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Spatial Distribution and Abundance of Ascidians in a Bank of Coralline Algae at Porto Norte, Arvoredo Island, Santa Catarina

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ABSTRACT

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Banks of coralline algae usually support a diverse fauna of both encrusting and vagile invertebrates. Since algal rhodoliths are independent and may be dislodged, local disturbances may cause different habitat conditions. The objective of this study was to test for the existence of a gradient of species composition and abundance of ascidians between the edge and the center of a coralline algal bank located at the Arvoredo Marine Biological Reserve. This is the most southern coralline algal bank along the Brazilian coast. The gradient is because marginal rhodoliths are less dense and shallower and consequently, more subject to disturbance. A 145 m transect was established, that extended from the edge to the center of the bank, with 10 algae rhodoliths collected at each of 17 points along the transect. Density of rhodoliths was estimated at each point, and rhodolith volume and shape were measured in the laboratory. Abundance of ascidians was estimated as the frequency of species in eight, nearly equal, fragments of each rhodolith. Simple regression between morphological variables of the rhodoliths and distance to the edge of the bank did not support the hypothesis that a gradient existed. However, four ascidian species showed small tendencies to increase (*Didemnum* sp.3 and *Eudistoma* sp.) or decrease (*Didemnum* sp.1 and *Trididemnum orbiculatum*) from the edge to the center of the bank, supporting the hypothesis that a gradient indeed exists, in which other habitat conditions, not accessed in this research, are selected by ascidians.

ADDITIONAL INDEX WORDS: *Maerl, spatial gradient, tunicates.*

INTRODUCTION

Ascidians (Tunicata, Ascidiacea) are solitary or colonial organisms, essentially marine, filter-feeders and most of which needs a stable substrate on which to fix. While some ascidians appear to have little preference for organic or inorganic surfaces, others are selective, but it is unclear whether these preferences are determined by surface structure or chemistry (MILLAR, 1971).

In marine ecosystems space is one of the primary limiting factors for sessile organisms, and often, other organisms are used for substrate (JONES *et al.,* 1994). Calcareous algae are optimal substrates for colonial organisms because of the solid, three-dimensional structure as well as the shelter they offer (DOMMASNES, 1969; SUMIDA and PIRES-VANIN, 1997). By having large internal spaces, rhodoliths, a kind of calcareous algae that does not adhere to substrates, can shelter ascidians on both, external and internal surfaces. Rhodolith banks can form structurally complex environments providing substrate and refuges for many colonizing species. Refuges usually offer protection against predators as well as ameliorating physical stress due to the environment, such as water currents that can detach unprotected organisms. In areas subjected to tidal actions refuges can reduce wave impacts on the fauna (MCGUINNESS and UNDERWOOD, 1986; STOCKER and BERGQUIST, 1987). In structurally complex substrates, sediments may accumulate in the spaces within the substrate, thereby increasing structural heterogeneity, which thereby allows further increases in species diversity (MCQUAID and DOWER, 1990).

Coralline algae banks are particularly common in Brazil, and represent the largest carbonate deposits in the world (TESTA and BOSENCE, 1999). The algae bank of Porto Norte, Arvoredo Island, Santa Catarina, is one of the latest discovered banks in southern Brazil, emphasizing the importance of studies to understand the ecological dynamics of this ecosystem.

An environmental gradient may occur from the margins to the interior of a bank of coralline algae due to the differential influence of mechanical perturbations. In wave-dominated banks, rhodolith distribution appears to be controlled by water movements, such that rhodoliths in the shallower margins move more often due to wave actions than those in deeper waters (ca. 12 m) (MARRACK, 1999; STELLER and FOSTER, 1995). Additionally, rhodoliths shape seems to be a stabilizing factor since they often fit together, somewhat like a jigsaw puzzle, thereby consolidating the bank (STELLER and FOSTER, 1995).

The disturbance gradient should be reflected in the structural characteristics of the rhodoliths, depending upon where in the energy gradient they should be found. Marginal rhodoliths, therefore, should experience wear due to more frequent movements caused by wave actions, and thus be smaller than interior rhodoliths. Also, due to this movement, marginal rhodoliths should be more rounded as compared to interior rhodoliths. Since abundance of organisms is influenced by habitat characteristics (SCHAFF and LEVIN, 1994, WALTERS and WETHEY, 1996), a gradient of ascidian distribution, related to the gradient influencing the rhodoliths, is predicted.

Thus, the objectives of this study were to test for the gradient in rhodoliths from the center to the edges of the bank, and for a gradient in ascidian species and abundance associated with the rhodolith gradient, and finally, to attempt to related habitat characteristics to the distribution and abundance of ascidians.

MATERIAL AND METHODS

Study Location

This study was carried out at the Arvoredo Marine Biological Reserve, located on the coast (approximately 11 km from the coast) of the state of Santa Catarina, north of the city of Florianópolis, SC (27°11'S - 27°16'S e 48°19'W - 48°24'W). The reserve comprises four islands, *Calhau de São Pedro*, Arvoredo, Desert and Galé. This area has a great biological diversity due to the influence of the cold Malvinas current and for its location at the interface of tropical and subtropical climates.

On the northern end of the island is a small bay, known as Porto Norte (North Port), where a coralline algae bank is adjacent to the rocky shore. This bank comprises rhodoliths formed by approximately five species of algae: *Mesophyllum erubescens*, *Lithophyllum stictaeforme, L. margaritae, Titanoderma* sp. e *Neogoniolithon* sp.

The bank is found between 5-15 m deep on a uniformly sandy bottom. Rhodoliths tend to be less dense at the margins of the bank, while towards the interior of the bank the distribution is uniformly dense and continuous. A few patches of open sand occur within the bank and are probably caused by human actions, such as anchoring boats.

Sampling

Collections were carried out on 16 June 2000 and 17 March 2001. A lead cable marked at 1 m intervals was extended from the bank margin oriented N-S. Perpendicular to this cable another cable was extended for 2 m, at 5 m intervals up to 50 m in the first collection, and 0, 2, 5, 25, 45, 65, 85, 105, 125, 145 m in the second collection in order to include more area. Ten rhodoliths where collected along these 2 m cables, one every 20 cm. A total of 210 rhodoliths were collected (110 in 2000, 100 in 2001).

Rhodolith density was estimated at each sampling point using a square of 50 cm on the side, divided into 9 equal and smaller squares. The number within four of these squares, chosen randomly, was counted and then an average of those four was calculated, providing a density estimate.

Rhodoliths, upon collection, were placed in sea water with menthol crystals to anesthetize the animals. Later, entire rhodoliths were fixed in 4% formalin. Rhodoliths were measured, in the laboratory, in three orthogonal directions (diameters) each with the maximum diameter possible. Volume was measured by immersing the rhodolith in water (v2), and covering the rhodolith with plastic and immersing in water again (v1), to measure the water displaced. The difference between the two is the volume of the spaces inside the rhodolith. These measurements represent the area and structure of the rhodolith that organisms may use to establish themselves therein. Each rhodolith was broken into eight approximately equal pieces. In each piece the presence of ascidians was noted. The sum of ascidian presences in the eight pieces was used as an abundance estimate. In previous work, this frequency was correlated with true abundance, and for the simple reason that estimating abundance was much more easily carried out using this substitute for true abundance, considerably reducing sample processing time (METRI, 2002).

Zoanthidian (Cnidarian, Anthozoa) polyps (*Protopalithoa variabilis*) were also counted in each rhodolith. In field observations it was noted that these zoanthids are very abundant around the rhodoliths occasionally even covering them, thereby stabilizing them against perturbation. In other words, zoanthids served as indicators of rhodolith stability.

Table1. *Simple regression between rhodolith measurements and frequencies of the most abundant ascidians, and distance from the margin of the calcareous algae bank at Arvoredo Island, S.C., Brazil. NS = not significant, * = p < 0.05.*

Variable	r^2	P
X	0,01	NS
Y	0,00	NS
Z	0,01	NS
Rhodolith "shape"	0,03	NS
V1	0,00	NS
V2	0,00	NS
V1 V2	0,00	NS
Density	0,05	NS
Zoanthids	0,05	*
Didemnum sp.1	0,30	*
Didemnum sp. 2	0,00	NS
Didemnum sp. 3	0,04	*
Diplosoma listerianum	0,00	NS
Trididemnum orbiculatum	0,08	*
Eudistoma sp.	0,03	*

Data Analysis

First, simple linear regression was use to test for a relationship (gradient) between distance from the margin (independent variable) and rhodolith density, dimension, volume and shape (dependent variables). The shape of the rhodolith was calculated as:

$$shape = 2x/(y+z)$$

where "x" was the greatest diameter and "z" the smallest. Thus, a perfectly spherical rhodolith would have a *shape* = 1, and any more flattened or oblong rhodoliths would have *shape* > 1.

Simple linear regression was also used to test for a relationship (gradient) between ascidian abundance and distance from bank margin, using the method of estimating ascidian abundance as previously described.

RESULTS

No gradient in rhodolith shape and size was detected, as these varied randomly with respect to distance from the bank margin. (Table 1).

Rhodolith shape is important from the standpoint of the bank stability. If we consider rhodoliths spherical if *x* is less than 20% greater than the other two diameters, then only 17% of the rhodoliths can be considered spherical. The majority (175 of 210) showed a strong tendency to be much longer than thick (Figure 1).

The difference between volumes (v1-v2) provides an indication of the internal volume of the rhodolith and of the space available for colonization by other organisms. The average internal volume of rhodoliths was 50 ml, which was 82% that of the rhodolith volume (61 ml), and approximately half of the total external rhodolith volume (110.5 ml).

Rhodolith density showed no gradient with respect to distance from the margin of the calcareous algae bank. While the first two sampling points, at 0 and 2 m, had a lower rhodolith density, the rest of the bank was homogeneous, with a continuous cover of rhodoliths.

The zoanthids (Cnidaria, Anthozoa) were very abundant, showing a tendency to increase towards the interior of the bank. However, the variance in zoanthid abundance was large, from 0 to 30 polyps per rhodolith. Since polyps are large with respect to the other organisms inhabiting rhodoliths, they can be considered to occupy space that would otherwise have been available to those other organisms. Yet, the number of zoanthid polyps showed no relationship with the internal volume of the rhodoliths, thus they did not reduce the internal volume of the rhodoliths.

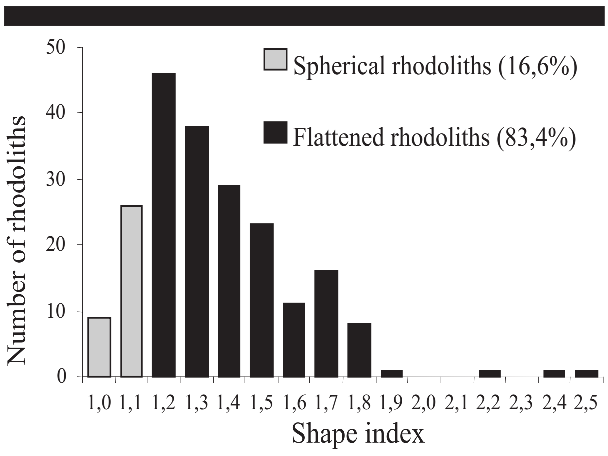

Figure 1. Number of rhodoliths with different shape indices.

Ten colonial ascidian *taxa* were found in the rhodoliths, usually as small colonies in the ascidian family Didemnidae: *Didemnum vanderhorsti, Didemnum* sp.1, *Didemnum* sp.2, *Didemnum* sp.3 *Trididemnum orbiculatum*, *Polysyncraton amethysteum*, *Diplosoma listerianum*; Clavelinidae: *Clavelina oblonga*, Polycitoridae: *Eudistoma* sp.; and Styelidae: *Botrylloides nigrum.*

Most of these species showed a random distribution with respect to distance from the calcareous algae bank (Tables 1, 2). *Didemnum* sp.1 and *Trididemnum orbiculatum* declined with distance from the margin, however ($p < 0.05$). While abundant up to 50m into the bank, they declined further into the bank, with *Didemnum* sp.1 disappearing altogether. On the other hand, *Eudistoma* sp. and *Didemnum* sp.3, increased towards the bank center. *Eudistoma* sp. was sporadic in occurrence in the first 50m, but found in all samples thereafter. The regression relationship was weak, however, probably due to the wide variation in the first 50 m, and little variation afterwards. *Didemnum* sp.3 occurred frequently in all points along the transect, but was more abundant towards the bank center. *Didemnum vanderhorsti*, while in low abundance, showed a tendency to be more often found after 35 m into the bank.

DISCUSSION

The initial hypothesis was of a gradient between the calcareous algae bank margin and interior that would be reflected in the rhodoliths and their inhabiting community. This hypothesis was based on the tendency of the bank margin to be more often physically perturbed than the interior, due to the attenuation of wave energy (Marrack, 1999). Thus, we expected the marginal rhodoliths to be smaller and rounder, due to erosion from wave action. On the other hand, in the bank center, for lack of movement, rhodoliths should be larger and more irregularly shaped. It therefore followed that ascidian species should show a response to these trends in the rhodoliths, since abundance of encrusting organisms is directly linked to habitat characteristics (Schaff and Levin, 1994; Walters and Wethey, 1996).

Our results, however, show that no strong gradient exists in this bank of calcareous algae, neither for rhodolith shape nor for the majority of inhabiting species, whose distributions were random with respect to distance from the bank margin. Possibly the great availability of space within these rhodoliths provides a refuge from mortality caused by perturbations due to wave actions, thereby offering habitat throughout the bank. These refuges are fundamental for the reduction of perturbation for the inhabiting organisms (Barry and Dayton, 1991; Townsend *et al.,* 1997). Calcareous algae are considered some of the most perturbation-resistant organisms, and therefore present high quality refuges in terms of resistance and stability (Padilla, 1984; Steneck and Dethier, 1994). The difference in rhodolith volumes (internal *versus* external) serves as an indicator of the quantity of refuge space offered (Masunari, 1983). Thus, the space available as a refuge in rhodoliths is the same as the rhodolith volume, since rhodolith internal volume was approximately half that of the entire rhodolith volume.

On the other hand, four ascidian species showed a gradient in abundance from margin to interior of the algal bank. Yet, their abundances were unrelated to rhodolith shape. Perhaps other factors, not measured in this study, such as current action, nearness to the coast, sand accumulation and light influence colonization patterns within the algae bank.

Perturbations can often be important causes of mortality for marine organisms (McGuiness, 1987). Storms are considered strong selective agents in marine environments, as well as a control of population sizes for many benthic, shallow-water, organisms, thereby influencing community structure (Posey *et al.,* 1996). Yet, the algal banks are found more often in more protected areas (Freiwald, 1998). The principal sources of perturbations in this study of calcareous algae ecosystem were ship anchoring and occasional storms that accompany cold fronts, but these perturbations did not appear to be important

Table 2. *Number of rhodoliths in which ascidians are present with respect to distance from the calcareous algae bank margin, at Arvoredo Island, SC (n=10). At distances of 0, 5, 25 and 45 m, at which 20 rhodoliths were collected, values were adjusted to represent a sample size of 10, that of the other sampling points.*

Distance (m) from margin	*Didemnum* sp.3	*Didemnum vanderhorsti*	*Didemnum* sp.1	*Didemnum* sp.2	*Trididemnum orbiculatum*	*Diplosoma listerianum*	*Polysyncraton* sp.	*Clavelina oblonga*	*Eudistoma* sp.	*Botrylloides nigrum*
0	7	1	8	6	4	6	4	3	1	2
2	9	0	8	10	10	8	0	3	0	8
5	7	1	9	9	5	7	0	2	7	3
10	5	0	10	7	1	9	0	0	0	0
15	6	0	9	9	4	9	0	1	0	0
20	6	0	9	8	4	8	1	1	0	2
25	8	0	8	9	4	8	0	1	7	2
30	7	0	9	6	1	8	2	0	0	0
35	10	3	10	8	8	7	0	0	0	0
40	10	3	10	8	4	9	0	1	0	1
45	10	3	9	10	7	9	0	1	4	1
50	7	0	5	10	10	10	0	0	0	0
65	10	2	6	10	1	8	0	0	7	2
85	10	3	1	10	1	9	0	0	6	0
105	9	6	0	6	2	9	0	0	7	2
125	8	4	0	5	2	9	0	0	5	1
145	8	1	0	10	1	5	0	0	3	1

influences of the ascidian community as shown by the analysis herein.

Rhodolith morphology and distribution depend upon a combination of factors, such as bioturbation and environmental energy (Marrack, 1999). Rhodolith morphology is often used by paleoecological studies to indicate the degree of water circulation (Steller and Foster, 1995; Freiwald, 1998; Marrack, 1999). The analysis herein shows that rhodolith shape can serve to suggest stability. Since most rhodoliths studied (83%) were far from spherical, it can be supposed that they had a preferential position in which they laid with little movement. Thus, this calcareous algae bank may be considered stable with respect to perturbations in this region, at least during the period of study.

Soft substrates may be barriers that impede the colonization of benthic organisms, especially ascidians, who may be covered by sediments or filled with silt, causing difficulties in filtration for feeding, or may find it difficult to settle as larvae (Monniot *et al.,* 1991). Solitary ascidians tend to me more common than colonial species where water turbidity is high (Gabriele *et al.,* 1999). It could be expected, therefore, that colonial ascidians should have problems with adhering to rhodoliths on sandy ocean floors. However, the stability of this bank, and the rhodoliths themselves, appeared to favor colonial over solitary ascidians.

Also, the size of a refuge may be important with respect to the size of the organisms using it (Walters and Wethey, 1996). In the rhodoliths under study, the crevices, holes and cracks may be small for solitary ascidians, but they provide ample space for colonial species, as only colonial species were found.

Thus, calcareous algal rhodoliths may be considered ecosystem engineers (Jones *et al*., 1994, 1997), as they create habitat for other organisms due to their architecture, with their cracks, crevices and holes that other species colonize so readily. These provide refuge not just for ascidians, but for many other smaller organisms, such as polychaetes, sipunculans, crabs and other invertebrates. The existence of an environmental gradient may further increase the variety of habitats made available. However, this calcareous algae rhodolith bank in Porto Norte, Arvoredo Island appears to be homogenous in nearly all aspects studied. The cause of the gradient for some few species remains to be discovered.

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