VERTICAL AND HORIZONTAL DISTRIBUTION OF SUBLITTORAL MACROBENTHIC COMMUNITIES IN THE ARRÁBIDA / ESPICHEL COAST (PORTUGAL)

By DIANA BOAVENTURA [1] & PEDRO RÉ [1]

With 8 figures

ABSTRACT. The distributional gradient of macrobenthic communities was analysed in seven stations along the Arrábida/Espichel coast (Portugal). Winter and summer samples were taken in each station using scuba diving and non-destructive methods. Six different assemblages, dominated by the following macroalgae were found: *Gigartina acicularis / Caulacanthus ustulatus / Gelidium* spp., *Corallina elongata*, *Mesophyllum lichenoides*, *Asparagopsis armata*, *Saccorhiza polyschides* and *Cystoseira usneoides*. The vertical and horizontal distribution of these assemblages was assessed by zonation patterns and cartography of the area. *Gigartina acicularis / Caulacanthus ustulatus / Gelidium* spp., *Corallina elongata*, *Mesophyllum lichenoides* were sequentially distributed as depth increased along the entire coast. Assemblages dominated by *Asparagopsis armata*, *Saccorhiza polyschides* and *Cystoseira usneoides* were found at the deepest levels, depending on the location. *Cystoseira usneoides* dominates over *Asparagopsis armata* and *Saccorhiza polyschides* in most of the studied area. These results were compared with previous work suggesting a great reduction of *Saccorhiza polyschides*, possibly related to plant-animal interactions or long-term variations.

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RESUMO. O gradiente de distribuição das comunidades macro-bentónicas ao longo da costa da Arrábida/Espichel (Portugal), foi analizado em 7 estações. Em cada estação, foram feitas amostragens no Inverno e no Verão, com recurso ao mergulho com escafandro autónomo e a métodos não destrutivos. Foram encontradas seis associações diferentes, dominadas pelas seguintes macro-algas: *Gigartina acicularis / Caulacanthus ustulatus / Gelidium* spp., *Corallina elongata*, *Mesophyllum lichenoides*, *Asparagopsis armata*, *Saccorhiza polyschides* and *Cystoseira usneoides*. A distribuição vertical e horizontal destas associações foi avaliada através de padrões de zonação e de cartografia da área. A distribuição ao longo de toda costa de *Gigartina acicularis / Caulacanthus ustulatus / Gelidium* spp., *Corallina elongata*, *Mesophyllum lichenoides* foi sequencial à medida que a profundidade aumentou. Nos níveis mais profundos, os agrupamentos foram dominados por *Asparagopsis armata*, *Saccorhiza polyschides* and *Cystoseira usneoides*, dependendo da localização. Na maior parte da área estudada, *Cystoseira usneoides* dominou sobre *Asparagopsis armata* e *Saccorhiza polyschides*. Os resultados do presente trabalho foram comparados com outros anteriores e sugerem uma grande redução de *Saccorhiza polyschides*, possivelmente relacionada com interacções animal/planta ou variações a longo prazo.

INTRODUCTION

The interest of marine biologists for the rich fauna and flora of the Arrábida coast started many years ago with the first systematic explorations of this area conducted by King D. Carlos I on his yacht *Amélia*. Since then, scientists such as Augusto Nobre, A. Ricardo Jorge, A. Xavier da Cunha, R. Lami, F. Palminha, F. Ardré, J. Picard e J. M. Pérès, worked in this region contributing to a greater understanding of sublittoral marine communities (see SALDANHA, 1974 for references).

The study of the benthic associations of the superior levels of the littoral rocky bottoms by SALDANHA (1974) brought a considerable amount of qualitative and quantitative data on large portions of the coast both in extension and depth. More recently, other studies were focused on a specific area or taxonomic group: for example algological studies were carried out by MELO & SANTOS (1979, 1984), BRODIE & GUIRY (1988), DUARTE & FERREIRA (1993), SANTOS (1993a, 1993b, 1993c) and DUARTE (1994, 1995a, 1995b); the sponge fauna was studied by LOPES & BOURY-ESNAULT (1981) and LOPES (1989); and ichthyological studies were conducted out by ARRUDA (1979) and ALMADA *et al*. (1990a, 1990b, 1992, 1993), OLIVEIRA *et al*. (1992), GONÇALVES *et al*. (1993).

Following the guidelines of SALDANHA's (1974) work, BOAVENTURA (1993, 1996) and BOAVENTURA *et al*. (1994) studied the structure and function of the sublittoral communities of this area. In the present paper, the results of the vertical and horizontal gradient of distribution of the main macrobenthic communities are presented.

The Arrábida coast shows a great potential for the development of underwater activities. Most studies of Portuguese sublittoral communities involving scuba diving equipment have been carried out in this region. The Arrábida underwater Natural park was created recently (28 July 1998) and was named after Professor Luiz Saldanha (1937/1997).

The main objective of the present work was to describe the macrobenthic communities of Arrábida coast. Specific objectives included the analysis of the vertical and horizontal patterns of distribution, seasonal variations (summer/winter), a preliminary cartography of this marine area, and a comparison of the results with former studies carried out in the same study area by SALDANHA (1974).

MATERIAL AND METHODS

Study site

The present study was carried out between Portinho da Arrábida and Cabo Espichel, *i. e*. along approximately 20 km of coast located in central west region of Portugal.

The Arrábida coast extends WSW-ENE (38º 24' 55" and 38º 28' 36" N – 8º 58' and 9º 13' 10" W). The geomorphology of this coast is irregular and composed mainly of limestone. Sublittoral bottoms are rocky and sandy, with the latter prevailing. The depth and extent of the rocky substrate decrease from Cabo Espichel to Portinho da Arrábida. Exposure to wave action and currents is a very important factor in the distribution of the benthic populations, with its intensity diminishing along a gradient (W-E), being very exposed at Cape Espichel and sheltered at Portinho da Arrábida (SALDANHA, 1974).

The sampling sites were chosen according to previous studies carried out in Arrábida/Espichel coast (SALDANHA, 1974; BOAVENTURA, 1993; BOAVENTURA *et al*., 1994) and after a preliminary survey. Seven stations were selected, according to contrasting differences in topography and zonation patterns (Fig. 1).

Sampling methods

Sampling was carried out during summer (July and August, 1994) and winter (January and February, 1995) periods. A total of two samples per location were taken.

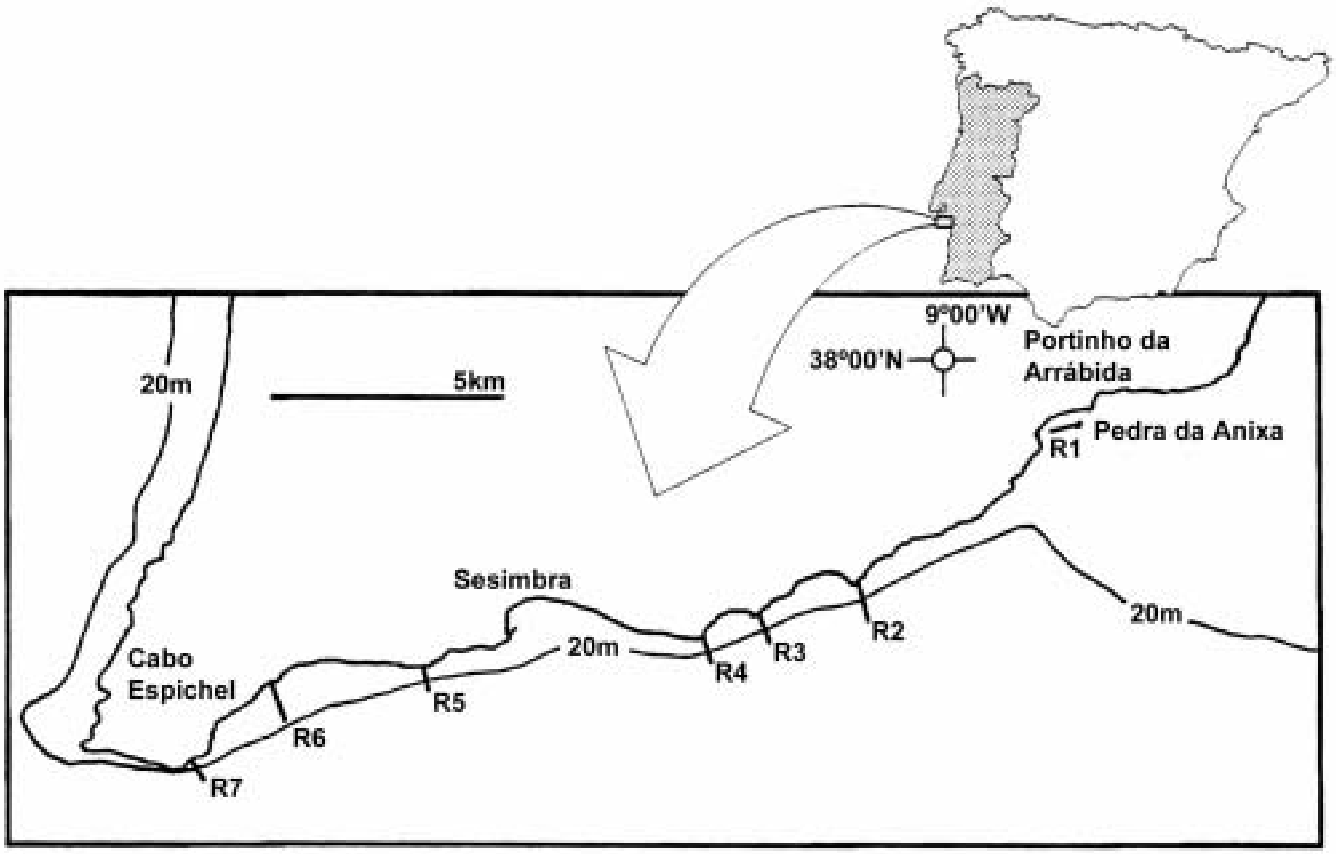

Fig. 1 - Stations sampled at Arrábida/Espichel Coast (R1 to R7).

The zonation patterns were assessed using a cable marked at metre intervals placed perpendicularly to the coast, following the bottom topography until the end of the rocky substrate. At each metre the depth was recorded and the slope estimated. The principal species and boundaries of the different assemblages were also registered along the transects. These methods were previously used by other authors (GILI & ROS, 1982, 1984; LOGAN *et al*., 1984; RALLO *et al*., 1988).

Quantitative sampling was carried out using non-destructive methods (HAWKINS & JONES,1992), namely photographic methods and visual samples, in each of the previously identified dominant macrobenthic assemblages. The percent cover of algae and sessile animals was estimated using a quadrat of 50 x 50 cm subdivided in quadrats of 10 x 10 cm. An abundance scale similar to Braun-Blanquet was (BRAUN-BLANQUET & PAVILLARD, 1922 in BOUDOURESQUE, 1971). Mobile macroinvertebrates were counted. Several aspects of the benthic communities were photographed with an underwater camera *Nikonos III* / *Nikonos V*, equipped with an electronic flash.

Identification of organisms was done *in situ* when possible or at the laboratory after collection.

Data analyses

The cartography of the coast and zonation patterns were analysed and compared with previous studies (SALDANHA, 1974).

Quantitative data of macrobenthic species obtained with non-destructive methods were treated with multidimensional analysis. A cluster analysis (Q-type) was performed on the matrix of *taxa vs* stations (winter and summer situations). Bray and Curtis coefficient was used since it is not affected by joint absences and is sufficiently robust for marine data (FIELD *et al*., 1982). The method used for classification was UPGMA (“Unweighted Pair Group Method using Arithmetic Averages).

RESULTS

Zonation patterns

Figures 3 to 5 represent zonation patterns in some of the studied locations: Pedra da Anixa (R1), Cabo Afonso (R3), and Boca dos Bobaleiros (R6). The graphics provide a general overview of the topographic profile and main assemblages found in these areas. The different zones were identified considering the dominant macroalgae. Only the most representative *taxa* were included (Fig. 2). It is important to mention that these figures correspond to a summer situation since seasonal variations occur especially at *Asparagopsis armata*, *Saccorhiza polyschides* and *Cystoseira usneoides* levels.

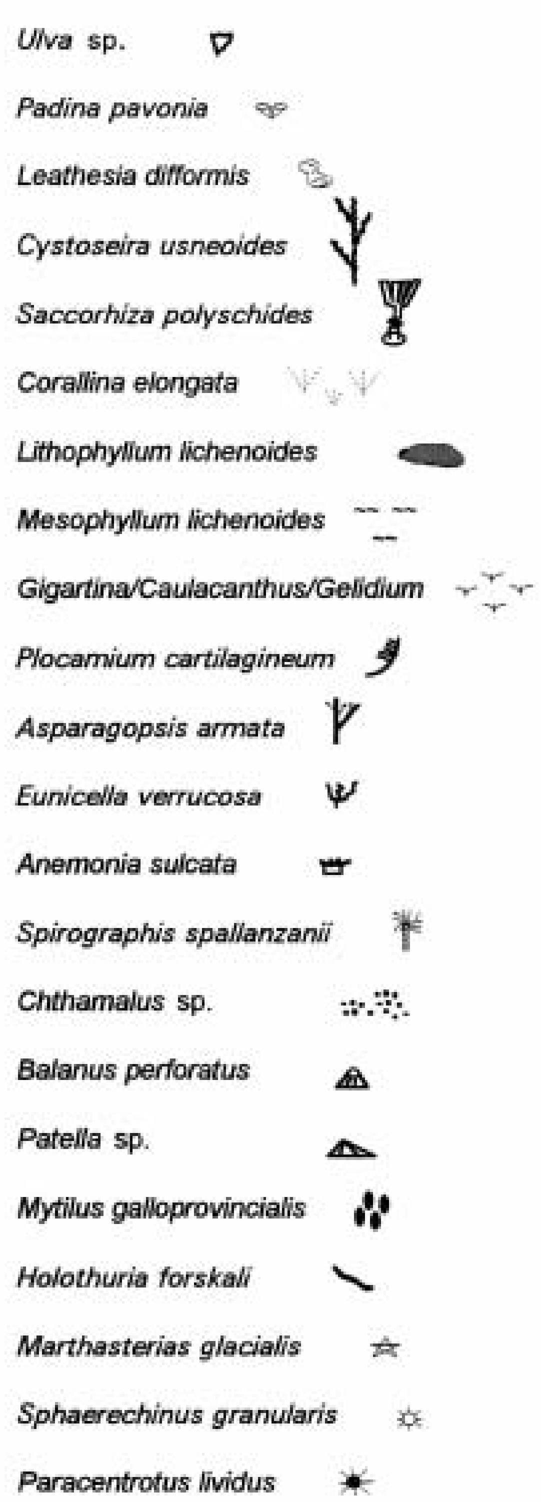

Fig. 2 - Symbols used in the zonation patterns. Only the most representative *taxa* were included.

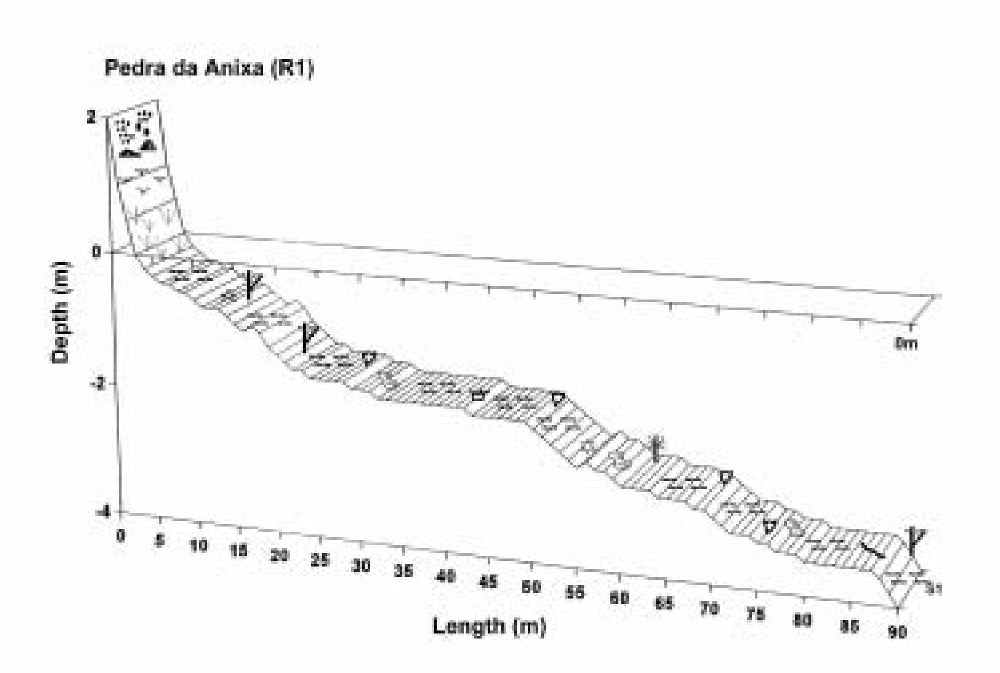

Fig. 3 - Zonation pattern at Pedra da Anixa (R1).

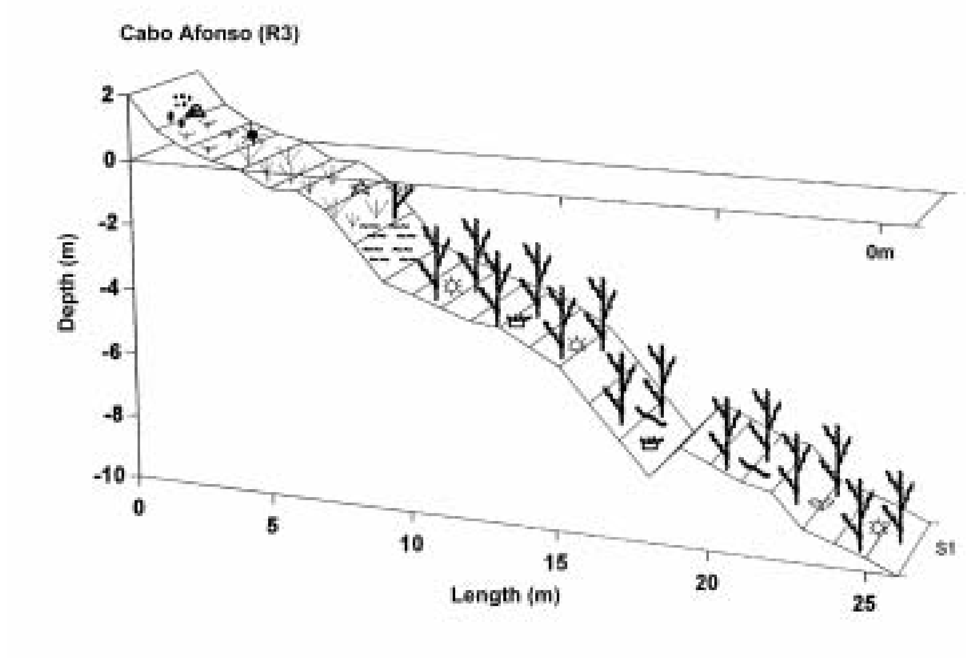

Fig. 4 - Zonation pattern at Cabo Afonso (R3).

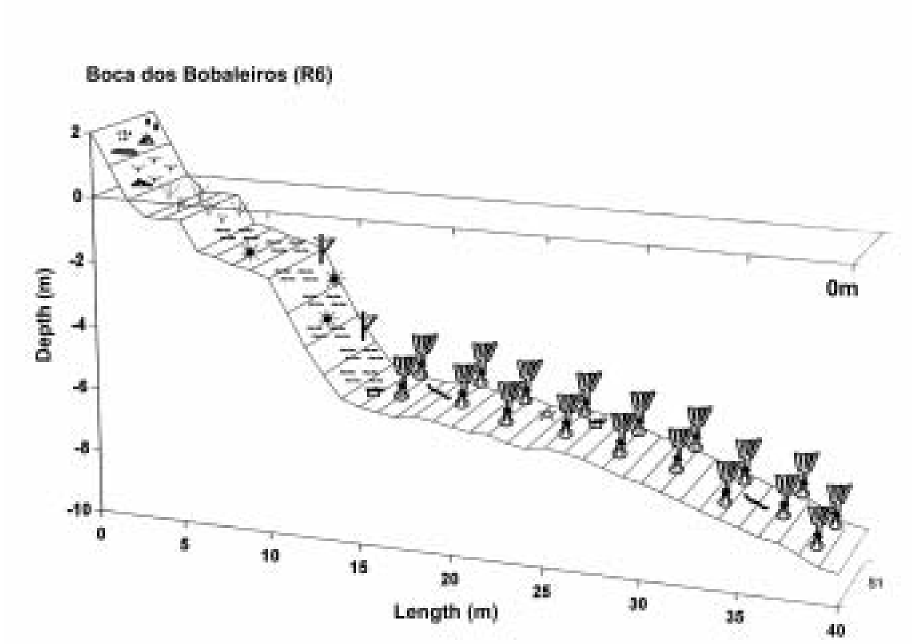

Fig. 5 - Zonation pattern at Boca dos Bobaleiros (R6).

Vertical distribution of macrobenthic assemblages

Six different macrobenthic assemblages were identified in the present work: *Gigartina acicularis / Caulacanthus ustulatus / Gelidium* spp., *Corallina elongata*, *Mesophyllum lichenoides*, *Asparagopsis armata*, *Saccorhiza polyschides* and *Cystoseira usneoides*.

Gigartina acicularis / Caulacanthus ustulatus / Gelidium spp.

This particular assemblage is located immediately after the eulittoral zone being still affected by periodical emersion. The extension of this zone is approximately 1 m. It essentially consists of mats of red algae species with small thalli such as *Gigartina acicularis, Caulacanthus ustulatus* and *Gelidium* spp. and is generally referred to as red algal turf (STEWART, 1982; KENDRICK, 1990; NORTON, 1985; HAWKINS *et al.*, 1992).

Corallina elongata

Corallina elongata can be found below the red turf assemblage. *Corallina elongata* forms a few centimetres high stratum; usually more developed in vertical surfaces. According to SALDANHA (1974), *Gigartina acicularis* facies replaces

Corallina elongata in the sheltered area of the coast. They can however coexist as described above when the hydrodynamic conditions are favourable (*e. g.* low). Presently, this latter situation is the prevailing one and *Corallina elongata* facies occurs below *Gigartina acicularis / Caulacanthus ustulatus / Gelidium* spp. in most parts of the studied area.

Mesophyllum lichenoides

Mesophyllum lichenoides was located immediately after *Corallina* elongata, usually on flat or gently sloped surfaces. *Mesophyllum lichenoides* is an alga forming small, thin leaf-like flattened lobes. Individual lobes measure 1 cm, but collectively can form large masses (HISCOCK, 1986). During the summer, this zone can be covered with a mosaic of other algal species, which form a kind of canopy (*e. g. Gelidium latifolium*, *Gelidium sesquipedale*, *Dictyota dichotoma*, *Cystoseira tamariscifolia*, *Ulva* sp., *Codium* sp.).

The vertical distribution mentioned so far was observed in the whole studied coast. The lower limit of *Mesophyllum lichenoides* zone is replaced by *Asparagopsis armata, Saccorhiza polyschides* or *Cystoseira usneoides* depending on location. In Pedra da Anixa (R1) this assemblage is followed by *Asparagopsis armata*, while in Frade (R5) and Boca dos Bobaleiros (R6) *Saccorhiza polyschides* extends from the lower limit of *Mesophyllum lichenoides* until the end of the rock substrate. At all other stations (R2, R3, R4 e R7), *Cystoseira usneoides* dominates in greater depths.

Asparagopsis armata

Asparagopsis armata was very dense in the deepest part of rock substrate at Pedra da Anixa, although it was also observed in the algal mosaic that covers *Mesophyllum lichenoides*. Several layers can be distinguished in this assemblage: i) a canopy layer composed of *Asparagopsis armata*; ii) an understorey layer with *Plocamium* sp., *Ceramium* sp., *Gelidium* sp., etc.; iii) and an encrustant layer with *Litophyllum incrustans* and small portions of *Mesophyllum lichenoides*. This alga occurs in late winter and spring in the studied region, since it has alternate phases (tetra sporophyte *Falkenbergia rufolanosa*).

Saccorhiza polyschides

Saccorhiza polyschides was located immediately bellow *Mesophyllum lichenoides* and extended until the end of the rocky platform. This alga has great proportions and can reach 2m height (RIEDL, 1986; SALDANHA,1995). *Saccorhiza polyschides* is an annual alga (CABIOC'H *et al*., 1992) and the sporophyte phase reaches the maximum development during the summer (SALDANHA, 1974). The holdfast is a large warty bulb attached by rhizoids. The stipe is markedly flattened with narrow wavy lamina on each side, expanding into a broad leathery lamina divided into fingers (HISCOCK, 1979; RIEDL, 1986; CABIOC'H *et al*., 1992; SALDANHA, 1995). As previously observed by SALDANHA (1974), this assemblage was stratified in different layers: i) a canopy layer formed by *Saccorhiza polyschides* itself; ii) a layer with shorter canopy algae composed, among other species, by *Asparagopsis armata*, *Gelidium sesquipedale*, *Codium* sp.; iii) an understorey stratum with *Plocamium* sp., *Gelidium* sp., *Ceramium* sp.; iv) and an encrusting layer mainly composed of the calcareous alga *Lithophyllum incrustans* and *Mesophyllum lichenoides*, to which some other animal species are associated (diverse sponges, serpulid polychaets and bryozoans).

Cystoseira usneoides

Cystoseira usneoides is an alga of big dimensions reaching up to 3 or 4 metres. The assemblage of *Cystoseira usneoides* alternates with *Saccorhiza polyschides* depending on location but presents similar aspects: i) this zone is also located immediately after the *Mesophyllum lichenoides* assemblage and extends until the end of the hard substrate, ii) the stratification is identical to the one referred for *Saccorhiza polyschides*, iii) it becomes more developed during summer.

Plants from this genus are perennial but they loose a great part of their ramifications during the rest period (RIEDL, 1986). In fact, during the winter only the basal parts of this alga were observed in the studied area.

The three main types of vertical gradients are shown in Fig. 6.

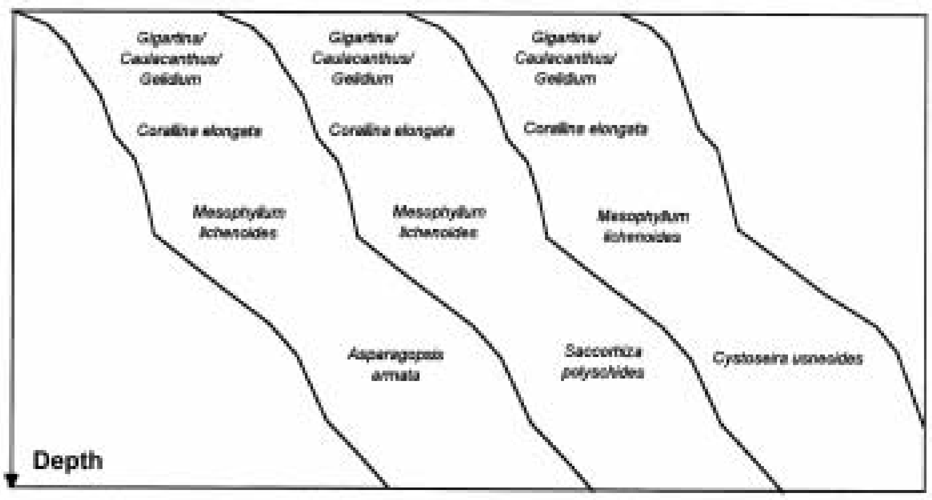

Fig. 6 - The three types of vertical gradients found in the Arrábida/Espichel Coast.

Horizontal distribution of macrobenthic assemblages

In addition to the transects and sampling carried out in each station, several surveys of the entire coast from Portinho da Arrábida to Cape Espichel were performed providing a preliminary cartography of the horizontal distribution of sublittoral communities in this region (Fig. 8b).

Gigartina acicularis / Caulacanthus ustulatus / Gelidium spp., *Corallina elongata*, *Mesophyllum lichenoides* are distributed continuously along the entire coast. The most important variations both in temporal and horizontal distribution tend to occur at deepest stands. At this level, *Cystoseira usneoides* assemblage, dominates over *Asparagopsis armata* and *Saccorhiza polyschides* in most of the area during the summer period. This assemblage is present from Portinho da Arrábida until Sesimbra, where it disappears due to the absence of rocky substrate in the bay. On the rocky coast from Sesimbra to Forte da Baralha, this assemblage occurs again, with the exception of the area between Frade and Boca dos Bobaleiros, where it is replaced by *Saccorhiza polyschides*. Dense algal stands of *Saccorhiza polyschides* can only be found in this area. In the rest of the coast this alga occurs isolated.

Neither *Cystoseira usneoides* nor *Saccorhiza polyschides* developed on rocky shores of Portinho da Arrábida bay (Pedra da Anixa). *Asparagopsis armata* is dominant at this station in late winter.

Multidimensional analysis

Cluster analysis results (Q type) are represented in Fig. 7. Two main groups can be considered. Group A includes most of the studied stations and contains two subgroups (A1, A2) and an isolated station (VR5). VR5 (Summer-Frade) corresponds to the only station where *Saccorhiza polyschides* formed a very dense canopy. This alga was present in another station (VR6) but with lower values of percentage cover, being associated, in the cluster analysis, with two winter situations (IR3, IR6). Subgroup A1 contains locations 7 and 4 and summer samples from location 2. Subgroup A2 includes stations 6 and 3 and winter situations of stations 5 and 2. Group B consists of winter and summer samples of Pedra da Anixa and it is clearly isolated from the other stations. There are no clear divisions in seasonal variability.

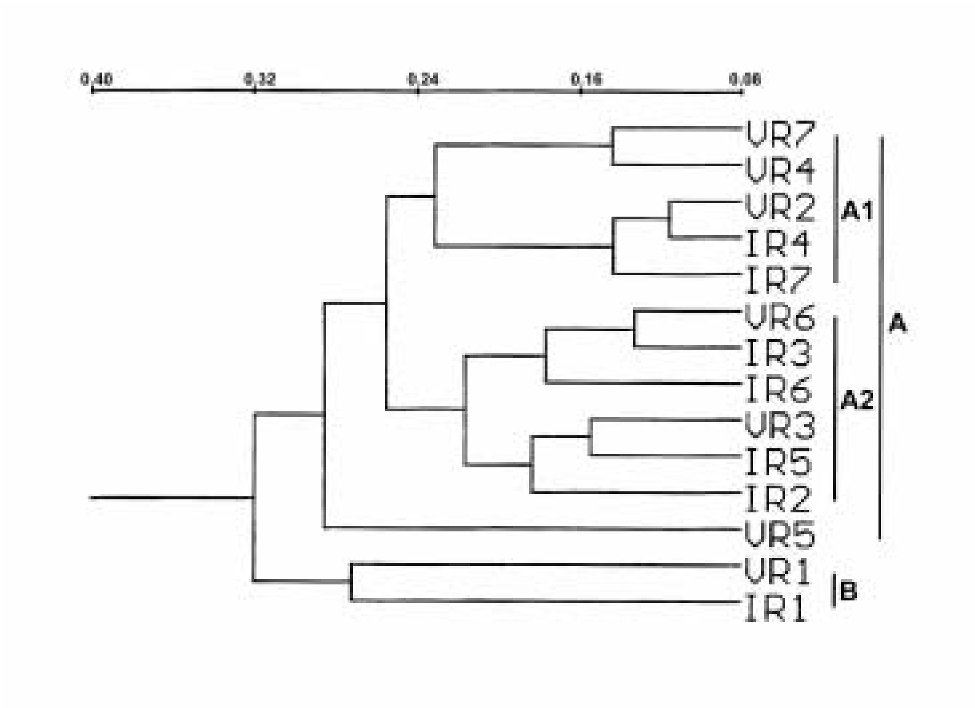

Fig. 7 - Cluster analysis results (Q type). V- Summer, I- Winter, R- Transect.

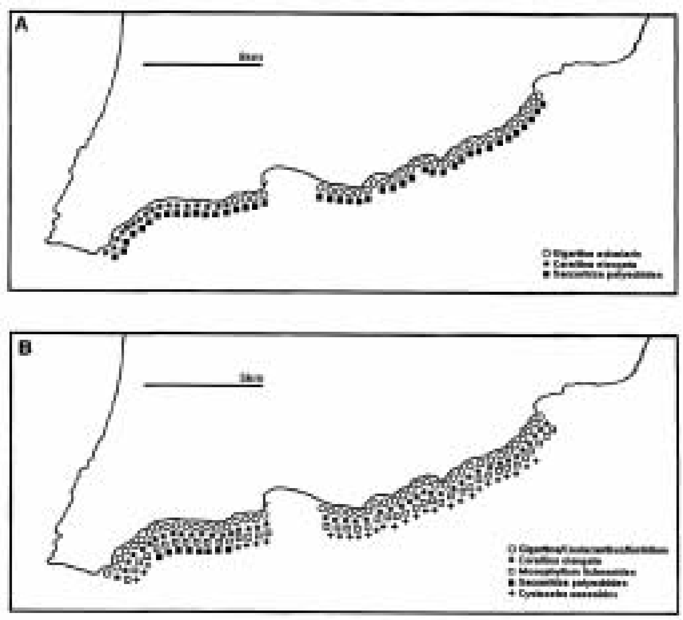

Fig. 8 - Schematic summary of the distribution of most important sublittoral assemblages in the Arrábida/Espichel Coast (A- Saldanha, 1974, B- Present work).

DISCUSSION

Vertical and horizontal gradients of distribution of sublittoral communities were studied.

Gigartina acicularis / Caulacanthus ustulatus / Gelidium spp., *Corallina elongata*, *Mesophyllum lichenoides* are sequentially distributed as depth increases along the entire coast. The lower limit of *Mesophyllum lichenoides* assemblage is replaced by *Asparagopsis armata*, *Saccorhiza polyschides* and *Cystoseira usneoides* depending on location. At this level *Cystoseira usneoides* dominates over *Asparagopsis armata* and *Saccorhiza polyschides* in most of the studied area.

The benthic communities of Arrábida coast were previously studied by SALDANHA (1974). More than 20 years after this work, it is extremely useful to compare results. Although a different methodology was used in the present work (non-destructive methods) it is possible and useful to compare general variations related to facies distribution.

SALDANHA (1974) described all the macrobenthic assemblages previously mentioned, with the exception of *Mesophyllum lichenoides* and *Cystoseira usneoides*. However, these algae were observed by this author in other zones. The first occurred at encrusting layers of other assemblages and the second was found in the *Saccorhiza polyschides* assemblage.

Additionally, SALDANHA (1974) described other assemblages - *Gelidium sesquipedale*, *Litophyllum incrustans* e *Mytilus galloprovincialis* - located in the area between Forte da Baralha and Cape Espichel and, therefore, not included in the present work.

Figure 8 provides a schematic summary of the distribution of most important sublittoral assemblages, in the studied area.

One of the main differences is related to the regression of *Saccorhiza polyschides* and the dominance of *Cystoseira usneoides*. The work of SALDANHA (1974) does not include a detailed study of the life history of this alga, but he described the periods of development of the sporophyte. The juvenile sporophytes occur between January and March and the loss of the fronds and stipe takes place in November. Most of the bulbs are detached from the rock surface during winter. Summer (August) corresponds to the period of the maximum development of the sporophyte.

Several factors can affect the distribution and abundance of this species. According to NORTON (1985), both *Saccorhiza polyschides* and *Laminaria digitata* are very sensitive to occasional periods of emersion. Sublittoral algae are less tolerant to desiccation, however, this does not seem to be the most reasonable explanation. Additionally, plant-animal interactions can also be responsible for the variation of this species (HAWKINS *et al.*, 1992). The influence of grazing by sea urchins and inter-specific competition between *Saccorhiza polyschides* and *Cystoseira usneoides*, are possible hypotheses to be analysed in the future.

There is also the possibility that this situation is related to a long-term variation. According to CONNELL (1985), it is extremely important to record variations of distribution and abundance, during a long time series. In fact, persistence and variations of populations are related to the adopted temporal scale. A monitoring study of *Saccorhiza polyschides* should be carried out in order to understand this situation.

Regarding seasonal variations, drastic changes were recorded in the deepest zones - *Saccorhiza polyschides* and *Cystoseira usneoides*. The exuberant canopy observed during Summer was reduced to the lower layers during Winter. Nevertheless, results of multidimensional analysis do not suggest a clear division of stations according to temporal variation. This means that the variations in the general aspect of the deepest assemblages do not have a direct effect on the other layers and organisms found in that zone.

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