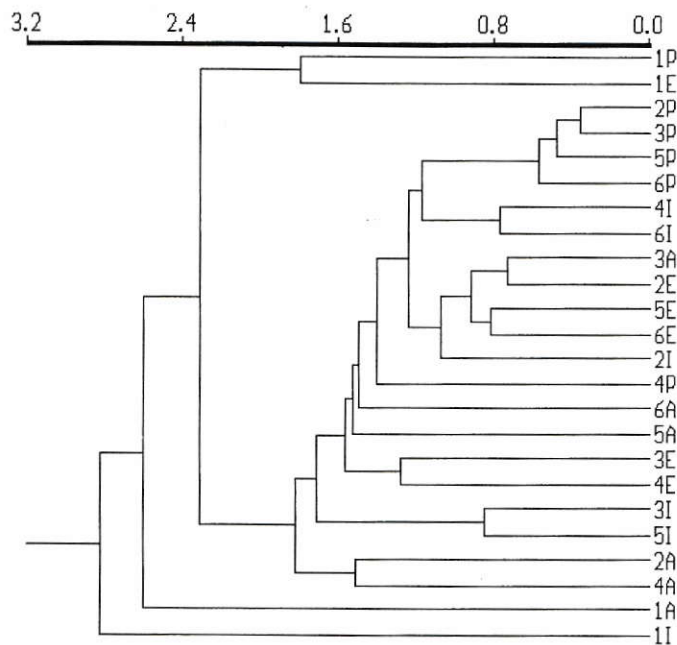


Figure 8. Dendrogram of the samplings, using χ^2 index and UPGMA clustering method.

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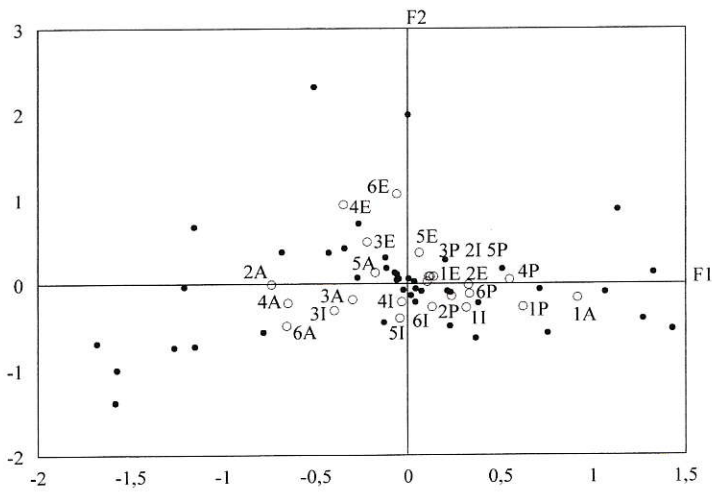


Figure 9. Factorial Correspondence Analysis on the presence/absence data.

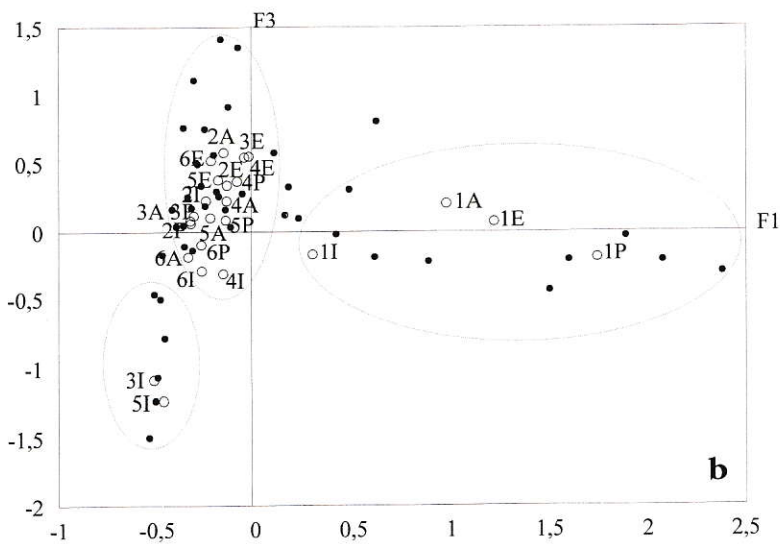
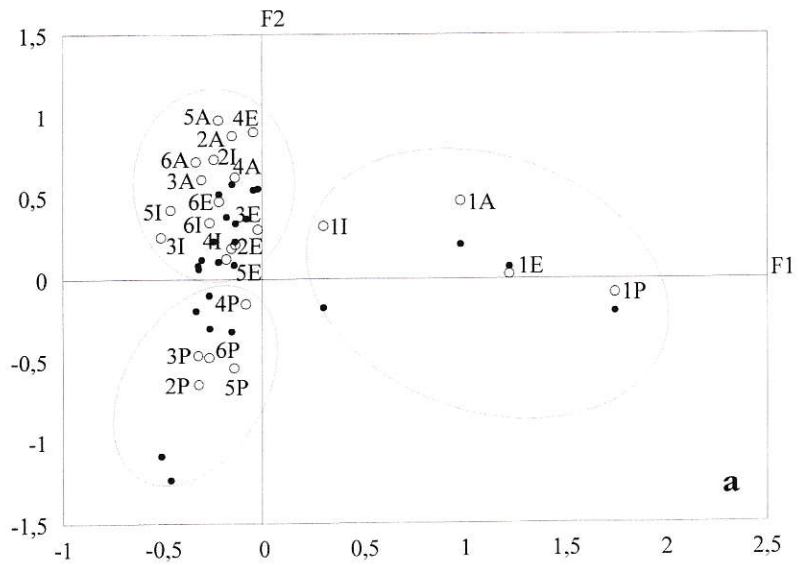


Figure 10a-b. Factorial Correspondence Analysis on the abundance data.

Fig. 10a is relative to the F1-F2 axis plan while

Fig. 10b th the F1-F3 axis plan.



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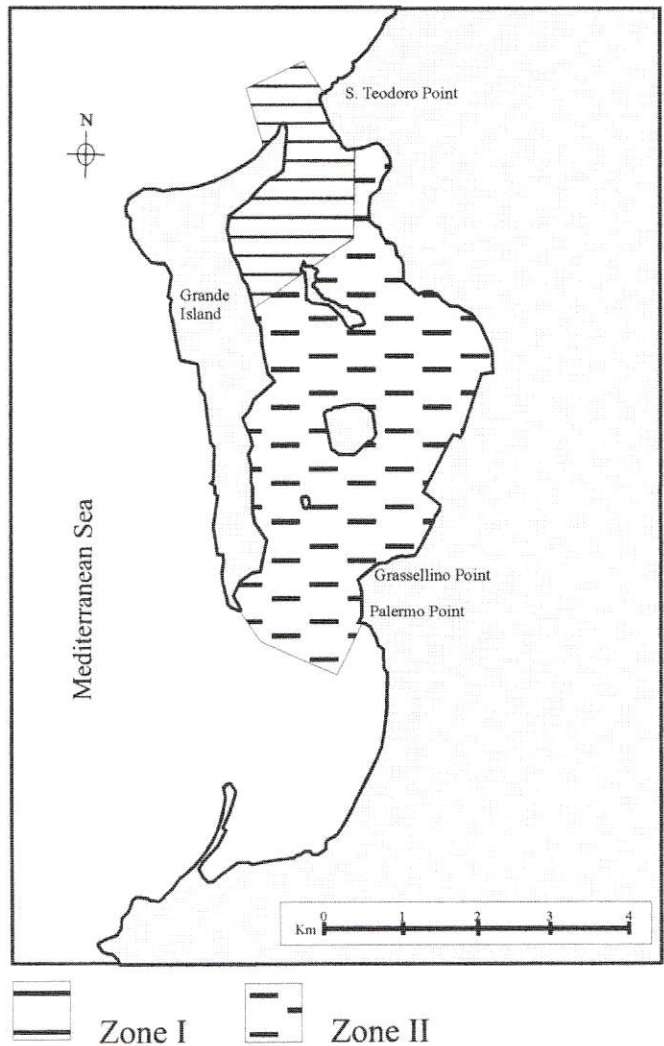


Figure 12. Model of the species distribution.

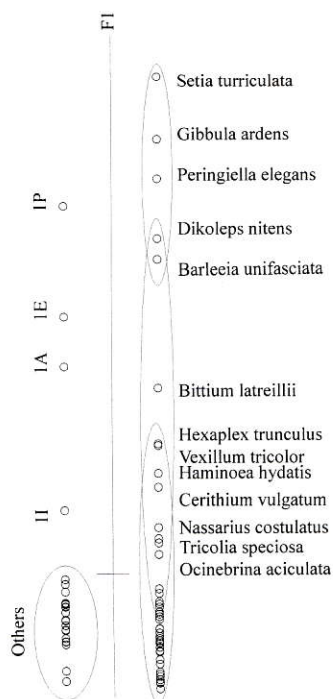


Figure 11. Barycentres of the species and the samples plotted on F1 axis.



	Fr%
Tricolia speciosa	100
Pusillina dolium	95,83
Columbella rustica	95,83
Granulina occulta	95,83
Pusillina marginata	91,67
Ocinebrina aciculata	91,67
Vexillum tricolor	91,67
Rissoa paradoxa	87,5
Retusa truncatula	87,5
Nassarius costulatus	83,33
Haminoea hydatis	83,33
Parvicardium exiguum	79,17
Conus mediterraneus	66,67
Gibbula ardens	62,5
Cerithium vulgatum	62,5
Rissoa similis	54,17
Vexillum ebenus	50
Alvania cimex	45,83
Haminoea sp.	45,83
Pisinna glabrata	41,67
Chrysallida nanodea	37,5
Alvania pagodula	33,33
Tragula fenestrata	29,17
Dikoleps nitens	25
Bittium latreillii	25
Barleeia unifasciata	25
Rissoella globularis	25
Odostomia plicata	25
Chrysallida sp juv	20,83
Peringiella elegans	16,67
Odostomia sp juv	16,67
Setia turriculata	12,5
Nodulus contortus	12,5
Hexaplex trunculus	12,5
Runcina sp.	12,5
Pollia scabra	8,333
Gibberula philippii	8,333
Raphitoma purpurea	8,333
Anisocycla pointeli	8,333
Hypselodoris messinensis	8,333
Polycera dubia	8,333
Sinezona cingulata	4,167
Calliostoma laugieri	4,167
Jujubinus striatus	4,167
Pirenella conica	4,167
Rissoa sp.	4,167
Alvania discors	4,167
Truncatella subcylindrica	4,167
Nassarius corniculus	4,167
Mangelia costulata	4,167
Aeolidiidae ind.	4,167

	Dt%
Pusillina marginata	27,42
Granulina occulta	14,72
Pusillina dolium	13,85
Tricolia speciosa	13,42
Gibbula ardens	5,495
Retusa truncatula	4,598
Vexillum tricolor	2,854
Columbella rustica	2,265
Nassarius costulatus	2,092
Setia turriculata	1,485
Rissoa paradoxa	1,446
Haminoea hydatis	1,35
Cerithium vulgatum	1,253
Conus mediterraneus	0,819
Parvicardium exiguum	0,771
Alvania cimex	0,684
Ocinebrina aciculata	0,665
Rissoa similis	0,588
Odostomia plicata	0,588
Odostomia sp juv	0,366
Dikoleps nitens	0,357
Haminoea sp.	0,337
Peringiella elegans	0,299
Vexillum ebenus	0,251
Pisinna glabrata	0,241
Chrysallida nanodea	0,241
Alvania pagodula	0,231
Runcina sp.	0,222
Barleeia unifasciata	0,193
Tragula fenestrata	0,164
Chrysallida sp juv	0,135
Rissoella globularis	0,116
Bittium latreillii	0,087
Alvania discors	0,067
Nodulus contortus	0,048
Hexaplex trunculus	0,039
Gibberula philippii	0,029
Raphitoma purpurea	0,029
Sinezona cingulata	0,019
Pollia scabra	0,019
Mangelia costulata	0,019
Anisocycla pointeli	0,019
Hypselodoris messinensis	0,019
Polycera dubia	0,019
Calliostoma laugieri	0,01
Jujubinus striatus	0,01
Pirenella conica	0,01
Rissoa sp.	0,01
Truncatella subcylindrica	0,01
Nassarius corniculus	0,01
Aeolidiidae ind.	0,01

Table 1a. Frequency of occurrence for each species, according to the Dajoz Index. Table 1b. Total dominance for each species, according to the Glemarec Index.



The molluscan taxocoene of differently-exposed *Cymodocea nodosa* beds: year-long structural patterns and sampling methods

Antonio Terlizzi & Giovanni Fulvio Russo

KEY WORDS: Molluscs, Community structure, Sampling methods, Seagrass ecology.

ABSTRACT The structural changes during one year in the mollusc taxocoene living in two differently-exposed *Cymodocea nodosa* beds of the island of Ischia (Gulf of Naples - Italy) are discussed. The efficiency of two sampling devices, the hand-towed net and the suction sampler, is also compared. Higher values of abundance and species richness are recorded throughout the year in the sheltered bed, which is characterized by a well-developed turf and a high density of shoots. In both beds, year-long trends of basic community parameters show maxima during the summer and minima during the winter, as the does density of plant cover. The suction-sampler collects more species and more individuals, although it covers a smaller surface than the hand-net. This device is also more effective at sampling molluscs from both the leaves and the sediment at the base of the plant, while the hand-net collects almost exclusively the malacofauna living on the leaf stratum. From a bionomic point of view, the *Cymodocea* system seems to be more than a simple *facies* of one of the coenotic units with which it has been associated.

RIASSUNTO Vengono discussi i dati relativi alla distribuzione ed alla composizione della componente malacologica di due siti limitrofi dell'isola d'Ischia caratterizzati da praterie di *Cymodocea nodosa* differenziate strutturate. I campionamenti sono stati effettuati tra l'estate del 1988 e quella del 1989, con cadenza bimestrale ed utilizzando due differenti attrezzi di campionamento, il retino manovrato a mano e la sorbona. Il contributo maggiore, sia in termini quantitativi che qualitativi, è stato fornito dai campioni di sorbona con il 79% del totale degli individui, appartenenti a 38 specie. La differenza tra le strutture dei popolamenti delle due stazioni considerate è piuttosto marcata. In particolare, indipendentemente dai metodi di campionamento adottati, la stazione con il prato a maggiore densità risulta essere caratterizzata da un numero sia di specie che di individui di gran lunga maggiore rispetto all'altra. Il trend stagionale è piuttosto evidente in entrambi i siti, con valori massimi di abbondanza e ricchezza specifica durante il periodo estivo e valori minimi in inverno. Tale andamento generale è evidente soprattutto nei campioni di retino e, in particolare, in quelli del prato meno denso, in cui è minore la presenza di specie tipiche del substrato e, quindi, il taxocene risulta dipendere maggiormente dalla densità dello strato foliare, molto variabile durante l'anno. I dati ottenuti sembrano suggerire una maggiore efficienza della sorbona, che campiona ugualmente bene sia lo strato foliare sia il substrato alla base delle piante. Tuttavia, soprattutto in estate, con il massimo sviluppo dello strato foliare, il campionamento con retino, particolarmente efficiente per questo strato, potrebbe fornire informazioni complementari sulla struttura complessiva dell'associazione malacologica.

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INTRODUCTION

Along the coast of the Mediterranean Sea, *Cymodocea nodosa* (Ucria) Aschers. is the most common and widespread seagrass, together with *Posidonia oceanica* (L.) Delile. The former generally occurs in shallow (not more than 5-6 m deep) sandy-muddy bottoms, characterized by sheltered conditions, as in the case of closed bays, ports and lagoons. However, *Cymodocea* beds have recently also been reported along open coasts, but on bottoms of greater depth (from 5 to about 20m deep) (BUIA *et al.* 1985a; GIANGRANDE & GAMBI, 1986).

The rhizomes and the root system of *Cymodocea* form a complex interlaced structure called 'turf'. This structure stabilizes the soft bottom and is well developed in sheltered conditions, where it may be over 20 cm thick (BUIA *et al.*, 1985b) lying a few centimeters under the surface of the sediment (Fig. 1).

Early studies considered the *Cymodocea* bed to be a seral stage of succession, as it is thought that it prepares the soft bottom

for colonization by the *Posidonia* prairie, which represents the *climax* ecosystem in the coastal areas of the Mediterranean (MOLINIER & PICARD, 1952; DEN HARTOG, 1977). However, recent evidence seems to support the theory that the two seagrasses are independent as concerns substrate colonization (BOUDOURESQUE *et al.*, 1989). Likewise, contrasting opinions have been put forward regarding the benthic fauna associated with *Cymodocea nodosa* plants. There are doubts as to whether these associations of organisms have a coenotic identity or whether they are simply *facies* of other biocoenoses. Some authors (e.g. PÉRÈS & PICARD, 1964) consider the animal associations occurring on soft bottoms covered by *Cymodocea* as just "*facies a épiflore*" of the coenotic unit of 'well-sorted fine sands' (French acronym, SFBC). On the other hand, LEDOYER (1966) emphasized that the vagile fauna living in the foliar stratum of *Cymodocea* beds give rise to what may be considered an impoverished *facies* of the *Posidonia oceanica* coenotic unit. In any case, data are

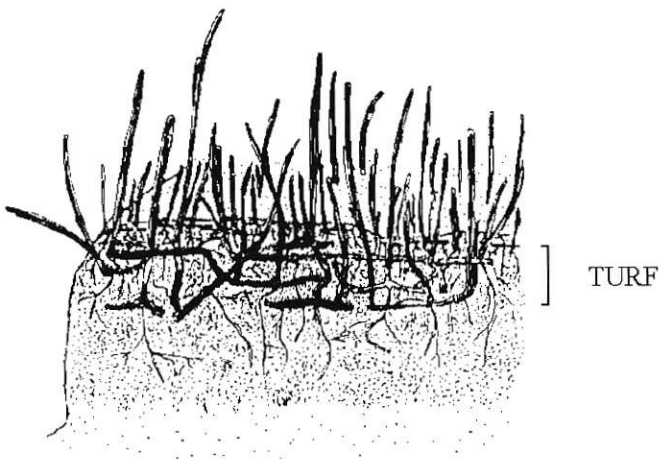


Figure 1. The Stagnone di Marsala lagoon with the stations of sampling (1-6).

rather scarce and mainly concern the variability of the association in space (DIEUZEIDE & GOEAU-BRISSENIERE, 1951; LEDOYER, 1962; 1966; 1968; HARMELIN & SCHLENZ, 1963), even though *Cymodocea* beds show a strong seasonality, in terms of growth rate and plant density (BUIA *et al.*, 1992). As regards Italian coasts, synecological studies have been conducted only for polychaetes (GIANGRANDE & GAMBÌ, 1986; LANERA & GAMBÌ, 1993; GAMBÌ & BREMEC, in press).

The methods used to sample the vagile fauna from the *Cymodocea* seagrass beds are mainly the hand towed-net and the suction-sampler (or air-lift), which are the same as those adopted for the fauna of *Posidonia*. However, unlike that dotained for the latter seagrass (e.g. RUSSO *et al.*, 1985; RUSSO & TERLIZZI, this issue), no comparative information is available on the efficiency of sampling gears in collecting the different faunistic components of *Cymodocea* beds.

The aim of the present paper is, firstly, to shed light on the structure and the year-long dynamics of the mollusc taxocene living in two differently-exposed *Cymodocea* beds and, secondly, to compare the information on the taxocoene dotained using the two sampling methods mentioned above.

METHODS

Sampling sites

Two *Cymodocea nodosa* beds facing San Pietro beach along the northern coast of the island of Ischia (Gulf of Naples) were studied (Fig. 2a). They colonize adjacent soft bottoms (at a depth range of 0.5-4.5 m) separated by a rocky artificial barrier (Fig. 2b). The presence of the barrier influences the characteristics of the two beds: one of the in station 1 was found to be very sheltered, being characterized by muddy-sandy sediments and a well developed 'turf', while the other (st. 2) is more exposed, being characterized by sandy sediments without the presence of 'turf'. In the sheltered bed (station 1) seagrass density (shoots/m²) ranges from approximately 1100 (November-May) to 2300 (July-

September), while it ranges from approximately 550 (May) to 950 (September) in the exposed bed (Figs 2 and 3). In the *Cymodocea nodosa* bed with 'turf', the co-occurrence of the seagrass *Zostera noltii* contributes to approximately 30% of the high density values for the bed (BUIA *et al.*, 1985 b).

Collecting methods and data analysis

In both sites, sampling was performed bimonthly during the course of a year (July 1988 - May 1989), at a depth of 2.5 m. Vagile fauna was collected by SCUBA divers using two different techniques: (a) a hand-towed net, over a surface of about 20 m² (RUSSO & VINCI, 1991), and (b) a suction-sampler, over a surface of 1 m² (RUSSO *et al.*, 1986).

Molluscs were sorted and identified following SABELLI *et al.* (1990). The descriptive analysis was carried out taking into account the presence of species and their relative and absolute abundances in the samples. A comparison of the results obtained using the two collection methods in the different beds allowed a preliminary evaluation of their efficiency with respect to the different mollusc species.

In order to identify coenotic patterns on a temporal scale, a structural comparison of the malacological associations was performed starting from a matrix of raw data and using the multivariate ordination technique of correspondance analysis (CA) (PIELOU, 1984). The significance of the axes was tested according to the method proposed by FRONTIER (1974).

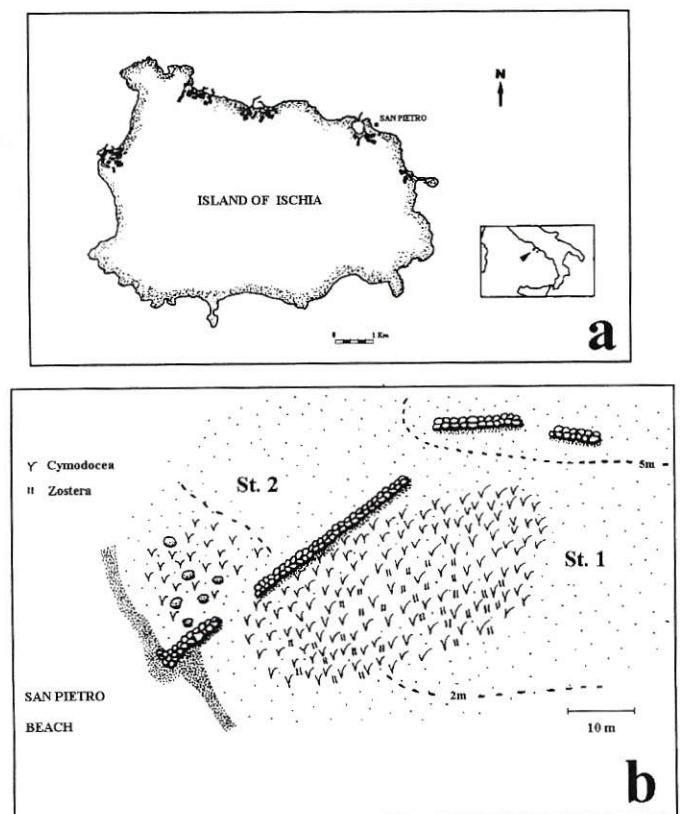


Figure 2. The hydrodynamic model of surface currents (from DI PISA & RIGGIO, 1982, slightly modified).

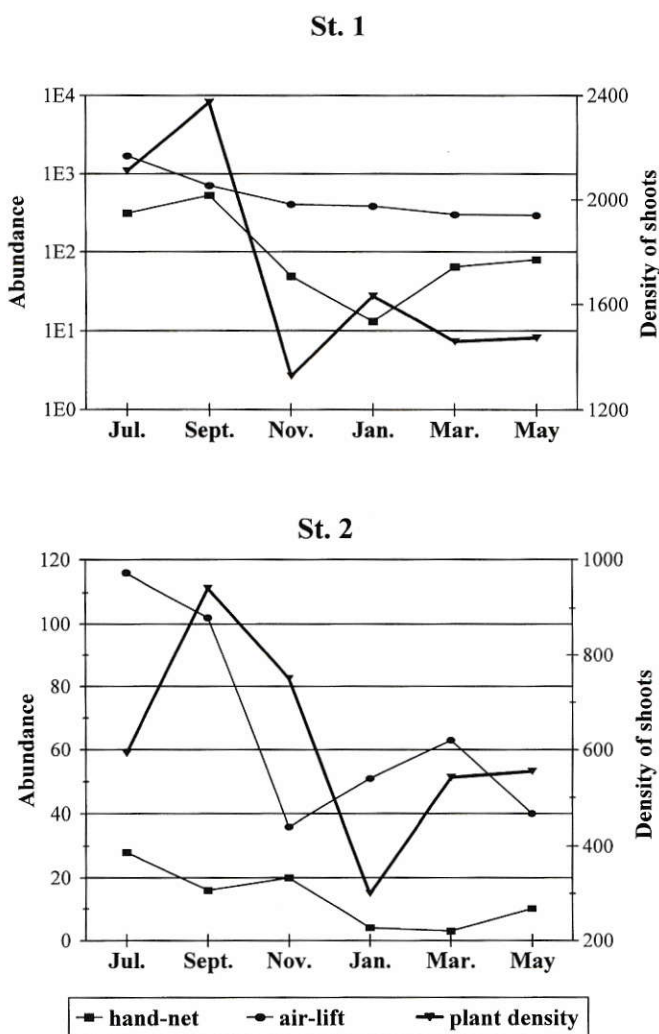


Figure 3. Rarefaction curve of sampling area/number of species ratio.

RESULTS

Descriptive analysis

Sampling yielded 5318 Mollusc individuals of, 3623 Gastropods (68%) and 1695 Bivalves (32%). Of these, 4191 (79%) were collected by suction sampler and 1127 (21%) by hand towed net. In both stations, and in every month, the air-lift collected more individuals than the net, despite the fact that the former sampled from a much smaller area (1m²) than the latter (about 20 m²) (Fig. 2).

The species with the highest abundance values were, from the gastropods, and *Bittium reticulatum* (2811; 53%) *Jujubinus gravinae* (293 ind.; 5.5%). As for the bivalves high abundance values were obtained by *Loripes lacteus* (1398; 26%).

Different time-trends of abundance values were observed in the samples collected by the two sampling methods (Fig. 3). Regarding data obtained by air-lift, in both stations the values remained quite constant during the year, with higher values during summer and a slight decrease in November. However, a

difference of one order of magnitude was found between the abundances recorded in station 1 (about 1000 individuals) and station 2 (about 100 individuals). As for the data obtained by hand-net, the values were more variable, showing a remarkable decrease during the winter. Also using the hand-net, there was a difference of one order of magnitude between the abundances recorded for station 1 (hundreds) and those recorded for station 2 (tens). The two stations reached their minimum abundance in different months: January and March.

In totals 42 species were sampled, 28 Gastropods (67%) and 14 Bivalves (33%). Of these 42 species, 19 (45%) were collected using both methods (e.g. *Bittium reticulatum*, from the gastropods, and *Loripes lacteus*, from the bivalves), 20 (48%) were exclusively present in the samples collected by air-lift (e.g. *Nassarius reticulatus*, from the gastropods, and *Tellina tenuis*, *Paphia rhomboidea* and *Chamelea gallina*, from the bivalves) and just 3 (7%) were exclusively present in the samples collected by hand-towed net (the gastropods *Tricolia speciosa*, *Rissoa variabilis* and *Rissoa violacea*). As abundance, species richness was also higher in the samples collected by air lift than in those collected by net, in both stations and in every month (except station 1 in September; cfr. Fig. 4).

In both stations, samples collected by hand-net had smaller fluctuations in species richness during the year than those collected by air-lift. In the latter case, lower values were recorded in November and higher values in March; secondary peaks occurred in July (station 1) and September (station 2).

The efficiency of the two tools at collecting species was variable during the year but the suction-sampler always collected more exclusive species than the hand-net (Fig. 5). The number of species collected by both methods was higher in station 1 than in station 2. Species which were exclusive to the hand-net were completely lacking in January (station 1) and March (both stations), while they were quite abundant in July (station 2) and September (station 1).

Structural analysis

After the elimination of 9 'singletons', a first raw data matrix of dimensions 34 x (2 x (2x6)) (i.e. species x (stations x (sampling methods x months))) was obtained. The matrix was utilized to obtain a CA ordination model in which the first two factors were significant. However, the distribution of the 24 sample-points on the plane described by the factors was difficult to interpretate as too many sources of variability were present together in the starting matrix. Therefore, as a second step, two matrices of (species x (methods x months)), i. e. each containing the data of a single station, were utilized separately in the multivariate analysis.

The CA ordination model of the samples collected from station 1 was obtained from a 29 x (2 x 6) matrix of raw data and is shown in Fig. 6. Only the first factor of the model was significant (F1= 48.8%; F2= 17.7% of the total variance). Along the axis expressed by this factor, two main patterns of sample-points may be observed. First, points are clustered according to the collecting method, as most of the samples by air-lift have negative values of saturation (only two have low positive

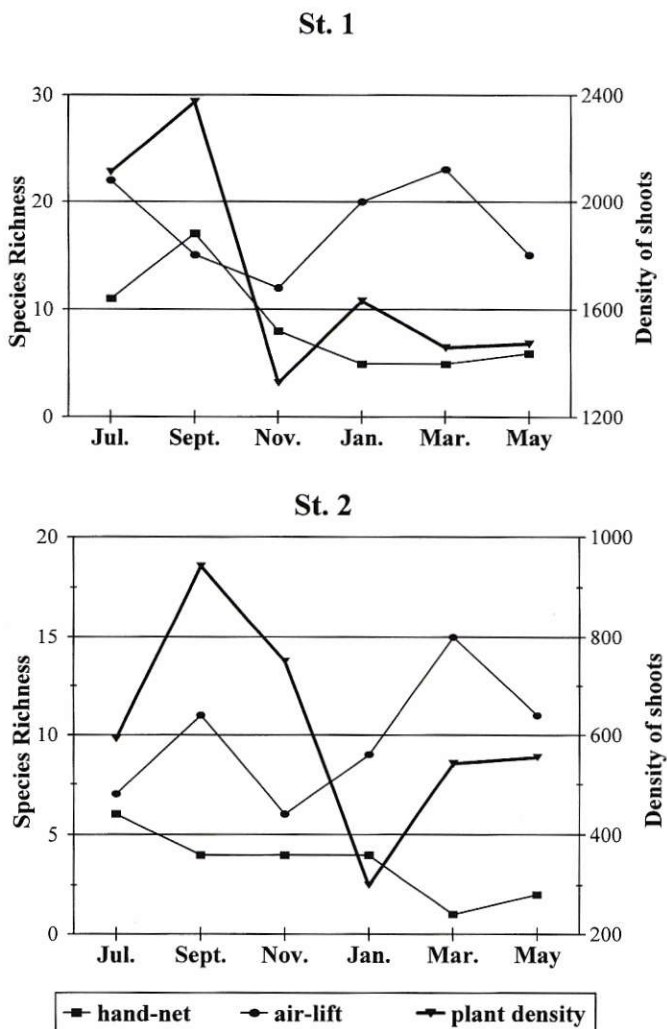


Figure 4. Distribution of the sampled species in orders.

values), while those by hand-net are strongly polarized in the positive portion of the axis. Second, the distribution of sample-points into each cluster is well related to their time-position along the year cycle, describing the consistent temporal drift of the station. In particular, in the cluster related to the hand-net (N), increasing saturation values are associated with the samples of January (1N), March (3N), May (5N) and July (7N); a strong discontinuity is evident between the samples of July (7N) and September (9N), showing a marked decrease in the value of saturation. As for the cluster related to the air-lift, a marked discontinuity between samples of the cold season (1S, 3S, 9S, 11S) and those of the warm season (5S, 7S) is evident.

The CA ordination model of the samples collected from station 2 was obtained from a 22 x (2 x 6) matrix of raw data and is shown in Fig. 7. Only the first axis of the model is significant ($F1 = 40.3\%$; $F2 = 14.6\%$ of the total variance). Also in this model sample-points are clustered along the first axis according to the collecting method, as samples by air-lift have negative values of saturation, while those by hand-net are distributed in

the positive portion of the axis (with the exception of 3N). As for the distribution of sample-points in each cluster (temporal drift of the station), the discontinuity between May (5S) and July (7S) in the cluster of samples by air-lift, and the strong polarization of September (9N) and especially November (11N) in the group of samples by hand-net should be noted.

DISCUSSION

The two *Cymodocea nodosa* beds showed remarkable differences in the structure of their mollusc taxocoene. Basic community parameters, such as abundance and species richness, have much higher values in the more dense bed (station 1), where a well-structured turf was present, than in the other bed (station 2). Seasonal trends in qualitative and quantitative community parameters were fairly clear, but were different depending on the sampling method used and the bed structure. In both stations, high values of species richness during winter (January-March) are associated with taxocoene living in the substrate (sandy sediment turf) which is better sampled by air-lift. As has also been pointed out for *Posidonia oceanica* beds (TERLIZZI & RUSSO, 1996), the greater effectiveness of the suction-sampler could be due to a lower 'obstruction effect' caused by leaves, which are less dense in this period.

High values of species richness during summer (July-September) are due to the important contribution of snails living in the leaf stratum (e.g. *Trochidae* and *Rissoidae*) when the density of the beds reaches a maximum. In this period the community parameters recorded by hand-net, which are strongly related to leaf cover, also reach their maxima, while the minima are recorded in winter (January-March). Descriptive analysis and the ordination model show that the period of November to January seems to be critical for the structure of the beds and for the associated malacological assemblages. This may be due to the fact that, during this period storms uproot the plants, causing a strong decrease in bed density and, as a consequence, a qualitative reduction in the malacofauna. This general trend is particularly evident in the more exposed bed (station 2), where the plant cover almost disappears during the winter.

As regards the two methods, they did not show marked qualitative differences in efficiency in sampling the characteristic species of the leaf stratum, although the hand net collected more individuals, as the surface sampled is greater. The suction sampler is more effective, both in qualitative and quantitative terms, at collecting species from the substrate. On the whole, the latter sampling gear is better suited to the structure of malacological associations, but in summer the hand-net may give some further quantitative information on the structure of leaf stratum taxocoenoses.

Although the mollusc association of *Cymodocea nodosa* showed several species present in the *Posidonia oceanica* leaf stratum, their total number was much lower. This is probably due to differences in morphology and phenology between the two plants. The smaller *Cymodocea* offers a lower degree of habitat structure than *Posidonia*. Furthermore, compared to the more stable beds of *Posidonia*, where the yearly variability in habitat structure is mainly related to changes in leaf length, *Cymodocea* beds show a

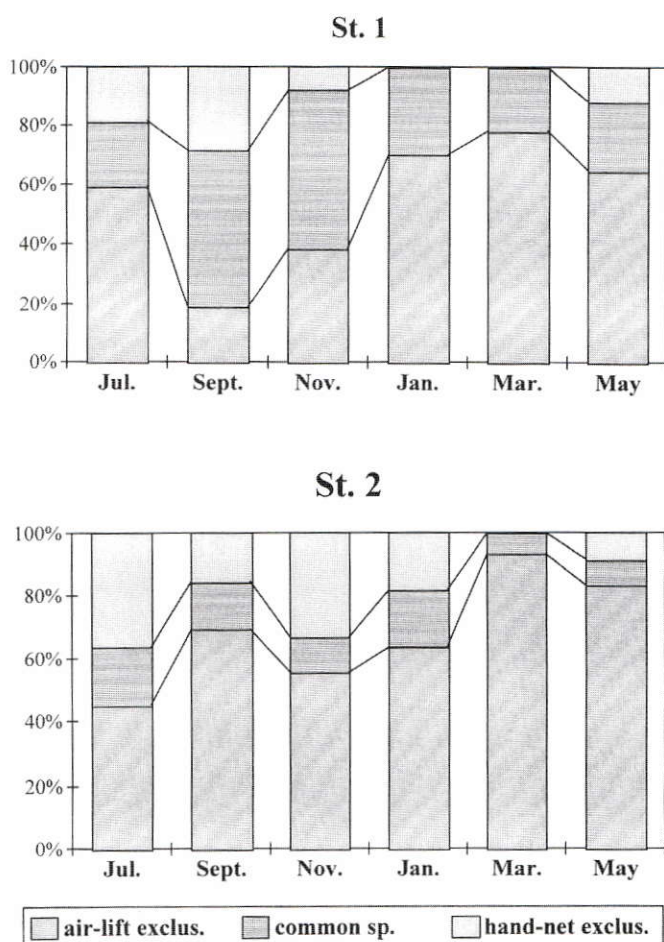


Figure 5. Shannon-Wiener diversity indices and their evenness. The open quadrats mean the values of the Shannon index while the black dots mean the relative values of the evenness.

higher degree of variability, related to the marked fluctuations in shoot density. The presence of the 'turf' (station 1) contributes to stabilizing the plant cover on the sandy bottom against uprooting by winter storms and provides for a higher faunistic diversification and a lower seasonal variability in the mollusc taxocoene.

In conclusion, the malacological association of *Cymodocea nodosa* beds considered here seems to be a component of a system which is more complex than a simple *facies* of a coenotic unit, of either enriched soft bottoms (PÉRÈS & PICARD, 1964) or of impoverished secondary hard bottoms (LEDOYER, 1966). This is particularly true in conditions which allow a more developed habitat structure (turf). In any case, this benthic system appears to have peculiar structural and functional characteristics, which make it particularly elastic.

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St. 1

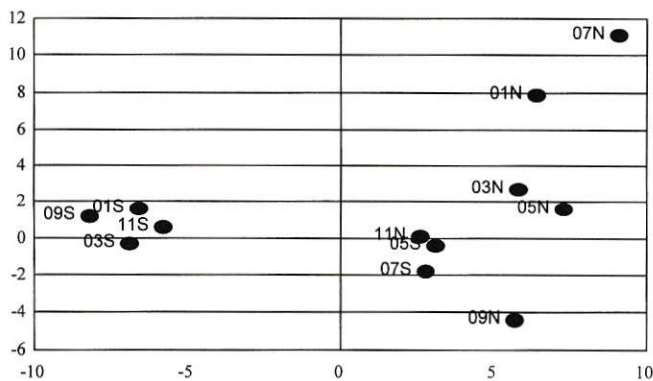


Figure 6. AC ordination model of st.1, where only the sampling-points were plotted. S=suction-sampler, N=hand-net. The number is related to the month (1=January, 3=March, 5=May, etc.).

St. 2

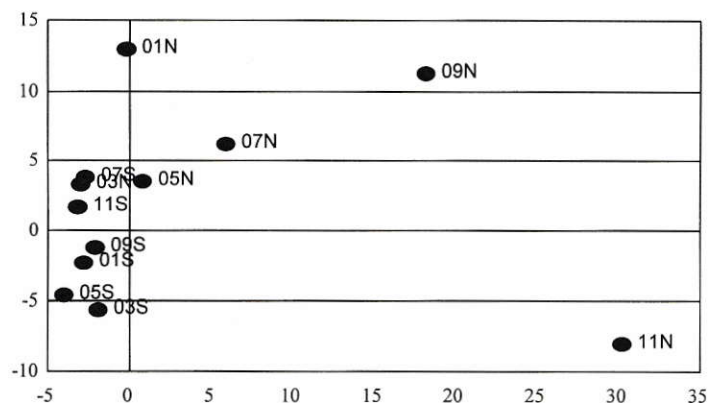


Figure 7. AC ordination model of st. 2, where only the sampling-points were plotted. S=suction-sampler, N=hand-net. The number is related to the month (1=January, 3=March, 5=May, etc.).



Sampling techniques and structure of the malacofauna associated to the rhizome zone in *Posidonia oceanica* (L.) Delile

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KEY WORDS: *Posidonia oceanica*, sampling techniques, abundance distribution models, nomocenosis, Mediterranean Sea.

ABSTRACT The introduction of methodological variants in sampling through air pump in the rhizome layer of *Posidonia oceanica* beds allows to stress a "filter effect" due to the presence of the leaves during the pumping. Inside the same *Posidonia* bed, on areas of the same surface, the sample areas in which all leaves are preventively cut off to uncover the rhizome layer show an increase of information with respect to areas with leaves. The comparative analysis of abundance distribution models shows that similar results are obtained by increasing the sample area.

RIASSUNTO Tecniche di campionamento e struttura della malacofauna associata alla zona dei rizomi di *Posidonia oceanica*. L'introduzione di varianti metodologiche nel campionamento con sorsona dello strato dei rizomi di una prateria di *Posidonia oceanica* (L.) Delile ha consentito di evidenziare un notevole "effetto filtro" operato dalle foglie all'azione di aspirazione. Considerando aree campione di stessa superficie all'interno di un medesimo posidonieto, aree preventivamente defoliate rendono disponibile una maggiore quantità di informazione rispetto ad aree non defoliate. L'analisi comparativa dei modelli di distribuzione di abbondanza, relativi ai due tipi di aree, mostra che i risultati sono analoghi a quelli ottenibili aumentando la superficie campione.

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INTRODUCTION

The analysis of structurally and ecologically complex environments, as *Posidonia oceanica* beds, needs setting up of suitable sampling techniques in order to obtain both the maximum information through the minimum effort and the preservation of the univocal relation between the surveyed element and its relative information.

Considering the elements of a bed (the rhizome stratum, the foliar stratum, the "mattes"), the relative information seems to point out the presence of different biocenosis associated to the different microhabitats (OTT & MAURER, 1977; IDATO *et al.*, 1983; RUSSO *et al.*, 1983; RUSSO *et al.*, 1984a; RUSSO *et al.*, 1984b; RUSSO *et al.*, 1984c; BIANCHI *et al.*, 1989), for which different sampling techniques have been set up. The most utilized techniques are direct ones as they foresee an active and aimed action by the scuba-diver operator. They can be summarized as:

- a) sampling through an air-pump, used in the rhizome layer and in the "mattes" (CORSELLI, 1980; DE METRIO *et al.* 1978; DE METRIO *et al.*, 1980).
- b) sampling through a hand-net, used in the leaf-layer (LEDOYER, 1962; LEDOYER, 1966; RUSSO *et al.*, 1985; RUSSO *et al.*, 1986; RUSSO & VINCI, 1991)
- c) removal of a whole clod of weed (BIANCHI *et al.*, 1989).

Each technique has some bias affecting the information about the population, because of the *Posidonia* weed structure with leaves covering the underlying rhizome. The most common bias is the veil-effect of the leaves and a mixing of material due to the hydrodynamic disturbance produced by the air-pump. This leads the animals falling according to the well known

"falling reflex" (ISSEL, 1912; RUSSO, 1989). Concerning the technique proposed by BIANCHI *et al.* (1989) there is no doubt that it involves a loss of information about the probable vertical distribution of the population but it allows a whole recover of the qualitative and quantitative information.

Because of these reasons and within a program of investigation of the biocenosis associated to the *Posidonia* beds at Isola del Giglio (Grosseto, Italy) we decided to test the most appropriate sampling techniques comparing, inside the same bed, two samples carried out with methodological variants on areas of the same surface.

MATERIALS AND METHODS

The samples have been collected at Campese (Isola del Giglio, Grosseto, Italy), (last week of March 1992, calm sea, cloudy weather) within a *Posidonia* bed growing on "mattes" lying on a detrital substrate 9 m depth. Two 3 m²-areas have been sampled using a PVC air-pump with a 7 cm-diameter opening and with a nylon sampling bag having a 0.5 mm-mesh. The first area (called area A) has been treated as usual: the rhizome layer having been pumped, while the 2nd area (area B) has been netted by 30 strokes in order to remove the leaf population. The net consists of a rectangular frame (40x20 cm) provided with a nylon sampling bag with a 0.5 mm-mesh. 30 more strokes have been carried out outside the investigated area in order to get a representative sample of the leaf population (RUSSO & VINCI, 1991). In the netted area, all the leaves have been cut off by scissors and the uncovered rhizome area has been pumped using the same air quantity (about 150 atm) used for area A.

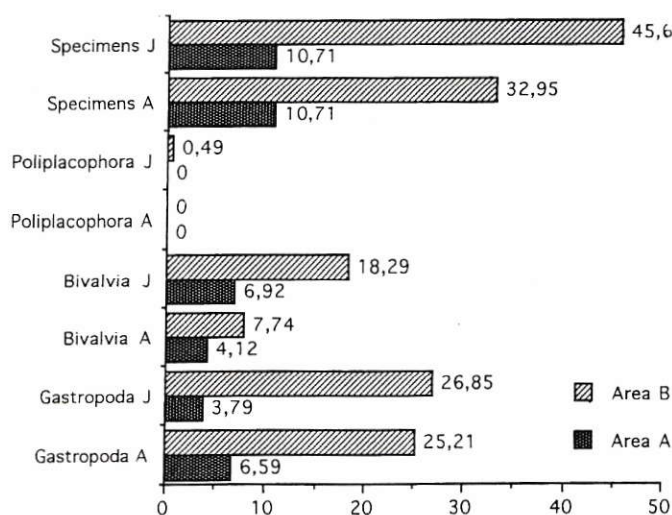


Figure 1. Percentages of adults (A) and juveniles (J) of the different classes.

The sorting has been carried out within few hours in order to an easier identification of the living specimens. The species occurring in all samples with only one individual and the parasitic species were not considered in the numerical analysis (FRESI & GAMBÌ, 1982). We consider the presence of the parasites related more to their guest than to the specific environment. Quantitative and qualitative analysis has been carried out on the samples considering also the juveniles of each species. We considered as juveniles smaller individuals with uncomplete aperture and peristome.

The structural differentiation degree of population has been evaluated by the Shannon-Weaver's diversity index and the comparison among the values has been carried out by the equitability index (PIELOU, 1966; PIELOU, 1966A; DAGET, 1976). We decided to use, as other authors (BIANCHI *et al.*, 1989) a model of abundance distribution, in particular the log-linear one of Motomura and the log-normal of Preston (DAGET *et al.*, 1972; DAGET, 1976; AMANIEU *et al.*, 1980), in order to test the range and the trend frequency to evaluate the possible analogy and dissonance among the samples. The correspondence degree to the models has been evaluated according to the values of the correlation coefficient, according to the empirical role, determined by INAGAKI (1967) for the Motomura model and extended by AMANIEU *et al.* (1980) for the Preston model, which establishes that the adjustment is bad if $|r| < 0,95$, approximate if $0,95 < |r| < 0,98$, sufficient if $0,98 < |r| < 0,99$ and strict if $|r| > 0,99$.

RESULTS AND DISCUSSION

A total of 59 species with 645 individuals have been collected in two samples (area A

and area B); in the sample coming from the leaves 11 species have been collected (of these *Jujubinus exasperatus* and *Rissoa violacea* are exclusive), with 303 individuals. The results of the biological analysis are reported in tab. 1. If we do not consider the species with only one specimen (FRESI & GAMBÌ, 1982) and the parasites (indicated in tab. 1 with an asterisc), we get a partial sub-sample, area A + area B, of 33 species and 607 individuals. 24 species (72,73%) and 130 individuals (21,42%) have been found in the area A, while 32 species (96,97%) and 477 (78,58%) individuals are present in the area B. Within the samples, the percentages of adults and juveniles of the different classes are shown in Fig. 1. Altogether, area B seems to be clearly richer in every component. The data referred to the juveniles seem to be extremely important, both in the total and among the classes, in particular 80,1% of all the juvenile and 87,6% of young gastropods have been found in the leafless area.

The diversity index, calculated for both samples, are 1,13489 for area A and 1,03058 for area B. According to the equitability index, that is to say according to the relationship between the observed diversity and the maximum diversity, the two samples are structurally different; in particular area A, with value of 0,822 shows a higher differentiation compared to area B having a value of 0,685. In area A the coefficient of correlation $|r|$ is approximate in both models (Motomura's model $|r| = 0,962$; Preston's model $|r| = 0,952$). In the leafless area the correlation is bad for the log-linear model ($|r| = 0,935$) and approximate for the Preston's model ($|r| = 0,950$).

Two are the remarkable aspects: the distribution of the commonest species approximate the normality in both samples (Fig. 2), and the frequency percentages of the species having the same rank are very similar (Fig. 3) except the first rank species. According to AMANIEU *et al.* (1980), in order to save the ecological information of the lengthened populations and don't overestimate the significance of the low frequency species, it is useful to consider the rarest species as only one class. These considerations lead us to group the 9 rarest species of the area B in order to obtain the same rank number (24) in the two samples.

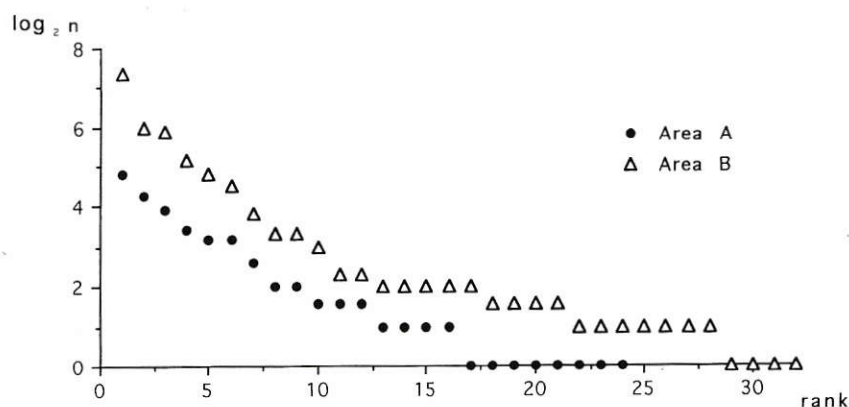


Figure 2. Distribution of the species on a log scale.

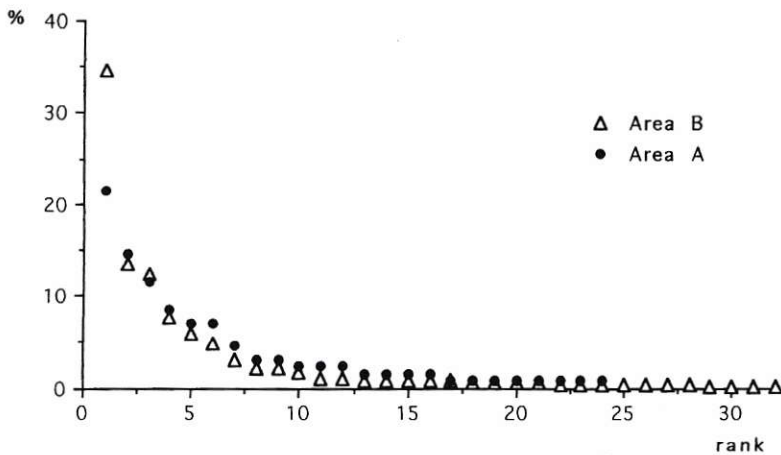


Figure 3. Frequency percentage of the species.

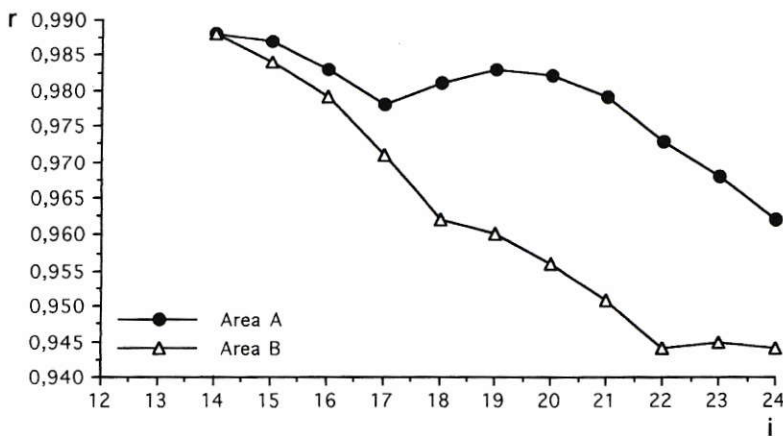


Figure 4. Trends of correlation coefficient $|r|$ related to the number of species (i) according to Motomura's model.

We have been able, in such a way, to compare exactly the $|r|$ values derived from models applied to samples with the same rank number (DAGET, 1976). We have then reduced, step by step, the rank number of each sample by grouping in the single class of rare species those ones having the lowest frequency. Variations in correlation coefficient of the two models are shown in Figs. 4 and 5. Such a data analysis indicates:

- 1) rare species contrast with the trend to normality by lengthening the end distribution of populations having several groups *ex aequo*;
- 2) rare species are chiefly responsible for differentiation of the information about the structure of the sample. Such a difference is going to disappear while the rank number reduces.

We especially have a strong analogy in the information regarding the distribution of the first 13 species plus a cumulate class (14 ranks model). In the area A the cumulate class represents 10,76% individuals of the sample; the percentage of the same class from the area B is very similar, that 9,6%.

In both samples the log-linear model seems the most appropriate to draw the distribution of the 14 frequencies (Fig. 6). The linear correlation coefficient reaches the sufficient level both in area A ($|r|=0,988$ (corresponding to a Motomura constant $m=0,824$) and in area B ($|r|=0,987$; $m=0,766$). Correlations are appropriate (i.e. lower) (area A $|r|=0,981$; area B $|r|=0,985$) according to the model of Preston if we consider the same rank number.

As regards the leaf population, this is made trivial by the rather infesting presence of *Bittium latreilli* (chiefly in adult stage) representing 81,13% of the whole individuals found. Such a massive presence could explain, to some extent, the very high relative frequency of this species in the sample from the area B where a greater handling of the leaf stratum was surely carried out. Another characteristic of the leaf population is the absence of bivalves.

CONCLUSIONS

In both areas the capture-collecting ranks are quantitatively and qualitatively significantly different. The cutting of leaves seems to induce a widening of the sampling area. As a consequence we observe an increase of information both about the increase of frequencies of the commonest species and juveniles and about the finding of new species not previously collected in area A. The apparent widening effect in area B is also evident if the abundance distribution models of the most common species are analyzed (14 ranks-model). As a matter of fact the relative relationships among these species distribution look totally comparable between the two samples; this similarity is evident above all by the m values. This constant is equal to the antilogarithm of the angular coefficient; the degree of the geometrical increase which exists

between the two species inside the distribution can be valued by it. Moreover it allows a balanced valuation of the structure of the sample because its value does not change when the structural level, sufficient to define a "nomocenosis", is reached; this means a population whose frequency distribution relates sufficiently to the models of Motomura or Preston (DAGET, 1972).

A nomocenosis is basically characterized by an m value and by the number of species, independently from their taxonomy. Moreover, once this has been defined, it becomes independent from the sample size. Practically the straight line laying under it moves parallel from itself maintaining the same angular coefficient and, therefore, the same m value too. This aspect seems to come out from the considered distributions: the first 14 ranks (see Fig. 6), in the area A and in the area B, are occupied by species with absolute frequency very different (higher in B than in A), but this does not seem to highly affect the relative distribution of the frequencies (same degree of correlation, same constant of Motomura). We can after all consider both samples as representatives of the same nomocenosis; we can consider suffi-

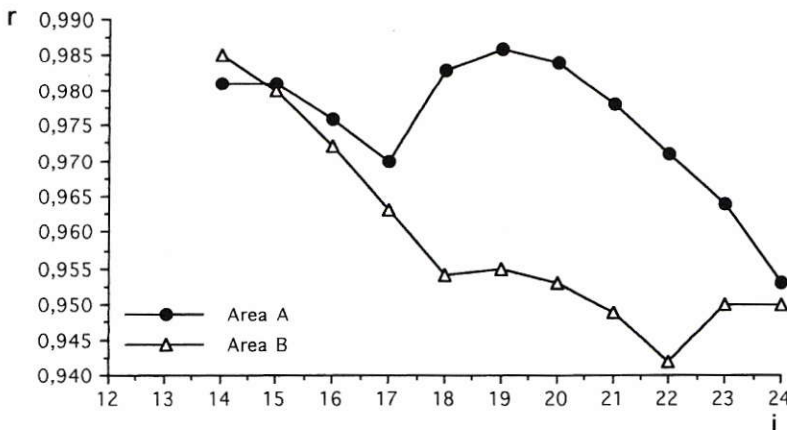


Figure 5. Trends of correlation coefficient $|r|$ related to the number of species (i) according to Preston's model.

cient the information hold in the area A as far as regards the sampling and the definition of a nomocenosis, while in the area B the cutting of leaves gives us a better qualitative but not quantitative information. In fact the relative relationships among the frequencies of the most common species, in B and in A, is constant. The juveniles of both bivalves and gastropods represent the main difference in the information surplus. The high number of young specimens collected in area B seems to indicate a clear preference as regards the microhabitat of the rhizome stratum. This clearly appears if we analyze the distribution of the most abundant species (*Bittium latreillii*). This can mean that this species, and more in general most of the gastropods, use such microhabitat as a nursery and move successively, as adults, preferably towards the leaf stratum. A bigger quantity of epiphytic nutrients and a higher hydrodynamic stability can determine this vertical seriation of the different developmental stages. As regards the bivalves, their absence from the foliar stratum is probably due to the higher hydrodynamic stability with respect to the rhizome stratum, which appears a more suitable substratum for the bivalve habitus.

The last aspect to be considered is the probable recruitment, on the rhizomes of species coming from foliar stratum. The analysis of the three samples (two air-pump samples and the net-sample) allows to partly minimize the effect of the hydrodynamic disturbance caused by the air-pump on the area with leaves. As a matter of fact we utilize the adults of *B. latreillii* as markers of this effect, considering the very high number of specimens on the leaves, we can stress how in the area A we collected few specimens. On the contrary, a quite high number of adults of *B. latreillii* in the area B, which slightly contributes to the increase of m value, seems to suggest that not the whole population living on leaves has been collected by the hand-net and the adjustment-rearrangement of these, during the leaf-cut, may have determined the falling of adults on the rhizome. Probably a second collection by the hand-net after few hours from the first one, on the area when the cutting leaves will be executed, could contribute to minimize this effect.

We can conclude that the variants introduced in the sampling

methodology are satisfactory concerning the amount of information collected. The variant introduced in sampling area B doesn't appear as an artefact able to affect the information about the population of the rhizome stratum collected in the area with leaves. Such an information is conversely preserved and enhanced leading to put in evidence a "filter effect" due to the presence of the leaves during the pumping which would not be suspected.

The last remark is about the presence of living specimens of the Fissurellidae *Emarginula pustula* Thiele in Kuester, 1913, that confirms its presence inside the biocenosis of *Posidonia oceanica*, as it was already pointed out in other samples collected at the Isola del Giglio (BONFITTO & SABELLI, 1992).

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SPECIES	Area A			Area B			Net-sample		
	ad.	juv.	Tot.	ad.	juv.	Tot.	ad.	juv.	Tot.
1 <i>Callochiton septemvalvis euplaeae</i>	0	0	0	0	3	3	0	0	0
2 <i>Smaragdia viridis</i>	1	0	1	3	0	3	0	0	0
3 <i>Emarginula pustula</i>	1	0	1	2	0	2	0	0	0
4 <i>Clanculus jusseui*</i>	0	0	0	1	0	1	0	0	0
5 <i>Jujubinus exasperatus*</i>	0	0	0	0	0	0	4	0	4
6 <i>Jujubinus gravinae*</i>	0	0	0	1	0	1	0	0	0
7 <i>Jujubinus striatus</i>	5	4	9	10	0	10	16	0	16
8 <i>Tricolia pullus pullus</i>	1	0	1	6	4	10	0	0	0
9 <i>Tricolia tenuis</i>	1	0	1	1	0	1	1	0	1
10 <i>Cerithium alucaster*</i>	0	0	0	1	0	1	0	0	0
11 <i>Cerithium vulgatum</i>	0	0	0	1	1	2	0	0	0
12 <i>Bittium jadertinum</i>	0	6	6	0	28	28	0	2	2
13 <i>Bittium latreillii</i>	4	11	15	53	112	165	231	14	245
14 <i>Rissoa auriscalpium</i>	0	1	1	0	0	0	1	0	1
15 <i>Rissoa decorata</i>	3	0	3	4	0	4	9	0	9
16 <i>Rissoa ventricosa</i>	2	0	2	2	0	2	11	0	11
17 <i>Rissoa violacea*</i>	0	0	0	0	0	0	4	0	4
18 <i>Alvania cimex</i>	2	0	2	3	0	3	0	0	0
19 <i>Alvania discors</i>	4	0	4	22	1	23	8	0	8
20 <i>Alvania geryonia</i>	1	0	1	1	0	1	0	0	0
21 <i>Alvania lineata</i>	1	0	1	1	0	1	1	0	1
22 <i>Alvania pagodula</i>	0	0	0	4	0	4	0	0	0
23 <i>Pusillina radiata</i>	2	0	2	1	0	1	1	0	1
24 <i>Rissoina bruguierei</i>	0	0	0	0	2	2	0	0	0
25 <i>Natica dyllwynii</i>	0	0	0	1	1	2	0	0	0
26 <i>Triphoridae</i> indet.*	1	0	1	0	0	0	0	0	0
27 <i>Marshallora adversa*</i>	0	0	0	7	0	7	0	0	0
28 <i>Cerithiopsis</i> sp.*	2	0	2	0	0	0	0	0	0
29 <i>Epitonium commune*</i>	0	0	0	0	1	1	0	0	0
30 <i>Melanella polita*</i>	1	0	1	2	0	2	0	0	0
31 <i>Desmomurex scalaroides*</i>	1	0	1	0	0	0	0	0	0
32 <i>Buccinum corneum*</i>	1	0	1	0	0	0	0	0	0
33 <i>Fusinus pulchellus*</i>	1	0	1	0	0	0	0	0	0
34 <i>Nassarius incrassatus</i>	9	2	11	22	14	36	0	0	0
35 <i>Coumbella rustica*</i>	0	0	0	1	0	1	0	0	0
36 <i>Vexillum tricolor*</i>	0	0	0	1	0	1	0	0	0
37 <i>Gibberula miliaria*</i>	0	0	0	0	1	1	0	0	0
38 <i>Gibberula philippii*</i>	1	0	1	0	0	0	0	0	0
39 <i>Granulina marginata</i>	0	0	0	8	0	8	0	0	0
40 <i>Fasciolaria lignaria</i>	0	0	0	2	0	2	0	0	0
41 <i>Mangelia stossiciana*</i>	0	1	1	0	0	0	0	0	0
42 <i>Mangelia vauquelini</i>	0	0	0	2	0	2	0	0	0
43 <i>Raphitoma linearis</i>	2	0	2	4	0	4	0	0	0
44 <i>Eulimella</i> sp.*	0	0	0	0	1	1	0	0	0
45 <i>Odostomia acuta*</i>	0	0	0	0	1	1	0	0	0
46 <i>Odostomia conoidea*</i>	3	1	4	0	0	0	0	0	0
47 <i>Turbonilla lactea*</i>	0	0	0	0	1	1	0	0	0
48 <i>Turbonilla striatula*</i>	0	0	0	1	0	1	0	0	0
49 <i>Arca noae</i>	0	1	1	0	5	5	0	0	0
50 <i>Barbathia barbata*</i>	1	0	1	0	0	0	0	0	0
51 <i>Striarca lactea</i>	15	13	28	16	48	64	0	0	0
52 <i>Gregariella petagnae</i>	0	4	4	0	4	4	0	0	0
53 <i>Modiolula phaseolina*</i>	0	0	0	0	1	1	0	0	0
54 <i>Ctena decussata</i>	0	0	0	1	3	4	0	0	0
55 <i>Chama gryphoides*</i>	0	0	0	0	1	1	0	0	0
56 <i>Neolepton sulcatulum*</i>	0	0	0	0	1	1	0	0	0
57 <i>Glans trapezia</i>	8	11	19	23	36	59	0	0	0
58 <i>Parvicardium ovale*</i>	1	0	1	0	0	0	0	0	0
59 <i>Venus verrucosa</i>	1	8	9	1	13	14	0	0	0
60 <i>Gouldia minima</i>	1	2	3	5	0	5	0	0	0
61 <i>Hiatella arctica</i>	1	2	3	2	1	3	0	0	0

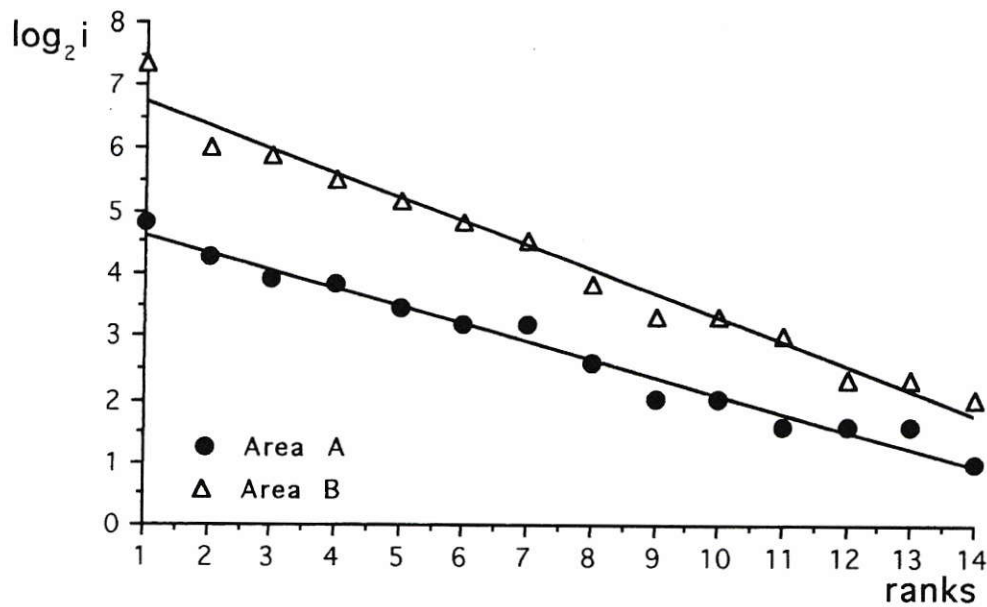


Figure 6. Log-linear models of the first 14 frequencies at two areas (13 ranks + cumulate class).

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Structural patterns in the mollusc assemblages of *Posidonia oceanica* beds: methodological, edaphic or biogeographical product?

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KEY WORDS: Molluscs, sampling methods, community structure, seagrass, *Posidonia*.

ABSTRACT Mollusc associations living in the *Posidonia oceanica* beds of five geographic areas of the Mediterranean were compared. Complementary sampling methods were adopted: the hand-towed net, more effective on the leaf stratum, and the suction-sampler, more effective on rhizomes. The aim of the study was to gather information on overall coenotic variability, taking into account the contribution of the two main mollusc assemblages stratified along the vertical axes of the plants.

Results show a wide variability in the composition of the assemblages, as few species were found to be living in more than one bed. On the basis of the assumptions of the bionomic model of PÉRÈS & PICARD (1964), it is very difficult to recognise a unique and well-defined malacological taxocoene for the *Posidonia* beds, which are, in turn, themselves considered as single bionomic units. Present a-ecological data agree better with the 'polybiocoenitic' hypothesis of BIANCHI *et al.* (1989), although b-ecology provides a better understanding of the ecological processes underlying the structural patterns described.

RIASSUNTO Vengono riportati i risultati relativi ad una campagna di campionamento effettuata durante la crociera oceanografica 'MAREVIVO', nell'estate del 1992, a bordo della n/o 'Minerva'. Nell'analisi sono state considerate le stazioni più superficiali (-5m) delle praterie di *Posidonia oceanica* di S.Domino (Isole Tremiti), Gallipoli (Costa Salentina), Lampedusa (Isole Pelagie), Marettimo (Isole Egadi) e Medas (Costa Brava, Spagna). In ciascuna stazione sono state compiute due raccolte: la prima, che campiona circa 20 m² di prateria mediante un retino manovrato a mano; la seconda, effettuata campionando 1 m² di prateria mediante una sorbona manovrata in immersione con A.R.A.

Nei campioni sono stati rinvenuti complessivamente 2122 individui di molluschi, appartenenti a 85 specie (62 di Gasteropodi e 23 di Bivalvi). Di queste solo 34 (40%) sono state campionate con entrambi i metodi, mentre ben 43 (51%) sono state rinvenute esclusivamente nei campioni da sorbona.

I prelievi da sorbona, nonostante la minore area campionata, fanno registrare ricchezze specifiche più elevate, ma presentano valori di abbondanza inferiori rispetto ai campioni di retino. Fra i Gasteropodi, 18 specie sono rappresentate da un solo individuo in un singolo campione. Le famiglie più strettamente legate allo strato foliare (*Trochidae* e *Rissoidea*) sono sempre state raccolte più efficacemente mediante retino. I Bivalvi, invece, sebbene presenti sempre in maniera piuttosto cospicua, sono limitati quasi esclusivamente ai campioni da sorbona.

Si osserva una marcata differenza tra le strutture dei popolamenti delle diverse praterie, ulteriormente sottolineata dall'analisi strutturale, effettuata mediante un modello di ordinamento. Per quanto riguarda l'aspetto qualitativo, solo *Bittium latreillii* è sempre presente in tutti i campioni. *Alvania discors*, *Vitreolina philippi* e *Gibberula philippii* sono comuni a tutti i campioni da sorbona, mentre *Jajubinus striatus* e *Bittium reticulatum* sono presenti in tutte le raccolte effettuate mediante retino.

Tali risultati, se da un lato confermano la diversa efficacia di raccolta degli strumenti utilizzati (il retino per lo strato foliare e la sorbona per il substrato d'impianto e lo strato dei rizomi), dall'altro evidenziano una forte differenza strutturale tra i popolamenti malacologici considerati. Non si registra, infatti, almeno per il taxocene a Molluschi, l'esistenza di una comunità che nel suo complesso possa definirsi 'tipica' del sistema a fanerogame considerato. Ciò suggerisce che vari fattori, tra quali soprattutto la densità dei ciuffi foliari, la natura del substrato d'impianto, e la storia locale delle associazioni malacologiche (piuttosto che la distribuzione biogeografica delle specie), concorrono a determinare le differenze strutturali osservate nei diversi siti.

Quanto rilevato nel presente lavoro sembra essere in contrasto con gli assunti del modello di PÉRÈS & PICARD (1964), in cui i sistemi bentonici costituiti dalle praterie di *Posidonia oceanica* del Mediterraneo sono considerati appartenere ad un'unica entità cenotica e bionomica. Il presente studio a-ecologico, invece, sembra meglio supportare l'ipotesi di BIANCHI *et al.* (1989) del 'crocevia ecologico' o della natura 'poli-biocenotica' dei sistemi a *Posidonia oceanica*, che, pertanto, avrebbero caratteristiche strutturali differenti a seconda della storia geologica e biologica dei siti.

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INTRODUCTION

The multifunctional role exerted in the littoral zone by the ecosystem represented by the seagrass *Posidonia oceanica* has, in the last 20 years, prompted a series of investigations. Apart from its widespread and extensive quality (it covers about 2% of the bottoms in the Mediterranean basin), this plant plays an important ecological role as oxygen producer, shelter and nursery site for a rich benthic and necto-benthic littoral fauna. It also provides a stable environment offering opportunities for coevolutionary processes to take place.

The vagile fauna represents one of the most important compo-

nents of this littoral system, both in terms of abundance and species richness. However, the vertical structure of the plant, which increases the habitat complexity and heterogeneity, and the large number of organisms from a variety of taxonomic groups, body sizes and life habits, are all factors which add to the difficulty of collecting this important faunistic component in the most appropriate manner. To overcome this difficulty, different collecting tools and techniques have been proposed and efforts have been made to minimize, or at least standardize, the bias introduced by these different methods (for a review, see RUSSO *et al.*, 1986).

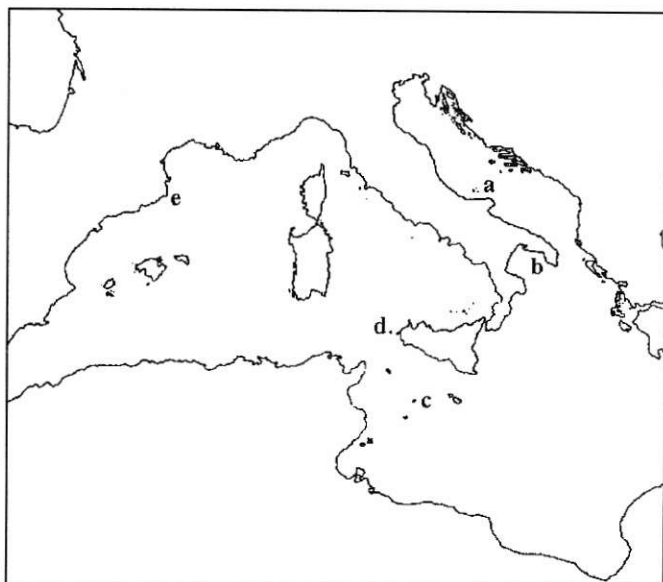


Figure 1. Map with the five sampling sites.

Molluscs are one of the best-represented groups in the vagile fauna of *Posidonia* beds (GAMBI *et al.*, 1992) and have for some time been the object of sinecological studies. The results obtained from recent research indicate a notable structural variability in the malacological community, despite the early studies of LEDOYER (1962, 1966), utilised in the bionomic model of PÉRÈS & PICARD (1964), which recognize a single 'biocoenosis' inhabiting the *Posidonia* beds of the Mediterranean.

The 'intra-site' variability of the mollusc community has been studied both in time, taking into consideration diel and year cycles (RUSSO *et al.*, 1984; 1991 a), and in space, taking into account environmental gradients related to water movement (RUSSO *et al.*, 1983). The 'inter-site' variability is poorly understood, as few comparative analyses on a large geographic scale are available (e.g. RUSSO *et al.*, 1985 a, 1991 b).

This latter aspect seems to be of particular importance in assessing the bionomic 'status' of seagrass systems as, in the most complete study carried out so far, which took into account several *Posidonia* beds of a well defined geographic area (Apulia), BIANCHI *et al.* (1989) found such a high structural variability in the macrobenthic associations as to hypothesize that this system represents a sort of ecologic 'cross-roads', in which four compartments which are 'eco-ethologically' independent of each other are assembled in a 'poli-biocoenotic' complex.

The present paper is the second part of a study comparing a number of mollusc associations from different geographical areas of the Mediterranean. In a previous comparative analysis, a high quali-quantitative variability in the mollusc assemblages was observed (TERLIZZI & RUSSO, 1995). This characteristic of the associations was interpreted as a product of the sampling method utilised, the suction-sampler, which was considered to be effective mainly on the substrate and at the base of the seagrass leaves. This is the most variable portion of the habitat represented by the seagrass (i.e. ranging from rock to mud passing through gravel and sand), the leaf stratum being far more homogeneous in its constitutive components (leaf shoots).

Therefore, the observed coenotic variability may be considered 'topological', being related to 'intrinsic' factors such as the physical characteristics of the sites, rather than to 'extrinsic' ones such as the biological accommodations to large spatio-temporal scales, from which biogeographical and coevolutionary community patterns originate.

The complementary sampling method of the hand-towed net, more effective on the leaf stratum, was considered in the present study and compared with the suction sampler. The aim was to gather more information about both the overall coenotic variability and the contribution made to it by the different strato-coenoses.

MATERIALS AND METHODS

The investigations were part of the oceanographic cruise 'MAREVIVO' (o/s 'Minerva'), in the Adriatic and Ionic Seas and in the western Mediterranean, during summer (July-August)



Figure 2. Collecting methods: (a) suction-sampler (after Russo *et al.*, 1986); (b) hand-towed net (after Russo *et al.*, 1985 b).



1992. Samples were collected at a single depth (-5m), in the *Posidonia oceanica* beds of S. Domino (Tremi Islands, Adriatic Sea), Gallipoli (Puglia Region, Ionian Sea), Lampedusa (Pelagian Islands, Channel of Sicily), Marettimo (Egadi Islands, Channel of Sicily) and Meda Grande (Medas Islands, Balearic Sea) (Fig. 1).

The density of the prairies was recorded according to the classification of GIRAUD (1977). All the prairies fell into the 'very dense' category (more than 700 shoots/m²), except for that of the Medas, which was classified as 'dense' (500-700 shoots/m²).

For each station two different samples were collected by SCUBA divers. The first sample was collected by an 'air-lift' (or 'suction-sampler') (Fig. 2a) over a surface of one square meter; the second was obtained by a 'hand-towed net' (Fig. 2b), over a surface of about twenty square meters, according to the technique described by LEDOYER (1962) and standardized by RUSSO *et al.* (1985 b).

Molluscs were sorted and identified following SABELLI *et al.* (1990). The descriptive analysis was carried out taking into account the presence of species and their relative and absolute abundances. The comparison of the results obtained by the two collecting methods in the different beds allowed a preliminary evaluation of their efficiency with respect to the different species.

In order to identify coenotic patterns on a large geographical scale, a structural comparison of the malacological associations was performed starting from a matrix of raw data and using the multivariate ordination technique of Correspondence Analysis (CA) (PIELOU, 1984). The significance of the axes was tested according to the method proposed by FRONTIER (1974).

RESULTS

Descriptive analysis

Samples yielded 2122 specimens of Molluscs: 1847 Gastropods (87%) and 275 Bivalves (13%). 907 specimens (43%) were collected by suction sampler, 1215 (57%) by hand-towed net.

With the exception of the Medas, in all other stations the net collected many more individuals than the suction sampler (Fig. 3a). On the contrary, the air lift sampled more species than the net, except from the station of Lampedusa (Fig. 3b).

Overall, 85 species were collected, of which 62 were Gastropods (73%) and 23 Bivalves (27%). 34 species (40%) were collected by both sampling methods, 43 (51%) were exclusively sampled by air-lift and just 8 (9%) exclusively by hand-net.

The number of species yielded by the two sampling tools was quite different in all the stations. In S. Domino, about 50% of species were exclusively collected by net, while in Medas about 70% of species were exclusively collected by suction sampler.

The number of species collected by both sampling tools is quite high in Lampedusa and Marettimo (about 40%), and very low in the other three stations (about 20%). By considering the exclusive and the common species, it is once again evident that in all the stations the suction sampler collected many more species than the net (Fig. 4).

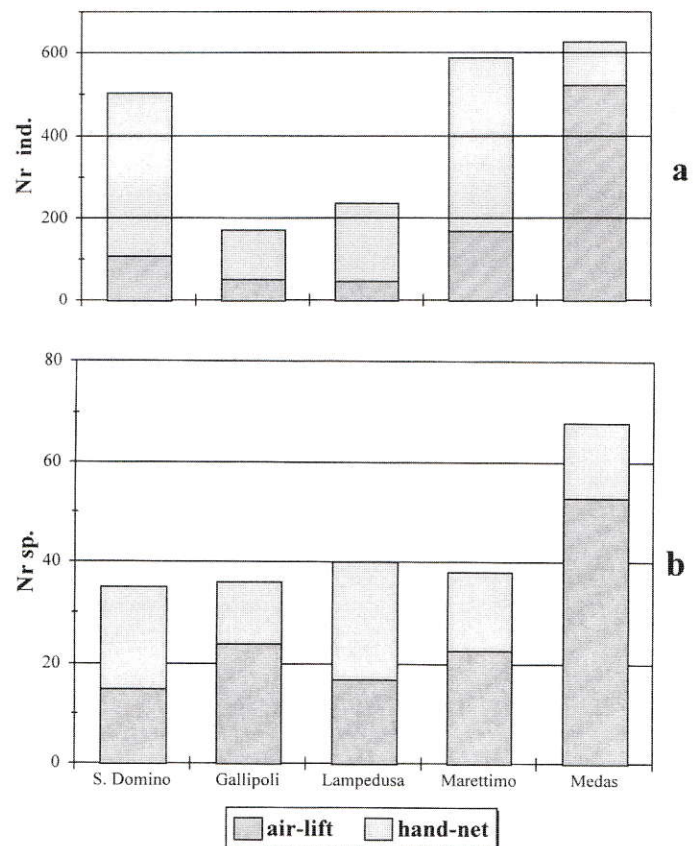


Figure 3. Values of (a) abundance and (b) species richness per sampling method, in the five stations.

As regards the samples collected by air lift, the station of Medas showed the highest values of species richness (53 species, 69 %); lower values of qualitative dominance were observed for Gallipoli (31%), Marettimo (30%), Lampedusa (22%) and S. Domino (19%) (Fig. 5a). The highest values of abundance obtained by air-lift were recorded in the station of Medas (523 individuals 58%), the lowest for Gallipoli (6%) and Lampedusa (5%); intermediate values were observed for Marettimo (19%) and S. Domino (12%) (Fig. 5b).

Regarding the samples collected by hand-towed net, the ranking of stations according to species richness has an almost opposite trend: Lampedusa and S. Domino showed the highest values (55 species and 48%), intermediate values were observed for Marettimo (36%) and Medas (36%) while the lowest values were observed in the prairie of Gallipoli (only 12 species, 29%) (Fig. 6a). The highest values of abundance using the hand-towed net were recorded for the prairies of Marettimo and S. Domino (35% and 32%, respectively), while lower values were observed for Lampedusa (15%), Gallipoli (10%) and the Medas (8%) (Fig. 6b).

As regards the distribution of single species in the samples, quite a high number of species (18 species, 21%) were 'singletons' (e.g. present in only one station with a single individual). Only *Bittium latreillii* was present in all the stations and in all

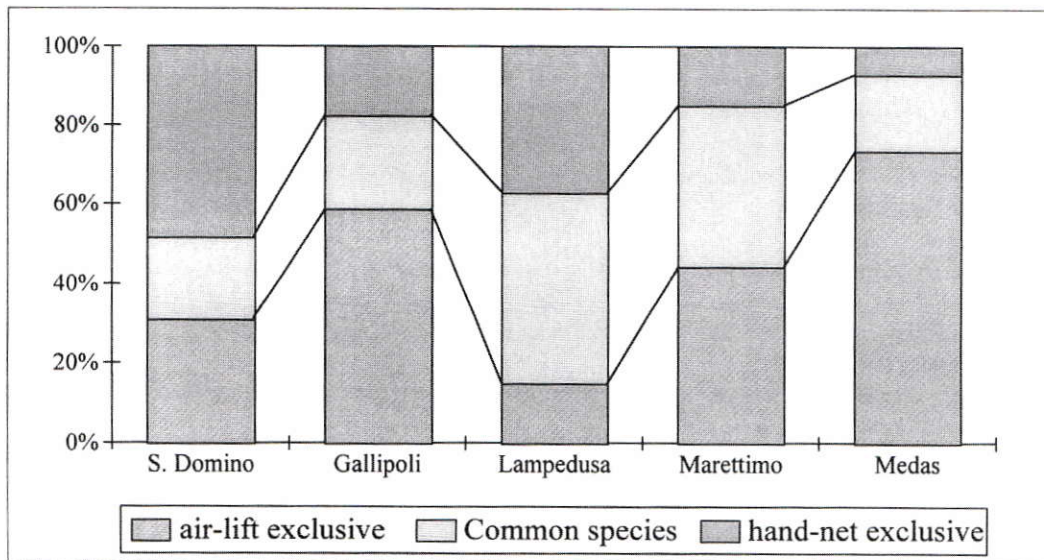


Figure 4. Percent of species collected by both the methods and exclusively by each single method.

the samples, collected by both air lift and hand-towed net. *Alvania discors*, *Vitreolina philippi* and *Gibberula philippii* were present in all air lift samples, while *Jujubinus striatus* and *Bittium reticulatum* were present in all hand-towed net samples. The bivalve species, almost exclusively collected by air lift, were well represented, in quantitative terms, in all the stations and especially in Medas.

Each prairie was well characterised by the high quantitative dominance of particular species: S. Domino by *Rissoella inflata*; Gallipoli by *Bittium reticulatum*, *Bittium latreillii*, *Nassarius incrassatus*, *Calliostoma conulum*, *Jujubinus striatus* and *Venericardia antiquata*; Lampedusa by *Rissoa auriscalpium*, *Tricolia pullus* and *Alvania lineata*; Marettimo by *Rissoa variabilis*, *Alvania discors* and *Vitreolina philippi* and Medas by *Bittium reticulatum*, *Nassarius incrassatus*, *Gibberula philippii* and *Musculus costulatus*.

Structural analysis

A first structural analysis was carried out starting from a 82 x 10 matrix (species x (stations x methods), mathematically treated to obtain a CA ordination model. The model showed, along the first factor, a strong opposition between the samples from the Medas (both hand-net and air lift) and all other samples and, along the second factor, the opposition of the samples of S. Domino to all others (both factors were significant).

A second 54 x 9 matrix (species x samples) was then set up by erasing the samples of the Medas, in order to eliminate distortion in the first factor of the model. In the new CA ordination obtained from this matrix (Fig. 7) the first two factors were significant and showed, along F1, the same pattern present along F2 in the previous model, that is, the opposition of the samples from S. Domino to all others. In addition, some other interesting ordination patterns can be observed in this latter model. Along F1, the two sample points (air-lift and hand-net) of the same site have a saturation which is more similar to that

of other sites; station points have saturations which follow one another consistent with their geographic position: S. Domino and Gallipoli, Lampedusa and Marettimo were ordered respectively, proceeding from the positive to the negative portion of the factor, which could therefore be interpreted as an East-West longitudinal gradient. Along F2, apart from the strong polarisation of the samples collected by air lift at Gallipoli, a clear separation of the samples according to the collecting method was obtained:

all the samples by air lift had positive scores, while all those by hand-towed net were in the negative part of the factor.

DISCUSSION

Remarkable differences in the structure of the mollusc associations living in the five seagrass beds of the Mediterranean were observed. This high structural variability may be interpreted as the result of a number of interacting factors.

First of all, differently-structured malacological assemblages were obtained by the two sampling methods, as clearly shown by the ordination model, in which along F2 the samples by net have an opposite polarisation with respect to those by air-lift.

The material obtained by the two sampling tools was different in both qualitative and quantitative terms. Despite the fact that the hand-net covers a larger sampling area (about 20 m² compared to 1 m²) and collects many more individuals, the suction-sampler gives more complete information on the overall species composition living in a particular prairie stand. Samples collected by air-lift are richer in species and more variable, the apparatus being more effective at the base of the leaves, where the malacological stock is richer in species and reflects the variety of the substrate. Conversely, samples collected by hand-net are less rich in species and less variable, this tool being more effective on the leaves which are inhabited by a more homogeneous malacological stock. Therefore, the suction-sampler would be preferable when the qualitative aspects are to be emphasized with respect to the quantitative ones, as is the case for collections for structural analyses of communities; the hand-net may be more useful when the quantitative aspects prevail over the qualitative ones, as in the case of population analyses.

Secondly, in the large-scale structural comparison of the associations from the five *Posidonia* beds, both sampling methods were effective and gave similar information. This is clearly shown by the AC (F1/F2) ordination model, where the intra-site



sample-points were more closely arranged than the inter-site ones. As a consequence, the hypothesis that the 'inter-site' variability of the malacological associations is the effect of a bias introduced by the sampling method should be excluded. The large-scale variability of the malacofauna of the seagrass beds seems to be so intrinsic to the associations, and the structural 'signal' so strong, that they are recognisable independently of the sampling method utilised. Consequently, the strong structural differences between the Mediterranean sites seem to be related mainly to the edaphic factors characterizing each seagrass bed. The density of the prairie seems to have an important role in determining the strong structural differentiation of the malacological assemblage of the Medas, with respect to all other sites. In this site, in fact, the air-lift was far more efficient than the hand-net, as indicated by the high presence of molluscs more strictly related to the substrate, such as bivalves and, among gastropods, the families of Alvaniidae and Marginellidae. Apart from the vegetal cover of the substrate (e.g. density of plant shoots), the quality of the substrate itself, its exposure to water movements and the related sedimentation rates may be among the main edaphic factors affecting the qualitative composition of the malacological associations and determining the variety of functional adaptation. In fact, the dominance of herbivore-deposit feeders (e.g. *Bittium* spp.) is typical of seagrasses under conditions of low environmental energy, while, on the contrary, brusher-herbivores (e.g. *Jujubinus* spp. and *Tricolia* spp.), are abundant in conditions of high water movement.

In addition, the information collected suggests the presence of a latitudinal coenotic gradient. This is fairly evident in the ordination model, where the station points show saturation along F1 consistent with their geographical (i.e. longitudinal) positions. There are no species with narrow biogeographical distributions affecting the composition of the assemblages. Therefore, this latitudinal pattern is likely to be of the structural type, a product of the way widely distributed species are sorted together, rather than the result of the presence of endemic species in a narrow region of the Mediterranean. This geograph-

ical aspect is of particular interest and may be a promising field of investigation. In fact, up to now most malacological research activity has focused on investigating the historical aspects of single species, such as their evolution and biogeography, with little or no attention paid to the study of the history of assemblages they form.

Last, but not least, the large variability in the composition of the assemblages described in the present paper implies a great difficulty in recognising a unique and well-defined malacological taxocoene for the *Posidonia* beds. Species co-occurring in the different beds constitute a very low percentage of the total.

Therefore, the present analysis of one of the main faunistic components of the vagile fauna does not agree with the model of PÉRÈS & PICARD (1964), where the Mediterranean *Posidonia* beds are considered as a single biocoenotic and bionomic unit (HP). Present a-ecological data agree better with the 'poly-biocoenotic' hypothesis (BIANCHI *et al.*, 1989), although b-ecology needs to be focused in the future in order to gain a better understanding of the ecological processes underlying the structural patterns described.

CONCLUSIONS

- The suction-sampler and the hand-towed net discriminate the *intra*-site variability, as they sample different parts of the habitat produced by the seagrass. This gives rise to 'method-dependent' patterns which correspond to a real 'topological' stratification of the malacological association within the seagrasses. Therefore, the study of this type of variability needs sampling by both the above complementary techniques.

- When *inter*-site comparisons are performed, a new and stronger structural variability is added, against which the discriminating power of the two methods becomes ineffective, as they produce similar patterns. This new variability may be considered as 'edaphic', being related to local factors affecting the seagrasses. Consequently, for the study of this second type of variability, one of the two techniques may be adopted indifferently.

- A longitudinal trend was observed even if no species with narrow biogeographical distributions were recorded. Therefore this pattern is more likely to be related to the 'history' of the assemblage (e.g. successional stages) rather than to the history of some of the species belonging to them (e.g. evolutionary ecology).

- The high variability in the composition of the malacological assemblages does not fit with the model by Pérès and Picard which considers the Mediterranean systems of *Posidonia oceanica* beds as belonging to a single bionomic unit; on the contrary, our findings represent additional evidence in support of the hypothesis considering the system as an 'ecological cross-roads'.

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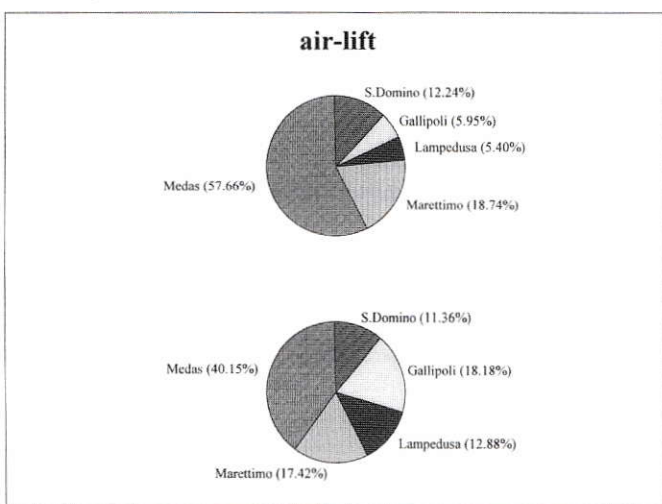


Figure 5. Samples by air-lift: (a) qualitative and (b) quantitative dominances among the sites.

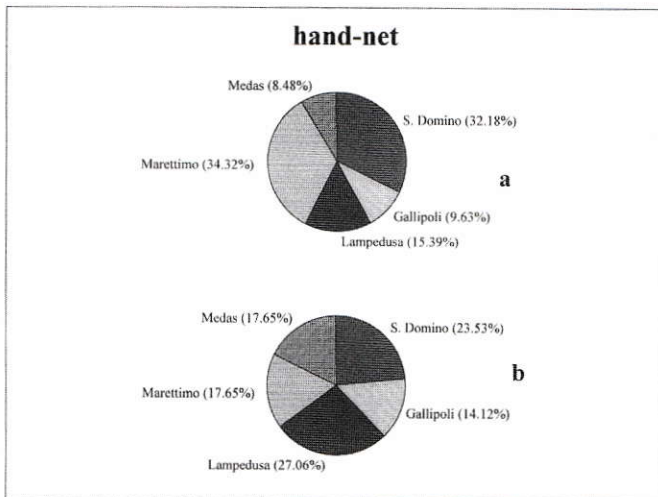


Figure 6. Samples by hand-net: (a) qualitative and (b) quantitative dominances among the sites.

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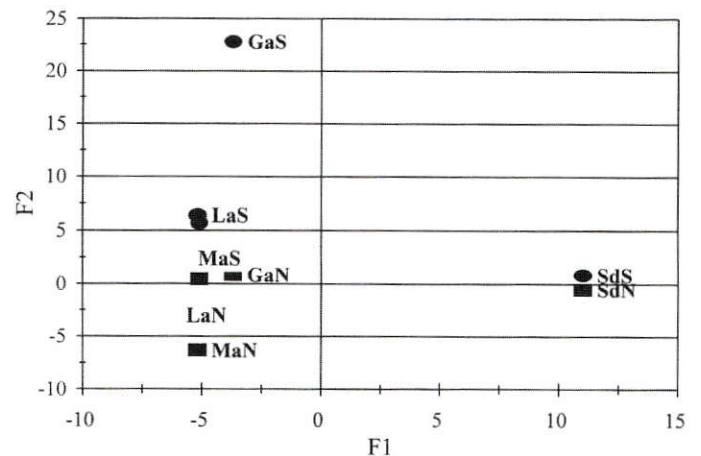


Figure 7. CA ordination model (F1-F2) of sample-points, obtained after the elimination of the peculiar samples of Medas (LaS= Lampedusa, Suction-sampler; LaN= Lampedusa, hand-Net; GaS= Gallipoli, Suction-sampler; GaN= Gallipoli, hand-Net; etc.).



The molluscan Taxocoene of photophilic algae from the Island of Lampedusa (strait of Sicily, southern Mediterranean)

Renato Chemello & Giovanni Fulvio Russo

KEY WORDS: Molluscs, Photophilic algae, Habitat complexity, Mediterranean.

ABSTRACT In the Mediterranean Sea, photophilic algae are the main feature of well-lit littoral rocky bottoms. Despite differences in the structure of the algal cover, their faunistic associations are considered to fairly be homogeneous. The aim of the present study is to relate the structural variations in space of photophilic algae assemblages and their associated malacological taxocoenes. Two main structural patterns, respectively depth-related and algae-related, have been found for the mollusc associations. The first pattern may be considered as a sort of biological record of overall depth-related changes in water movement. The second better reflects the variability in habitat complexity resulting from the morphology of the dominant algal thalli.

RIASSUNTO Il taxocene a molluschi delle alghe fotofile dell'isola di Lampedusa (Stretto di Sicilia, Mediterraneo meridionale). Nel Mediterraneo, le alghe fotofile sono la principale emergenza fisionomica dei fondi rocciosi ben illuminati. Nonostante le differenze nella struttura della copertura algale, le associazioni faunistiche sono considerate come abbastanza omogenee. Scopo del presente lavoro è di correlare le variazioni strutturali nello spazio delle associazioni di alghe fotofile e delle malacocenosi ad esse legate. Sono stati evidenziati due diversi patterns strutturali delle associazioni malacologiche, rispettivamente 'profondità-dipendente' e 'alga-dipendente'. Il primo può essere considerato una sorta di registratore biologico della variazione complessiva dell'energia ambientale (idrodinamismo) che si sviluppa con la profondità. In particolare, una prima associazione, composta da poche e selezionate specie, sembra essere strettamente legata alla zona di frangente; una seconda associazione, più diversificata, si rinviene al livello immediatamente sottostante. Queste due malacocenosi superficiali sono nettamente separate da un sottostante cenocline, che si sviluppa con l'aumentare della profondità, attraverso una forte discontinuità faunistica. Il secondo pattern è ben correlato con la variabilità nella complessità di habitat prodotta dalla morfologia dei talli algali dominanti. In particolare, sono state messe in evidenza tre malacocenosi principali, associate rispettivamente a macrofite di grande taglia con cauloide singolo eretto e ben articolato (ad esempio *Cystoseira spinosa*), macrofite erette di taglia media con cauloide cespitoso (ad esempio *Cystoseira amentacea*) ed, infine, a macrofite di taglia medio-piccola con talli poco articolati, ad esempio le feofite dei generi *Halopteris* e *Dictyota*.

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INTRODUCTION

According to the bionomic model of PÉRÈS & PICARD (1964), photophilic algae are the main feature of well-lit littoral rocky bottoms in the Mediterranean Sea and are at the same time, the structuring component of the coenotic system of the infralittoral plain. Yet, the algal components of rocky bottoms are very variable both qualitatively and quantitatively, in space and time.

This state of affairs was bionomically resolved through the identification of a number of 'facies' of the same single biocoenosis, named according to the dominant species. Facies are the result of rearrangements in the dominance of different algal populations which are mainly related to light intensity, water movement and nutrient supply. More recently, PÉRÈS (1982) considered these bionomic units merely as 'assemblages', i.e. groups of co-occurring species which are the direct effect of the historical evolution of the environment. MEINESZ *et al.* (1983) re-evaluated the ecological meaning of 'facies', considering them as single, different 'biocoenoses', i. e. well-integrated systems recurring in space and time.

Despite this bionomic re-evaluation, the ecological organization of these systems, in terms of structure and function, has been poorly investigated, mainly as regards the animal component. The first comprehensive studies of BELLAN-SANTINI (1962)

and LEDOYER (1962) gave a descriptive analysis of the vagile fauna associated with the different algal facies of shallow rocky bottoms, but little attention was paid to their variability in space and time. Molluscs seem to be an important group in the fauna living in these systems. POULICEK (1985) found an almost homogeneous mollusc assemblage between 3 and 30 m depth, on a rocky bottom near Calvi (Corsica), but gave no information on the structure of the associated algal cover.

The problem is therefore to couple investigations on different types of algal cover with those on their associated fauna. The aim of the present study, carried out on the rocky bottoms of Lampedusa, a southern Mediterranean island, is to examine variations with depth and exposure of both the photophilic algae assemblages and the associated malacological taxocoene. Little is known about the malacological associations living around this island, as the qualitative collections of SPADA *et al.* (1973) represent the only data available. In their study, each species was attributed to a biocoenosis *sensu* PÉRÈS & PICARD (1964), and the presence of a certain number of littoral systems was deduced by simply assuming a strict relationship between species and ecological systems. Apart from the faunistic interest of this work, the Authors did not provide information on the structure of the different mollusc assemblages and on the habitat they originated from.

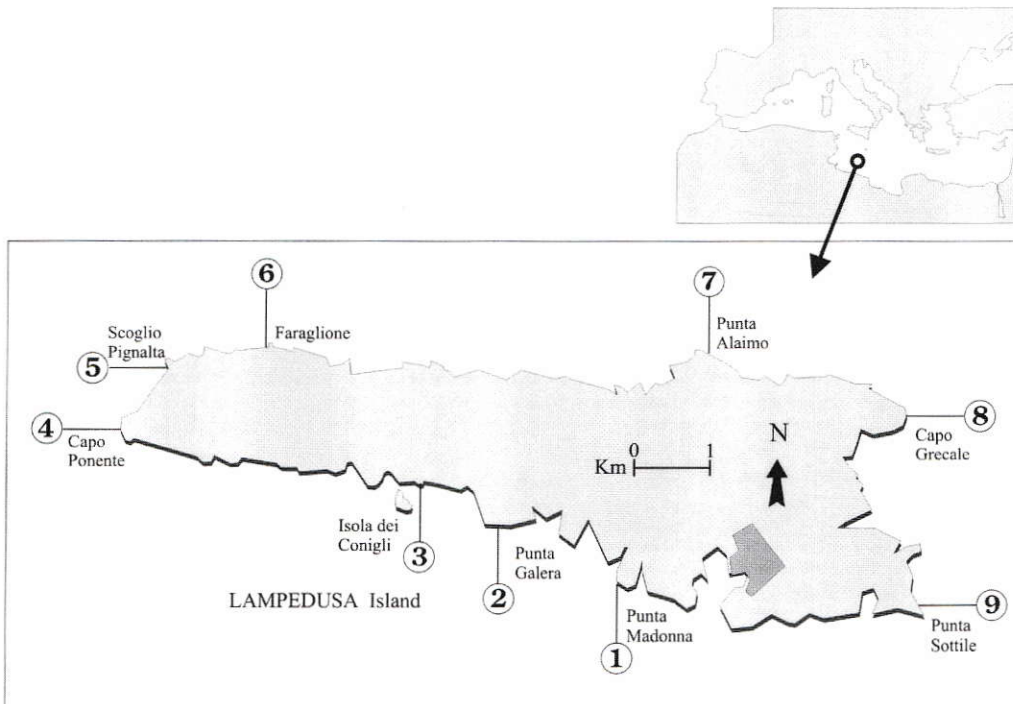


Figure 1. The Island of Lampedusa with the sampling transects.

MATERIALS AND METHODS

Study area

The island of Lampedusa, in the Pelagian archipelago (Strait of Sicily), is a calcareous plateau belonging to the North-African platform (Fig.1). The name 'Pelagian', meaning "island of open sea", explains why the island has only 40-60 days/year of calm waters. The morphology of the coast and the slope of the bottom are varied: the northern side is characterized by high cliffs with fallen boulders, the southern side is indented by rias which descend gently into the sea.

A preliminary analysis of the biocoenoses highlighted two main environmental factors characterizing the coastal area: water movement and sanding down. The former affects the northern coast, characterized by pebbles and gravel while the latter factor affects the southern coast, where sandy bottoms are covered by dense beds of *Posidonia oceanica*. As regards the hard substrata, above 12 m depth these are covered by rich assemblages of photophilic algae, without marked differences in composition around the island (CHEMELLO & DI GERONIMO, 1992).

Sampling procedures

In July 1990 a total of forty-five samples of benthos were collected from hard bottoms by scuba divers. The sampling protocol considered 5 levels (0, -1, -3, -5, -10 m) along 9 transects distributed around the island (Fig. 1).

A homogeneous area of 900 cm² (30x30cm) was sampled in three phases, in order to prevent the escape of the vagile fauna. First, a suction sampler was used for the collection of vagile fauna; the algal cover was then scraped off with a hammer and chisel and stored in a nylon bag; lastly, the suction sampler was used

again to remove the organisms of the hypostratum (CHEMELLO, 1991). After evaluation of the algal cover, the samples were washed through a 0.5mm mesh sieve and all living specimens were sorted, identified and counted.

Data analysis

Community parameters, *sensu* BOUDOURESQUE (1971), such as abundance, species richness, qualitative and quantitative dominance, frequency and diversity, were calculated on the raw data, arranged in a species/samples matrix. The SHANNON & WEAVER (1948) diversity index (H'), based on the probabilistic sorting of individuals among species and evenness (J), calculated according to the formula

proposed by PIELOU (1966), were utilized as measures of assemblage organization.

Structural analysis was performed using multivariate techniques of correspondence analysis (BENZECRI, 1973). The significance of the factors in the ordination model was evaluated using the test of FRONTIER (1974).

RESULTS

Descriptive analysis

A total of 10562 individuals belonging to 176 species were collected. 138 species (78.4%) and 9356 individuals (88.6%) were Gastropods, 10 species (5.7%) and 617 individuals (5.8%) were Polyplacophorans, and 28 species (15.9%) and 589 individuals (5.6%) were Bivalves (Tab.1). Among the gastropods, the family Rissoidae (26 species and 3491 individuals) was dominant in both qualitative and quantitative terms, with some species of particular biogeographical interest, such as *Rissoa scurra* and *Alvania oranica*.

On the whole, the most frequent species (100% of samples) were *Vermetus triquetrus*, *Dendropoma petraeum* and *Sinezona cingulata* at 0 m; *Acanthochitona crinita* at 1 m; *Jujubinus gravinae* and *Columbella rustica* at 3 m; *Jujubinus gravinae* and *Rissoa variabilis* at 5 m; *Bittium latreillii*, *Tricolia tenuis* and *Alvania lineata* at 10 m depth (Fig. 2).

The dominant species were *Dendropoma petraeum* (57.0%), *Sinezona cingulata* (9.4%), *Alvania beniamina* (7.0%), *Vermetus triquetrus* (6.6%) and *Cardita calyculata* (3.5%) at 0m; *Setia ambigua* (13.3), *Acanthochitona crinita* (11.3%), *Alvania beniamina* (10.7%), *Dendropoma petraeum* (9.2%) and Rissoidae spp. juv.



(8.4%) at 1m; *Setia ambigua* (25.7%), *Bittium latreillii* (17.5%), *Rissoa similis* (5.7%), *Acanthochiton crinita* (4.8%) and *Jujubinus gravinae* (3.8%) at 3m; *Bittium latreillii* (18.0%), *Eatonina fulgida* (6.6%), *Setia ambigua* (6.4%), *Musculus costulatus* (5.5%) and *Rissoa similis* (5.2%) at 5m; *Bittium latreillii* (20.3%), *Alvania lineata* (8.3%), *Tricolia tenuis* (7.8%), *Alvania oranica* (6.8%) and *Pisinna glabrata* (4.7%) at 10m.

In Fig. 3, the values of abundance (log scale) and species richness, obtained by grouping the samples according to depth, are reported in a direct biplot. A linear trend of increasing values for both parameters is evident, except for the 5 m level, which is characterized by a decrease in abundance.

The variation with depth of the quantitative dominance of molluscs in the hypostratum and epistratum is reported in Fig. 4. At the 0 m level, the malacofauna of the hypostratum dominates with 75% of total abundance. From a depth of 1m, the dominance of the epistratum malacofauna increases, with the increase in algal cover, reaching values between 50% and 80% between 3 and 10 m depth.

As regards the diversity indexes, the same pattern is found in all the transects: H' increases with depth (Fig. 5) as does J, which shows a particularly marked increase between 0 and 1 m (Fig. 6).

Structural analysis by ordination

Fig. 7 shows the ordination model obtained by correspondence analysis (two significant factors: F1= 17.1% and F2= 10.4% of the total variance). In the factorial plane, the station-points have a parabolic distribution, typical of a quadratic relationship

between the two factors (FRESI & GAMBI, 1982). Along F1, the station-points are distributed with their consistent position along the depth transects, with the shallowest ones strongly polarized in the positive portion and the deepest ones in the negative. The lack of strong discontinuities accounts for the development of a coenotic gradient (coenocline). However, the shallow station-points (0-1m) are less clumped than the others, as a result of a higher coenotic variability at these levels (note the small discontinuity among the 1m stations). Along F2, the intermediate and the deepest stations are rather spread out, with the latter strongly polarized in the positive part.

In order to better distinguish the patterns of the model, the saturation values of the station-points along each of the two axes were considered separately (Fig. 8). In the plot, the 'depth-related' pattern along F1 becomes more clear, while the distribution of station-points along F2 is well related to the changes in the dominant species of the algal cover. This 'algae-related' pattern is due to the opposition of the stations characterized by *Cystoseira* spp., and the stations characterized by 'other phaeophyceae', in the negative part of the factor. Among the *Cystoseira* spp. stations, the displacement along F2 is, in turn, 'depth-related'. In fact, the deep stations (characterized by *C. spinosa*) have a strong polarization while the shallow stations (characterized by *C. amentacea* and *C. compressa*) have low saturation values.

In order to assess how the malacological taxocoene behaves in relation to the 'depth-related' gradient described, a plot of the saturation values along F1 of both station-points and species-points was made (Fig. 9). Three clusters of species, accounting

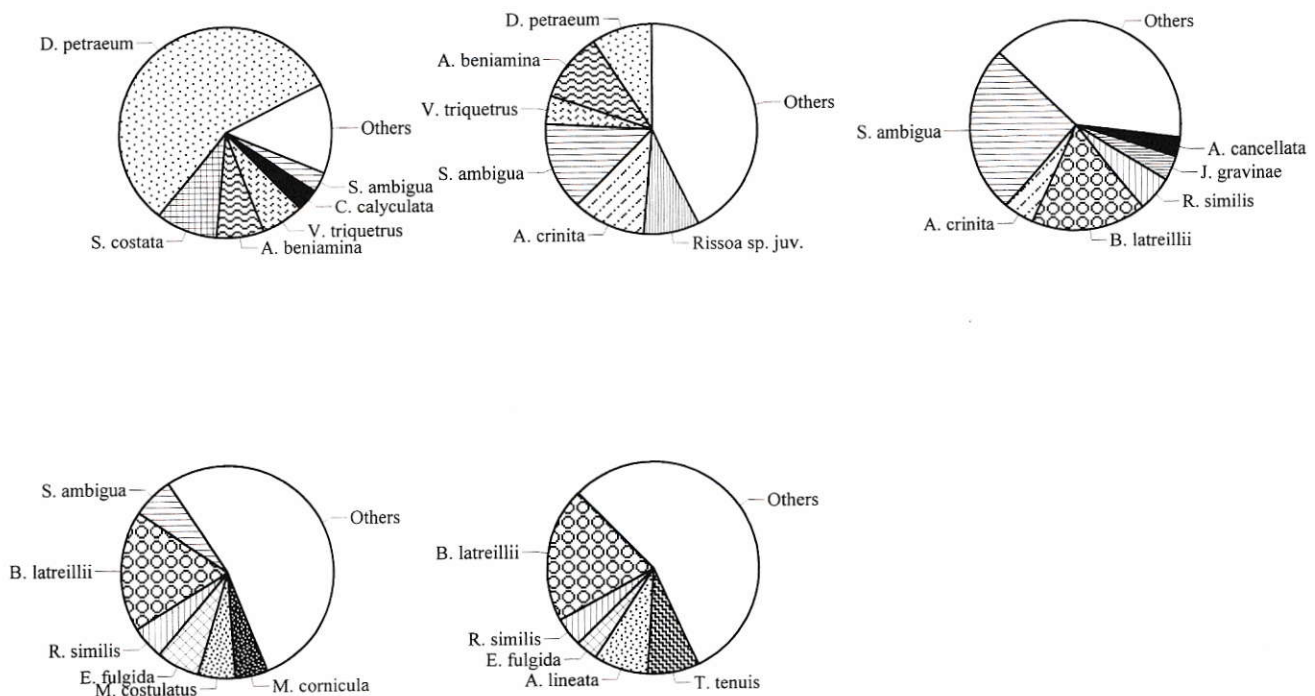


Figure 2. dominant species per depth.

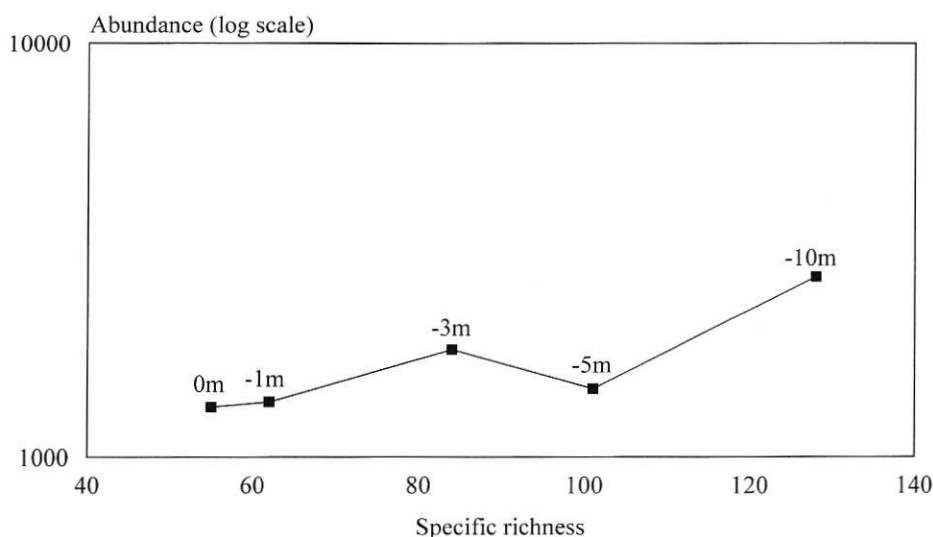


Figure 3. Direct biplot of abundance values, in log scale, and specific richness per depth.

for three different malacological assemblages, are evident (Tab. 3). Cluster A is associated with the 0 m stations, cluster B is associated with the 1 m stations, and cluster C includes the species related to the stations in the 3-10 m depth range, where a clear coenocline is evident.

In order to assess how the mollusc taxocoene is related to the algae-related gradient, a plot of the saturation values along F2 of both the station-points and the species-points was made (Fig. 10). A malacological coenocline is displayed along this axis. However, some slight discontinuities may be observed, consistent with the pattern of the station-points. A first discontinuity in the malacological coenocline (between clusters A and B; cfr. Tab. 3) separates the species associated with *Cystoseira* spp. from those associated with *Halopteris* spp., *Dictyopteris* spp. and other Phaeophyceae. A further slight dis-

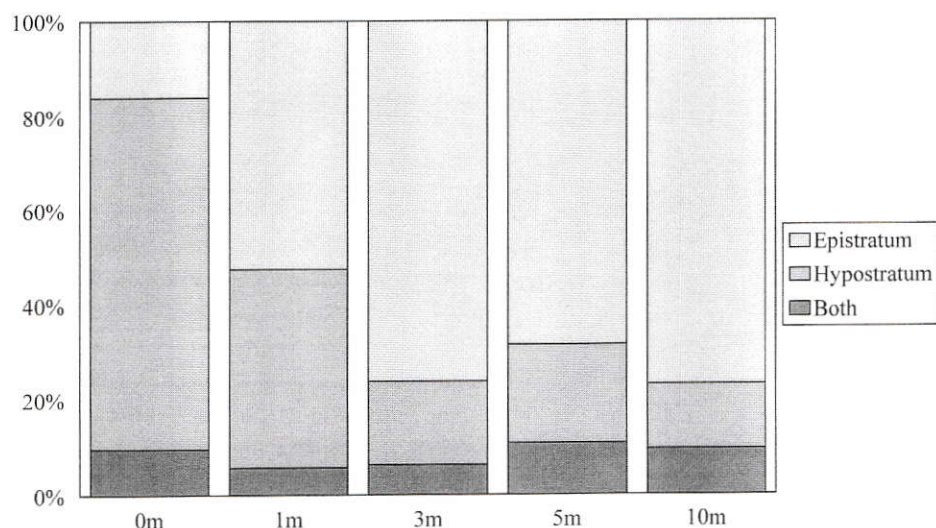


Figure 4. Variations with depth of quantitative dominance of molluscs in the epistratum and hypostratum of *Cystoseira* algal tuft.

continuity within cluster A separates, in turn, the malacological association related to the deep species of *Cystoseira* from that related to the shallow ones.

The shallow stations PM1 and PG1, characterized by a turf composed of rhizoids of *Dictyota fasciola* and *Amphiroa rigida*, are strongly polarized in the negative part of the factor, together with the molluscs *Rissoa scurra*, *Setia ambigua* and *Acanthochitona crinita*. Together with the deepest stations, colonized by *Cystoseira spinosa*, is clustered an intermediate one (PG3), characterized by *Sargassum vulgare*, which has a similar malacological association despite the difference in depth.

DISCUSSION AND CONCLUSION

The Pelagian archipelago is along way from polluted areas and is influenced by large exchanges of water masses between the western and eastern basins of the Mediterranean. Also from a biogeographical point of view, the islands may be considered a transitional zone between the eastern and western Mediterranean sub-regions. The co-occurrence in the malacological associations of abundant populations of eastern (e.g. *Rissoa scurra*) and western taxa (e.g. *Alvania oranica*) is further evidence of a biographical crossroads.

The coastal environment around the island is of particular interest, as a high variability in environmental and biological parameters occurs over a restricted area. The environmental gradients are particularly steep, allowing a more effective interpretation of the natural patterns. On the other hand, the main littoral feature of shallow rocky bottoms, above 10 m depth, is the presence of luxuriant algal associations which are almost homogeneous in species composition (SCAMMACCA *et al.*, 1993).

The malacological taxocoene living in this environment show their two main structural patterns, related to depth and to type of algal cover respectively. The first pattern may be considered as a sort of biological record of depth-related changes in environmental energy (i.e. water movement). Two malacological assemblages (groups F1-A and F1-B in Tab. 3) may be recognized in the upper levels of the transects (0 and 1m). In the literature (PÉRÈS & PICARD, 1964; BELLAN-SANTINI, 1962; 1964; PANDOLFO *et al.*, 1992), these assemblages are mixed in the single association of the 'exposed upper



Species ordered by frequency of occurrence		Fr%	Species ordered by total dominance		Dt%
1	<i>Vermetus triquetrus</i>	77,8	1	<i>Dendropoma petraeum</i>	17,8
2	<i>Rissoa similis</i>	75,6	2	<i>Bittium latreillii</i>	11,2
3	<i>Acanthochitona crinita</i>	75,6	3	<i>Setia ambigua</i>	8,27
4	<i>Mitra cornicula</i>	73,3	4	<i>Alvania beniamina</i>	4,07
5	<i>Bittium latreillii</i>	68,9	5	<i>Rissoa similis</i>	3,56
6	<i>Setia ambigua</i>	68,9	6	<i>Sinezona cingulata</i>	3,5
7	<i>Jujubinus gravinae</i>	68,9	7	<i>Acanthochitona crinita</i>	3,45
8	<i>Sinezona cingulata</i>	66,7	8	<i>Vermetus triquetrus</i>	3,07
9	<i>Cardita calyculata</i>	66,7	9	<i>Eatonina fulgida</i>	2,7
10	<i>Columbella rustica</i>	64,4	10	<i>Alvania lineata</i>	2,63
11	<i>Conus mediterraneus</i>	64,4	11	<i>Tricolia tenuis</i>	2,6
12	<i>Eatonina fulgida</i>	57,8	12	<i>Alvania oranica</i>	2,26
13	<i>Tricolia tenuis</i>	55,6	13	<i>Cardita calyculata</i>	2,17
14	<i>Musculus costulatus</i>	53,3	14	<i>Mitra cornicula</i>	1,93
15	<i>Alvania lineata</i>	48,9	15	<i>Musculus costulatus</i>	1,8
16	<i>Cerithium sp. juv.</i>	46,7	16	<i>Haminoea hydatis</i>	1,64
17	<i>Rissoa variabilis</i>	46,7	17	<i>Pisinna glabrata</i>	1,49
18	<i>Alvania beniamina</i>	44,4	18	<i>Jujubinus gravinae</i>	1,37
19	<i>Alvania oranica</i>	42,2	19	<i>Alvania cancellata</i>	1,23
20	<i>Haminoea hydatis</i>	42,2	20	<i>Lepidochitona corrugata</i>	1,15
21	<i>Nassarius costulatus</i>	42,2	21	<i>Cerithium sp. juv.</i>	1,07
22	<i>Alvania cimex</i>	40	22	<i>Rissoa scurra</i>	0,86
23	<i>Alvania cancellata</i>	37,8	23	<i>Columbella rustica</i>	0,85
24	<i>Chiton olivaceus</i>	33,3	24	<i>Chiton olivaceus</i>	0,82
25	<i>Gibberula miliaria</i>	33,3	25	<i>Barleeia unifasciata</i>	0,81
26	<i>Musculus discors</i>	31,1	26	<i>Gibberula miliaria</i>	0,8
27	<i>Rissoa guerinii</i>	31,1	27	<i>Granulina clandestina</i>	0,74
28	<i>Chauvetia submamillata</i>	31,1	28	<i>Nodulus contortus</i>	0,71
29	<i>Muricopsis cristata</i>	31,1	29	<i>Nassarius costulatus</i>	0,67
30	<i>Arca noae</i>	31,1	30	<i>Runcina sp.</i>	0,65
31	<i>Coralliophila meyendorffii</i>	31,1	31	<i>Conus mediterraneus</i>	0,57
32	<i>Dendropoma petraeum</i>	28,9	32	<i>Musculus discors</i>	0,55
33	<i>Pisinna glabrata</i>	28,9	33	<i>Rissoa variabilis</i>	0,53
34	<i>Barleeia unifasciata</i>	28,9	34	<i>Pusillina radiata</i>	0,52
35	<i>Gibbula turbinoides</i>	28,9	35	<i>Rissoa guerinii</i>	0,47
36	<i>Lepidochitona corrugata</i>	26,7	36	<i>Chauvetia submamillata</i>	0,43
37	<i>Rissoa scurra</i>	26,7	37	<i>Pisania striata</i>	0,35
38	<i>Granulina clandestina</i>	26,7	38	<i>Muricopsis cristata</i>	0,34
39	<i>Runcina sp.</i>	26,7	39	<i>Gibbula turbinoides</i>	0,33
40	<i>Cerithium rupestre</i>	26,7	40	<i>Vexillum savignyi</i>	0,32
41	<i>Vexillum savignyi</i>	24,4	41	<i>Alvania cimex</i>	0,31
42	<i>Hexaplex trunculus</i>	24,4	42	<i>Marshallora adversa</i>	0,29
43	<i>Vexillum ebenus</i>	24,4	43	<i>Cerithium vulgatum</i>	0,25
44	<i>Nodulus contortus</i>	22,2	44	<i>Fissurella nubecula</i>	0,23
45	<i>Pisania striata</i>	22,2	45	<i>Arca noae</i>	0,22
46	<i>Clanculus cruciatus</i>	22,2	46	<i>Hexaplex trunculus</i>	0,22
47	<i>Striarca lactea</i>	22,2	47	<i>Patella caerulea</i>	0,22
48	<i>Marshallora adversa</i>	20	48	<i>Coralliophila meyendorffii</i>	0,21
49	<i>Cerithium vulgatum</i>	17,8	49	<i>Cerithium rupestre</i>	0,21
50	<i>Chrysalida doliolum</i>	17,8	50	<i>Clanculus cruciatus</i>	0,17

Table 1. species arranged in order of their frequency of occurrence and dominance, respectively.



Transect	Sample	Depth	S	N	H'	J
PMA	PM0	0	26	870	2,20802	0,6777
	PM1	-1	17	250	1,57613	0,55631
	PM3	-3	27	167	2,81862	0,85521
	PM5	-5	39	136	3,26383	0,89089
	PMX	-10	49	141	3,4137	0,87715
PGA	PG0	0	19	350	1,27545	0,43317
	PG1	-1	26	487	2,28575	0,70156
	PG3	-3	45	185	3,31119	0,86984
	PG5	-5	39	103	3,42221	0,93412
	PGX	-10	56	1028	2,77008	0,68816
IDC	IC0	0	13	337	0,75717	0,2952
	IC1	-1	14	42	2,35989	0,89422
	IC3	-3	17	71	2,25832	0,79709
	IC5	-5	30	335	2,13024	0,62632
	ICX	-10	51	482	2,46501	0,62694
CPO	CP0	0	25	390	1,6783	0,52139
	CP1	-1	21	137	2,36557	0,77699
	CP3	-3	30	126	2,97955	0,87603
	CP5	-5	48	423	2,77096	0,71579
	CPX	-10	35	291	2,27678	0,64038
SPI	SP0	0	12	178	1,35472	0,54518
	SP1	-1	20	164	2,01587	0,67291
	SP3	-3	19	63	2,30063	0,78135
	SP5	-5	22	89	2,35434	0,76167
	SPX	-10	35	100	3,10392	0,87303
FAR	FR0	0	17	299	0,9153	0,32306
	FR1	-1	12	64	2,01602	0,81131
	FR3	-3	26	63	2,84451	0,87306
	FR5	-5	28	76	2,99829	0,89979
	FRX	-10	26	62	3,075	0,9438
PAL	PA0	0	12	277	0,715	0,28774
	PA1	-1	14	60	2,099	0,79536
	PA3	-3	17	114	2,043	0,72109
	PA5	-5	28	64	2,944	0,8835
	PAX	-10	49	142	3,499	0,89907
CGR	CG0	0	17	156	1,422	0,5019
	CG1	-1	27	92	2,8401	0,86172
	CG3	-3	32	415	2,0001	0,57711
	CG5	-5	31	165	2,894	0,84275
	CGX	-10	45	338	2,701	0,70955
PSO	PS0	0	18	204	1,752	0,60615
	PS1	-1	24	196	2,003	0,63026
	PS3	-3	32	610	1,678	0,48417
	PS5	-5	30	67	3,232	0,95025
	PSX	-10	42	153	3,1701	0,84815

Table 2. Number of species (S), number of individuals (N), Shannon diversity index (H') and evenness (J) of each sample.



	Groups			Groups			
	F1	F2		F1	F2		
1	<i>Vermetus triquetrus</i>	A	B	51	<i>Chrysallida doliolum</i>	C	A'
2	<i>Rissoa similis</i>	C	A''	52	<i>Polia dorbignyi</i>	C	A'
3	<i>Acanthochitona crinita</i>	B	B	53	<i>Calliostoma laugierii</i>	C	A''
4	<i>Mitra cornicula</i>	C	B	54	<i>Chauvetia brunnea</i>	C	A'
5	<i>Bittium latreillii</i>	C	A'	55	<i>Alvania discors</i>	C	A'
6	<i>Setia ambigua</i>	C	B	56	<i>Bittium reticulatum</i>	C	A'
7	<i>Jujubinus gravinae</i>	C	B	57	<i>Pinctada radiata</i>	C	A'
8	<i>Sinezona cingulata</i>	A	B	58	<i>Patella caerulea</i>	A	A'
9	<i>Cardita calyculata</i>	B	B	59	<i>Polia scabra</i>	C	A'
10	<i>Columbella rustica</i>	C	A''	60	<i>Fusinus rudis</i>	C	A'
11	<i>Conus mediterraneus</i>	C	B	61	<i>Jujubinus striatus</i>	C	A'
12	<i>Eatonina fulgida</i>	C	A''	62	<i>Lamellaria perspicua</i>	C	B
13	<i>Tricolia tenuis</i>	C	A'	63	<i>Odostomia erjaveciana</i>	C	A'
14	<i>Musculus costulatus</i>	C	A''	64	<i>Fissurella nubecula</i>	A	A''
15	<i>Alvania lineata</i>	C	A'	65	<i>Mytilaster minimus</i>	A	A''
16	<i>Cerithium</i> sp. juv.	C	A'	66	<i>Lepidopleurus scabridus</i>	C	B
17	<i>Rissoa variabilis</i>	C	A'	67	<i>Ischnochiton rissoi</i>	C	A'
18	<i>Alvania beniamina</i>	B	B	68	<i>Alvania semistriata</i>	B	A''
19	<i>Alvania oranica</i>	C	A'	69	<i>Ocenebrina edwardsii</i>	A	B
20	<i>Haminoea hydatis</i>	C	A''	70	<i>Ctena decussata</i>	C	A'
21	<i>Nassarius costulatus</i>	C	A'	71	<i>Emarginula octaviana</i>	C	B
22	<i>Alvania cimex</i>	C	A'	72	<i>Aplysia fasciata</i>	C	A'
23	<i>Alvania cancellata</i>	C	B	73	<i>Plagiocardium papillosum</i>	C	B
24	<i>Chiton olivaceus</i>	C	B	74	<i>Pusillina radiata</i>	C	B
25	<i>Gibberula miliaria</i>	C	A'	75	<i>Ammonicera fischeriana</i>	B	A'
26	<i>Musculus discors</i>	C	A'	76	<i>Myoforceps aristata</i>	C	B
27	<i>Rissoa guerinii</i>	B	B	77	<i>Elysia timida</i>	B	B
28	<i>Chauvetia submamillata</i>	C	A'	78	<i>Thuridilla hopei</i>	B	B
29	<i>Muricopsis cristata</i>	C	A'	79	<i>Mitrella scripta</i>	B	B
30	<i>Arca noae</i>	C	A'	80	<i>Elysia viridis</i>	C	A'
31	<i>Coralliophila meyendorffii</i>	C	A''	81	<i>Acmaea virginea</i>	B	B
32	<i>Dendropoma petraeum</i>	A	A''	82	<i>Stramonita haemastoma</i>	C	A'
33	<i>Pisinna glabrata</i>	C	A'	83	<i>Mitra nigra</i>	C	A'
34	<i>Barleeia unifasciata</i>	C	A'	84	<i>Acanthochitona fascicularis</i>	C	A'
35	<i>Gibbula turbinoides</i>	C	A'	85	<i>Alvania scabra</i>	C	A'
36	<i>Lepidochitona corrugata</i>	A	B	86	<i>Mitrella</i> sp. juv.	C	A'
37	<i>Rissoa scurra</i>	B	B	87	<i>Vexillum tricolor</i>	C	A'
38	<i>Granulina clandestina</i>	C	A'	88	<i>Rissoella inflata</i>	C	A'
39	<i>Runcina</i> sp.	B	A'	89	<i>Colubraria reticulata</i>	C	A'
40	<i>Cerithium rupestre</i>	C	B	90	<i>Lepidochitona cinerea</i>	B	B
41	<i>Vexillum savignyi</i>	C	A'	91	<i>Mitrella spelta</i>	C	B
42	<i>Hexaplex trunculus</i>	C	A'	92	<i>Clavagella melitensis</i>	C	A'
43	<i>Vexillum ebenus</i>	C	B	93	<i>Mangiliella taeniata</i>	C	A'
44	<i>Nodulus contortus</i>	C	A'	94	<i>Clanculus jussieui</i>	C	A''
45	<i>Pisania striata</i>	A	B	95	<i>Megalomphalus azonus</i>	C	A'
46	<i>Clanculus cruciatus</i>	C	A'	96	<i>Lithophaga lithophaga</i>	C	B
47	<i>Striarca lactea</i>	C	B	97	<i>Gibbula varia</i>	B	B
48	<i>Marshallora adversa</i>	C	A'	98	<i>Alvania geryonia</i>	C	A'
49	<i>Rissoa</i> juv. ind.	C	B	99	<i>Buccinum corneum</i>	B	B
50	<i>Cerithium vulgatum</i>	C	A'	100	<i>Aplysiopsis elegans</i>	C	A'

Table 3. Groups of species according their position of F1 and F2. The species are numbered according to their frequency of occurrence.

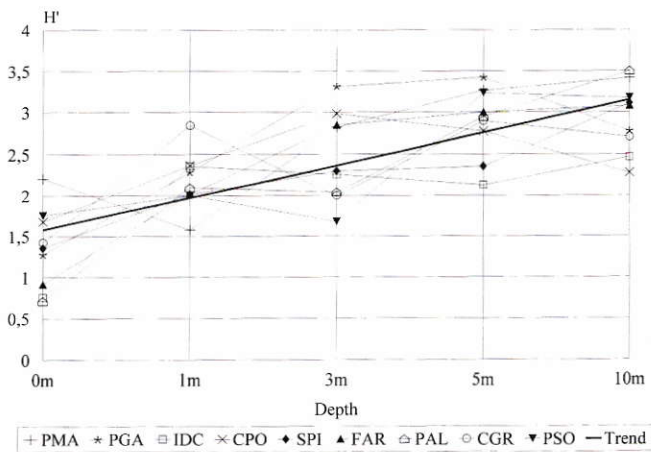


Figure 5. Patterns of Shannon diversity index in all the transects.

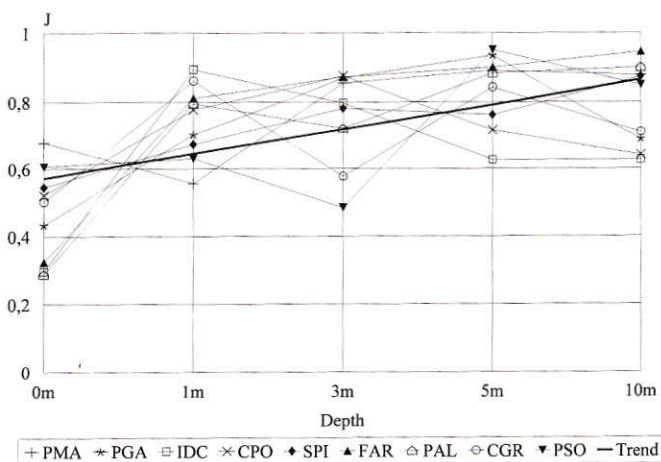


Figure 6. Patterns of evenness index, according to PIELOU, in all the transects.

infralittoral'. In the present study they are clearly secluded, marking a discontinuity between the true surf zone and a deeper level with relatively low water movement. The assemblage of the upper level (0m) is characterized by low evenness values due to the dominance of a few selected species such as *Dendropoma petraeum*. A more even and diversified assemblage is present in the lower level (1m) due to the less selective environmental conditions.

Below 3m, a depth-related coenocline (group F1-C in Tab. 3) follows a coenotic discontinuity which probably marks the change from lacerating to oscillating water movements ('first critical depth' of the zonation model of RIEDL, 1971). The coenocline is characterized by an increase in community organization with depth, reflected by the increasing values of diversity and evenness.

Apart from depth-related changes in environmental energy, the malacological assemblages show a second structural pattern related to the habitat complexity of the dominant algal morphology. Two main assemblages related to different types of algal thallus morphology were recognized. The first (group F2-A in Tab. 3) is associated with structurally complex

macrophytes of large size (10-40 cm) with erect and well-articulated cauloids, which were found at all depth levels (e.g. species of the genus *Cystoseira*). The second malacological assemblage (group F2-B in Tab. 3) is associated with simple structured macrophytes of small or medium size (5-15 cm) with less articulated thalli, such as the phaeophytae *Halopteris* spp. and *Dictyota* spp.

In addition, among the species associated with *Cystoseira* spp., a further distinction may be made (AMICO *et al.*, 1985) between those living on large algae with single cauloids (e.g. *C. spinosa*), which mainly colonize the lower levels of the transects, and those living on medium-sized algae with coespitose cauloids (e.g. *C. amentacea*), which colonize the upper levels (sub-groups F2-A¹ and F2-A² respectively in Tab. 3).

Similar coenotic patterns on hard substrates, more related to biological (e.g. algal cover) than physical conditions (e.g. depth-related water movement), have been described for Polychaetes (ABBIATI *et al.*, 1987; GIANGRANDE, 1988). On the basis of species composition, these studies point out the co-occurrence on rocky bottoms of a faunistic and a floristic coenotic gradient. However, the relationships between the different structural morphologies of the thalli and the related faunal association living 'on' and 'inside' this biological substrate were not investigated.

The present study shows how the habitat structure represented by the organisms is an environmental parameter which plays an important role in the marine environment.

ACKNOWLEDGEMENTS

We wish to thank Dr. Michele Lucido for his invaluable help during sampling operations. Prof. Giuseppe Giaccone kindly helped with the complex systematics of the Genus *Cystoseira* as well as solving some problems related to the taxonomy of other algae. Thanks are also due to Prof. Gian Carlo Carrada, Prof. Ferdinando Boero and Prof. Silvano Riggio for their advice and for the critical revision of the manuscript. Dr. Mario Lo Valvo collaborated in refining the statistics.

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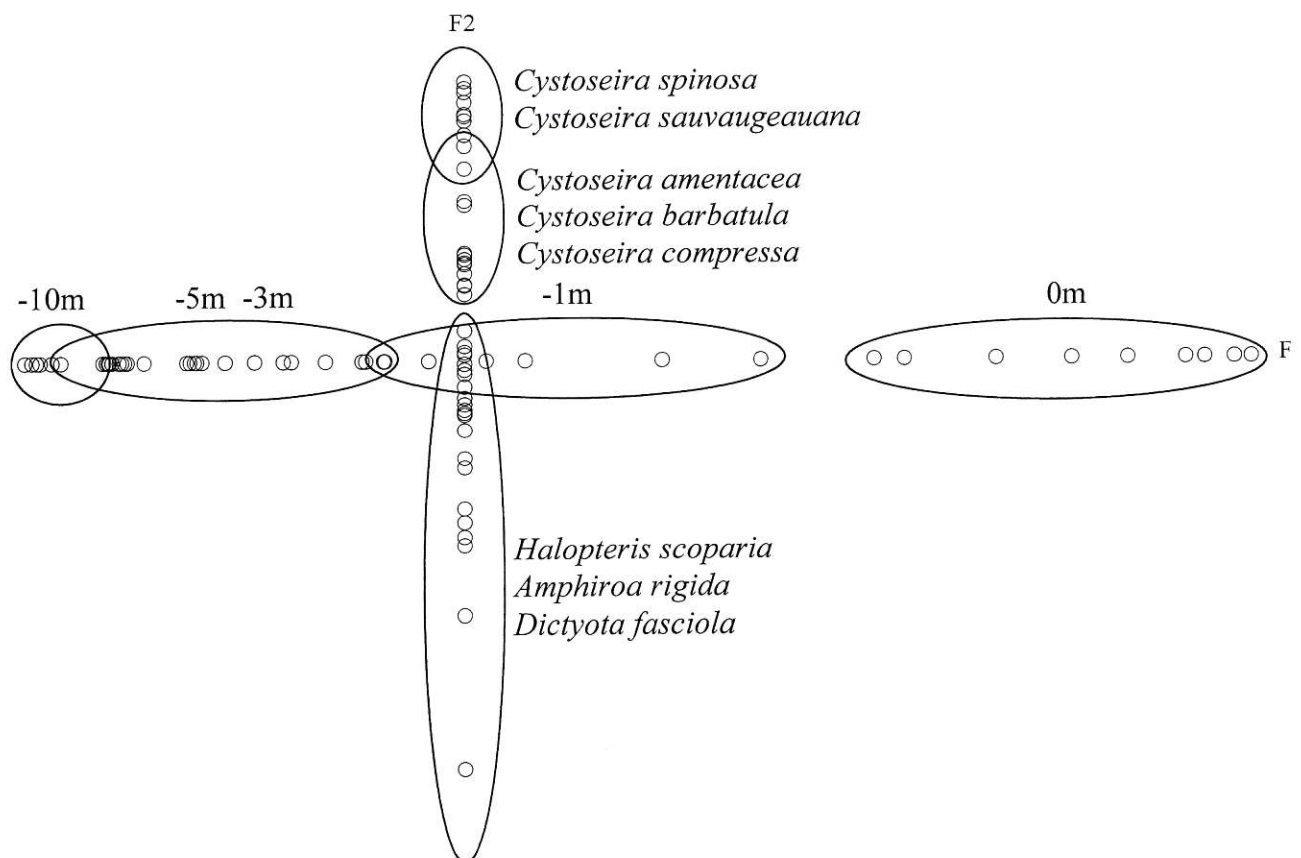


Figure 7. Factorial analysis of correspondances, axes 1 and 2.



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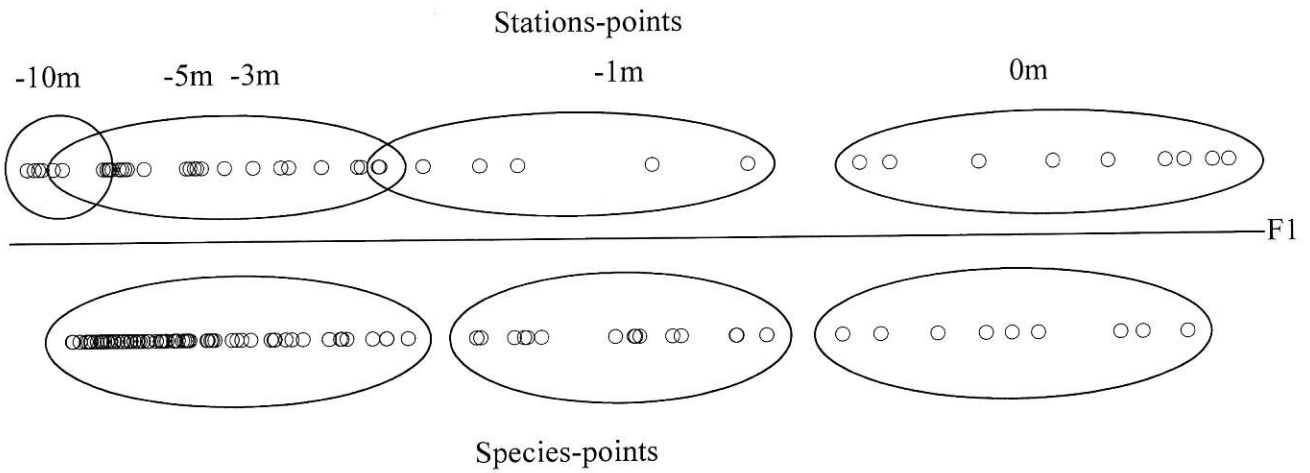


Figure 9. Saturations of station-points and sample-points along F1.

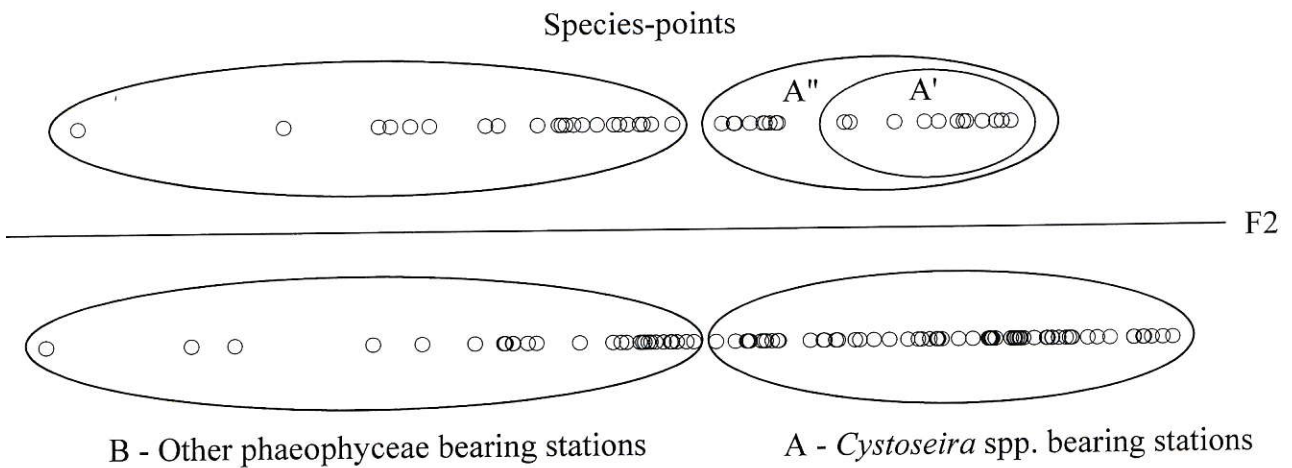


Figure 10. Saturations of station-points and sample-points along F2.



Molluscan assemblages associated with intertidal vermetid formations: a morpho-functional approach

Renato Chemello, Ignazio Ciuna, Amalia Pandolfo & Silvano Riggio

KEY WORDS: intertidal, vermetid formations, mollusc, Sicily, Mediterranean.

ABSTRACT Vermetid platforms are peculiar bioconstructions stretching along the calcareous shores of western Sicily where they appear as a rocky framework at the intertidal level. A survey of their gastropod fauna was carried out based on their shell morphology and the feeding role of each species. The results further substantiate our previous hypothesis refers to the vermetid platform as a horizontal extension of the spatial niches of the most significant infralittoral taxa. Species distribution along a multifactorial gradient is also indicated. Two major dimensions characterize the spacing of the biotic components: one refers to the sea-land axis; the second is related to the height of the structure above mean sea level.

RIASSUNTO L'approccio morfo-funzionale allo studio del popolamento a Molluschi associato alle formazioni a vermeti. La malacofauna di una biostruttura a vermeti della Sicilia nord-occidentale è stata esaminata utilizzando alcuni descrittori morfologici e funzionali, basati sui parametri conchigliari e sulle caratteristiche trofiche delle specie. I risultati, ottenuti utilizzando i soli Gasteropodi conchigliati, hanno consentito di confermare il ruolo ecologico del "trottoir" a vermeti, inteso come dilatazione della nicchia spaziale di molte specie, soprattutto infralittorali. In secondo luogo di leggere in maniera molto più dettagliata la distribuzione delle specie lungo l'ipotetico gradiente multifattoriale che regola la comunità, disposto sia secondo la direzione costa-mare sia secondo l'altezza della struttura sul livello medio del mare. I morfogruppi "leggono" questo doppio gradiente e si dispongono lungo la piattaforma in relazione ad esso.

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INTRODUCTION

"Trottoir à vermetes" (PÉRÈS & PICARD, 1952) are biogenic constructions (*sensu* LABOREL, 1987) formed by the species *Dendropoma petraeum* (MONTEROSATO, 1884) and are typical of the rocky coasts the northwestern Sicily. They are flat horizontal reefs lining most rocky calcareous shores in the southern Mediterranean where they make up a highly indented structure.

They grow perpendicular to the coastline, from land to sea, forming true "récif-barrière" in which a well-developed community is found (CHEMELLO, 1989; MANNINO, 1992; ORLANDO, 1978; PANDOLFO *et al.*, 1992a, 1992b; SAFRIEL & BEN-ELIAHU, 1991). Vermetid platforms were first reported on the rocky shores of Isola delle Femmine (northwestern Sicily) (QUATRE-FAGES, 1842; PÉRÈS & PICARD, 1952; MOLINIER & PICARD, 1953) and are documented to inhabit the rocky coasts of temperate and tropical seas (KEEN, 1961). With the isolated exceptions of the Caribbean Sea (JONES & HUNTER, 1995) and the Island of Fernando de Noroña in Brazil (KEMPF & LABOREL, 1968), the most important constructions are found in the Mediterranean sea. Apart from in Sicily, vermetid platforms are present along the coasts of Israel (SAFRIEL, 1966; 1974; 1975) and Lebanon (DALONGEVILLE, 1977; BITAR & BITAR-KOULI, 1995a; 1995b), southern Turkey (LABOREL, 1987), Crete (KELLETAT, 1979; LABOREL, 1987), Malta (AZZOPARDI, 1992), Algeria (MOLINIER & PICARD, 1953), Corsica (MOLINIER, 1955a; 1955b) and Spain (TEMPLADO *et al.*, 1992).

The "trottoirs" of NW Sicily are by no means simple structures, but are complex systems which share the major features of mid- and infralittoral levels and include many habitats subject-

ed to diverse environmental conditions. A typical vermetid platform can be divided into a number of different zones (CHEMELLO, 1989): a- *Lythophilum lichenooides* cushions, the biological marker of the inner margin of the vermetid platform; b- one or more "cuvettes", little pools which remain covered by sea water and separated from each other by small vermetid crests; c- an elevated outer margin; d- the upper infralittoral fringe. Level is characterized by a "facies" of the Phaeophyceae *Cystoseira amentacea* var. *amentacea* (GIACCONE & DE LEO, 1966).

Information on the malacofauna of Sicilian platforms is restricted to a few taxonomic reviews (ORLANDO, 1978; PANDOLFO *et al.*, 1992a), dimensional analyses of the "trottoir" (BADALAMENTI *et al.*, 1992a; 1992b; CHEMELLO, 1989) and descriptions of the assemblage structure (CHEMELLO *et al.*, 1990; PANDOLFO *et al.*, 1992b) while the relationships between habitat complexity and associated polychaete communities have been indicated only for formations in Israel (SAFRIEL & BEN-ELIAHU, 1991).

Attempts to propose simple developmental models of the "ecological functioning" of vermetid bioconstructions and to trace significant relationships between gastropod growth and the abiotic environment have been frustrated by the high degree of complexity of the ecosystem. Water movement and turbulence through the platform are the main physical factors affecting the vermetid constructions. Their high variability and chaotic growth make assessment difficult and rather unreliable.

Our attempt to overcome this constraint has led to the use of appropriate biological descriptors, based on the supposed corre-

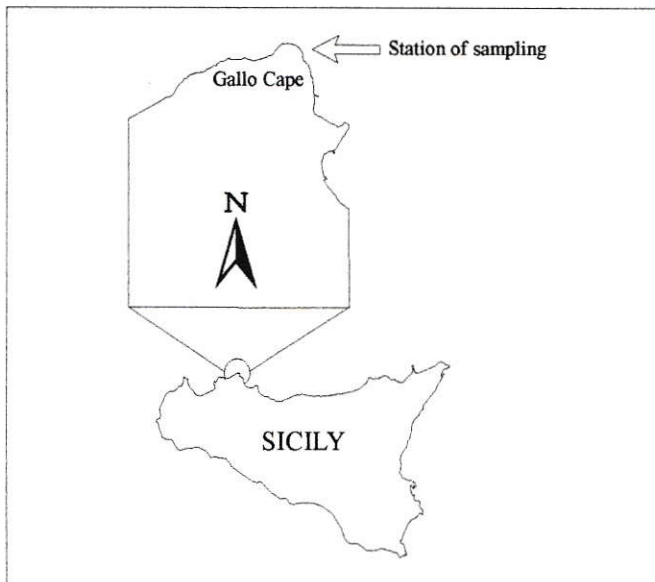


Figure 1. Gallo Cape (Northwestern Sicily): station of sampling.

spondence between the morphology of shelled gastropod molluscs and the structure of their settlements under the influence of the main abiotic factors. A number of morpho-functional parameters have been chosen, which have already been tested in other molluscan communities (RUSSO 1986; RUSSO, 1989). Our survey has resulted in a thorough analysis of the effects of hydrodynamism on the distribution of shelled gastropods along a short environmental gradient. The result is significant despite the fact that non-shelled and non-fit molluscan species were not included in the analysis. Bivalves, polyplacophorans and non-shelled gastropods are therefore not taken into consideration, although they play an important role in the structuring of the malacocoenosis (PANDOLFO *et al.*, 1992b).

MATERIALS AND METHODS

Eight square samples (400 cm² in area) were scraped from the surface of the biogenic platform using a hammer and chisel in March 1994. The study site was Cape Gallo, at the westernmost limit of the Gulf of Palermo (NW Sicily) (Fig. 1). Samples were collected from the following zones and bionomic facies characterizing the platform (Fig. 2): 1 - *Lithophyllum lichenoides* (LIT) cushions; 2 - inner border (BI) formed by a thin vermetid layer; 3 - first cuvette (CV1); 4 - second cuvette (CV2); 5 - *Dendropoma petraeum* (CR) crest; 6 - third and deepest cuvette (CV3); 7 - outer border (BE) formed by a thick vermetid layer; 8 - outer side of reef at the "biological zero", populated by the *Cystoseira amentacea* var. *amentacea* (CYS) facies. Sampling was then carried out along a shore-sea transect, taking into account the "internal-external" hydrodynamic gradient highlighted in previous surveys (PANDOLFO *et al.*, 1992b).

Samples were washed through sieves with mesh sizes decreasing from 2mm to 0,5mm, and then sorted. After sorting and taxonomic determination to the species level, the collected *taxa* were arranged in a species/station matrix (Tab. 1). The abundance for each species in each sample was also reported as percent age dominance (Fig. 3).

A number of morphological characters (Fig. 4) for each species (RUSSO, 1989) were measured using a Wild M3Z microscope: a - shell length (sl); b - shell width (sw); c - mouth height (al); d - mouth width (aw); e - foot length (fl); f - foot width (fw).

The following morphological descriptors were then obtained from the above measurements (RUSSO, 1989): 1 - size (TG); 2 - slenderness (SL= sl/sw); 3 - spiralization (SP= sl/aw); 4 - mouth opening (AP= al/aw); 5 - shape of foot (PI= al/aw); 6 - tenacity (AD= PI/SL).

The attribution of each species to a trophic guild (CT) was based on the literature data (e.g. GRAHAM, 1988) and on the first-hand observations of the Authors. The relationships with the substratum have been inferred by *in situ* observations made by the Authors.

The progressive ranking order for each morphological descriptor (Tab. 2) was produced, based on the mean values per species (Tab. 3). The abundance and relative dominance of each single descriptor was obtained by summing the individual numbers of each species included in each rank class. Data analysis was then performed on a three-way matrix rank/sample/abundance, by the separate analysis of each single descriptor.

Factorial analysis of correspondence (FAC) was carried out on the malacofauna using a semi-quantitative species/station matrix (BENZECRI, 1976). This made it possible to arrange the taxonomic descriptors (species) along a gradient. The significance of the explained variance for each axis was tested using the FRONTIER (1974) method.

RESULTS

Twenty eight species of shelled gastropods was identified from the examination of 307 sampled specimens. The quantitative

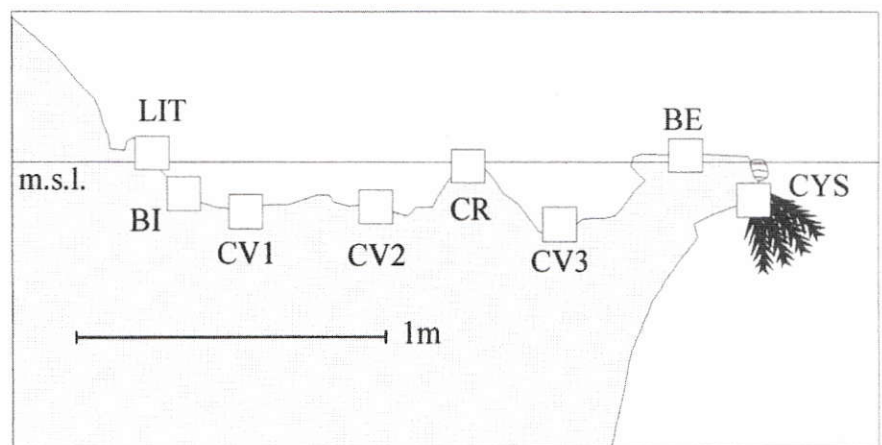


Figure 2. Scheme of the platform in cross section

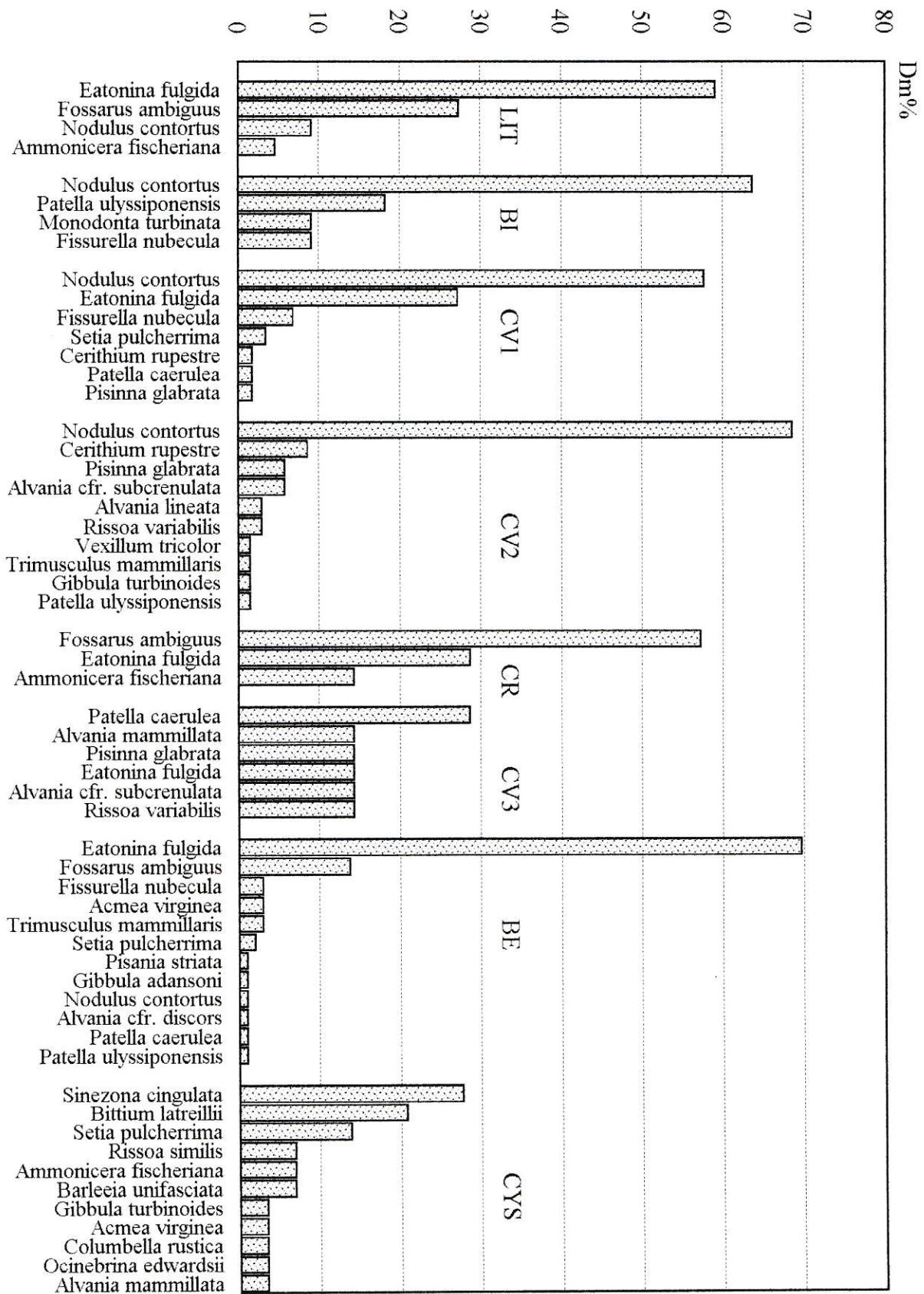


Figure 3. Percentage dominance.

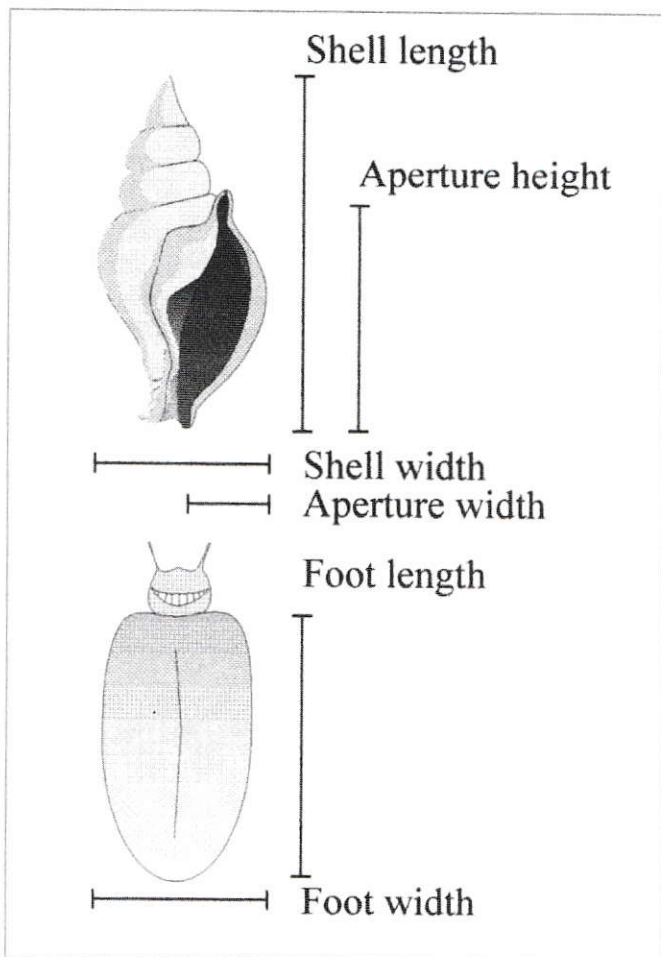


Figure 4. Measures taken on the shell and the foot.

dominance analysis for each morpho-functional descriptor produced the following results:

a) height

Five size classes were identified and arranged into ranks of increasing order (Fig. 5). Individuals of the smallest size-class (TG1) appear in all samples, with a lower frequency in CV3 and CYS, where the largest-sized individuals are more numerous. TG2 is lacking from LIT and CR, and is rare in the remaining samples, with the exclusion of BI and CV3, where it is at its maximum. TG3 is found in CV2, CV3 and in the *Cystoseira* facies. TG4 is only found in CV1 and CV2, whereas TG5 appears in BE and CYS. There is a trend of an increase in the size of the shells from the inner margin to the outer.

b) slenderness

Slenderness was divided into four decreasing classes (Fig. 6). SL1 is only found in CYS. SL2 is present in CV2, CV3 and CYS. SL3 is dominant among the classes, but its role is quite negligible in CYS, CV3 and BI, whereas SL4 is found in all samples, attaining a maximum value in BI and CYS and a minimum in LIT.

c) coiling

Three classes of coiling (Fig. 7) were plotted in decreasing order. SP1 is dominant in BI, CV1 and CV2, and is a minor component of the CV3 and CYS malacofauna. SP2 is represented in all samples, although in smaller numbers in BI and CV2, whereas it is dominant in CR. Few individuals make up SP3, which is absent from LIT and CR, while attaining its maximum in BI and CV3.

d) mouth

Among the four classes identified (Fig. 8), in decreasing order, the highest value is represented by AP1 in which the aperture is more or less circular. The frequency of AP1 is particularly low in CV2, BE and CYS, whereas AP2 characterizes only BE and CYS. AP3 and AP4 are the dominant classes along the transect.

e) foot

Foot shape was also divided into four classes (Fig. 9). The largest-foot class, PI1, appears only in CV1, CV2 and CYS. PI2 is missing from BI and increases in LIT and BE. PI3 is ubiquitous, but with lower percentages. Class PI4 is also uniformly represented in all samples.

f) tenacity

The values of the four AD classes are arranged on a low-to-high scale (Fig. 10). The lowest tenacity, AD1, is typical of CV1, CV2 and CYS, all environments with reduced wave action. AD2 is found in LIT and represented by low numbers in CV1, CV2 and BE. It is more abundant in CR and CV3 and missing from BI. Its peak is attained in CYS. AD3 is ubiquitous. AD4 is present in BI, CV1, CV3 and BE; low numbers of this class appear in CV2.

g) relationships with substratum

The relationships of the functional descriptors with the substratum were grouped into the following categories (Fig. 11):

- endolithic (ST1), i.e. organisms finding refuge in the trottoir matrix. These are typical of LIT, CR and BE;
- epilithic (ST2), living on the "trottoir" surface and collected from all samples, with a minimum in CV1 and CYS, and missing from LIT;
- epiphytic (ST3), living on benthic algae and present in all samples;
- ST4 groups species which present more than one relationship with the substratum (e.g. *Bittium latreillii*) but this category is restricted to CYS. CYS seems to represent a more diversified habitat and the same gastropod can occupy different layers of its substratum (e.g. both algae and incrustation).

h) trophic guilds

Three trophic guilds were recognized (Fig. 12): algal grazers (BRV); detritus feeders (DET) and carnivores (CAR). The BRV, feeding both on diatoms and/or on macroalgae, are the more represented along the transect. The DET appear in all samples, although in small numbers; whereas the CAR are a non-negligible component of the CYS sample. This last group includes



sponge-eating species (*Vexillum tricolor*) and predators of polychaetes (such as *Pisania striata* and *Columbella rustica*) and small bivalves like *Ocenebrina edwardsii* that feed on *Mytilaster minimus*.

FCA

Three clusters along the first two axes (F1=36.8% and F2=32.1% of the total explained variance) are evident from FCA (Fig. 13), arranged at the tips of a triangle (FRESI & GAMBI, 1982). This figure shows strong polarization due to the presence of the CYS sample, which probably belongs to the different system of the infralittoral fringe. On the other, all the remaining samples belong to an intertidal system.

The first cluster includes only the CYS sample, which included the following species: *Sinezona cingulata*, *Bittium latreilii*, *Rissoa similis*, *Barleeia unifasciata*, *Ocenebrina edwardsii* and *Columbella rustica*. CR, LIT and BE are grouped in the second cluster, with the following 5 associated species: *Gibbula adansoni*, *Fossarus ambiguus*, *Eatonina fulgida*, *Alvania discors* and *Ammonicera fischeriana*. The remaining stations, i.e. CV1, CV2, CV3 and BI are represented in the third cluster, with which are associated: *Patella ulyssiponensis*, *Monodonta turbinata*, *Cerithium rupestre*, *Rissoa similis*, *Alvania lineata*, *Alvania* cfr. *subcrenulata*, *Nodulus contortus*, *Pisina glabrata* and *Trimusculus mammilaris*.

These three clusters identify two major gradients. The first gradient refers to the F1 axis and is due to a marked separation between all the samples on the horizontal platform and the *Cystoseira* sample. This can be explained as the "midlittoral Æ infralittoral" factor. The F2 axis intercepts an "emersion / immersion" factor due to the relative position of each sample with respect to average sea level.

DISCUSSION

The spectrum of dominance of each single descriptor highlights the major role of small-sized gastropods in the entire habitat. Calcareous algae such as *Neogoniolithon notarisii* (MANNINO, 1992), small crevices and empty vermetid shells are very likely to act as refuges for this fauna, and thus ensure a higher survival rate during the frequent and long-lasting periods of desiccation

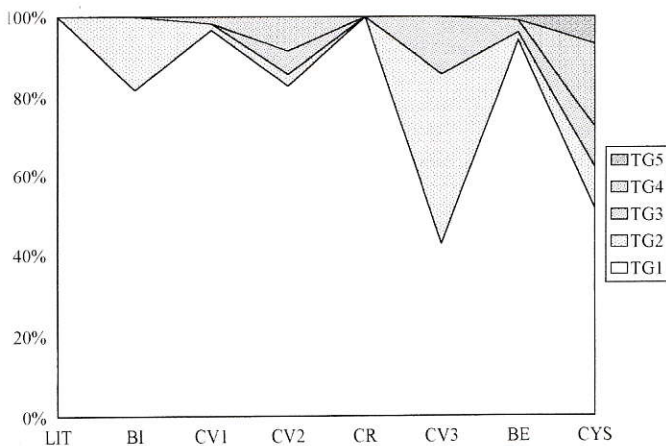


Figure 5. Distribution of height ranks.

Rank: HEIGHT	TG1<3mm 3<TG2<6mm 6<TG3<9mm 9<TG4<12mm TG5>12mm
Rank: SLENDERNESS =SL/SW	SL1>3,5 2,5<SL2<3,5 1,5<SL3<2,5 0<SL4<1,5
Rank: COILING =SL/AW	SP1>3 1<SP2<3 SP3<1
Rank: MOUTH =AL/AW	AP1>2 1,6<AP2<2 1,2 <AP3<1,6 0,8<AP4<1,2
Rank: FOOT =FL/FW	PI1>4 3<PI2<4 2<PI3<3 1<PI4<2

Table 2. Division in classes for each rank.

of the platform, which occur especially during the spring and autumn syzygial tides.

Taxa with higher TG, AP, PI and SL values are restricted to the "cuvettes" (pools) and the *Cystoseira* fringe. The relatively low hydrodynamism at the bottom of the "cuvettes" very probably has a stabilizing effect on the habitat, whereas the network of branches and leaflets of the thick *Cystoseira amentacea* stands effectively dissipates high wave energy, thereby contributing to the creation of a shelter zone during storms.

The elongated foot shape, which affords less contact the bottom, should account for the lack in CR and BE of low-tenacity taxa, which are unable to withstand wave action; the reverse is true regarding the presence of highly adhesive (AD4) species at BI and BE. AD4 species, namely *Patella ulyssiponensis* and *Patella caerulea*, are also found in the "cuvettes", due to their optimal tenacity to the substratum.

Intriguingly enough, the arrangement of organisms included in the ST1 class closely fits with the spatial development of the platform, in which the incrustation in CR and BE is proportionately thicker, whereas the highly irregular ground at LIT prevents a large number of opportunities for refuge and settlement. The algal assemblage dominated by *Laurencia papillosa*, distributed along the whole platform, shelters a rich epiphytic malacofauna with some Rissoacea



	LI	BI	CV1	CV2	CR	CV3	BE	CYS	Fr%	Dt%
1 <i>Patella caerulea</i>			1			2	1		38	1,3
2 <i>Patella ulyssiponensis</i>		2		1			1		38	1,3
3 <i>Acmea virginea</i>							3	1	25	1,3
4 <i>Fissurella nubecula</i>		1	4				3		38	2,6
5 <i>Sinezona cingulata</i>								8	13	2,6
6 <i>Gibbula adansonii</i> juv							1		13	0,3
7 <i>Gibbula turbinoides</i> juv				1				1	25	0,7
8 <i>Monodonta turbinata</i>		1							13	0,3
9 <i>Cerithium rupestre</i>			1	6					25	2,3
10 <i>Bittium latreillii</i>								6	13	2
11 <i>Fossarus ambiguus</i>	6				4		14		38	7,8
12 <i>Eatonina fulgida</i>	13		16		2	1	71		63	34
13 <i>Rissoa similis</i>								2	13	0,7
14 <i>Rissoa variabilis</i>				2		1			25	1
15 <i>Alvania lineata</i>				2					13	0,7
16 <i>Alvania mammillata</i>						1		1	25	0,7
17 <i>Alvania</i> cfr <i>discors</i>							1		13	0,3
18 <i>Alvania</i> cfr <i>subcrenulata</i>				4		1			25	1,6
19 <i>Setia pulcherrima</i>			2				2	4	38	2,6
20 <i>Nodulus contortus</i>	2	7	34	48			1		63	30
21 <i>Pisinna glabrata</i>			1	4		1			38	2
22 <i>Barleeia unifasciata</i>								2	13	0,7
23 <i>Ocinebrina edwardsii</i>								1	13	0,3
24 <i>Pisania striata</i>							1		13	0,3
25 <i>Columbella rustica</i>								1	13	0,3
26 <i>Vexillum tricolor</i>				1					13	0,3
27 <i>Ammonicera fischeriana</i>	1				1			2	38	1,3
28 <i>Trimusculus mammillaris</i>				1			3		25	1,3
Number of species	4	4	7	10	3	6	12	11		
Number of individuals	22	11	59	70	7	7	102	29		

Table 1. Species/station matrix.

such as *Eatonina fulgida*, *Nodulus contortus* and *Pisinna glabrata*.

The distribution of detritivorous species can be explained by the presence of small detritus pools represented, again, by empty shells and microcavities in the platform. The only record of carnivorous species on the *Cystoseira amnetacea* belt is due to the high degree of habitat complexity that enhances the presence of such sessile organisms as sponges, hydroids and bivalves which are the favourite prey items of carnivorous gastropods.

The total set of gastropod species making up the "trottoir à vermetes" taxocoene can be thought of as composed of the following 4 leading morphogroups (Fig. 14) (CIUNA *et al.*, 1995),

which have no real taxonomic significance, and are similar to those indicated by MOORE (1960):

1. **patelloid**, with morphological parameters like those of *Patella* and *Acmaea*, i.e.: short shell, low slenderness and high tenacity due to a large, round foot;
2. **trochoid**, resembling to *Monodonta* or *Gibbula*, with medium height, medium slenderness and high tenacity;
3. **rissoid**, in accordance with the data obtained from *Rissoa* or *Pisinna*, with low or medium height, high slenderness and low tenacity;
4. **muricoid**, with parameters like those of *Pisania* or *Muricopsis* i.e. very high shell, high slenderness and low tenacity.



		TG	SL	SP	AP	PI	AD	ST	CT
1	<i>Patella caerulea</i>	2	4	4	3	4	4	2	BrV
2	<i>Patella ulyssiponensis</i>	2	4	4	3	4	4	2	BrV
3	<i>Acmea virginea</i>	1	4	4	2	4	4	1	BrV
4	<i>Fissurella nubecula</i>	1	4	4	3	3	4	2	BrV
5	<i>Sinezona cingulata</i>	1	4	3	4	4	2	3	Det
6	<i>Gibbula adansoni</i>	1	4	3	4	4	3	3	BrV
7	<i>Gibbula turbinoides</i> juv.	3	4	3	4	4	3	3	BrV
8	<i>Monodonta turbinata</i> juv.	1	4	3	4	4	3	2	BrV
9	<i>Cerithium rupestre</i>	4	3	1	3	1	1	2	Det
10	<i>Bittium latreillii</i>	4	1	1	2	1	1	4	Det
11	<i>Fossarus ambiguus</i>	1	3	3	4	3	3	1	Det
12	<i>Eatonina fulgida</i>	1	3	2	3	2	3	3	Det
13	<i>Rissoa similis</i>	3	2	1	3	3	3	3	Det
14	<i>Rissoa variabilis</i>	3	2	1	3	3	3	3	Det
15	<i>Alvania lineata</i>	1	4	2	3	2	2	3	Det
16	<i>Alvania mammillata</i>	2	3	2	3	2	2	3	Det
17	<i>Alvania</i> ctr <i>discors</i>	1	3	2	3	2	2	3	Det
18	<i>Alvania</i> ctr <i>subcrenulata</i>	1	3	2	3	2	2	2	Det
19	<i>Setia pulcherrima</i>	1	3	2	3	2	2	3	Det
20	<i>Nodulus contortus</i>	1	3	1	4	4	3	3	Det
21	<i>Pisinna glabrata</i>	1	3	1	4	4	3	3	Det
22	<i>Barleeia unifasciata</i>	2	3	1	4	3	3	3	Det
23	<i>Ocinebrina edwardsii</i>	5	3	1	1	3	2	2	Car
24	<i>Pisania striata</i>	5	3	2	1	3	2	2	Car
25	<i>Columbella rustica</i>	5	3	1	1	3	2	3	Car
26	<i>Vexillum tricolor</i>	2	2	1	1	3	2	2	Car
27	<i>Ammonicera fischeriana</i>	1	4	3	4	4	2	3	BrV
28	<i>Trimusculus mammillaris</i>	3	4	4	3	4	4	2	BrV

Table 3. Classification in rank for each species.

Finally, Fig. 15 shows the distribution patterns of the above morphological groups along the platform, which closely agree with the capacity of the species to sense the environmental parameters, above all the hydrodynamic pattern. This pattern can be modelled (Fig. 16) using the distribution of the morphogroups as descriptors of the average hydrodynamic conditions along the platform. Obviously this "indirect" model could be considered descriptive only of the environmental conditions during the sampling. A more accurate study will be performed combining two seasons of sampling (summer and winter).

CONCLUSION

From this survey, the gastropod taxocoene alone can be deemed an exhaustive and quite satisfactory descriptor of the gradient examined. Moreover, the information provided by this *syntaxon*

are in close agreement with the conclusions from previous research (PANDOLFO *et al.*, 1992a; 1992b).

Three groups of species are highlighted: the first is related to the *Cystoseira amentacea* belt, and can be considered as belonging to the true infralittoral; a second group is restricted to the highest portions of the platform (midlittoral species-group) and a third one is restricted to the tide-pools and crevices inside the reef (infralittoral species-group). These species belong to four different morphogroups which are distributed differently along the platform, reflecting their hydrodynamic tolerance.

One conclusion of the above discussion is that there exist at least two distinct conditions in the same environment which are responsible for the diversity of the faunistic assemblages: one can be deemed as an emersion condition and is related to the vermetid crests and protruding edges which emerge above the

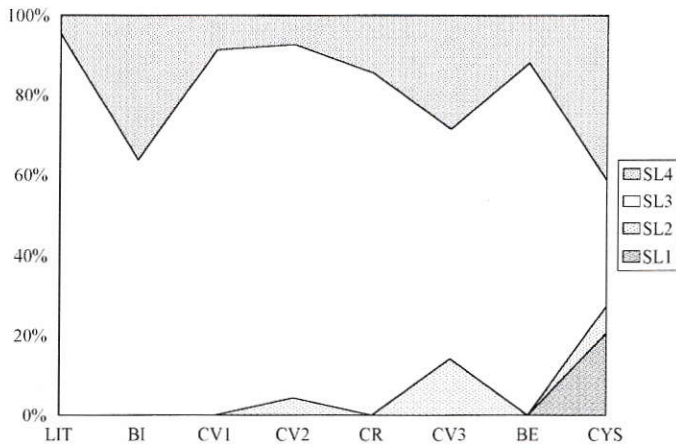


Figure 6. Distribution of slenderness ranks.

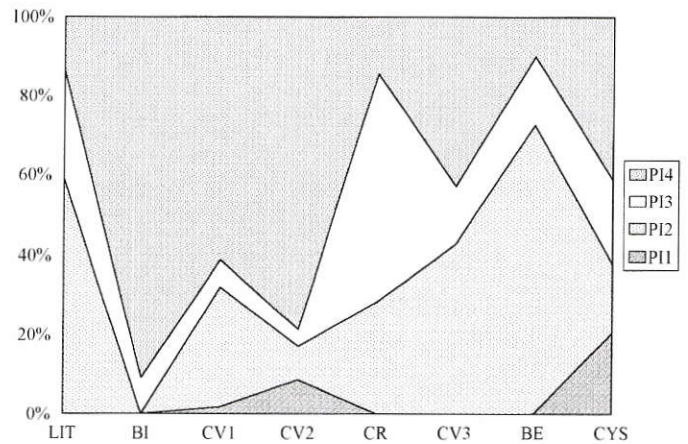


Figure 9. Distribution of foot shapes.

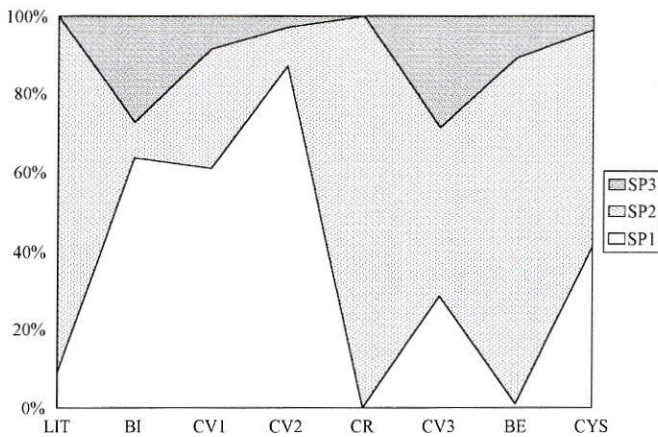


Figure 7. Distribution of coiling ranks.

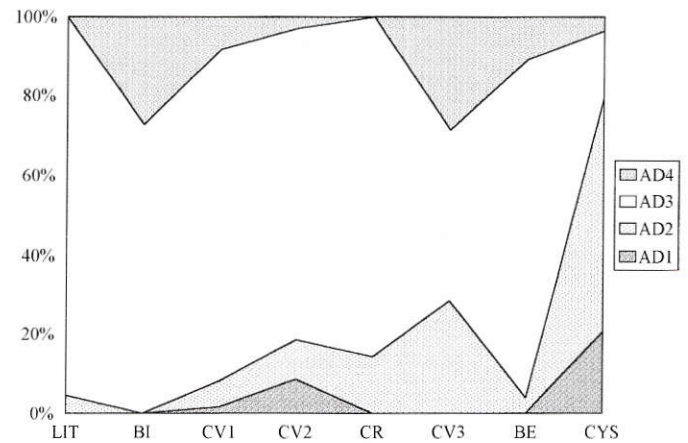


Figure 10. Distribution of tenacity.

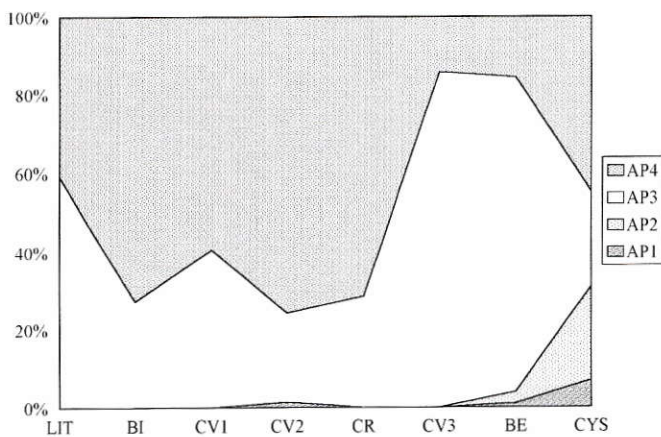


Figure 8. Distribution of aperture shapes.

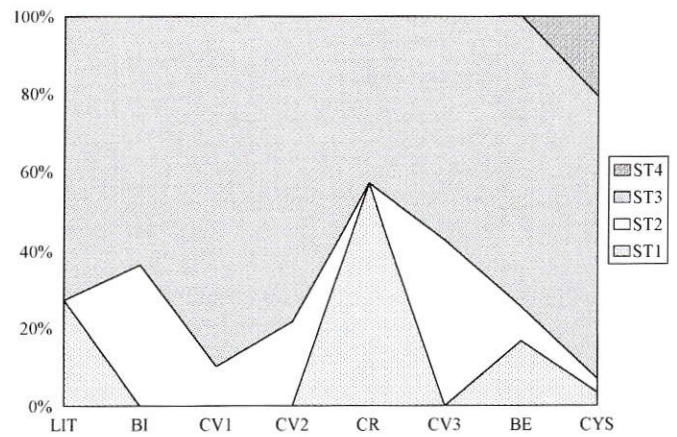


Figure 11. Distribution according the relationships with substratum.

tide level and therefore endure more or less long intervals of complete drought. The second condition is related to those portions of the platform continuously submerged or lined with a thin film of water. The transition between these two extremes, complicated by the wave action, can be seen as the hydrodynamic gradient highlighted by the distribution cluster of FAC.

The identification of an “emersion-immersion” factor along

the vermetid platform is the major finding of our survey. Such a finding gives new insight in the understanding of the role and spatial distribution of the platform’s biotic components, and aids the designing a of new dynamic model of this habitat. This model indicates the coexistence of at least two distinct zones in a restricted space, distinguished by the prevalence of hydrodynamic factors.

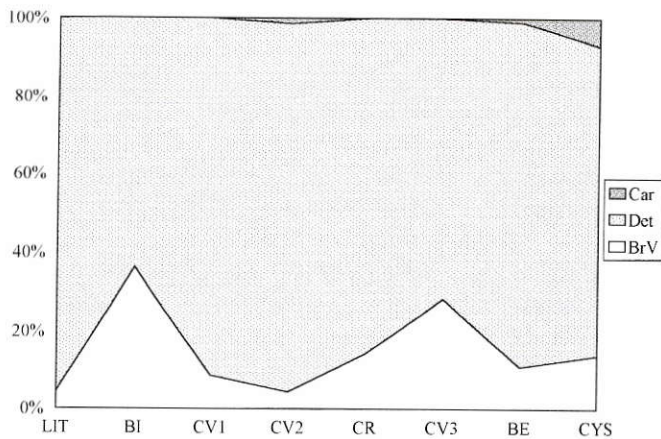


Figure 12. Distribution of the trophic guilds.

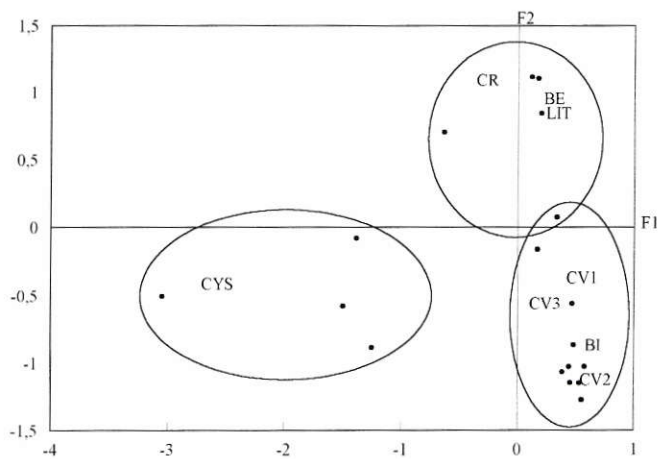


Figure 13. Factorial analysis of correspondance on raw data.

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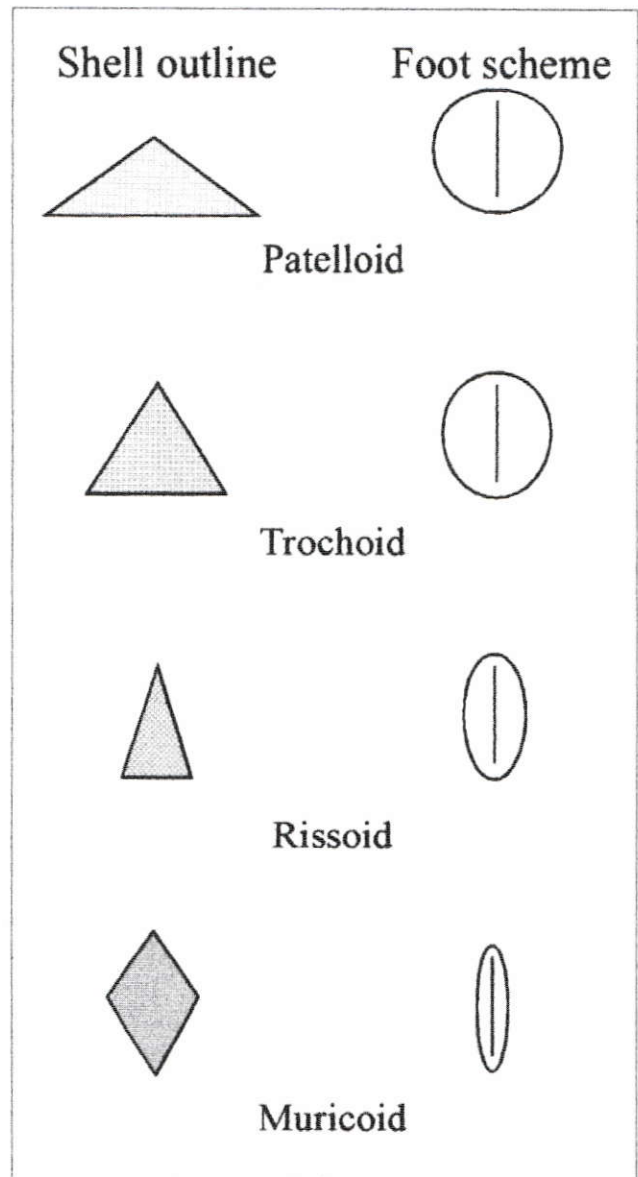


Figure 14. Morphogroups.

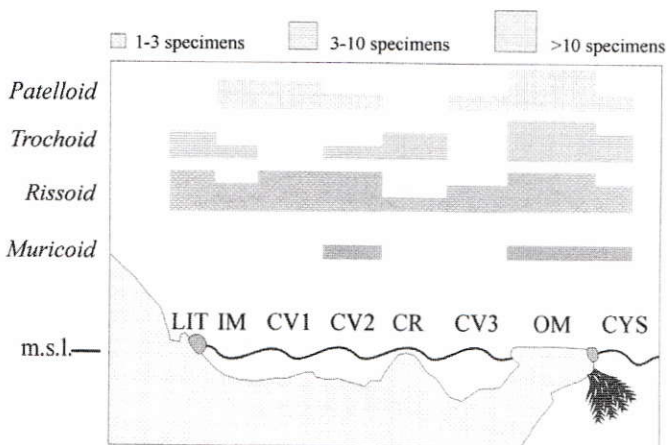


Figure 15. Distribution of morphogroups along the platform.

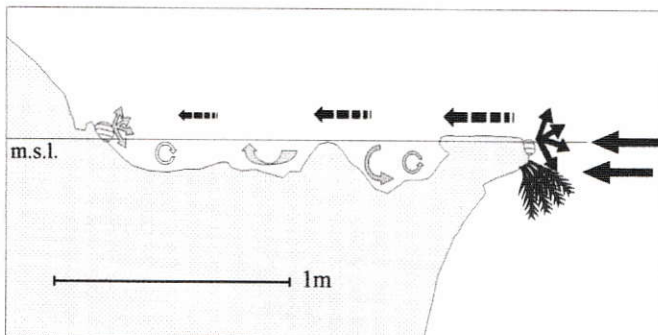


Figure 16. Hydrological model.

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Lavoro accettato il 7 Marzo 1998



Malacological associations from the marine reserve of S. Maria di Castellabate (southern Tyrrhenian sea): multivariate analysis and cartographic representation by the Kriging interpolation technique

Giovanni Fulvio Russo & Silvia Sgrosso

KEY WORDS: Marine reserves, Mollusc communities, Guilds, Multivariate analysis, Kriging.

ABSTRACT A formal procedure that allows the identification of mollusc community structures and the spatial patterns associated with them in the area of the marine park of S. Maria di Castellabate was tested. A set of qualitative data from the literature was transformed and reorganized in such a way as to become robust enough to undergo statistical treatment. Significant community patterns were recognized which, on one hand, provide information on the bionomic features and, on the other, allow the description in functional terms of the associations as the products of the integrated action of the main dynamic and hydrological characteristics. This analytical procedure was shown to be effective for utilizing, in synecological analyses, information which was originally collected for different purposes, as is the case for most conchological collections.

RIASSUNTO Nel presente lavoro vengono presentati i risultati della sperimentazione di una procedura di analisi che potrebbe consentire una lettura 'formale' di dati provenienti da raccolte qualitative e da meri elenchi faunistici. Per l'analisi sono stati considerati dati malacologici provenienti da raccolte subacquee effettuate con metodiche molto diverse nell'area del Parco marino di S. Maria di Castellabate (Salerno), all'epoca della sua istituzione (nei primi anni '70). L'area era stata suddivisa in 31 settori per ognuno dei quali era stato fornito un elenco faunistico con indicazioni qualitative dell'abbondanza delle specie e dell'intervallo batimetrico in cui erano state rinvenute. I settori sono stati raggruppati in 4 sub-aree, ciascuna alquanto omogenea al suo interno per fisionomia della linea di costa e del substrato marino antistante. Nel presente studio sono state considerate le due sub-aree più meridionali, quella di Vallone Alto (dal porto di S. Marco di Castellabate a Punta Licosa), comprendente 7 settori, e quella di Licosa (dalla punta omonima alla Baia di Ogliastro Marina), comprendente 9 settori. Ogni settore è stato assimilato ad un transetto costa-largo di stazioni arbitrariamente fissate alle profondità di 0, 5, 10, 20, 30 e 40 m. Le associazioni malacologiche presenti in queste stazioni sono state definite in base agli intervalli batimetrici riportati, per ciascuna delle specie, nell'elenco faunistico qualitativo. Le indicazioni qualitative di abbondanza delle specie (rara, scarsa, comune, abbondante) sono state convertite in ranghi numerici. La matrice di rango così ottenuta è stata trattata con tecniche di analisi multivariata per ottenere modelli di ordinamento che consentissero di evidenziare le principali tipologie strutturali e funzionali delle associazioni malacologiche presenti nell'area. Sono stati utilizzati tre differenti tipi di descrittori: tassonomici, trofici e bionomici. Questi sono stati ottenuti raggruppando gli individui rispettivamente in base alla loro affinità tassonomica a livello di specie; alla affinità di alimentazione ed alla affinità di ambiente di appartenenza. L'analisi spaziale delle diverse tipologie cenotiche presenti nelle sub-aree in esame è stata ottenuta con la tecnica di interpolazione su mappa denominata *kriging*, utilizzando i valori delle saturazioni sugli assi dei punti-stazione nei modelli di ordinamento. Oltre alla classica zonazione con la profondità dei popolamenti malacologici, nell'analisi sono emersi 'gradienti laterali' che rivelano discontinuità cenotiche tra i diversi settori, soprattutto nei livelli più profondi. Un'interessante relazione tra tipologie geomorfologiche e cenotiche è stata evidenziata nel settore più meridionale di Vallone Alto, ove la risalita della soglia del bassofondo di Licosa è marcata da un ripidissimo cenocline malacologico, che comprende un drastico cambiamento delle tipologie alimentari dominanti. I risultati ottenuti, consentendo una efficace capacità analitica delle tipologie cenotiche ed una restituzione grafica di immediata lettura, confermano, da un lato, l'efficienza della procedura di organizzazione e di elaborazione formale adottata nel recupero di dati raccolti qualitativamente e, dall'altro, la robustezza e l'affidabilità del taxocene a molluschi per analisi interpretative dell'ambiente marino su larga scala quali, ad esempio, quelle necessarie per gli studi di fattibilità delle aree protette.

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INTRODUCTION

Mollusc communities are among the best descriptors of littoral benthic systems (GAMBI *et al.*, 1982), as they integrate the environmental variability well thanks to their species richness (the result of wide adaptive radiation) and the heterogeneity of their assemblages. Therefore, their structural and spatial patterns can be utilized successfully to characterize coastal areas in terms of biodiversity and habitat heterogeneity, as in the case of planned marine reserves.

In spite of the considerable collecting activity carried out by malacologists, quantitative data obtained by standardized sampling and sorting procedures, which allow the use of a mathe-

matical approach in the inference of community traits are quite rare in the literature. Most of the information is confined to species lists, at best accompanied by broad indications, sampling depth and, sometimes, qualitative estimates of species abundance (i.e. rare, common, abundant, etc.). One of the main problems when dealing with such inadequate qualitative information is the difficulty of assembling and comparing sets of data to allow the evaluation of molluscan community structures and, hence, associated ecological patterns.

A paper by OTERO (1985), which contains the most complete malacological list available for the marine reserve of S. Maria di Castellabate, represents a typical example of a considerable sam-

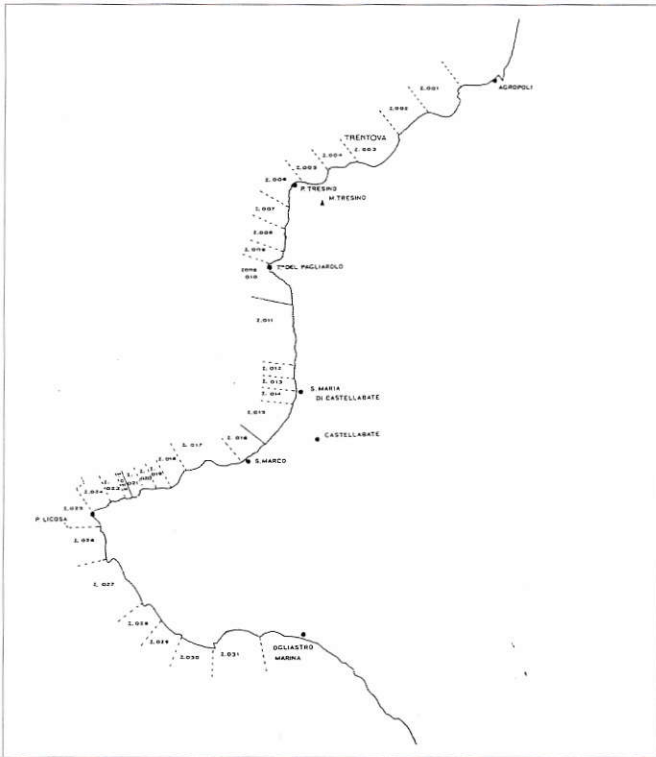


Figure 1. Map of the Marine Park of S. Maria di Castellabate with the subdivision in 31 sectors (after OTERO, 1985).

pling effort merely resulting in a qualitative set of data. The information contained in the paper of OTERO is utilized were in an attempt to set up a formal procedure which allows the identification of molluscan community structures and the spatial patterns generated by them. Qualitative data were transformed and reorganized into a set robust enough for statistical treatment so as to reveal recognizable and significant community patterns.

MATERIALS AND METHODS

Site and sampling procedures

The marine reserve of S. Maria di Castellabate is one of the earliest established in Italy (Ministerial Decree, August 25 1972), and has recently been included in the list of national marine parks (Law n. 394, 1991). It covers the southernmost coastal area of the Gulf of Salerno, in the region of Cilento (southern Tyrrhenian coast), where a terrestrial national park has also recently been established (RUSSO & SGROSSO, 1995).

Since the institution of the marine reserve, some floristic and faunistic studies have been carried out, including a malacological one, assembled and published several years later by OTERO (1985). The author divided the reserve into 31 arbitrarily-chosen sectors, from the Cape of Agropoli to the Bay of Ogliastro Marina (Fig. 1), collecting with different sampling procedures in each sector. The shallow malacofauna (0-12 m) was mostly sampled by snorkelling, while the deeper malacofauna (12-40 m) was collected by picking up specimens trapped in fishing

nets and by washing the algal tufts and seagrass leaves collected by SCUBA divers. Dredging was also used on soft bottoms to a depth of 60 m.

This activity generated a list of 279 taxa at the species or sub-species level, including for each taxon the sector and depth of collection, the overall depth range (e. g. 0-5 m; 10-45 m; 40-60 m) and the presence rank (RR= extremely rare; R= rare; S= scarce; C= common; A= abundant).

Organization of data

In the present work, 16 of the 31 sectors were taken into account, covering the area from the port of S. Marco to the bay of Ogliastro Marina (sectors Z.016-031 in Fig. 1). Each sector was considered as a depth-transect, along which six formal stations of 1, 5, 10, 20, 30 and 40 m were located. For each station, a list of species (present within the sector and the depth range) was compiled.

Species names were updated according to the recent nomenclature (SABELLI *et al.*, 1990). All sub-species or varieties were grouped into the species taxon. To each species, the following numerical ranks were assigned on the basis of the qualitative code of abundance used by OTERO (1985): RR=1; R and S = 2; C=3; A= 4.

The numerical data set was arranged at first in a matrix of ranks with dimensions which proved too large to be dealt with on a personal computer, and was therefore split into two subsets which included sectors Z.16-22 (called Vallone Alto) and Z.23-31 (called Licosa). The 131 species x 42 stations (6 depths x 7 transects) rank matrix of Vallone Alto and the 91 species x 54 stations (6 depths x 9 transects) rank matrix of Licosa were therefore utilized in the multivariate analysis. In these matrices, all the species whose total for each row was 1 or 2 (very rare in one or two stations; rare or scarce in only one station) were excluded in order to avoid distortion in the structure of the data (PIELOU, 1977).

Considering the species from the point of view of their feeding habits, as proposed by STENEK & WATLING (1982), PUR-

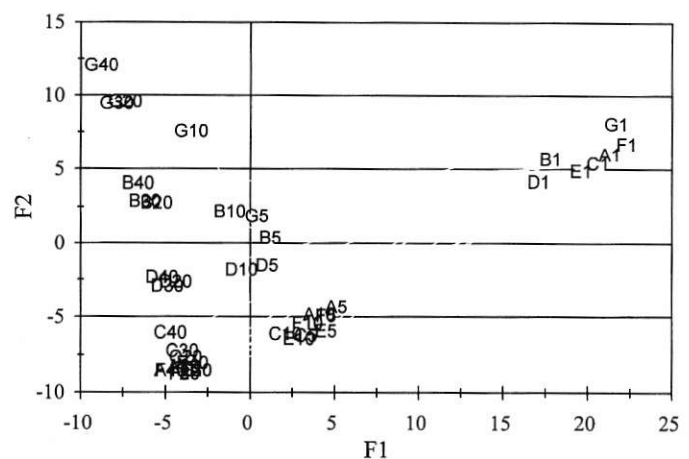
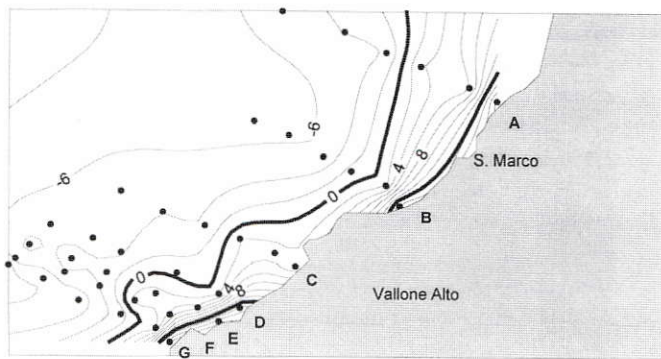
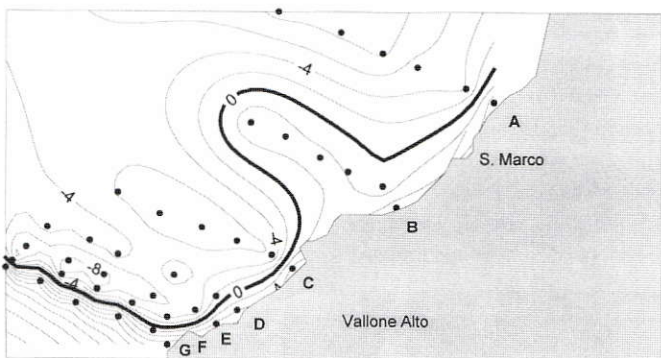


Figure 2. VALLONE ALTO, AC ordination model (F1-F2) of station-points (in the labels, letters indicate transects, numbers are referred to depth): matrix of taxonomic descriptors.



a



b

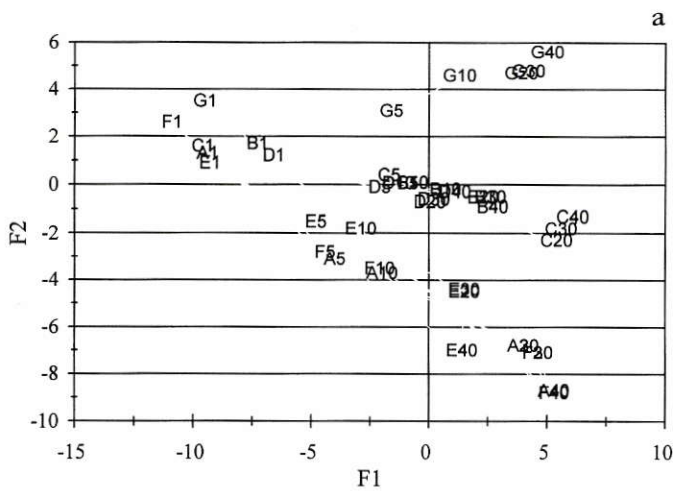
Figure 3. VALLONE ALTO, kriging maps: scores of taxonomic descriptors on F1 (a) and on F2 (b).
Transects from A to G correspond to sectors from Z.016 to Z.022.

Analysis of data

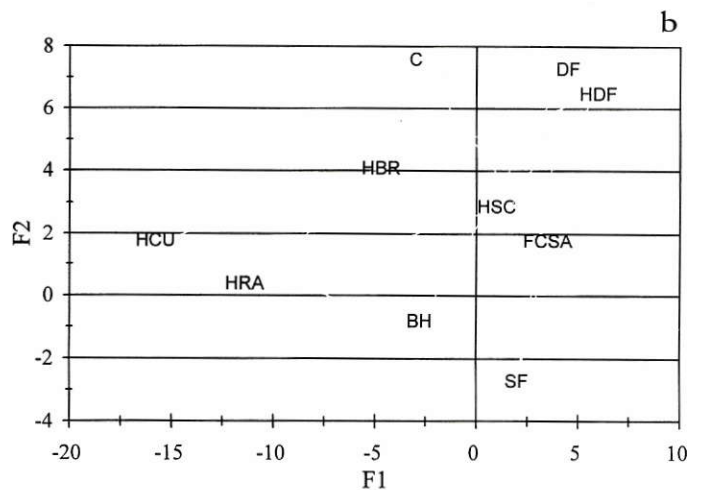
The six data matrices were utilized as the bases for the ordination models obtained by Correspondence Analysis (CA) (PIELOU, 1984). Six ordination models were generated, utilizing three different types of descriptors (taxonomic, trophic, and bionomic) for each of the two areas (Vallone Alto and Licosa). The significance of the factors was tested according to the method proposed by FRONTIER (1974).

The factor scores (three at the most) of the station points, which can be considered as synthetic variables of the different coenotic patterns, were then utilized for *kriging*, a cartographic method which uses stochastic interpolation techniques (CRESSIE, 1991).

Kriging is a very flexible method and is useful for interpolating almost any type of data set. A total of 1000 interpolating values, arranged on 20 x 50 rectangular grids, with their longest side almost parallel to the coastline, were utilized (mesh size of about 110 m). The known values were 42 (Vallone) and 54 (Licosa) respectively, so that 5% of the grid points were interpolated. The maps were drawn using the best-fitting surface, i.e. a quadrant and a linear variogram. Eighteen isoline maps were obtained from the F1, F2 and F3 scores of each of the six ordination models.



a



b

Figure 4. VALLONE ALTO, AC ordination models (F1-F2) of descriptor-points (a) and of station-points (b): matrix of trophic descriptors.

CHON (1977) and BARNES *et al.* (1988), the following 10 trophic guilds were identified: herbivore brusher (HBR); herbivore scraper (HSC); herbivore rasper (HRA); herbivore-deposit feeder (HDF); herbivore cutter (HCU); benthic hunter (BH); deposit feeder (DF); suspension feeder (SF); feeder on colonial sessile animals (FCSA); commensal (C).

In order to set up the 10 (guilds) x 42 (stations) functional matrix of Vallone Alto and the 10 (guilds) x 54 (stations) functional matrix of Licosa, the number of species belonging to each functional guild was calculated on the basis of the presence/absence data matrix (species x stations).

Considering the distribution of the species in accordance with the model of PERES & PICARD (1964), the following 9 bionomic units were identified: photophilic algae (AP); *Posidonia* seagrass beds (HP); sciaphilic or 'coralligen' (C); fine sand on shallow bottoms (SFHN); well-sorted fine sand (SFBC); muddy sand of sheltered environments (SVMC); coastal terrigenous mud (VTC); muddy detritus (DE); coarse sand under the effect of bottom currents (SGCF). Starting from the presence/absence data matrix (species x stations), the number of species 'characteristic' (*sensu* PÉRÈS & PICARD, 1964) of each of the above bionomic units was calculated for the stations in order to generate the bionomic matrices of Vallone Alto (9 units x 42 stations) and of Licosa (9 units x 54 stations).

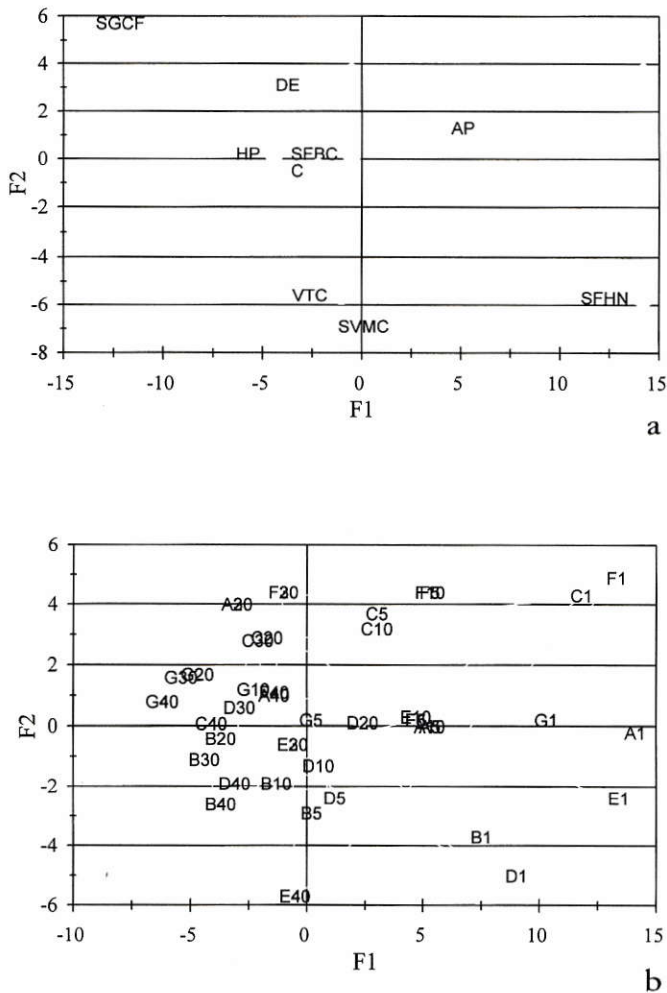


Figure 5. VALLONE ALTO, AC ordination models (F1-F2) of descriptor-points (a) and of station-points (b): matrix of bionomic descriptors.

RESULTS

1) Vallone Alto

a) Taxonomic descriptors

In the AC ordination model, obtained from the rank matrix of taxonomic descriptors (Fig. 2), the first three factors are significant ($F1 = 23.0\%$; $F2 = 14.3\%$; $F3 = 11.3\%$ of the total variance). Along the first axis, the station points are displayed according to their depth. The shallow stations are polarized in the positive side of the axis, those of the intermediate depth levels (5-10 m) are distributed close to the origin of the axes, the deep ones (20-40 m) have negative scores. Along the second axis, the station points belonging to the same transect have similar scores. Although transects are displayed at different levels of polarization, clearer discontinuities among the deep stations are shown. A similar pattern is expressed by the third factor.

The cartographic representation of the pattern expressed by the first factor (Fig. 3a) shows isolines parallel to the coastline, marking changes in the coenotic structures that occur at well-defined critical depths along the transects. A high contiguity of isolines and an isoline pattern which is oriented differently is,

however, evident in the area near Punta Licosa (transects E-G).

In the maps interpolating the scores of the stations related to the second (Fig. 3b) and third factors, the isolines are nearly perpendicular to the coastline, indicating the co-occurrence of 'lateral gradients', the result of coenotic changes in stations with similar depths. Once again, the high contiguity of isolines in the area near Punta Licosa (transects E-G) is evident.

b) Trophic descriptors

The AC ordination model obtained from the matrix of trophic descriptors (Figs. 4a, 4b) has three significant axes ($F1 = 42.4\%$, $F2 = 30.2\%$ and $F3 = 11.0\%$ of the total variance). The station points are distributed along the first factor consistent with their depth, the shallow stations have negative scores and are opposed to the deep ones (positive scores), with the intermediate ones in the middle, close to the origin of the axes. It is worth noting how different types of herbivore guilds characterize the levels of the transects: HCU and HRA are associated with the shallow stations, HBR and HSC with the intermediate, and HDF with the deep ones. As for the other guilds, C and BH are related to the intermediate stations and DF, SF and FCSA to the deep stations. Along the second factor, the different transects are separated, particularly with regard to the deep stations. The opposi-

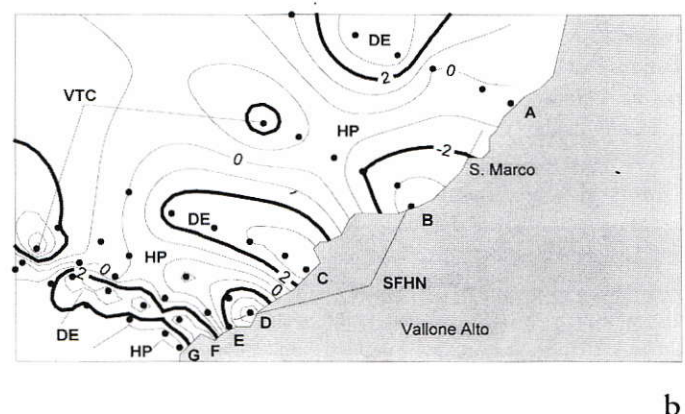
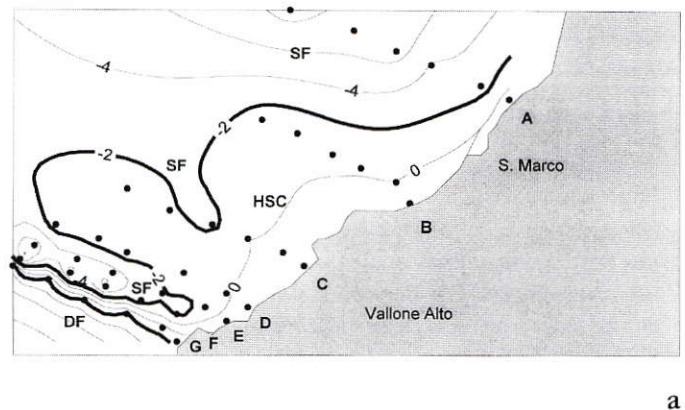


Figure 6. VALLONE ALTO, kriging maps: scores on F2 of trophic (a) and bionomic (b) descriptors.

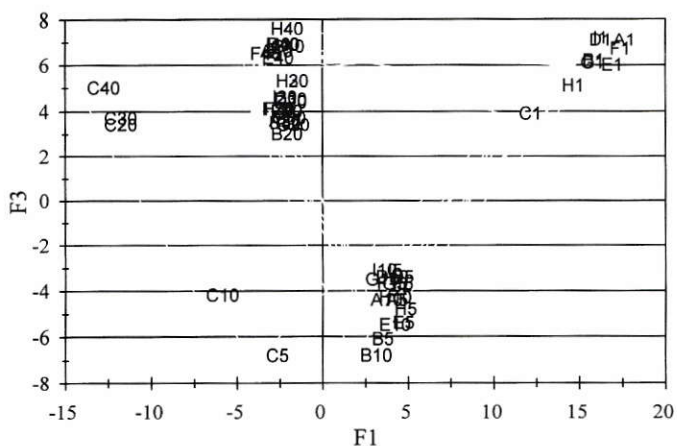
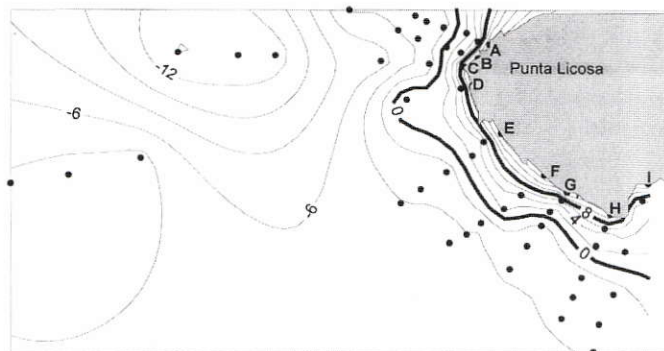


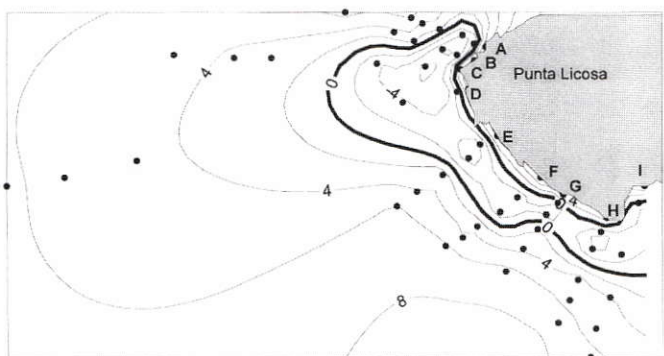
Figure 7. LICOSA, AC ordination model (F1-F3) of station-points: matrix of taxonomic descriptors.

tion between DF and HDF, on the positive portion of the axis, and SF, on the negative one, is evident. Deep stations (20–40 m) of transect G are polarized in the ‘deposit feeder’ factorial pole, the remaining stations in the ‘suspension feeder’.

In the case of these descriptors the cartographic representation of the coenotic gradient expressed by the first factor also shows isolines parallel to the coastline, with a pattern similar to



a



b

Figure 8. LICOSA, kriging maps: scores of taxonomic descriptors on F1 (a) and on F3 (b). Transects from A to I correspond to sectors from Z.023 to Z.031.

that shown in Fig. 3a. In the maps interpolating the scores of the stations related to the second (Fig. 6a) and the third factors, the isolines have a very low contiguity, indicating weak spatial gradients of trophic specialization within the associations. The area of punta Licosa appears to be an exception, with a very high contiguity of isolines, indicating a marked rearrangement in the trophic structure occurring in transect G, which is characterized by ‘deposit feeders’, with respect to the other transects which are characterized mainly by ‘suspension feeders’.

c) Bionomic descriptors

In the AC ordination model, obtained from the matrix of bionomic descriptors (Figs. 5a, 5b), the first two factors are significant (F1= 60.1% and F2= 14.8% of the total variance). Along the first axis, the station points are displayed according to their depth. The shallow and intermediate stations (1–10 m) are polarized in the positive portion of the factor, while the deep ones (20–40 m) have negative scores. Along the second factor, transects are again displayed at different levels of polarization (transects A, C, F and G in the positive portion, and transects B, D and E in the negative), with more marked discontinuities among the deep stations.

It is interesting to note how different types of bionomic guilds characterize the levels of the transects: AP and SFHN are strongly associated with shallow stations, while the remaining bionomic units are associated with deeper levels. Along F2, where intermediate and deep stations are well spaced, three clusters of stations are associated with DE (in the positive portion), HP and C (close to the axis) and VTC (in the negative portion).

As for the previous descriptors (taxonomic and trophic), the cartographic representation of the pattern expressed by the first factor shows isolines parallel to the coastline, with the exception of the area by Punta Licosa. In the maps interpolating the scores of the stations related to the second factor (Fig. 6b), the isolines show a complex pattern with concentric distributions that enclose the whole transect. This pattern becomes more evident in the area near Punta Licosa (transects F and G), marking a high bionomic variability.

2) Licosa

a) Taxonomic descriptors

In the AC ordination model obtained from the rank matrix of taxonomic descriptors (Fig. 7), the first three factors are significant (F1= 25.4%; F2= 21.5%; F3= 10.8% of the total variance). Along the first axis, the station points are displayed according to their depth. The shallow stations (1 m) are polarized in the positive portion of the factor, those of the intermediate depth levels (5–10 m) are distributed close to the origin of the axes and the deep ones (20–40 m) have negative scores. The same pattern is shown along the second axis. A particular trend is, however, associated with transect C, the only one completely polarized in the positive part of the factor. Along the third axis (displayed in figure 7), shallow and deep stations are opposed to the intermediate ones, grouped in the negative part.

The cartographic representation of the pattern expressed by the

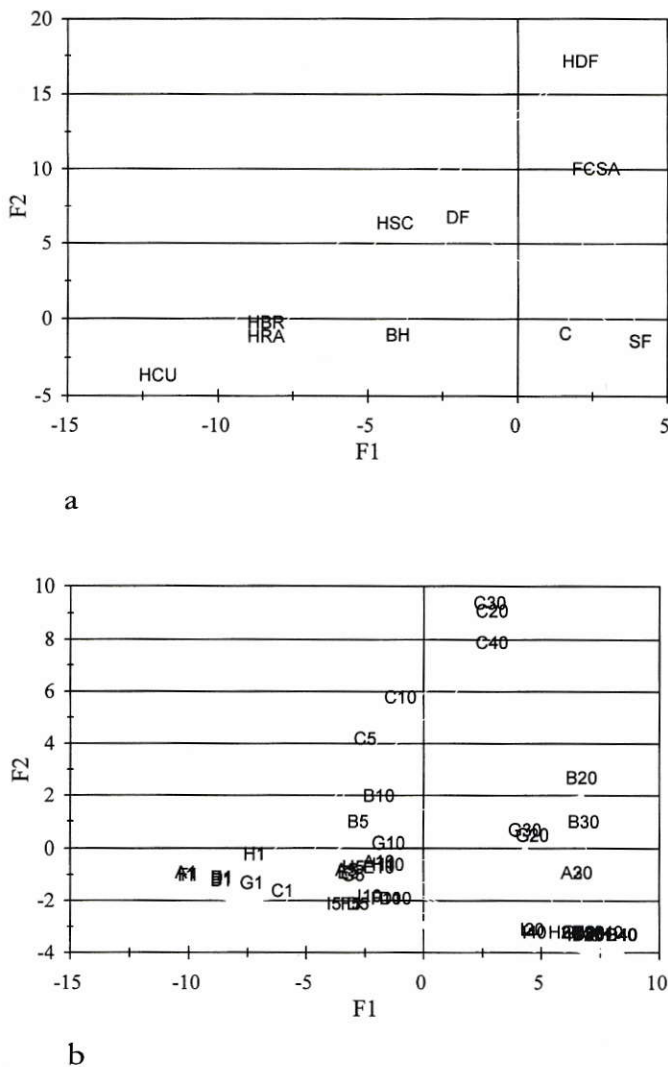


Figure 9. LICOSA, AC ordination models (F1-F2) of descriptor-points (a) and of station-points (b): matrix of trophic descriptors.

first factor (Fig. 8a), shows a remarkable coenotic homogeneity in the area between Punta Licosa and Ogliastra Marina (transects D-I), with a small number of widely-spaced isolines. The opposite pattern is present in the area facing Punta Licosa (transects A-C), where tightly spaced isolines, perpendicular to the coastline, are evident. This pattern indicates well the peculiarity of the coenotic structure occurring along transect C and the steep coenoclines connecting this particular transect with the adjacent ones. By mapping the scores of the second factor, a depth-related pattern becomes evident, with coenotic isolines tightly-spaced and parallel to the coastline throughout the area, except for the zone facing Punta Licosa. This zonal pattern is more evident when the map interpolating the scores of the stations related to the third factor is considered (Fig. 8b).

b) Trophic descriptors

The AC ordination model obtained from the matrix of trophic descriptors (Figs. 9a, 9b) has three significant axes (F1 = 42.3%, F2 = 27.1% and F3 = 9.6% of the total variance). Again this mod-

el, the station points are distributed along the first factor consistent with their depth. The shallow stations have negative scores and are opposed to the deep ones (positive scores) with the intermediate stations in the middle, close to the origin of the axes. As in the area of Vallone Alto, it is interesting to note how the different types of herbivore guilds characterize the levels of the transects: HCU, HRA and HBR are associated with the shallow stations (1 m), HSC with the intermediate (5-10 m), and HDF with the deep stations (20-40 m). As for the other trophic guilds, DF and BH are related to the intermediate stations while C, SF and FCSA are related to the deep ones. Along the second factor the opposition between DF and HDF, in the positive part, and SF, in the negative, is evident. Transect C is the only completely clustered one in the positive portion of the factor.

The cartographic representation of the coenotic gradient expressed by the first factor shows isolines parallel to the coastline (Fig. 10). Also in the case of these descriptors, the area of Punta Licosa is the exception, with isolines oriented perpendicular to the coastline, describing a lateral coenotic gradient which develops from transect C to the adjacent transects. This pattern is clear and is basically reposed by the maps interpolating the scores of the stations related to the second and the third factor.

c) Bionomic descriptors

In the AC ordination model obtained from the matrix of bionomic descriptors (Figs. 11a, 11b), the first three factors are significant (F1 = 45.5%, F2 = 22.6% and F3 = 14.2% of the total variance). Along the first axis, the station points are displayed according to their depth. The shallow and intermediate stations (1-10 m) are polarized in the negative portion of the factor, while the deep stations (20-40 m) have positive scores.

As regards the displacement of the different types of bionomic guilds, along this factor AP, SFHN, SVMC and SFBC are associated with shallow and intermediate stations, while HP, C, VTC and DE are associated with deep levels.

Along the second factor, the opposite of the bionomic unit SFHN (strongly polarized in the negative part) with respect to all the others has the effect of clusterizing all the points.

An interesting ordination is observed in the third axis (Figs. 11a, 11b). Transects are displayed at different levels of polariza-

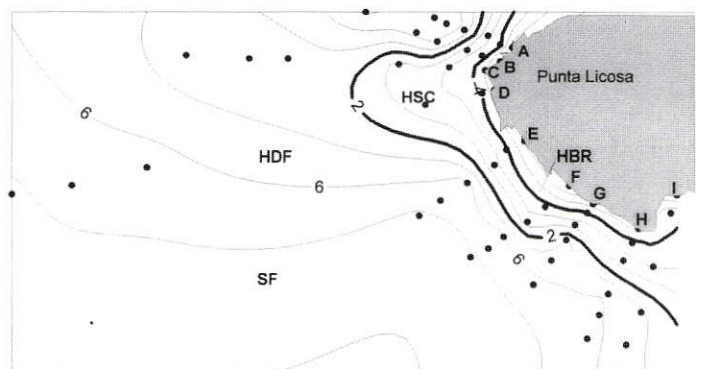


Figure 10. LICOSA, kriging map: scores on F1 of trophic descriptors.

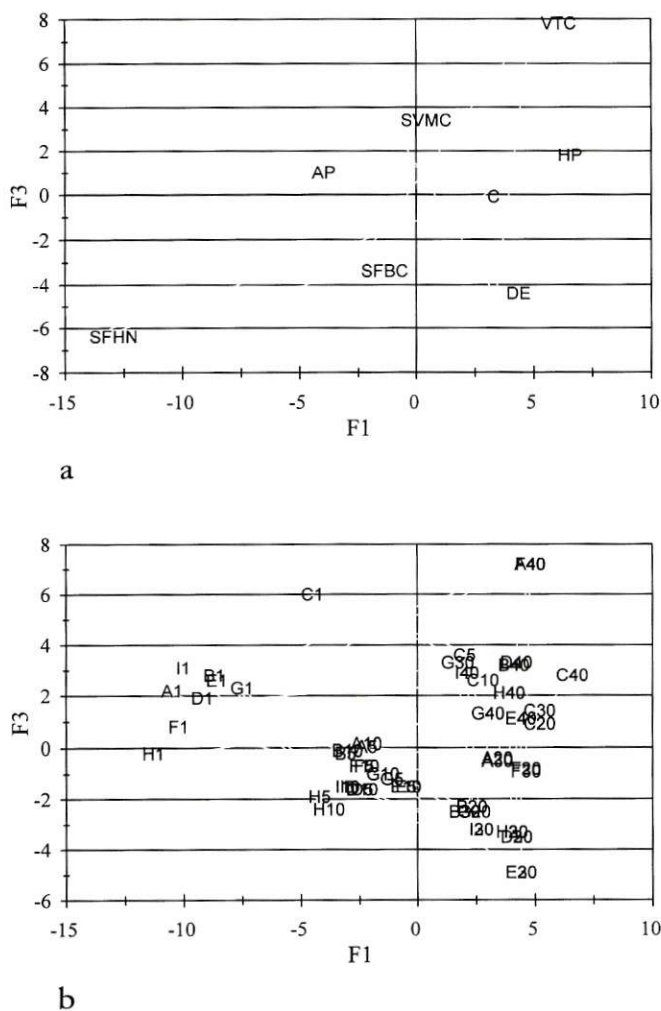


Figure 11. LICOSA, AC ordination models (F1-F3) of descriptor-points (a) and of station-points (b): matrix of bionomic descriptors.

tion, with more clear-cut discontinuities within deep stations. The deepest stations of transects A and F (40 m) are positively polarized and are associated with the VTC guild. Conversely, some of the deep stations (20-40 m) of transects B, D, E, G, H and I are associated with the DE guild in the negative part of the factor, the others being associated with HP or C in the intermediate part of the factor.

The cartographic representation of the pattern expressed by the first factor shows isolines parallel to the coastline (Fig. 12a). In the maps interpolating the scores of the stations related to the second and third factors (the latter in Fig. 12b), the isolines show a complex pattern with lateral gradients and concentric distributions enclosing different transects and stations. This pattern is particularly evident in the area near Punta Licosa (transect D), a probable indication of high bionomic variability.

DISCUSSION AND CONCLUSIONS

In ecological research it often proves useful to represent environmental variables on maps. As regards the marine environment, this manner of representation is widely applied to prepare

maps where, for example, depths and bathymetric isolines are displayed. What may be of particular interest is the use of cartographic representation, not only for simple physical and chemical parameters (e.g. depth, temperature, salinity, nutrient concentration etc.), but also for biological (SCARDI *et al.*, 1989) and community parameters (SCARDI & FRESI, 1985; SCARDI & FRESI, 1986).

When working with communities, the main problem is the selection of both descriptors and their synthetic variables, to allow the correct inference of ecological spatial patterns. Factor scores may represent a powerful synthetic variable of community descriptors, the most widely used of which are taxonomic ones (taxa at the species level). Apart from information provided on the community structure, based on the co-occurrence of species in stands, the functional aspects may also be viewed by considering life habits (e. g. feeding strategies, reproductive tactics, etc.). Therefore, these important elements, at the basis of the 'taxonomic organization' of communities, may be utilized as further descriptors of coenotic system organization, allowing the passage to be made from a descriptive (a ecology) to a causal (b ecology) analytical stage.

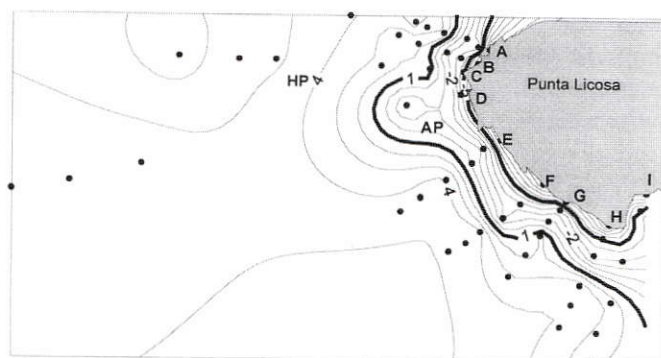
Additional complementary descriptors may be obtained by considering the association to which single species preferentially belong. In several malacological studies, such associations are utilized to infer bionomic information, assuming a straightforward relationship between the species and their associations.

This allows the bionomic characterization of stations on the basis of their taxocoene. The theory behind this method is questionable. As most species may participate in different associations, it is unrealistic to assume a straightforward relationship between single species and single associations. This procedure has, however, been adopted in the present study, with interesting results.

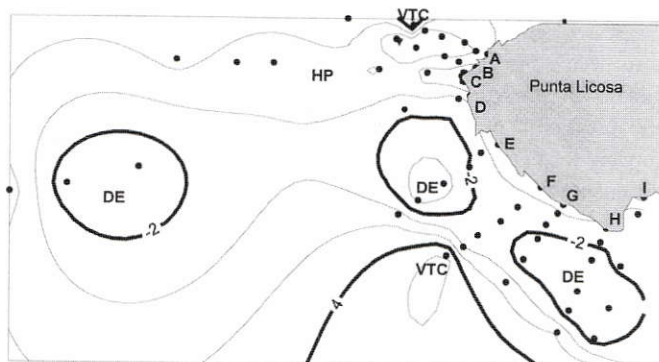
The taxonomic, functional (trophic) and bionomic information obtained from the study of the malacological taxocoene living in the marine reserve of S. Maria di Castellabate gives a well-integrated picture of the main benthological features of the area. The ordinations and cartographic representations obtained starting from the different coenotic descriptors are consistent.

The main spatial patterns of the malacological assemblages are related to depth, which can be easily interpreted as the first factor of the ordination models, independently of the descriptors taken into account. Three depth-related zones, sequentially distributed from the coast to the open sea, may be recognized: the shallow zone (1m £ stands < 5m), the intermediate zone (5m £ stands £ 10m) and the deep zone (10m < stands £ 40m).

Hard substrate species of the mesolittoral and the upper infralittoral live in the shallow zone, which is restricted to a fringe which includes the first level of the transects. The malacological assemblage is functionally specialized in herbivory with high mechanical impact on the trophic substrate (cutters and rasps). The intermediate zone is mainly characterized by an association typical of hard bottoms covered by photophilic algae, specialized in herbivory with low impact on the trophic substrate (brushers and scrapers). This zone extends quite far from the coastline near Punta Licosa (transects C and D), mark-



a



b

Figure 12. LICOSA, kriging maps: scores of bionomic descriptors on F1 (a) and on F3 (b).

ing a large rocky shoal. The deep zone (greater than 10 m depth), shows a more complex ecological physiognomy, which may be better investigated by taking into account environmental factors expressed by the other axes of the models.

The ordination along the second and third axes is mostly the expression of spatial patterns related to 'lateral' gradients. These gradients mark the coenotic discontinuities that exist between the different sectors of the marine reserve, aside from the depth-related effects. Also in this case, consistent information was obtained by utilizing different types of descriptors. Coenotic discontinuities are more evident when the deep stands are compared as almost all the shallow associations are related to algal cover. A rather complex mosaic of ecological units is displayed in the maps. Large *Posidonia* seagrass beds, with a mollusc community dominated by scraper-herbivores, alternate with detritic areas dominated by suspension feeders. Muddy bottoms characterize just a few, very deep stations.

An interesting relationship between geomorphological and coenotic patterns can be observed in the southernmost area of Vallone Alto, where the of the Licosa shoal is marked by a very strong coenotic gradient, characterized by a drastic change in the trophic specialization of the taxocoene, from suspension to deposit feeding. This functional characterization represents a well integrated information on the hydrodynamic regime and the related features of the site, as it marks a low energy environment with large depositional area.

In conclusion, consistent information on the main bionomic features, and on the related structural and functional patterns gathered for the area of the marine park of S. Maria di Castellabate shows how the analytical procedure adopted in the present paper may prove to be effective in the recovery of information from malacological lists resulting from the activity of collectors.

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Direttore Responsabile: Carlo Smriglio

Coordinamento produzione: EVOLVER srl ROMA

Pre-stampa: FPM srl ROMA

Stampa: ARTI GRAFICHE LA MODERNA ROMA

Finito di stampare il 25 Maggio 1998

ISSN 5678 8976