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A N I N T E R N A T I O N A L J O U R N A L

Effect of Microhabitat Distribution and Substrate Roughness on Barnacle *Tetraclita stalactifera* (Lamarck, 1818) Settlement

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ABSTRACT

Studies were carried out on microhabitat distribution and substrate roughness on barnacle settlement at Cabo Frio region, Rio de Janeiro, Brazil. Ten commercial blocks of granite rock (100 cm^2) were attached to rocky coast at 0.6 tide level (5 smooth blocks and 5 rough with 20 holes). Experiment was conduced for five weeks, with repetitions each week. Settlement was higher on rough (398 individuals) than on smooth blocks (38 individuals) on the same week. There was no significant difference between settlement in the centre of the block and at the edge. Significant differences observed among weeks were affected by the variability of cyprid larvae density. This result showed that roughness was an important variable to be considered on barnacle settlement.

Key words: Barnacle, Substrate roughness, Settlement, upwelling

INTRODUCTION

Settlement of marine invertebrates in natural and artificial substrate is in general, affected by roughness of substrate and hydrodynamics (Judge and Craig, 1997). Pits, depressions and crevices affect water movement over substrate (Abelson, 1997; Abelson and Denny, 1997) and consequently, arrival of larvae. These irregularities of substrate also change abiotic conditions close to them, increasing, for example, moisture and reducing direct sunlight during air exposure. At immersion times, it could increase or reduce water movement.

Studies under laboratory or field condition have evaluated the effects of different levels of substrate roughness (Bourget et al., 1994; Harvey et al., 1995; Harvey and Bourget, 1997) demonstrating its effect on arrival of larvae as well as on their behaviour. Many authors suggest that behaviour is responsible for small-scale patterns of distribution while oceanographic conditions are responsible for large-scale distribution pattern (Eckman, 1996; Underwood and Chapman, 1996; Judge et al., 1998).

The aim of this work was to estimate *Tetraclita stalactifera* settlement rate related to substrate roughness (presence or absence of crevices) and position of these crevices (centre or edge). The hypothesis tested was that barnacle settlement is different among blocks. If the first hypothesis was true a second hypothesis was tested and there was no difference on barnacle settlement in the edge or centre of block (no edge effect). This study is part

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of a wide program of barnacle population dynamic study at Cabo Frio region, Brazil and was important to show differences on settlement due to substrata roughness, mainly on tropical region.

MATERIALS AND METHODS

Study site

This study was conducted at Ponta da Cabeça (22^0 59' S, 42^0 30' W) in Arraial do Cabo, Brazil. This region was chosen due to the occurrence of an upwelling event caused by prevailing northeast wind, topographical and geographical characteristics of seafloor and coastline (Valentin, 1984; 1988). Wind condition and/or site location may influence distribution of tropical and temperate species (Valentin, 1984; Valentin and Monteiro-Ribas, 1993; Valentin and Coutinho, 1990; Guimaraens and Coutinho, 2000). Tidal regime is semidiurnal with a 1.4 m range and slope of the rocky coast at the study site varies from 45^0 to 90^0.

Experimental design

Ten blocks (100 cm^2 area) of commercial granite rock were used. Five blocks were smooth and five contained twenty holes (5 mm ∅, 3 mm deep, 15 mm distance each other – thereafter refereed as rough blocks). Blocks were attached to rock with an epoxy adhesive (Tubolite ®) at the *Tetraclita* zone (0.6 m). The position of each block was randomly sorted out in a 20 m transect. Settled barnacles were counted and, in rough blocks, their position was assigned to compare it for the same treatment (inside or outside hole; edge or centre of block). Counts were done up to one week and then, blocks were strongly brushed to remove all settled barnacles and other species. The total experiment duration was 5 weeks (from April to May 2000).

Data analysis

Student t tests were used to compare in each week, total settled barnacles on smooth and rough blocks. A one-way ANOVA was also performed to test differences for barnacle position (edge or centre) at rough blocks (one factor – position, Type I) (Zar, 1984). ANOVA test was used to increase the power of analysis since the number of holes on edge and centre of blocks are different and all holes of all blocks were used and not only mean values.

RESULTS

Mean sea surface temperature in five weeks of experiment was 21.8 $^oC \pm 2.4$ and observations were conduced both during upwelling and non-upwelling conditions. The mean water temperatures for each week was 19.3 $^0C \pm 2.9$; 23.3 $^0C \pm 2.8$; 18.2 $^0C \pm 2.8$; 22.8 $^0C \pm 2.8$ and 21.6 $^0C \pm 2.4$ respectively. A surface temperatures value below 20 ^0C indicate subsidence events (Valentin, 1984). These differences in water temperature could also indicate differences on larval availability, lower during upwelling times (Skinner and Coutinho, 2002).

Barnacle settlement was always higher on rough blocks. Lowest mean number of settled barnacles on rough blocks was 2.2 and the highest was 320.0 individuals (max. 398 ind.). For smooth blocks, this number was 0.0 and 12.0 (max. 38) individuals respectively (Table 1). The results showed that settlement on rough blocks could be up to 74 times higher than on smooth ones. Significant differences were observed for settlement on smooth and rough blocks using t test for the same week as show on Table 1.

ANOVA test applied for barnacle settlement on edge or centre of rough blocks showed no significant difference for position of settled barnacles (Table 2).

Table 1 - Mean number of settled barnacles (ind. $0.1m^{-2}$), standard deviation and t test results for smooth and rough blocks during 5 weeks of experiment.

Week	Smooth	Rough	t test	p
1^{st}	0.0	12.6 ± 6.3	NP	
2^{nd}	4.6 ± 1.8	58.8± 41.7	2.9	**0.05***
3^{rd}	0.0	2.2 ± 1.6	NP	
4^{th}	12.2 ± 15.3	320.0 ± 71.9	8.4	**0.01***
5^{th}	0.0	74.6 ± 42.3	NP	

NP, Not performed because barnacle number in smooth blocks was zero. * Significant differences.

Table 2 - Results of ANOVA test for position (source= edge or centre) of settled barnacles on rough blocks in each week of experiment.

Source /week	Df error	MS Effect	MS Error	F	P
1st	95	2.1	0.8	2.8	**0.10**
2nd	95	0.6	7.6	0.01	**0.93**
3rd	97	0.3	0.1	2.2	**0.14**
4th	78	4.5	83.8	0.1	**0.82**
5th	94	2.0	12.1	0.2	**0.69**

DISCUSSION

Results showed that settlement of barnacle larvae was influenced by substrate heterogeneity. Increasing substrate heterogeneity increased settlement. This fact was related to holes on substrate, which might have changed water flow and also physical characteristics of substrate, like moisture retention, creating microhabitats and then, favouring settlement of cyprids. Also, larval retention could have increased by flow over substrata and inside the crevices (Abelson, 1997; Abelson and Denny, 1997).

In barnacle and/ or communities studies, the use of smooth or low roughness substrate like plain PVC, fibreglass, glass or wood is usual (Silva et al., 1980; 1989; O'Connor and Richardson, 1994), contrasting with studies in natural rocky substrate (Dineen Jr and Hines, 1994; Underwood and Chapman, 1996, Menge, 2000). Our results showed that this increase in settled number could be up to 74 times in roughed blocks, hence, the use of smooth or low roughness substrate could under estimate the number of settlers (Chabot and Bourget, 1988; Bourget et al., 1994; Lemire and Bourget, 1996; Wahl and Hoppe, 2002) compared to natural substrate studies.

Larval swimming capacity and/or behaviour may have influenced settlement at rough blocks. Over smooth substrate, water flows with high velocity, shows no turbulence and it may prevent settlement of cyprids (Judge and Craig, 1997). While studying larval behaviour, Harvey and Bourget (1997), using arborescent structures, showed that the water flow drove larvae to specific points of substrate called "hot spots". After substrate encounter, larval behaviour is important to settlement. Many other studies have showed the importance of larval behaviour (Pineda, 1994; Jeffery, 2000; Navarrete and Wieters, 2000) on larval settlement choice and on population and community dynamics. Sometimes, substrate heterogeneity could reduce settlement through behaviourally rejection of sites by barnacle settlers as registered for *B.improvisus* (Berntsson et al., 2000), but this was not the case in present work.

Barnacles attachment also increases heterogeneity. Some researchers that investigate natural heterogeneity generated by barnacles (Jarret and Pechenik, 1997; Jeffery, 2000) showed that clumps of barnacles increase larval settlement close to adults. Nevertheless, in these works, it is difficult to separate effects of substrate heterogeneity from chemical cues generated by barnacle adults or shells of dead barnacle. In this experiment, all substrate were immersed free of cues and weekly, all settled barnacles were removed, reducing these cues. Substrate heterogeneity was the main tested characteristic in this case. Although bacteria, protozoan, algae and organic molecules over substrate could act as signals and influence barnacle settlement (Dineen Jr and Hines, 1994; O'Connor and Richardson, 1998; Menge, 2000), in this experiment, blocks were exposed to the same field conditions and we do not expect to have difference caused by these factors.

Position of crevices on edge or centre has no influence on number of settled barnacles. In many studies (Keough, 1984; Tanaka and Magalhães, 2002), edge effect has been described to affect settlement or succession due to the size of available area or increasing heterogeneity. In our experiment, size of blocks and its attachment closely to natural and heterogeneous substrata did not produce edge effect on barnacle settlement. Hence, water flow, larval flux and site selection acted at the same scale on rough blocks. This revealed that a $100cm^2$ area could be used to estimate larval settlement in that region.

Differences observed on number of settlers for all 5 weeks of experiment could be related to upwelling or subsidence conditions that could influence larval availability and also, barnacle settlement rate, increasing or decreasing it (Skinner and Coutinho 2002). The results showed that substrate heterogeneity could increase larval settlement and this would be important too estimating changes on population or community dynamics on natural or artificial substrate.

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RESUMO

A rugosidade dos substratos afeta o assentamento de larvas de invertebrados marinhos, tanto em substratos naturais quanto em substratos artificiais. Elevadas taxas de assentamento são esperadas em substratos com maior rugosidade/ heterogeneidade devido aos microhabitats formados e também à alteração do movimento da água sobre o substrato. Neste estudo foi avaliado o assentamento de cracas em substratos lisos e rugosos, dispostos na região de Cabo Frio, RJ, Brasil (22^0 59' S, 42^0 02' W). Dez blocos de granito comercial (100 cm^2) foram fixados ao costão rochoso no nível de maré 0,6. Cinco blocos eram lisos (controle) e cinco blocos apresentavam 20 pequenas cavidades (5 mm ϕ, 3mm profundidade) regularmente distribuídas no bloco. O experimento foi conduzido por 7 dias e repetido em 5 semanas. Como resultado observamos o maior assentamento nos blocos rugosos (Max. 398 indivíduos) do que nos blocos lisos (Max. 38 ind.). Não foi observada diferença significativa entre o número de assentados no centro do bloco em relação à sua margem, indicando que não houve o efeito de borda. Foram observadas diferenças significativas no assentamento entre as 5 semanas do experimento, afetada pela maior presença de larvas cípris durante algumas semanas. Este experimento mostra como a variabilidade estrutural pode influenciar o assentamento de larvas de Cirripedia.

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