



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

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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.

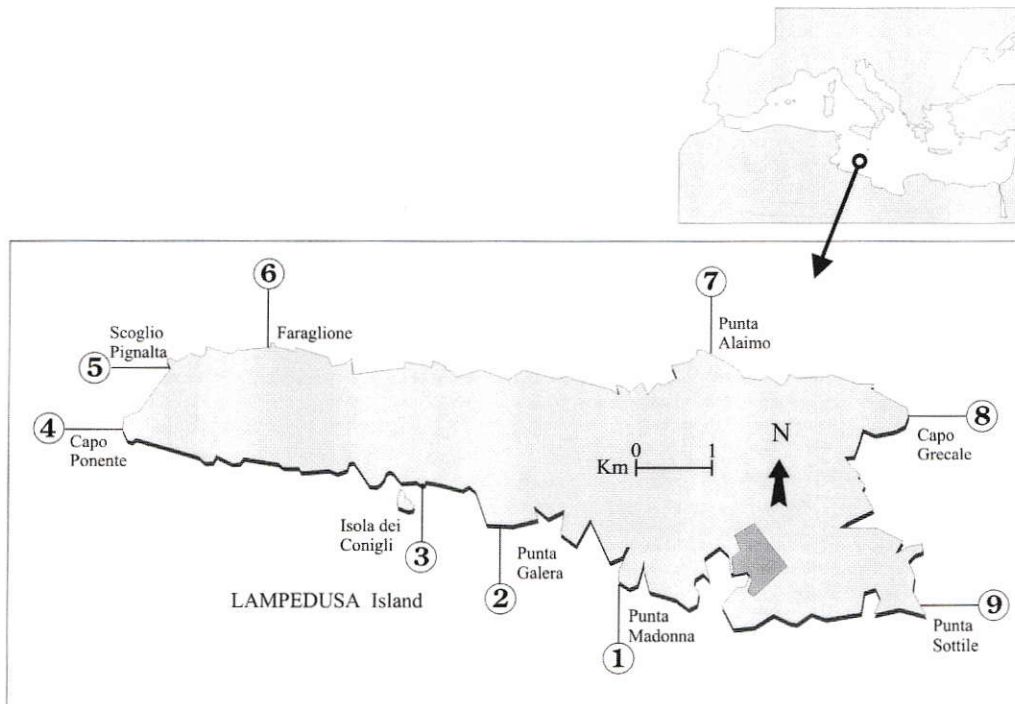


Figure 1. The Island of Lampedusa with the sampling transects.

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

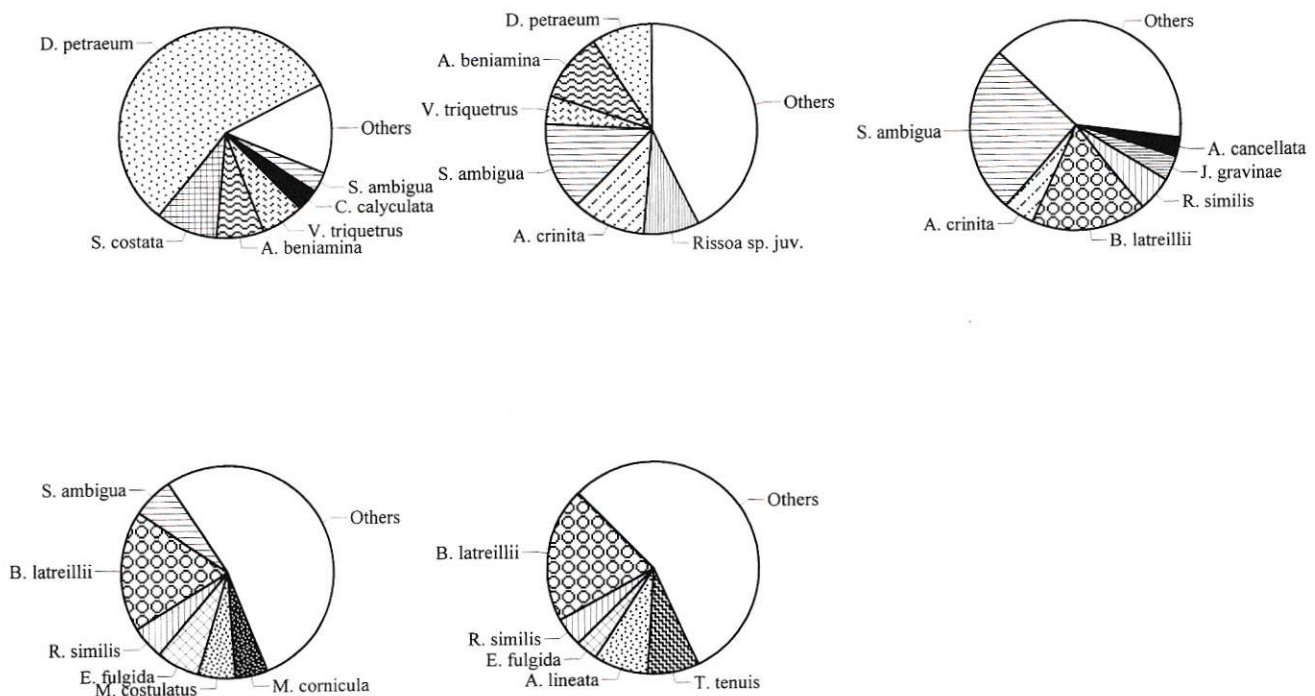


Figure 2. dominant species per depth.

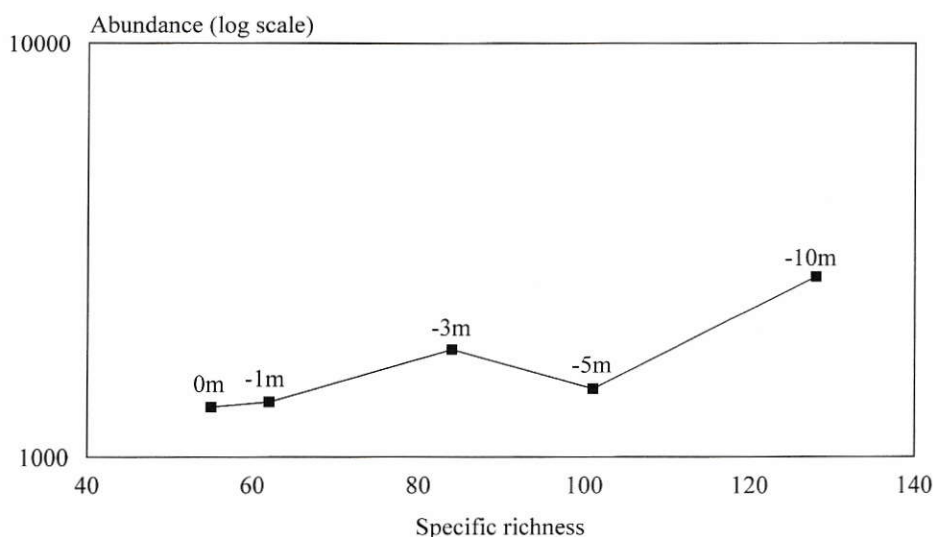


Figure 3. Direct biplot of abundance values, in log scale, and specific richness per depth.

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-

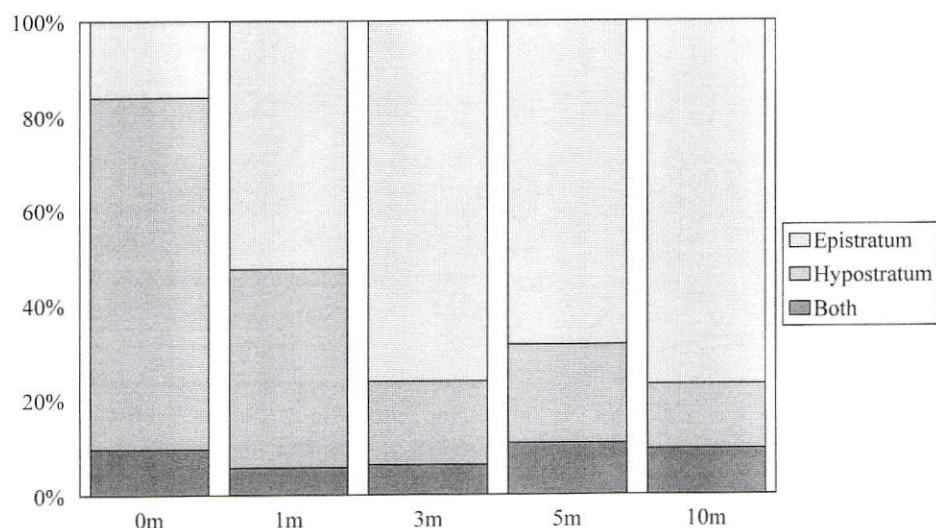


Figure 4. Variations with depth of quantitative dominance of molluscs in the epistratum and hypostratum of *Cystoseira* algal tuft.

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.

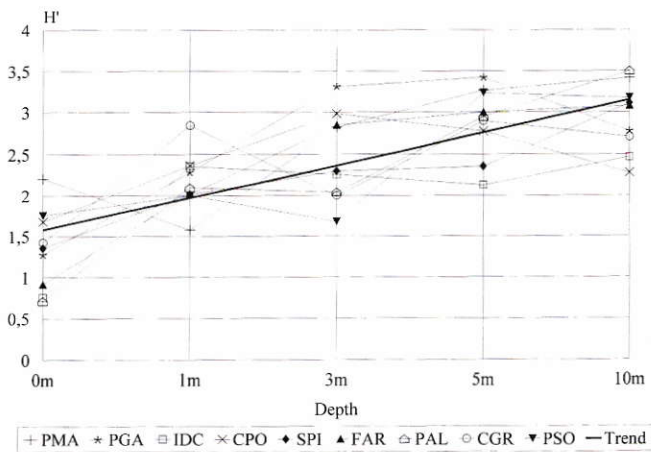


Figure 5. Patterns of Shannon diversity index in all the transects.

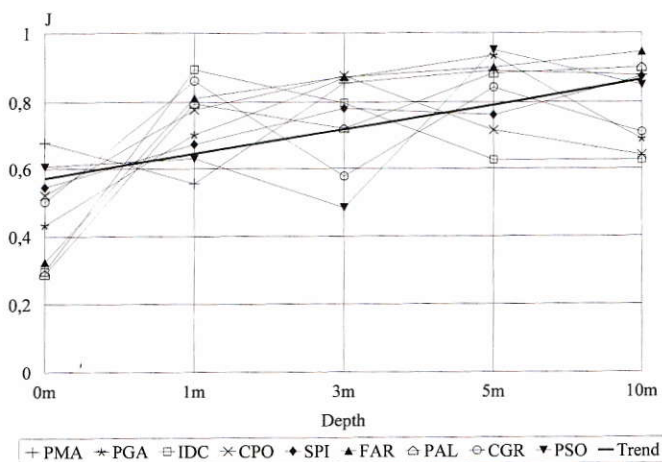


Figure 6. Patterns of evenness index, according to PIELOU, in all the transects.

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.

REFERENCES

- ABBIATI M., C.N. BIANCHI, A. CASTELLI, 1987 - Polychaete Vertical Zonation along a Littoral Cliff in the Western Mediterranean. *P.S.Z.N.I: Marine Ecology*, 8 (1): 33-48.
- AMICO V., G. GIACONE, P. COLOMBO, P. COLONNA, A.M. MANNINO, R. RANDAZZO, 1985 - Un nuovo approccio allo studio della sistematica del genere *Cystoseira* C. Agardh (Phaeophyta, Fucales). *Boll. Acc. Gioenia Sci. Nat.*, 18 (326): 887-986.
- BELLAN-SANTINI D., 1962 - Etude floristique et faunistique de quelques peuplements infralittoraux de substrat rocheux. *Rec. Trav. St. Mar. Endoume*, 26 (41): 237-298.
- BELLAN-SANTINI D., 1964 - Etude qualitative et quantitative du peuplement a *Cystoseira crinita* Bory (Note préliminaire). *Rec. Trav. St. Mar. Endoume*, 34 (50): 249-261.
- BENZECRÌ J.P., 1973 - *L'analyse des données. Tome II: l'analyse des correspondances*. Dunod, Paris: 619 pp.



- BOUDOURESQUE C.F., 1971 - Méthodes d'étude qualitative et quantitative du benthos (en particulier du phytobenthos). *Tethys*, 3 (1): 79-104.
- CHEMELLO R., 1991 - *Contributo alla cartografia biocenotica dei fondali delle Isole Pelagie e struttura del popolamento a Molluschi ai fini della costituzione della Riserva Marina*. Università degli Studi di Messina, Dottorato di ricerca in Scienze ambientali, IV ciclo: 235 pp.
- CHEMELLO R. & S.I. DI GERONIMO, 1992 - Primi dati sulla malacofauna bentonica delle Isole Pelagie (AG) nell'ambito degli studi di fattibilità della Riserva Marina. *Oebalia*, suppl. XVII: 479-484.
- PANDOLFO A., R. CHEMELLO & S. RIGGIO, 1992 - Notes sur la signification écologique de la malacofaune d'un "Trottoir à Vermets" le long le cote de Palerme (Sicile). *Rapp. Comm. Int. Mer Médit.*, Trieste, 33: 47.
- FRESI E. & M.C. GAMBI, 1982 - Alcuni aspetti importanti dell'analisi matematica di ecosistemi marini. *Naturalista sicil.*, s. IV, VI (suppl.), 3: 449-465.
- FRONTIER S., 1974 - *Contribution à la connaissance d'une écosystème néritique tropical: étude descriptive et statistique du peuplement zooplanctonique de la région de Nosy-Bé (Madagascar)*. Thèse d'Etat, Aix-Marseille: 628 pp.
- GIANGRANDE A., 1988 - Polychaete zonation and its relation to algal distribution down a vertical cliff in the western Mediterranean (Italy): a structural analysis. *J. Exp. Mar. Biol. Ecol.*, 120: 263-276.
- LEDOYER M., 1962 - Etude de la faune vagile des herbiers superficiels de zoosteracees et de quelques biotopes d'algues littorales. *Rec. Trav. St. Mar. Endoume*, 25 (39): 117-235.
- MEINESZ A., C.F. BOUDOURESQUE, C. FALCONETTI, J.M. ASTIER, D. BAY, J.J. BLANC, M. BOURCIER, F. CINELLI, S. CIRIK, J. CRISTIANI, I. DI GERONIMO, G. GIACCONE, J.J. HARMELIN, L. LAUBIER, A.Z. LOVRIC, R. MOLINIER, J. SOYER, C. VAMVAKAS, 1983 - Normalisation des symboles pour la représentation et la cartographie des biocénoses benthiques littorales de Méditerranée. *Ann. Inst. océanogr.*, Paris, 59 (2): 155-172.
- PÉRÈS J.M., 1982 - Major benthic assemblages. In: *Marine Ecology*, Otto Kinne Ed., 5 (1): 521 pp.
- PÉRÈS J.M. & J. PICARD, 1964 - Nouveau manuel de bionomie benthique de la Méditerranée. *Rec. Trav. St. Mar. Endoume*, 31 (47): 5-137.
- PIELOU E.C., 1966 - The measurement of diversity in different types of biological collections. *J. Theor. Biol.*, 13: 131-144.
- POULICEK M., 1985 - Les Mollusques des biocénoses a algues photophiles en Méditerranée: II - Analyse du peuplement. *Cab. Biol. Mar.*, 26 (2): 127-136.

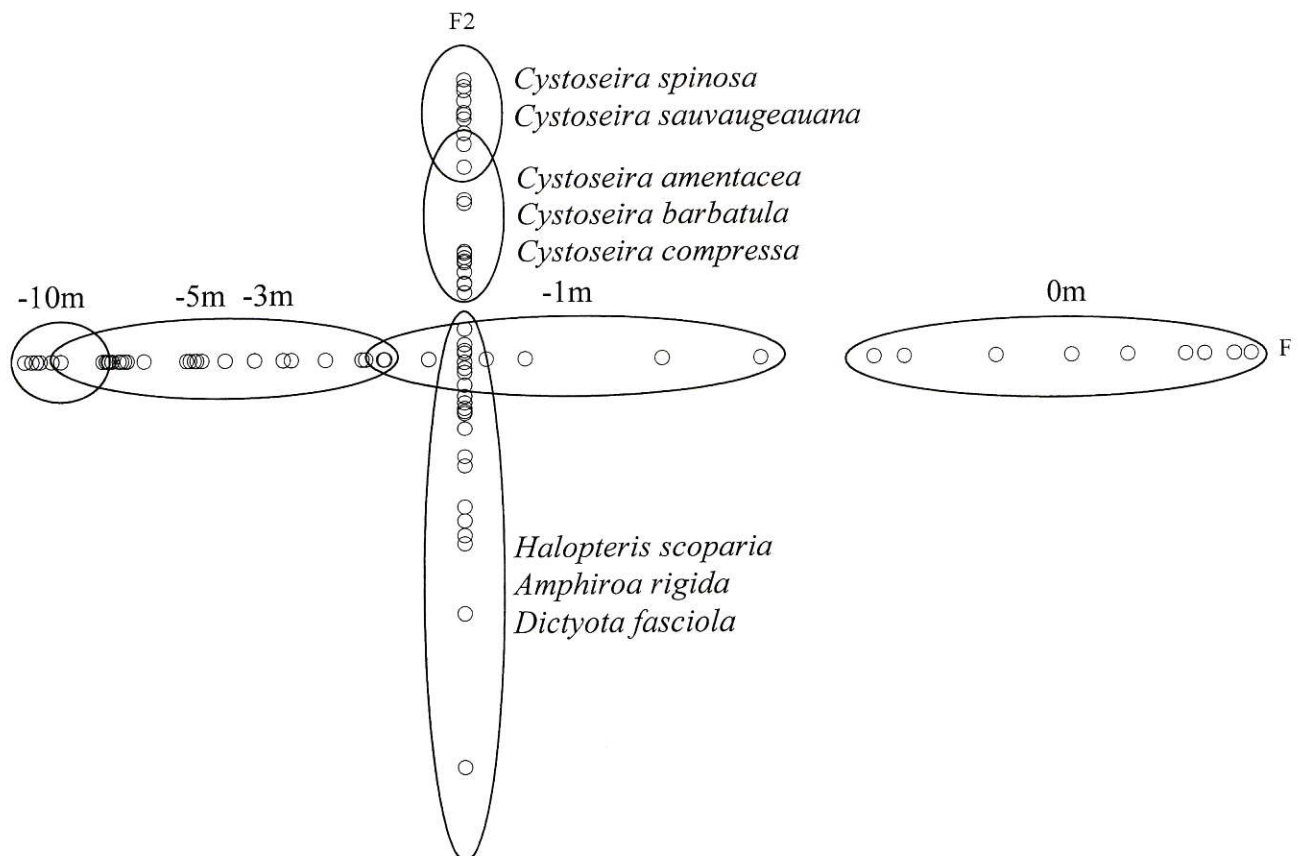


Figure 7. Factorial analysis of correspondances, axes 1 and 2.



RIEDL R., 1971 - Water movements. Animals. In: *Marine Ecology*, Otto Kinne Ed., 1 (5): 1123-1156.
SCAMMACCA B., G. GIACCONE, F. PIZZUTO, G. ALONGI, 1993 - La vegetazione marina di substrato duro dell'Isola di Lampedusa (Isole Pelagie): *Boll. Acc. Gioenia Sci. Nat.*, 26 (341): 85-126.

SHANNON C.E. & W. WEAVER, 1948 - *The mathematical theory of communication*. Illinois University Press, Urbana: 117 pp.
SPADA G., B. SABELLI, V. MORANDI, 1973 - Contributo alla conoscenza della malacofauna marina dell'Isola di Lampedusa. *Conchiglie*, Milano, 9 (3-4): 29-67.

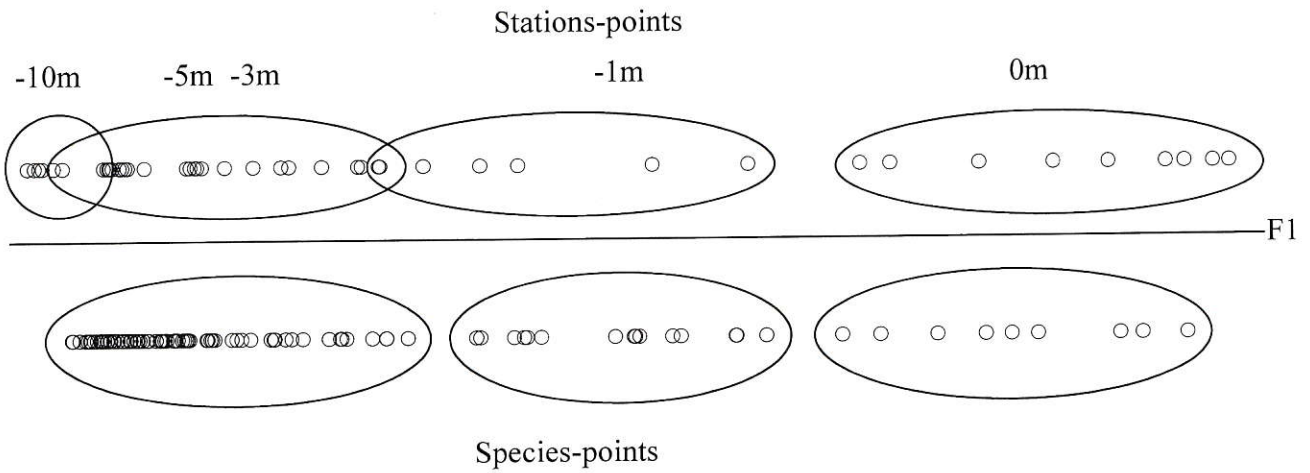


Figure 9. Saturations of station-points and sample-points along F1.

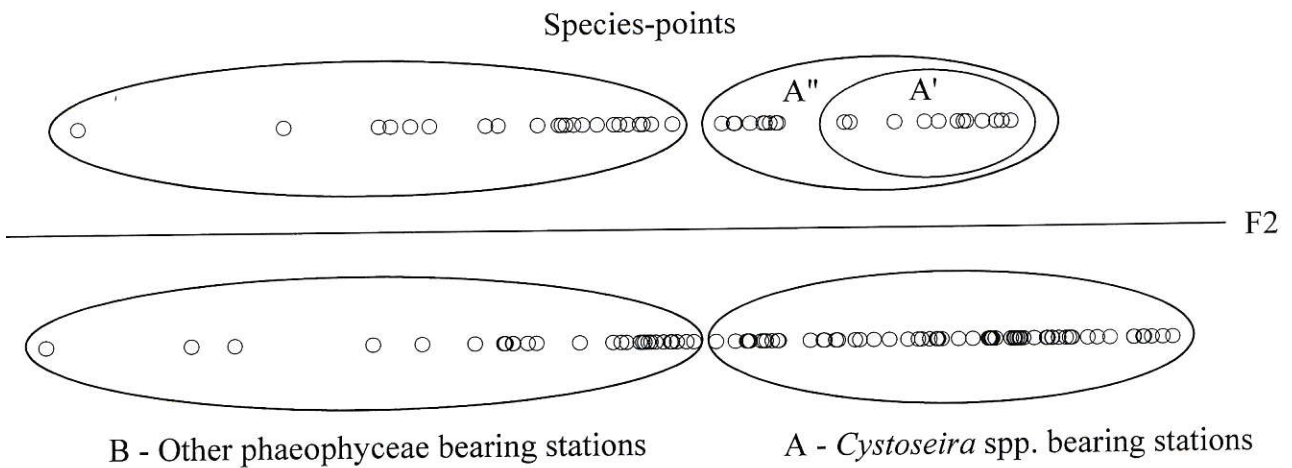


Figure 10. Saturations of station-points and sample-points along F2.