

# Cnidarian Zonation at Ilha do Sal (Arquipélago de Cabo Verde)

## Cnidarier-Zonierung an der Insel Sal (Kapverdische Inseln)

by

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### Abstract

A total of 19 conspicuous species was inventoried by SCUBA diving along 10 depth-transects, 0 to 33 m depth. Multivariate analysis allowed the recognition of 5 cnidarian zones, namely: lower midlittoral zone, *Millepora* zone, mixed coral zone, overhang zone, gorgonian-antipatharian zone. Species substitution with depth is mainly related to gradients in light intensity and water movement; the possible role of competition and predation is also discussed. Although no true coral reefs exist at Sal, the observed zonation patterns are consistent with those typical of coral reef areas.

### Zusammenfassung

Entlang von 10 Tiefentransekten (0–33 m Wassertiefe) konnten 19 „auffällige“ Arten bei Scuba-Tauchabstiegen festgestellt werden. Mittels einer multivariaten Analyse ließen sich 5 Cnidarier-Zonen ausscheiden: untere Mittlitoral Zone, *Millepora* Zone, gemischte Korallen Zone, Überhang Zone, Gorgonien-Antipatharien Zone. Artsubstitutionen mit der Tiefe können mit Gradienten der Lichtintensität und Wasserbewegung korreliert werden; die mögliche Rolle von Wettbewerb und Beutefang wird auch diskutiert. Obwohl auf der Insel Sal keine Korallenriffe existieren, zeigt die beobachtete Zonierung starke Ähnlichkeiten zu jenen wie sie für Korallenriffe typisch sind.

### 1. Introduction

Cnidarians are important constituents of shallow-water epibenthic communities (MORRI et al., 1991) especially in tropical seas, where they comprise the main frame-builders of coral reefs (FAGERSTROM, 1987). Cnidarian species are zoned in the different parts of a

coral reef according to their ecological requirements with respect to a number of abiotic and biotic factors (see DONE, 1983, for a review). However, little is known on the cnidarian zonation in tropical areas deprived of coral reefs.

The Eastern Tropical Atlantic is one of such areas (EKMAN, 1953). Although no true coral reefs exist along the West African coast or in the neighbouring archipelagos, nevertheless there are a number of sites with rich coral communities (WELLS, 1988) and several species of hermatypic corals are known from the region (LABOREL, 1974; BOEKSCHOTEN & BOREL-BEST, 1988).

Corals and other reef cnidarians turned out to be abundant on shallow (0 to 33 m deep) rocky bottoms at Ilha do Sal (Arquipélago de Cabo Verde), during a SCUBA diving expedition organised in the winter of 1990–1991, by the Zoological Institute of Genova University.

The aim of this paper is to describe the cnidarian zonation we observed at Sal, and to relate it to depth, substrate inclination, and wave exposure.

### 2. Materials and Methods

Cnidarian zonation was examined according to the method frequently adopted in the Mediterranean Sea for SCUBA benthic surveys (BIANCHI et al., 1991; GILI & ROS, 1985).

Two divers working together swam along idealised depth-transects perpendicular to the shore (note that “transect” here is not intended in the sense of LOYA, 1978). One of these depth-transects was effectuated at each of ten stations (Fig. 1). Due to persistent bad weather conditions, only west and, to a lesser extent, south coasts of Sal were explored.

In each depth-transect (numbered 1 to 10), the two divers recognised homogeneous areas (named a, b, c ...: Fig. 2) through a physiognomic approach (BEARD, 1978): i.e., areas were considered homogeneous for substratum type and the “aspect” of their biotic cover (a similar approach was used by GOMEZ & ALCALA, 1984, to divide the reef in sampling “strata”). These areas had varying sizes,

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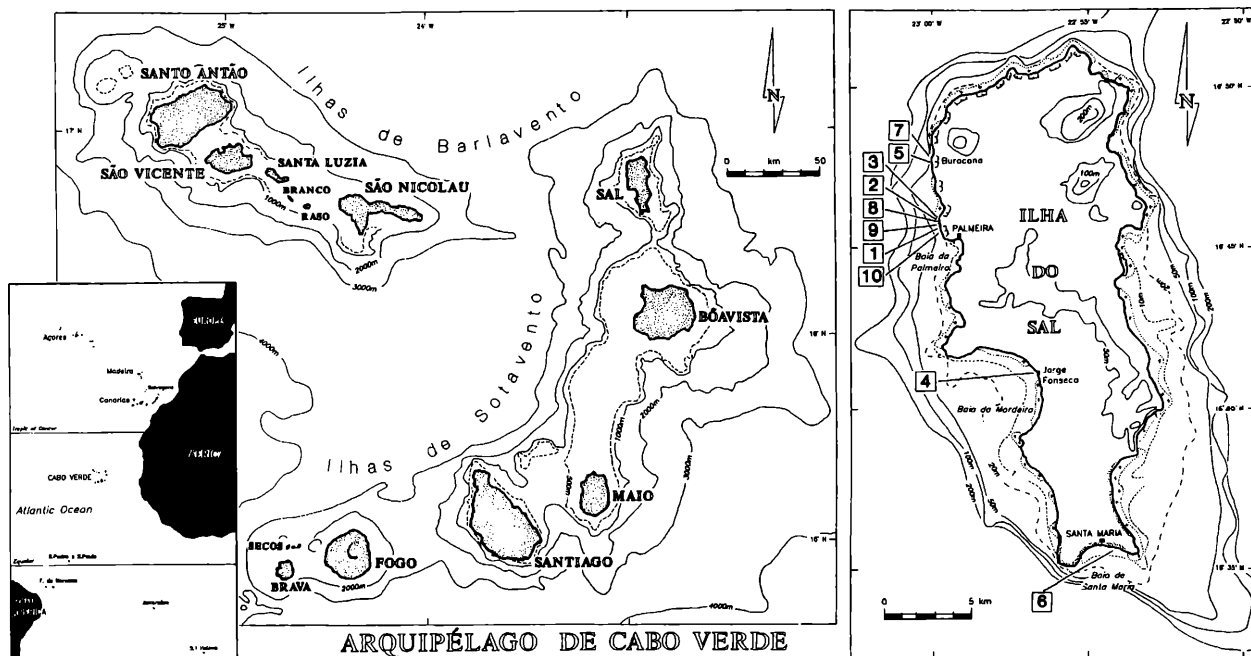


Figure 1: Geographical setting of the study area. Numbers in boxes are stations.

usually about 20 m<sup>2</sup> or more, and were treated as “relevés”, according to phytosociological usage (BOUDOURESQUE, 1971; COPPEJANS, 1980). In total, 29 “relevés” were sampled between 33 m depth and the water surface (transect 5 gave no cnidarians).

In each relevé, cnidarians were inventoried and, when necessary for identification purposes, collected. All species large enough to be easily seen underwater were taken into account. The smallest species of hydroids and cryptic anthozoans such as stoloniferans, if not abundant, might have escaped recording. No quantitative analysis was attempted. Species importance was evaluated through visual estimates of their substratum cover (DETHIER et al., 1993), subsequently converted into a semi-quantitative three-point scale (HISCOCK, 1987); absence was given a zero score.

Depth of each relevé was measured by diving computer, and substrate inclination with a hand-made clinometer (GAMBLE, 1984). Wave exposure was evaluated through the fetch-energy index proposed by HUMMON (1989): in order to account for the exponential decrease of water movement with increasing depth, the computed fetch-energy index was divided by the logarithm of depth.

The species x relevés matrix was submitted to multivariate analysis (WILDI & ORLOCI, 1980). Cluster analysis was performed on relevés, using VANDER MAAREL's coefficient as a similarity index, and clustering by complete linkage. Species and relevés were also ordered by correspondence analysis: the significance of the axes was evaluated using the tables of LEBART (1975). Significant axes were compared to depth, substrate inclination, and exposure index by standard linear correlation analysis.

### 3. Results

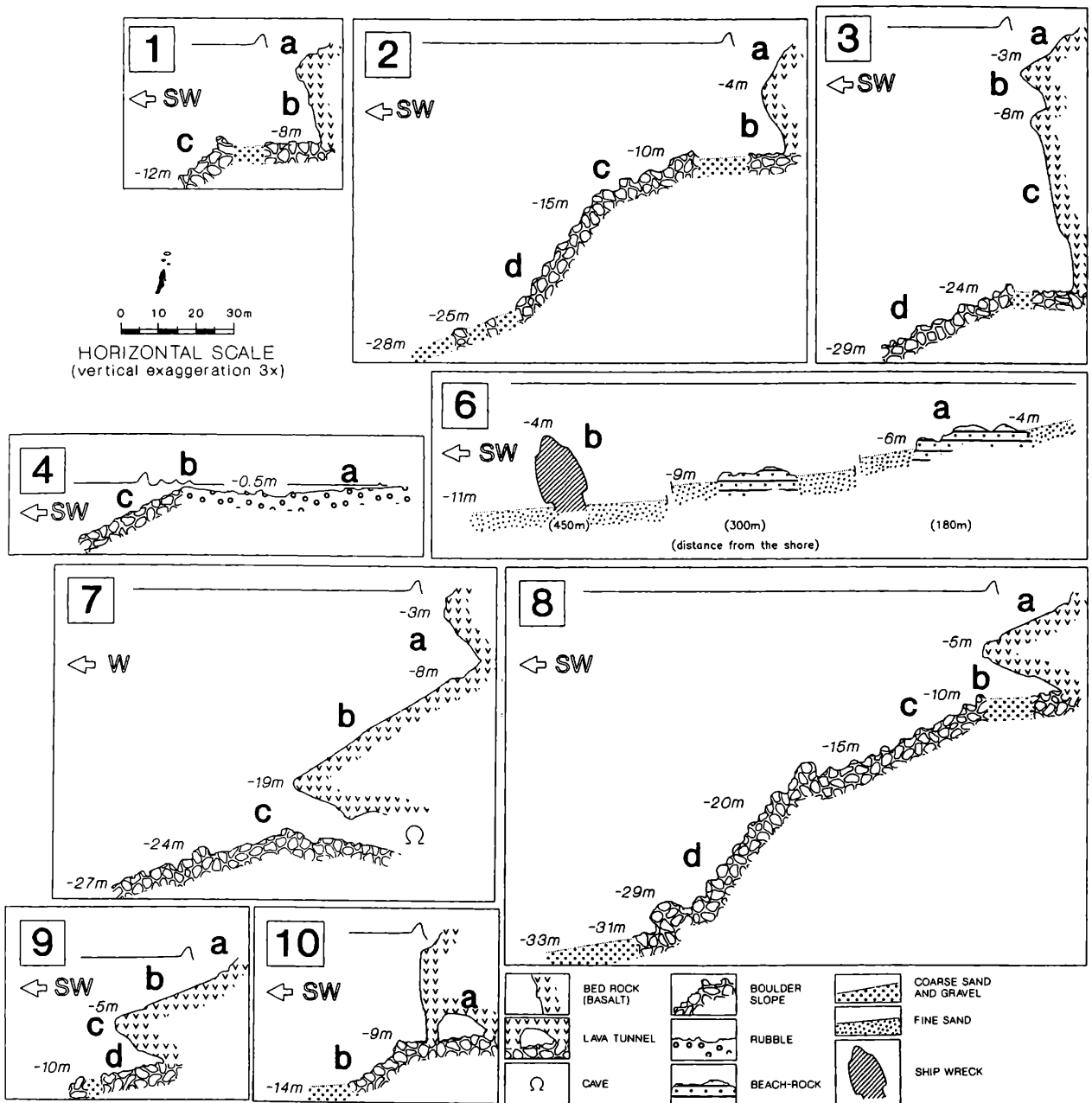
A total of 19 species was inventoried (Tab. 1). Due to the poor faunal knowledge of the zone, taxonomy was, to some extent, uncertain in a few cases. More detailed faunal and taxonomic notes will be given in a further paper.

Depth distribution of these species showed three major groups (Fig. 3): 1) surface species (*Actinia equina* and *Porites porites*), never found below 0.5 m depth; 2) shallow-water species (the remaining scleractinians, the hydrozoans, and *Palythoa caribaeorum*) preferring depths around 10 m but ranging from near the surface down to 20 m; 3) deep-water species (all the gorgonians and antipatharians), found between 20 and 33 m.

Relevés clustered in five major groups (Fig. 4). Group A was formed by relevé 9a alone, in which only *Actinia equina* was found.

Group B comprised 7 shallow-water relevés in exposed sites. All of them shared the presence of *Millepora* sp. (an encrusting and robust growth-form, yellow-greenish in colour, maybe an ecomorph of *M. alcicornis*), but *Halocordyle disticha* was equally abundant in some cases.

Group C contained 9 relevés, all in well-lit sites. They were largely dominated by zooxanthellate species, among which were all hermatypic corals. The most frequent species was *Porites astreoides*. *Siderastrea radians* was important in relevés in the vicinity of sand, whereas *Palythoa caribaeorum* was often dominant, forming carpets over rocks and large boulders, at around 5–10 m depth. *Porites porites* and *Balanophyllia “italica”* (sensu CHEVALIER, 1966; not *B. europaea*: ZIBROWIUS, in litteris) were found only once (relevés 4a and 7b, respectively).



**Figure 2:** Schematic profiles of depth-transects: note that vertical scale is exaggerated. Numbers in boxes are transect stations, bold lower-case letters are relevés. Transect 5 gave no conspicuous cnidarians and is not shown here.

Group D was formed by 9 relevés located under overhangs at the base of basaltic cliffs or in caves and lava tunnels. *Tubastraea aurea* was extremely abundant in all sites, covering large portions of rock, and sometimes accompanied by *Thyrosocyphus marginatus*. Finally, group E contained the remaining 3 relevés, the deepest ones. Cnidarians were represented by gorgonians (*Eunicella granulata*, *E. papillifera*, *Leptogorgia capverdensis*, *L. gaini*) and antipatharians (*Antipathes barbadensis*, *A. tanacetum*, *Stichopathes lutkeni*). On the whole, the most abundant species was *Leptogorgia capverdensis*. Correspondence analysis on semi-quantitative data (Tab. 2) produced three significant axes: taken together, they explained 67.5 % of the total variance, i.e., 27.1 %, 23.8 %,

and 16.6 %, respectively (Fig. 5). The first axis mainly discriminated between shallow-water relevés, dominated by zooxanthellate species, and deep ones, with only azooxanthellate species. The second axis separated overhangs and cave or tunnel vaults, with *T. aurea* and *T. marginatus*, from all the remaining relevés. The third axis mainly distinguished exposed relevés, with *Millepora* sp. and *H. disticha*, from the others, especially those at comparable depths but more sheltered and inhabited by hermatypic corals. Linear correlation analysis confirmed such a picture, the first axis being chiefly related to depth, the second to substrate inclination, and the third to the exposure index we adopted (Tab. 3).

**Hydrozoa**

Anthomedusae

- Hdi – *Halocordyle disticha* (GOLDFUSS)
- Mal – *Millepora alcicornis* L.
- Msp – *Millepora* sp.

Leptomedusae

- Tma – *Thyroscyphus marginatus* (ALLMAN)

**Octocorallia**

Gorgonacea

- Epa – *Eunicella papillifera* (MILNE-EDWARDS & HAIME)
- Egr – *Eunicella granulata* GRASSHOFF
- Lca – *Leptogorgia capverdensis* (GRASSHOFF)
- Lga – *Leptogorgia gaini* (STIASNY)

**Hexacorallia**

Antipatharia

- Slu – *Stichopathes lutkeni* BROOK
- Aba – *Antipathes barbadensis* (BROOK)
- Ata – *Antipathes tanacetum* POURTALÈS

Zoantharia

- Pca – *Palythoa caribaeorum* DUCHASSAING & MICHELOTTI

Actiniaria

- Aeq – *Actinia equina* (L.)

Scleractinia

- Sra – *Siderastrea radians* (PALLAS)
- Pas – *Porites astreoides* LAMARCK
- Ppo – *Porites porites* (PALLAS)
- Ffr – *Favia fragum* (ESPER)
- Bit – *Balanophyllia italica*, sensu CHEVALIER
- Tau – *Tubastraea aurea* (QUOY & GAIMARD)

**Table 1:** Systematic list of the species (coded as they appear in Fig. 5)

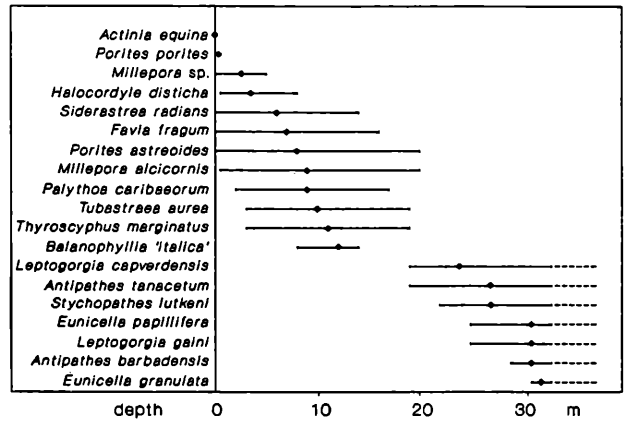
**4. Discussion and Conclusions**

The five groups of relevés identified through cluster analysis correspond well to as many different cnidarian zones (Tab. 4).

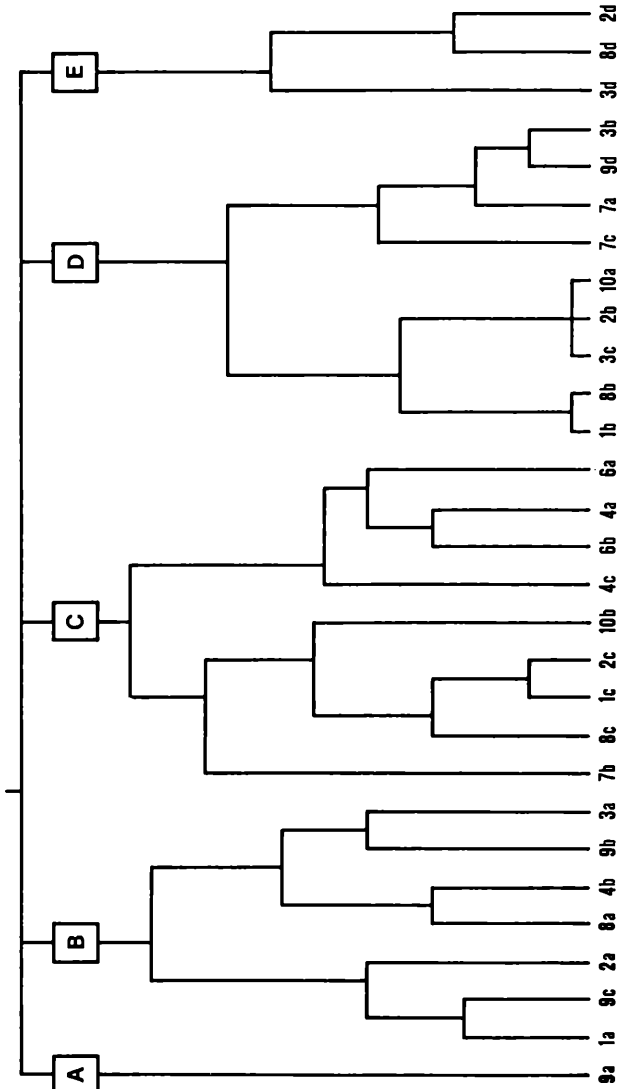
One zone (group A) might be the lower midlittoral, with *Actinia equina* as the main species, as typical on temperate Atlantic and Mediterranean coasts (PATRITI, 1970; SCHMIDT, 1972). However, this presumed zone was surely undersampled (one relevé only) and will not be discussed further here.

The following four, fully subtidal, zones are strongly consistent with those that can be encountered on a typical coral reef, especially in the Western Atlantic region (GOREAU & GOREAU, 1973; GEISTER, 1983).

On exposed infralittoral rocks, in shallow waters (group B), a *Millepora* zone could be defined: both the dominant species, *Millepora* sp. and *Halocordyle disticha*, can be considered photophilic and rheophilous (MERGNER, 1977; LEWIS, 1989).



**Figure 3:** Overall depth distribution of the species. Diamonds are the all-station means for each species.



**Figure 4:** Cluster analysis of relevés. VAN DER MAAREL's coefficient, complete linkage. Similarity range in the dendrogram: 0 to 1.

Depth-transects Relevés	1			2			3			4			6			7			8			9			10				
	a	b	c	a	b	c	d	a	b	c	d	a	b	c	a	b	c	a	b	c	a	b	c	d	a	b	c	d	a
Species																													
<i>H. disticha</i>	2	2	1	2				2												2								1	1
<i>M. alcicornis</i>			2		2							2		2	2		1			2									2
<i>Millepora</i> sp.	3			1				3						3	1	1			1	3							1	2	2
<i>T. marginatus</i>								2									2	3											2
<i>E. papillifera</i>																													1
<i>E. granulata</i>												2																	2
<i>L. capverdensis</i>								3			3							1											3
<i>L. gaini</i>								2																					1
<i>S. lutkeni</i>								2																					2
<i>A. barbadensis</i>								2																					2
<i>A. tanacetum</i>								2			2							2											2
<i>P. caribaeorum</i>			3			3		2									1	1	3								1	2	
<i>A. equina</i>																													2
<i>S. radians</i>												3	3	2	3														
<i>P. astreoides</i>			2			2						2	1	2	2	1		3									2		1
<i>P. porites</i>														2															
<i>F. fragum</i>			2			2						1	1	2		2													
<i>B. "italica"</i>																		2											
<i>T. aurea</i>		3	1		3					3	3							2	3	3								3	3

Table 2: Semi-quantitative estimates of cnidarian species importance (. = absent; 1 = < 1 % cover; 2 = 1–5 % cover; 3 = 5–20 % cover)

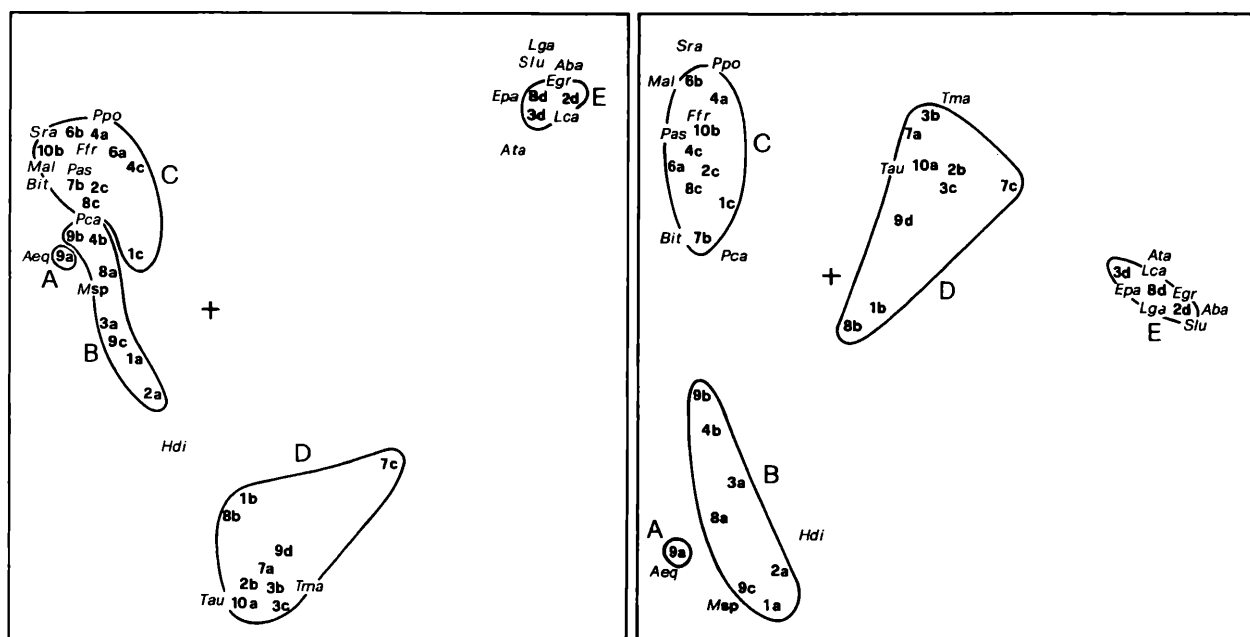


Figure 5: Correspondence analysis: combined plot of relevés and species (coded according to Tab. 1) on 1<sup>st</sup> and 2<sup>nd</sup> axis (left) and on 1<sup>st</sup> and 3<sup>rd</sup> axis (right). Relevé groups from cluster analysis are superimposed. Horizontal axis is 1<sup>st</sup> axis in both graphs. Explained variance: 1<sup>st</sup> axis = 27.1%; 2<sup>nd</sup> axis = 23.8%; 3<sup>rd</sup> axis = 16.6%.

Sheltered infralittoral rocks, down to about 15–20 m depth (group C), harboured a mixed coral assemblage, dominated by hermatypic species; the ecological distribution of these species is reminiscent of that described in Bermuda (LOGAN, 1988) and in the Caribbean-West Indian region (BUNT et al., 1981; LABOREL, 1982; KENNY,

1988; etc.). For example, *Porites astreoides*, *P. porites*, and *Siderastrea radians* are known to exhibit maximum growth rates within 15 m depth in Jamaica (HUSTON, 1985).

An ahermatypic coral (*Tubastraea aurea*) was the dominant species in the overhang zone (group D). Below

*Values of "r"*

	Depth	Substr. Incl.	Expos. Index
1 <sup>st</sup> axis	0.729 ***	0.379 *	-0.253 ns
2 <sup>nd</sup> axis	0.175 ns	-0.868 ***	-0.036 ns
3 <sup>rd</sup> axis	0.371 *	0.071 ns	-0.510 **

(\*\*\*:  $p < 0.001$ ; \*\*:  $p < 0.01$ ; \*:  $p < 0.05$ ; ns: not significant)

**Table 3:** Correlation coefficients (r) between axes from correspondence analysis and depth, substrate inclination, and exposure index.

20 m, a circalittoral gorgonian-antipatharian zone (group E) could be described. Both assemblages have their analogous counterparts in the west Atlantic reefs (e.g., GOLDBERG, 1973; SCATTERDAY, 1974).

Our *Millepora* and mixed corals assemblages can be ascribed to a typical "reefal biocoenosis", whereas overhang and gorgonian-antipatharian assemblages to a "subreefal biocoenosis", according to PICHON's (1978) terminology. It must be noted that most members of the aforementioned reefal biocoenosis, being zooxanthellate species, are autotrophic or at least polytrophic (SCHLICHTER, 1982), whereas members of the subreefal biocoenosis are strictly heterotrophic.

This implies that a major factor in differentiating the four subtidal cnidarian zones at Sal is light availability. The decrease of light is said to be the main factor affecting coral growth and community structure (HUSTON, 1985). Correspondence analysis, together with linear correlation, indicated that depth was likely to be the principal factor in influencing cnidarian zonation, being correlated especially to axis I. Substrate inclination was likely to be the second factor, in order of importance. Both depth and substrate inclination clearly affect the amount of light reaching the bottom on which colonies settle, and therefore the two parameters may in reality be the expression of the same ecological factor: light. This hypothesis may also be corroborated by the general parabolic shape of the point-cloud on the plane formed by the first two axes from correspondence analysis, since such a configuration is usually evident when a single polarising factor exists (GAUCH, 1984): light, once again, in our case.

The further important factor related to the coral zonation observed at Sal turned out to be wave-exposure, and hence water movement (GEISTER, 1977). RIEDL (1971) considered water movement as one of the major factors in selecting rocky subtidal benthos, and distinguished four depth-related water bodies: in these terms, our *Millepora* zone would mainly lie in the "lacerating" water body, the mixed coral zone in the "oscillating" water body, and the gorgonian-antipatharian zone in the "unidimensionally flowing" water body.

Thus, species substitution with depth was mainly determined by gradients in light intensity and water movement (Fig. 6), as in coral reefs of the Caribbean region (VAN DEN HOEK et al., 1978; GRAUS & MACINTYRE, 1989).

**Lower midlittoral zone**

Depth: 0 m  
Substrate inclination: 30°  
Exposure index: 45 %  
Important species: *A. equina*

***Millepora* zone**

Depth: 0–8 m; average: 2.5 m  
Substrate inclination: 0–90°; average: 55°  
Exposure index: 15–32 %; average: 21 %  
Important species: *Millepora* sp., *H. disticha*

**Mixed coral zone**

Depth: 0–20 m; average: 8 m  
Substrate inclination: 0–60°; average: 22°  
Exposure index: 9–21 %; average: 13 %  
Important species: *P. astreoides*, *M. alcicornis*,  
*S. radians*, *P. caribaeorum*

**Overhang zone**

Depth: 3–19 m; average: 10 m  
Substrate inclination: 100–150°; average: 124°  
Exposure index: 12–28 %; average: 16 %  
Important species: *T. aurea*, *T. marginatus*

**Gorgonian-antipatharian zone**

Depth: 19–33 m; average: 25 m  
Substrate inclination: 30–45°; average: 35°  
Exposure index: 10–11 %; average: 11 %  
Important species: *L. capverdensis*, *A. tanacetum*,  
*S. lutkeni*, *E. granulata*

**Table 4:** Cnidarian zones at Ilha do Sal: definition, and summary of main physical and biological features.

Biotic factors were not taken into account in this study. However, some speculations on their importance can be made discussing observational data.

The observed extreme abundance (up to 26 individuals per m<sup>2</sup>) of the fire-worm *Hermodice carunculata* PALLAS, which is known to feed on a wide variety of reef cnidarians (VREELAND & LASKER, 1989), might indicate a high degree of predation. Similarly abundant was the sea-urchin *Diadema antillarum* (PHILIPPI) and several coral-eating fishes, especially *Sparisoma cretense* (L.) and other Scaridae (but also Tetraodontidae, Monacanthidae, and Chaetodontidae). Thus, predation might act as a regulating factor at intermediate depth: for example, it might be responsible for the occurrence of huge colonies (2–3 m<sup>2</sup> in surface area, together covering up to 50 % of the substratum in some sites) of *Palythoa caribaeorum*, an impalatable species producing highly toxic biochemicals (MOORE & SCHEUER, 1971).

Competition between macroalgae and zooxanthellate cnidarians could play a role at shallow depths, where algal communities were flourishing (OTERO-SCHMITT, 1993). Similarly, the replacement of zooxanthellate species by azooxanthellate species at 15–20 m depth could be sharpened by competitive effects. However, total cover of the substratum was usually less than 100 %, and life



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