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**ESTRUTURA DE COMUNIDADE E DISTRIBUIÇÃO  
VERTICAL DE PEIXES CRIPTOBÊNTICOS EM ILHAS  
COSTEIRAS DE SANTA CATARINA, SUL DO BRASIL**

**Florianópolis/SC  
2010**



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Dissertação apresentada ao Programa de Pós-Graduação em Ecologia da Universidade Federal de Santa Catarina, para a obtenção do título de Mestre em Ecologia.

**Área de concentração:** Ecologia, Bases Ecológicas para o Manejo e Conservação de Ecossistemas Costeiros.

**Orientador:** Prof. Dr. Sergio R. Floeter

**Florianópolis/SC  
2010**



“Estrutura de comunidade e distribuição vertical de  
peixes criptobênticos no Sul do Brasil”

Por

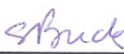
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## RESUMO

Peixes criptobênticos são espécies pequenas (<15cm) comuns em habitats marinho rasos. Possuem habito ou coloração críptica e passam a maior parte do tempo apoiados sobre o fundo. Devido a essas características os integrantes desse grupo são subestimados em trabalhos realizados com Censo Visual, metodologia comumente utilizada para a comunidade de peixes em geral. Por esse motivo a utilização de métodos que incluem a coleta dos indivíduos (ictiocidas ou anestésicos) é recomendada e freqüentemente utilizada. No entanto, além de exigirem autorizações governamentais, métodos que incluem coleta normalmente consomem mais tempo para amostrar uma mesma área quando comparados a métodos visuais. Em meio a essas metodologias existe também o censo visual com interferência, onde não somente se conta os indivíduos expostos, mas também se faz uma busca ativa em meio aos elementos do habitat (tocas, algas, cascalho). Durante o presente trabalho foram investigadas as diferenças entre estrutura de comunidade de peixes criptobentônicos entre profundidades em quatro localidades no litoral de Santa Catarina (Farol, Capim, Costão da Barra e Xavier). Também foram inferidos, através de correlações entre densidades, alguns mecanismos possivelmente responsáveis por essas diferenças (competição, predação e facilitação). A correlação entre a densidade de peixes criptobentônicos e a complexidade do habitat foi feita através da contagem do número de tocas. Como resultado obteve-se que a riqueza de espécies foi usualmente maior nas áreas rasas (3m) enquanto a equitabilidade mostrou-se maior em áreas mais profundas (10 e 15m). Em todos os locais a densidade total foi maior a 3m do que a 10m. Comparando entre locais, a densidade total foi a mesma na profundidade de 10m, no entanto variou a 3m. Considerando-se as espécies amostradas foi possível perceber padrões de preferência por distintas zonas de profundidade. A freqüência de ocorrência das espécies variou entre locais e profundidades. A correlação entre densidade de peixes criptobentônicos e a complexidade de habitat foi usualmente positiva. Não houve um padrão quanto a correlação entre densidade de peixes criptobentônicos e a densidade de predadores (garoupas e badejos) ou facilitadores (ouriços). No entanto a correlação entre a densidade de possíveis competidores (peixes territoriais: *Stegastes* spp), apesar de variar de acordo com a profundidade, manteve um mesmo padrão em duas localidades. A variabilidade encontrada entre as correlações é provavelmente reflexo de respostas de cada espécie sobre diferentes pressões. Experimentos manipulativos são necessários para uma melhor compreensão dos mecanismos envolvidos.

**Palavras-chave:** Peixes recifais; Atlântico Sul; Predação; Competição; Engenheiros ecossistêmicos.



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## INTRODUÇÃO GERAL

Peixes criptobênticos normalmente são espécies pequenas, de hábitos bentônicos, com coloração ou comportamento críptico (La Mesa *et al.*, 2006). Pertencem a diversas famílias agrupadas devido a semelhanças morfológicas ou comportamentais (*e.g.* Gobiidae e subordem Blennioidei: Bleniidae, Labrisomidae, Chaenopsidae). Formam uma comunidade diversificada e abundante em habitats marinhos rasos tropicais e subtropicais (Macpherson, 1994; Patzner, 1999; La Mesa *et al.*, 2004). De fato, sua densidade pode ser quatro vezes maior que a de peixes conspícuos (Allen *et al.*, 1992). No entanto, por serem pequenos e crípticos a metodologia comumente utilizada para estudar peixes recifais (Censo Visual) pode subestimar o número e a densidade das espécies crípticas em mais de 91% (Willis, 2001).

Tendo em vista essa problemática Beldade & Gonçalves (2007) adaptaram desenvolveram um método – Censo Visual com Interferência (I. V. C), onde o habitat é remexido em busca de espécimes – e compararam com o Censo Visual tradicional e com censos realizados com ajuda de anestésicos (óleo de cravo). O método desenvolvido mostrou-se mais eficaz que o censo visual comum, resultando em uma maior riqueza e densidade de espécies, com valores similares àqueles obtidos com o uso de anestésicos.

A importância de estudar a ecologia deste grupo relaciona-se ao seu papel trófico em ambientes costeiros. A história de vida destes peixes, caracterizada por altas taxas de mortalidades, vida curta, crescimento rápido e taxas reprodutivas elevadas (Kritzer, 2002; Depczynski & Bellwood, 2005, 2006), em conjunto com seu metabolismo elevado (Ackerman & Bellwood, 2000) colaboram para que sua atuação na cadeia trófica seja alta. Em alguns casos, com mais de 25% do fluxo de energia da ictiofauna recifal passando pelas espécies de peixes criptobênticos (Ackerman *et al.*, 2004). Além disso, devido aos diversos papéis e ligações tróficas a que estão relacionados, e às altas densidades em que são encontrados, os peixes criptobênticos situam-se no topo da cadeia de detritos e na base da cadeia predatória, sendo um importante elo entre as duas (Depczynski *et al.*, 2007). Portanto, conhecer a distribuição espacial deste grupo, assim como buscar entender os mecanismos responsáveis é um importante tema da ecologia de comunidades.

Uma visão inicial dos tipos de processos ecológicos que regulam as comunidades pode ser obtida através da investigação da distribuição espacial das espécies (Syms, 1995) em relação à influência da

complexidade de habitat e do efeito da presença de predadores, competidores ou “engenheiros ecológicos” (organismos que alteram a complexidade do habitat) (Jones *et al.*, 1994).

Para peixes recifais, a riqueza de espécies e a abundância dos indivíduos foram diversas vezes relacionadas a complexidade do habitat (Luckhurst & Luckhurst, 1978; Roberts & Ormond, 1987; Gratwicke & Speight, 2005; Orlando-Bonaca & Lipej, 2007). Substratos rugosos com presença de esconderijos (tocas) são especialmente importantes para pequenos peixes, pois além de oferecerem proteção contra predadores (Roberts & Ormond, 1987; Steele, 1999), proporcionam maiores possibilidades de locais para desova (Gratwicke & Speight, 2005). No Mediterrâneo, La Mesa *et al.* (2004) encontraram que as variações nos parâmetros da estrutura da assembléia (riqueza, diversidade e equitabilidade) eram principalmente afetadas por variáveis de microhabitat (Rangel, 2007), especialmente composição do substrato e tipo de cobertura bentônica.

Devido ao seu pequeno tamanho, para peixes criptobênticos o risco de ser predado por piscívoros maiores afeta tanto juvenis quanto adultos (Miller, 1979). Portanto, a presença de predadores (*e.g.* *Mycteroperca* spp) pode influenciar na distribuição e densidade de peixes pequenos (Macpherson, 1994; Almany, 2004). Através de um experimento com o uso de gaiolas para excluir predadores, Steele (1999) mostrou evidências diretas do forte efeito que os predadores têm na sobrevivência de duas espécies de peixes criptobênticos (*Coryphopterus nicholsii* e *Lythrypnus dalli*).

Devido a interações negativas resultantes da defesa do território, a presença de peixes territoriais (*e.g.* *Stegastes* spp) pode influenciar na distribuição das espécies criptobênticas (Almany, 2003), podendo este efeito ser mais forte sobre o recrutamento do que a própria complexidade do habitat (Almany, 2004). Outro tipo de interação biótica que pode influenciar a distribuição das espécies é a presença de ouriços, pois estes organismos podem atuar como “engenheiros ecossistêmicos”, aumentando a complexidade do habitat. Diversos estudos já relataram o uso de ouriços como refúgio para peixes criptobênticos (Patzner & Santos 1992; Hartney & Grorud 2002; Santos 2005).

O presente estudo investigou a estrutura de comunidade e os possíveis processos reguladores da densidade e distribuição espacial de peixes criptobênticos em diferentes profundidades de três ilhas costeiras do litoral de Santa Catarina. Este foi o primeiro trabalho relacionado com peixes criptobênticos da região Sul do Brasil.

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**Capítulo 1:**  
**Cryptobenthic fishes in South Brazil: community structure and  
depth distribution**

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# **Cryptobenthic fishes in South Brazil: community structure and depth distribution**

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## **ABSTRACT**

The differences among community structure of cryptobenthic fishes were accessed on different depths at four localities on the southwestern Atlantic Ocean. The cryptobenthic fish community was sampled through Interference Visual Census and then correlated with density of territorial damselfishes (*Stegastes* spp), predatory fishes (*Mycteroperca* spp) and sea urchins (*Echinometra* lucunter). Number and size of holes (refuges) were counted to quantify habitat complexity. Species richness and diversity were usually higher in the shallower zone (3m), while evenness reached its higher value at 10m depth zone. Total density of cryptobenthic fish community was always higher at the 3m depth zone. Among sites, density was similar at the 10m zone, however at 3m zone it varied greatly. Among species, it was possible to identify different depth preference patterns. The species frequency of occurrence varied between sites and depths. The correlation between habitat complexity and species density was usually positive. Correlation between cryptobenthic species and predatory fishes or sea urchins varied among sites. Density correlations between cryptobenthic and territorial fishes were suggestive. The general variability found on the community parameters is related to specific species responses. Manipulative experiments are necessary for further understanding of the mechanisms involved.

**Keywords:** reef fish, south Atlantic, predation, competition, ecosystem engineer

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## INTRODUCTION

Cryptobenthic fish assemblage includes small species, usually smaller than 10cm, which live in close association with the substratum and are visually or behaviorally cryptic (*e.g.* Blenniidae, Labrisomidae, Gobiidae) (La Mesa *et al.*, 2004). The group is usually very abundant in marine shallow water ecosystems, especially in tropical and subtropical regions (Macpherson, 1994; Patzner, 1999; La Mesa *et al.*, 2004; Wilson, 2009). They are so abundant, that despite their small size, they may reach ca. 35% of the overall reef fish biomass on coral reefs, playing a significant trophodynamic role (Ackerman & Bellwood, 2000; Ackerman *et al.*, 2004). Furthermore, some species feed on algae and detritus, providing a vital link between primary consumers and higher trophic levels taxa (Depczynski *et al.*, 2007).

Like other marine reef fishes, the abundance of local populations and the structure of local assemblages can show remarkable spatial variation, with species that are common on a site, being rare at other. However, what makes some species rare and others common? Why does a species occur at low population densities in some places and at high densities in others? Which mechanisms drive fluctuation in abundance of species? For reef fishes, some answers rely on biotic interactions, habitat structure and depth, which are known to play a major role in determining species distribution and abundance in marine habitats.

In terms of biotic interactions, predation may be one of the major processes that influence the size of populations (Paine, 1966; Sih *et al.*, 1985; Hixon, 1991; Steele, 1996) and has long been thought to influence the structure of reef fish populations (Talbot *et al.*, 1978). Many studies reported the predator effect over reef fish, especially over young individuals (Caley, 1993; Carr & Hixon, 1995; Johnson & Hixon, 2010). For cryptobenthic fishes, however, due to their small size, the risk of predation by larger fishes probably remains important throughout all their life history (Willis & Anderson, 2003). Interspecific competition is another biotic interaction that may exert influence on population dynamics and community structure by affecting habitat selection in fishes (Munday *et al.* 2001). Territorial damselfishes (*e.g.* *Stegastes* spp) are known to be very aggressive towards conspecifics or heterospecifics individuals that enter their territories, which may cause a modification on the distribution patterns of other species (Arnal & Coté, 1998; Jones, 2005).

The habitat structure has also a fundamental importance on

species distribution. The relationships between fish assemblage parameters and habitat complexity has been the focus of attention in many studies, which in many cases demonstrated positive correlations between complexity and species richness, diversity and total abundance of fish assemblage (Luckhurst & Luckhurst 1978; Gratwicke & Speight 2005). Among the many ways to measure habitat complexity; the number and diameter of possible refuge (holes) seems to be the better for rocky shores environments (Ferreira *et. al.*, 2001; Silveira, 2010). Due to the relative small home range (0.25 - 2m<sup>2</sup>) and benthic behavior, cryptobenthic fish assemblages are expected to show even stronger relationships with habitat characteristics (Depczynsky & Bellwood, 2004).

Depth is another factor that deserves attention on the cryptobenthic species distribution. Many studies already recognized the preference of some species for specific depth ranges (*e.g.* Macpherson, 1994; Patzner, 1999; Orlando-Bonaca & Lovrenc Lipej, 2007). This could occur due to a variety of reasons. Among them are the availability of resources (*e.g.* food, nesting sites) and interspecific competition, resulting in depth segregation, which reduces the spatial overlap between species with similar ecological demands (Illich & Kotrschal, 1990; Macpherson, 1994; Syms, 1995).

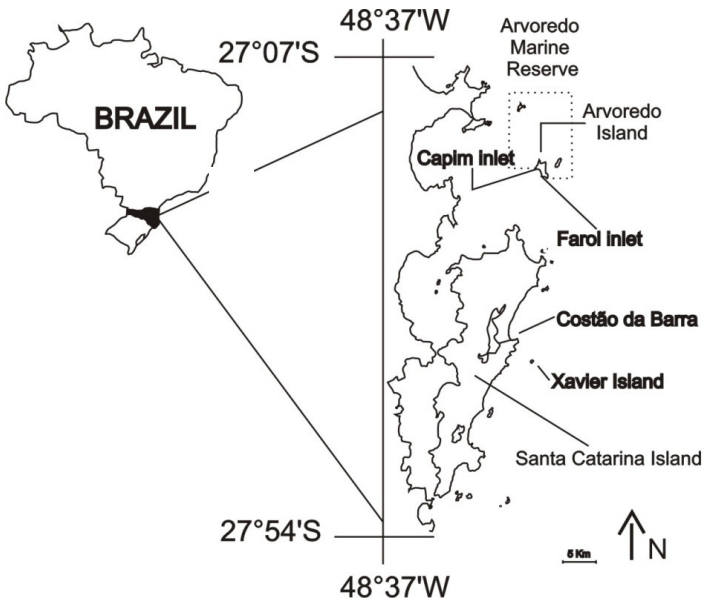
In the interface between biotic interactions and habitat structure are the ecosystem engineers (*i.e.* organisms that cause physical modification, maintenance, or creation of habitats; Jones *et al.*, 1997). Sea urchins may act as biogenic sources of habitat structure to reef fishes, providing a unique but spatially variable habitat for smaller fishes (Sakashita, 1992; Hartney & Grorud, 2002). However, compared to negative forces such as competition and predation, little emphasis has been placed on evaluating the conditions under which positive interactions are relevant.

So far, there have been only few studies on distribution patterns of cryptobenthic species in Brazil, and none in the Southern coast. The aim of the present investigation is to identify the distribution patterns of cryptobenthic fish species in relation to other fish species (predatory and territorial fishes), ecological engineers (sea urchins), depth distribution and habitat complexity on the rocky littoral zone of Santa Catarina Island and adjacent islands, Brazil.

## MATERIALS AND METHODS

### STUDY AREA

The coast of Santa Catarina state, Brazil, is characterized by narrow beaches of sand or gravel surrounded by a granitic rocky shore with intrusive diabase rocks. This study was carried out at four sites of Santa Catarina state, Brazil: Farol and Capim inlets (both at Arvoredo Island); Costão da Barra on Santa Catarina Island, and Xavier Island (Fig. 1).



**Figure 1.** Study area map 1.

The Farol inlet ( $27^{\circ}17'S$ ;  $48^{\circ}21'W$ ) subtidal environment is the most complex of the four studied sites. It is constituted by granitic rocks of various sizes, boulders up to 3 meters high, and patches of sand. Its rocky shore is also the largest one. It reaches out 200m from the coast, encountering sand at 18m depth. Since the inlet faces south, during winter storms the hydrodynamic at Farol is high. However, during northeast winds the inlet is relatively calm.

The Capim inlet ( $27^{\circ}16'S$ ;  $48^{\circ}22'W$ ) is more sheltered than Farol in relation with south storms, and is protected from northeast winds. The

subtidal environment, however, is slightly different from Farol's. Its rocks are usually smaller and most of them present the same size, forming a more homogeneous habitat. The rocky belt reaches approximately 70m out of the coast, where it begins the sand environment at 12m depth.

Both these sites are situated on Arvoredo Island, located approximately 14km from the North of Santa Catarina Island. The east face of the Arvoredo Island is part of the Arvoredo Marine Reserve (Fig.1).

Xavier Island (27°36'S; 48°23'W), distant 6km from the east coast of Santa Catarina Island, more specifically from Costão da Barra (one of the studied inlets). The site where the samplings were taken is located on the east side of the island, which is protected from east winds and waves, and from weak southeast waves/wind. The subtidal environment resemble Capim inlet, with intermediate sizes of rock (aprox. 1m high) forming a homogeneous habitat. The rocky shore extends for approximately 100m from coast and encounters sand at 12m depth. Spear-fishermen frequently visit the island.

The fourth site is Costão da Barra inlet (27°34'S; 48°25'W), situated on Santa Catarina Island is a more costal environment, with high influence of Conceição lagoon waters. The water visibility is usually lower on this site than on the others. The rocky shore reaches approximately 20m offshore, and it encounters sand on 6m depth. The inlet is protected from South storms and exposed to North quadrant winds. This site is located near a very touristic fishermen community.

The seasons in the area are well defined, with summer and winter very distinct and autumn and spring with similar characteristics (Koettker & Freire, 2006). In the coolest months, the mean surface air temperature varies between 15°C e 18°C, and in the warmest months, between 24°C e 26°C (Leal, 1998). The predominant wind comes from northeast (mean of 4.4kn), and the less frequent but stronger wind comes from the south (mean of 8.3kn) (Reuss-Strenzel *et al.*, 1997).

It has been already recognized the presence of three distinct water masses in the area. In the summer, the Tropical Water: nutrient poor, hot and salty ( $T^{\circ}\text{C} > 20^{\circ}\text{C}$ ; salinity  $> 36$ ), predominant in the superficial layer (Silveira *et al.*, 2001). During spring and summer, due to the Northeast winds, occurs the upwelling of the Atlantic South Central Water: nutrient rich, with low to moderate temperatures ( $7^{\circ}\text{C}$ – $19^{\circ}\text{C}$ ) and intermediate salinity (34.6–36) (Silveira *et al.*, 2001). In autumn and winter occurs the advection of Subantarctic Water (Carvalho *et al.*, 1998), that cools the water ( $14^{\circ}\text{C}$ – $17^{\circ}\text{C}$ ) and diminishes the salinity

(29.55) (Koettker & Freire, 2006; Bouzon & Freire, 2007).

## SAMPLING DESIGN AND PROCEDURE

The samplings were taken during daylight from May to October 2009. Fish community structure were sampled with 10x2 m (20m<sup>2</sup>) line transects over distinct depth strata (3m; 10m and 15m). Due to the inclination of the rocky shore and the depth limit of rocky environment, Farol inlet was the only site that presented the three different depths. Xavier and Capim presented two depth strata (3 and 10m), while Costão da Barra presented only one (3m). The number of samplings are represented on table 1

**Table 1.** Number of samplings on each depth and site.

Sites	Depth (m)		
	3	10	15
Farol	42	17	16
Capim	27	8	
Xavier	24	23	
Costão	5		

During samplings, the diver first counted cryptobenthic, potentially predatory fish (*Mycteroperca* spp) and territorial damselfish species (*Stegastes* spp). When this first step was over, the diver returned over the same line counting the number of sea urchins in the transect.

Two different methods were used to count target species: “traditional” Visual Census (VC) (Sale, 1997; Floeter *et al.*, 2007) and the Interference Visual Census (IVC) (Beldade & Gonçalves, 2007). The difference between them is that in the first one, the diver only counts the individuals that he or she can easily see. On the other hand, in the second method, the diver counts not only all visible fish over the substrate, but also systematically looks for hidden fishes (*e.g.* under rocks or sea shells, among algae).

Cryptobenthic fish assemblage was accessed through the I.V.C., while *Stegastes* spp (Jenyns 1840), *Mycteroperca marginata* (Lowe 1834), *M.acutirostris* (Valenciennes 1828) and sea urchins (*Echinometra lucunter*, Linnaeus 1758) were counted trough traditional

### Visual Census.

The habitat complexity was measured by the number of possible refuges. To do so, holes were classified in three different sizes classes (1–10cm, 11–20 and 21–30cm) and counted on three depth strata (3, 10 e 15m) in the same transects as the fishes. This procedure was replicated 8 times at each depth and was done only at Farol inlet.

## DATA ANALYSIS

The assemblage structure was analysed by calculating species richness ( $S$ =number of species), diversity (by the Shannon–Wiener index) and evenness (Pielou, 1966) for each transect. As expected in many ecological studies, the data generated by counts of individuals did not show a normal distribution. Then, Kruskal-Walis ANOVA by ranks was used to compare data among the sites on the same depth strata and, on Farol inlet, to compare the three depth strata. Multiple comparisons of mean rank for all groups were made to identify the differences. Mann-Whitney U test was used to compare depths in the sites with only two strata (Capim inlet and Xavier Island). The relation between the cryptobenthic fish assemblage and the possible interferences (predators, competitors, sea urchins, holes and depth) were analyzed through Spearman correlation.

## RESULTS

### SPECIES COMPOSITION

Overall, 13 species of cryptobenthic fishes were recorded. Among them, *Malacoctenus delalandii* (Valenciennes, 1836), *Parablennius marmoratus* (Poey, 1875), *Parablennius pilicornis* (Cuvier, 1829), *Hypoleurochillus fissicornis* (Quoy & Gaimard, 1824) and *Labrisomus nuchipinnis* (Quoy & Gaimard, 1824) were observed on all sites. *Coryphopterus glaucofraenum* (Gill, 1863) and *Emblemariopsis signifera* (Ginsburg, 1942) were recorded on almost all sites with the exception of Costão da Barra. *Starksia brasiliensis* (Gilbert, 1900) was only seen on Arvoredo Island, in both bays, and *Ophioblennius trinitatis* (Miranda Ribeiro, 1919) that was observed on almost all sites with exception of Capim inlet on Arvoredo Island.

*Callionymus bairdi* (Jordan, 1888), was observed only once at

Capim inlet on 8m depth on gravel. *Gobiesox barbatulus* (Starks, 1913) was encountered twice at Farol bay, between 3m depth rock crags. *Scartella cristata* (Linnaeus, 1758) was seen twice at 3m depth on Xavier Island. *Hypsoblennius invemar* (Smith-Vaniz & Acero, 1980) was seen during *all-occurrence* dives and was not included on the analysis since it was not seen during the transects.

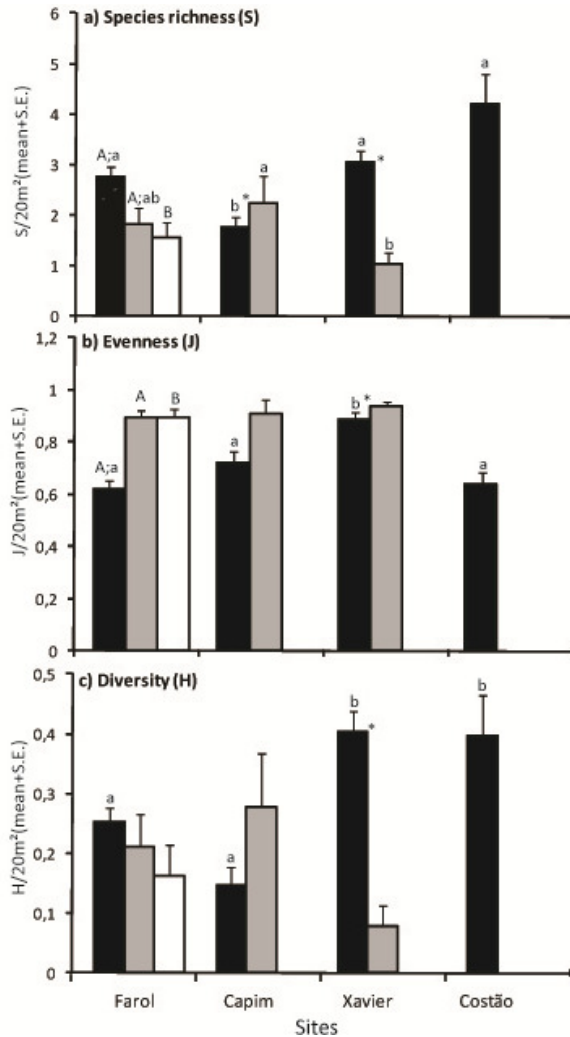
## DIFFERENCES IN ASSEMBLAGE PARAMETERS

Cryptobenthic assemblage patterns among depths changed on the different sites (Fig. 2). When comparing all sites on the same strata, 3m Capim presented the lowest Species richness (Kruskal-Wallis; N=95;  $p=0.001$ ), while at 10m, it presented the highest (Kruskal-Wallis; N=60;  $p=0.03$ ). When comparing depths on the same site, Species richness was smaller at 15m than at 3 or 10m on Farol (Kruskal-Wallis; N=75;  $p=0.004$ ). There was also a significant difference in **S** between 3 and 10m on Xavier Island (Mann-Whitney U test; N: 3m=29, 10m=23;  $p<0.000$ ).

The evenness at 3m depth was higher on Xavier than on the other sites (Kruskal-Wallis; N=95,  $p<0.000$ ). Farol, Capim and Costão presented no statistically differences of **J** among them. At 10 and 15m, **J** was equal on all sites. When comparing depths on the same site, Xavier Island was the only one where evenness showed significant difference (Mann-Whitney U Test; N: 3m=29, 10m=23;  $p<0.000$ ).

Diversity in the shallows (3m) was significant higher in Xavier and Costão than at Farol and Capim (Kruskal-Wallis; N=95;  $p<0.000$ ) where one species (*M. delalandii*) strongly dominated the community. At 10m, **H** was equal at all sites. Xavier Island was the only site where diversity was significantly different between depths (Mann-Whitney U test; N: 3m=29, 10m=23;  $p<0.000$ ).

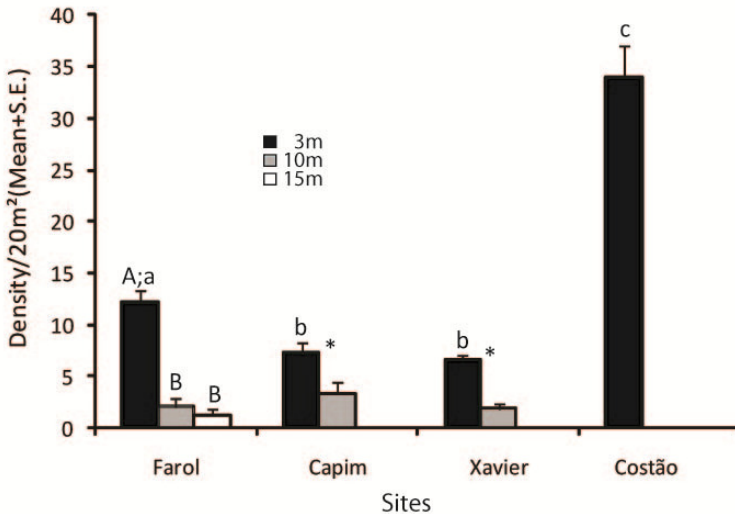




**Figure 2.** Cryptobenthic fish assemblage parameters (mean + S.E./20m<sup>2</sup>) observed by site and depth. ■ (3m); ▒ (10m) and □ (15m). (a) Species richness, (b) Evenness and (c) Diversity. Letters indicate groups formed by multiple comparisons of mean rank for all groups made in *a posteriori* test following Kruskal-Wallis ANOVA by ranks. Capital letters specify groups among depths on Farol and lower case letters indicates groups among sites on the same depth zone. \* indicates significant differences between depths on the same site (U test)

## DIFFERENCES IN FISH DENSITY AND FREQUENCY OF OCCURRENCE

Total mean density community of cryptobenthic fish by localities and depths is shown in Fig 3. At 3m depth, Costão da Barra was the site with the highest density of cryptobenthic fishes (median=30 ind/20m<sup>2</sup>), followed by Farol (median =11 ind/20m<sup>2</sup>). Capim (median =8 ind/20m<sup>2</sup>) and Xavier (median=6 ind/20m<sup>2</sup>) showed the lowest densities (Kruskal-Wallis; N=98; p<0.000). The density of cryptobenthic fishes at 10m depth did not differ among sites. Among depths, on the same site, the fish density at 3m zone was significantly higher than at 10 and 15m on Farol (Kruskal-Wallis; N=75; p=0.002), Capim (Mann-Whitney U test; N: 3m=27, 10m=8; p=0.03) and Xavier (Mann-Whitney U test; N: 3m=2, 10m=23, p<0.000).



**Figure 3.** Cryptobenthic fish community total density (mean + S.E.) by sites. ■ (3m); ▒ (10m) and □ (15m).

Letters indicate homogeneous groups formed by multiple comparisons of mean rank for all groups made in *a posteriori* test following Kruskal-Wallis ANOVA by ranks. Capital letters specify groups among depths on Farol and lower case letters indicates groups among sites on the same depth zone. \* indicates significant differences between depths on the same site (U test).

Considering each species separately (Fig.4), *M. delalandii* showed a representative density on all sites. However it was at the 3m zone on Farol and Capim where its density was more abundant

(Kruskal-Wallis; N=98;  $p < 0.000$ ). The density of *M. delalandii* varied among sites also at 10m (Kruskal-Wallis; N=48;  $p=0.02$ ). Its density presented a significant decrease with depth at all sites (Farol: Kruskal-Wallis; N=75;  $p < 0.000$ ; Capim: Mann-Whitney U test; N: 3m=27, 10m=8;  $p=0.005$ ; Xavier: Mann-Whitney U test; N: 3m=24, 10m=23;  $p < 0.000$ ). This lower density at deeper zones was detected by a negative correlation pattern that was held on all sites (Table 2).

Despite its presence on all sites, *P. pilicornis* was more abundant at 3m depth on Xavier and Costão da Barra (Kruskal-Wallis; N=98,  $p < 0.000$ ). Its density at 10m was equal on all sites (Kruskal-Wallis; N=48) and its density also suffered a significant decrease with depth on Xavier (Mann-Whitney U test; N: 3m=24, 10m=23;  $p < 0.000$ ).

The density of *P. marmoreus* was almost the same on all sites and depths, and had significant increase with depth on Xavier (Mann-Whitney U test; N: 3m=24, 10m=23;  $p=0.04$ ) showing a positive correlation with this variable (Table 2).

At 3 m depth, *L. nuchipinnis* density was significantly higher on Costão da Barra than on the other sites (Kruskal-Wallis; N=98,  $p < 0.000$ ). Its density decreased significantly with depth on Farol (Kruskal-Wallis; N=75,  $p < 0.000$ ) and Xavier (Mann-Whitney U test; N: 3m=24, 10m=23;  $p < 0.000$ ) showing a negative correlation with this variable (Table 2), and it almost disappeared at 10 and 15m.

*C. glaucofraenum* was present on all sites, with the exception of Costão. Its density increased significantly with depth on Farol (Kruskal-Wallis; N=75,  $p < 0.000$ ) and Capim (Mann-Whitney U test; N: shallow=27, medium=8;  $p=0.008$ ), demonstrating a positive correlation with this variable (Table 2). Its density was the same on all sites where it appeared.

*E. signifera* showed the same density on all sites and depths where it occurred, showing a tendency to increase with depth. Particularly on Capim this pattern was better represented, the density increase at 10m was statistically confirmed (Mann-Whitney U test; N: shallow=27, medium=8;  $p=0.007$ ).

*H. fissicornis* was also present on all sites, and it was more representative on Costão and Xavier, where it showed a negative correlation (Table 2), decreasing its density with depth (Mann-Whitney U test; N: 3m=24, 10m=23;  $p=0.006$ ).

*O. trinitatis* was present on all sites with exception of the Capim inlet. Its frequency of occurrence was more representative on Costão. However, it was on Farol inlet, with its large depth range, where it was possible to identify a significant negative correlation between its depth

and density.

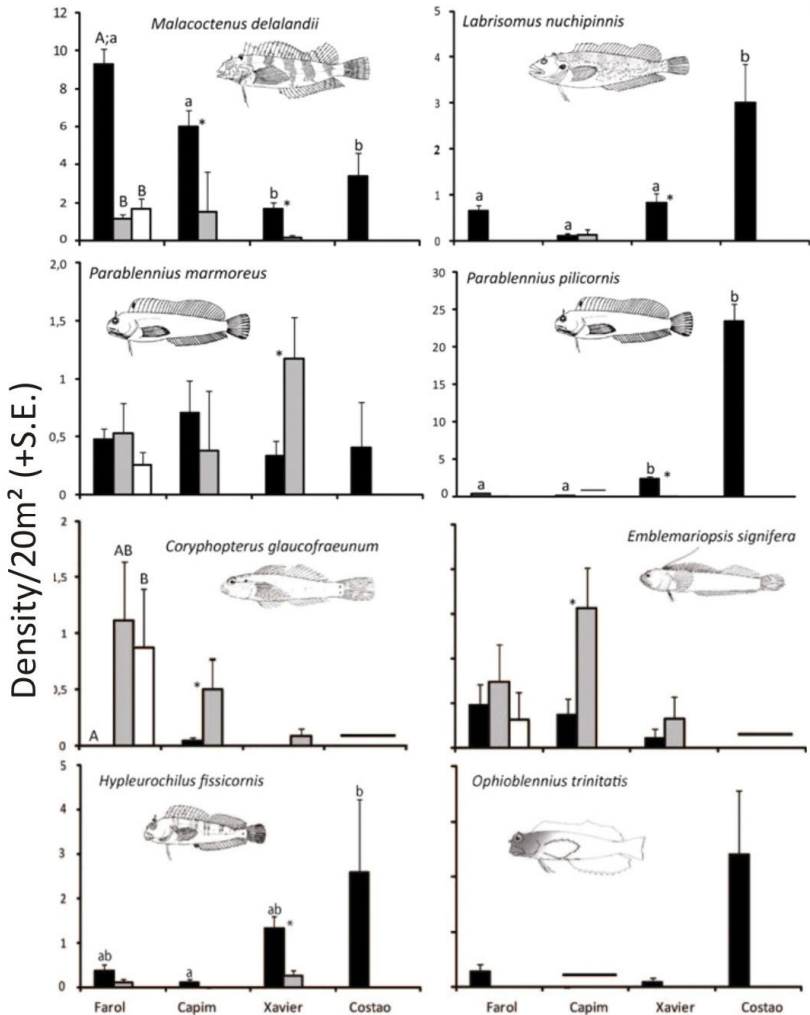
*S. brasiliensis* was recorded on Farol and Capim inlets (Arvoredo Island), but its occurrence was representative only on Farol (Table 2).

**Table 2.** Spearman correlation results among cryptobenthic species density and depth on Xavier (N= 47), Capim (N= 47) and Farol (N= 82). Statistically significant values are highlighted.

Species density	Xavier		Arvoredo			
	R	p	Capim		Farol	
			R	p	R	P
<i>C. glaucofraenum</i>	0.21	0.14	<b>0.36</b>	<b>0.01</b>	<b>0.48</b>	<b>0.00</b>
<i>E. signifera</i>	0.09	0.51	<b>0.31</b>	<b>0.03</b>	-0.01	0.92
<i>H. fissicornis</i>	<b>-0.50</b>	<b>0.00</b>	-0.10	0.49	-0.20	0.07
<i>L. nuchipinnis</i>	<b>-0.57</b>	<b>0.00</b>	-0.21	0.15	<b>-0.57</b>	<b>0.00</b>
<i>M. delalandii</i>	<b>-0.56</b>	<b>0.00</b>	<b>-0.58</b>	<b>0.00</b>	<b>-0.65</b>	<b>0.00</b>
<i>O. trinitatis</i>	-0.14	0.33	-----	-----	<b>-0.24</b>	<b>0.02</b>
<i>P. marmoreus</i>	<b>0.29</b>	<b>0.04</b>	-0.04	0.74	-0.14	0.20
<i>P. pilicornis</i>	<b>-0.75</b>	<b>0.00</b>	-0.11	0.44	<b>-0.25</b>	<b>0.02</b>
Total community	<b>-0.50</b>	<b>0.00</b>	<b>-0.50</b>	<b>0.00</b>	<b>-0.70</b>	<b>0.00</b>

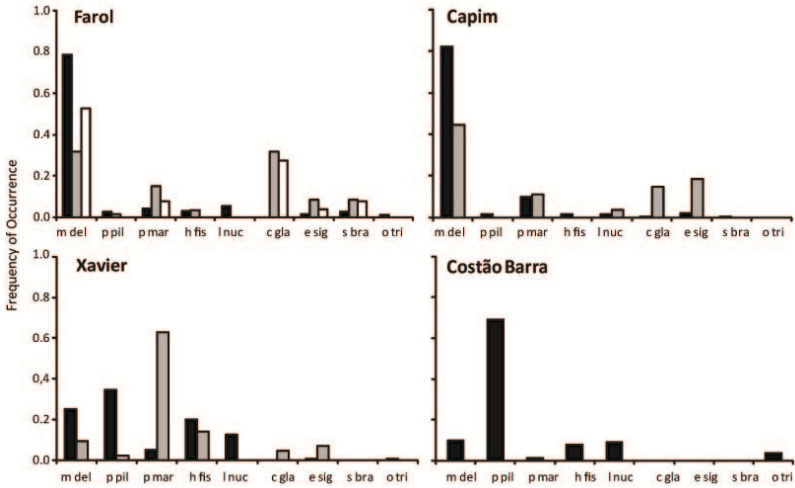
#### SIMILARITIES AMONG SAMPLING SITES IN RELATION TO FREQUENCY OF OCCURRENCE

Considering each species separately, on Capim and Farol inlets (Arvoredo Island), *M. delalandii*, *C. glaucofraenum* and *E. signifera* were the most representative species, independently of the depth zones. *S. brasiliensis* was more frequent on Farol, despite being present on Arvoredo island on both sites. At 3m depth, *P. marmoreus* showed a similar frequency of occurrence on all sampling sites with exception of Costão da Barra, where its density was less representative. On Xavier island 10m depth, *P. marmoreus* was the dominant species. And despite being present on all sites, *P. pilicornis*, *H. fissicornis* and *L. nuchipinnis* showed a higher frequency of occurrence on Xavier and Costão at 3m depth (Fig.5).



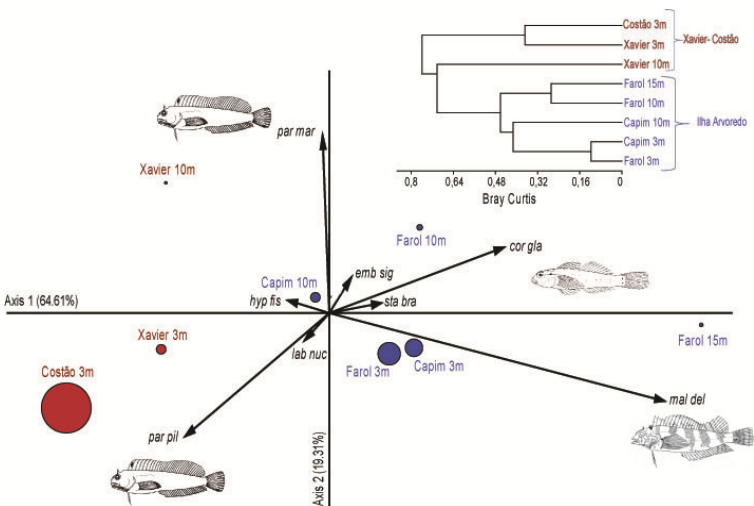
**Figure 4.** Cryptobenthic fish species density (mean + S.E.) by sites. ■ (3m); ▒ (10m) and □ (15m).

Letters indicate homogeneous groups formed by multiple comparisons of mean rank for all groups made in a *posteriori* test following Kruskal-Wallis ANOVA by ranks. Capital letters specify groups among depths on Farol and lower case letters indicates groups among sites on the same depth zone. \* indicates significant differences between depths on the same site (U test). P.S.: Note that each graphic has different density scale so the details are not lost when comparing abundant with rare species



**Figure 5.** Frequency of occurrence of cryptobenthic species by sites. ■ (3m); ▒ (10m) and □ (15m).

Legend: m del= *Malaccoctenus delalandii*; p pil= *Parablennius pilicornis*; p mar= *Parablennius marmoratus*; l nuc= *Labrisomus nuchipinnis*; c gla= *Coryphopterus gaucofraenum*; e sig= *Emblemariopsis signifera*; s bra= *Starksia brasiliensis*; h fis= *Hypleurochilus fissicornis* and o tri= *Ophioblennius trinitatis*.



**Figure 6.** Principal Component Analysis and sampling site dissimilarities (WPGMA Bray Curtis) in relation to cryptobenthic species frequencies of occurrence. Circles size is proportional to the cryptobenthic fish total density at each site.

Considering the species frequency of occurrence it was possible to identify distinct groups of similarities among sampling sites (Fig 6). It is interesting to note that neighboring sites with same depths ended up grouped together.

#### RELATIONSHIPS WITH MICROHABITAT FEATURES (NUMBER AND SIZE OF HOLES)

The relationship between species density and numbers of holes was analyzed with Spearman correlation. The “R” and “p” values were written in between parenthesis. For all the analyses N=8.

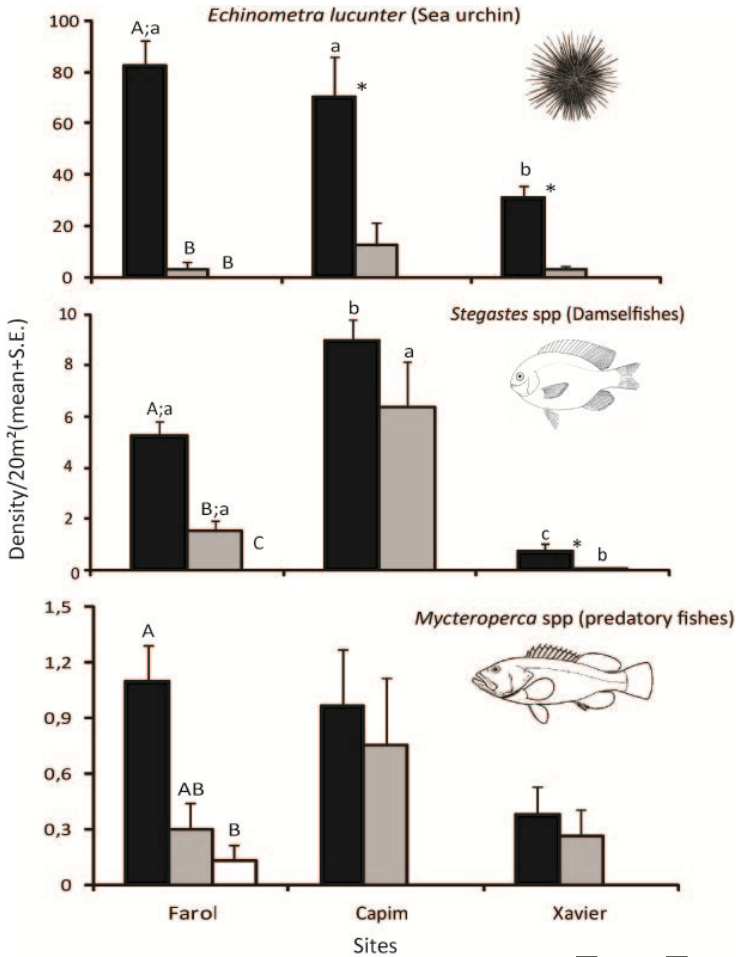
At 3m depth, the total community density showed a positive correlation with the 11–20cm (R=0.79; p=0.02) and 21–30cm holes (R=0.71; p=0.04), and with the total number of holes (R=0.71; p=0.04). When taking in consideration each species, *M. delalandii* showed a positive correlation with 11–20cm holes (R=0.86; p=0.01) and with the total number of holes (R=0.80; p=0.02). At the same depth, *L. nuchipinnis* showed a negative correlation with 11–20cm holes (R=-0.79; p=0.01). At 10m depth the whole community also showed a positive correlation with the sum of 11–20cm and 21–30cm holes class sizes (R=0.74; p=0.03). At 15m depth, *C. glaucofraenum* showed a positive correlation with 21–30cm holes (R=0.79; p=0.02).

#### INTERACTIONS WITH SEA URCHINS AND WITH TERRITORIAL AND PREDATORY FISH

The sea urchins mean density showed a significant difference between Farol inlet and Xavier Island (Kruskal-Wallis; N=93; p<0.001). On all sites was detected a significant difference on sea urchins mean density values among the 3m and the other depth zones (Farol: Kruskal-Wallis; N=75; p=0.002; Capim: Mann-Whitney U test; N: 3m=27, 10m=8; p=0.01; Xavier: Mann-Whitney U test; N: 3m=24, 10m=23, p<0.000)(Fig.7).

*Stegastes* spp density was higher on Capim at both 3m (Kruskal-Wallis; N=85; p<0.000) and 10m zones (Kruskal-Wallis; N=48; p<0.000). The difference was also significant between depths on the same site (Farol: Kruskal-Wallis; N=75; p<0.000; Xavier: Mann-Whitney U test; N: 3m=16, 10m=23; p<0.002), with exception of Capim inlet (Fig.7).

The predators (*Mycteroperca* spp) mean density values on Farol inlet showed a significant difference between the 3m and the 15m zones (Kruskal-Wallis; N=75; p=0.002) (Fig.7).



**Figure 7.** Biotic interactions density (mean + S.E) values. ■ (3m); □ (10m) and □ (15m). a) Sea urchin (*Echinometra lucunter*); b) Territorial fish (*Stegastes* spp) and c) Predators (*Mycteroperca* spp).

Letters indicate homogeneous groups formed by multiple comparisons of mean rank for all groups made in a *posteriori* test following Kruskal-Wallis ANOVA by ranks. Capital letters specify groups among depths on Farol and lower case letters indicates groups among sites on the same depth zone. \* indicates significant differences between depths on the same site (U test).



## RELATIONSHIPS BETWEEN BIOTIC VARIABLES AND CRYPTOBENTHIC FISH DENSITIES

The correlation between predatory and cryptobenthic fishes did not show a clear pattern among sites (Table 3). At Capim inlet 10m, the total density of the cryptobenthic assemblage showed a tendency to decrease with the increase of predators. The most negatively affected species were *M. delalandii* and *P. marmoreus*. At Capim 3m, *C. glaucofraenum* densities showed a tendency to increase with predators. At Farol 10m, the density of *E. signifera* suffered a significant rise with the increase of predators. It is interesting to note that places with higher numbers of samplings showed a positive correlation between predators and cryptobenthic species.

**Table 3.** Spearman correlation results between cryptobenthic and predatory fish (*Mycteroperca* spp) densities. The table shows only results with a p value smaller than 0.1. Statiscaly significative values are highlighted.

	Site/depth	N	Spearman R	p-level
<b>Total community</b>	<b>Capim 10m</b>	<b>8</b>	<b>-0.69</b>	<b>0.06</b>
<i>M. delalandii</i>	<b>Farol 3m</b>	<b>42</b>	<b>0.36</b>	<b>0.02</b>
	<b>Capim 10m</b>	<b>8</b>	<b>-0.89</b>	<b>0,00</b>
<i>P. marmoreus</i>	<b>Capim 10m</b>	<b>8</b>	<b>-0.74</b>	<b>0.04</b>
<i>C. glaucofraenum</i>	Capim 3m	27	0.38	0.05
<i>E. signifera</i>	<b>Farol 10m</b>	<b>16</b>	<b>0.54</b>	<b>0.03</b>

The pattern of interaction between cryptobenthic and territorial fishes (*Stegastes* spp) seemed to be clear (Table 4). At the 3m zone, the cryptobenthic assemblage presented a significant negative correlation with *Stegastes* spp densities. The pattern was the same on Xavier and Capim. When looking for each species, it was interesting to note that almost all the species that showed a significant correlation with the *Stegastes* spp density, presented a positive correlation at 3m depth and a negative correlation at 10m. The exception was *M. delalandii* on Farol inlet.

At Farol 3m, there was a significant positive correlation between cryptobenthic fishes and sea urchins. This could be seen when looking at the total cryptobenthic densities and separately at each species (*P. marmoreus*, *H. fissicornis*, *E. signifera* and *S. brasiliensis*). The pattern was kept at Capim 3m for *E. signifera* and at 10m for *L. nuchipinnis*. On

Xavier Island, the pattern was kept for *P. pilicornis*, but for *M. delalandii*, *H. fissicornis* and *L. nuchipinnis* it showed the inverse tendency (Table 5).

**Table 4.** Spearman correlation results between cryptobenthic and territorial fishes (*Stegastes* spp). The table shows only results with a p value smaller than 0.1. Statiscaly significative values are highlighted.

	Site/depth	N	Spearman R	p-level
Total community	Farol 3m	42	0.27	0.09
	<b>Capim 3m</b>	<b>27</b>	<b>-0.53</b>	<b>0.00</b>
	<b>Xavier 3m</b>	<b>16</b>	<b>-0.70</b>	<b>0.00</b>
	Xavier 10m	23	0.36	0.09
<i>M. delalandii</i>	<b>Farol 3m</b>	<b>42</b>	<b>0.33</b>	<b>0.03</b>
	Capim 3m	27	-0.36	0.06
<i>H. fissicornis</i>	Xavier 3 m	16	-0.44	0.09
	<b>Xavier 10m</b>	<b>23</b>	<b>0.51</b>	<b>0.01</b>
<i>L. nuchipinnis</i>	<b>Capim 3m</b>	<b>27</b>	<b>-0.50</b>	<b>0.01</b>
	Xavier 3m	16	-0.48	0.06
<i>C. glaucofraenum</i>	<b>Xavier 10m</b>	<b>23</b>	<b>0.69</b>	<b>0.00</b>
<i>E. signifera</i>	Capim 10m	8	0.68	0.06
	<b>Xavier 10m</b>	<b>23</b>	<b>0.66</b>	<b>0.00</b>

**Table 5.** shows the Spearman correlation results between cryptobenthic fishes and the sea urchins (*E. lucunter*) densities. The table shows only results with a p value smaller than 0.1. Statiscaly significative values are highlighted.

	Site/depth	N	Spearman R	p-level
Total community	<b>Farol 3m</b>	<b>42</b>	<b>0.40</b>	<b>0.01</b>
<i>M. delalandii</i>	Xavier 5m	24	-0.39	0.06
<i>P. pilicornis</i>	Xavier 5m	24	0.36	0.08
<i>P. marmoreus</i>	<b>Farol 3m</b>	<b>42</b>	<b>0.36</b>	<b>0.02</b>
	<b>Farol 3m</b>	<b>42</b>	<b>0.34</b>	<b>0.03</b>
<i>H. fissicornis</i>	Xavier 5m	24	-0.39	0.06
	<b>Capim 10m</b>	<b>8</b>	<b>0.76</b>	<b>0.03</b>
<i>L. nuchipinnis</i>	<b>Xavier 5m</b>	<b>24</b>	<b>-0.46</b>	<b>0.02</b>
	Farol 3m	42	0.30	0.06
<i>E. signifera</i>	Capim 3m	27	0.34	0.08
	<b>Farol 3m</b>	<b>42</b>	<b>0.39</b>	<b>0.01</b>

## DISCUSSION

### ASSEMBLAGE PARAMETERS AND COMPOSITION

When looking at community structure, it is noteworthy that *M. delalandii* largely dominated the fish assemblage (80% of total density) on Arvoredo Island (Capim and Farol inlet). As a result, the fish community structure was strongly unbalanced at those bays, which in turn negatively affected species Diversity and Evenness. On the other hand, Xavier Island showed higher Evenness and Diversity on shallow water, where no species showed a high dominance. The Evenness at 10m deep was always higher than at 3m, and it was pretty much the same on the three sites. This could be due to the higher stability of these environment at 10m depth, where physical disturbance (thermal stress, water flow and light incidence) are lessened (Bertness *et al.*, 2001), which do not favour a particular species. Species richness of cryptobenthic fishes showed a pattern in relation to depth among sites, i.e. generally dropping with depth. These could be explained by the fact that most cryptobenthic fishes dwell preferentially within a very shallow depth range, some of them being intertidal (Illich and Kotrschal 1990). The only exception was Capim inlet where species number increase with depth, probably due to the appearance of another habitat element at 10m, the rock-sand interface, the preferred microhabitat for some species (*C. glaucofraenum* and *P. bairdii*)(Santos, 2005; Rangel, 2007).

The actual species richness of cryptobenthic fishes on the studied rocky shores is probably higher than the reported here. Certain fishes already registered in the region were absent in this work, probably due to inadequacy of the sampling method and the short duration in samplings. This difference in the number of species was expected, since density and diversity of these small and highly cryptic fishes can be greatly underestimated by visual census methods (Willis, 2001). However, the Interference Visual Census is not strictly visual, since it makes an active search among algae, rocks and sand. It also includes the lifting of small habitat elements, what may render better abundance estimates, closer to those obtained with anaesthetics (Beldade & Gonçalves, 2007). Indeed rotenone and anaesthetic samplings often require special permits and are subjected to restrictions. Therefore, the Interference Visual Census should be considered as a regular protocol for preliminary assessments of cryptobenthic fishes, since it gives a good representation of species relative abundance (Rangel, 2007).

Some species already recorded in the region were not found on

this study: *Gnatholepis thompsoni* (Jordan 1904), (Barneche *et al.*, 2009), *Labrisomus kalisherae* (Jordan, 1904), *Paraclinus spectator* (Guimarães & Bacelar, 2002); *Hyleurochilus pseudoaquipinnis* (Bath, 1994), *Tomicodon fasciatus* (Peters, 1859), *Barbulifer ceuthoecus* (Jordan & Gilbert, 1884), *Bathygobius soporator* (Valenciennes, 1837), *Gobiosoma hemygymnum* (Eigenmann & Eigenmann, 1888) and *Gobiosoma nudum* (Meek & Hildebrand, 1928) (Hostim-Silva *et. al.* 2006).

## DIFFERENCE IN FISH DENSITY AND FREQUENCY OF OCCURRENCE

The density results of cryptobenthic fishes from this study seem to be surprisingly lower when compared with the results obtained by Rangel (2007). Here it was found a maximum of 30 ind/20m<sup>2</sup> whereas he found 225 ind/20m<sup>2</sup>. Part of this difference could be a reflection of the latitudinal gradient, since his study area was on a tropical region (22°59'S). Another reason may be due to the use of different methods, since he made use of clove oil for fish collection and this research used only the Interference Visual Methods. When both methods were compared on Arrabida Marine Park, in Portugal, Rangel (2007) founded that the percent difference in abundance between both methods was 37% lower for the Interference Visual Census.

When comparing among the studied sites, the discrepancy of cryptobenthic fish assemblage total density between Costão da Barra and the other sites could be a possible indicative of over-fishing in the area. This site is very accessible and the fishermen can reach the water by simply walking on the rocky shore. As consequence of intensified fishing on 'macrocarnivorous' fish, ecological models predict a higher abundance of cryptobenthic fishes (Pinnegar and Polunin 2004). This is corroborated by many studies comparing marine reserves and nearby fished areas. They documented reductions in the cryptobenthic fish density and diversity in areas where macrocarnivorous fish are abundant (*e.g.* groupers) (La Mesa and Vacchi, 1999; La Mesa *et al.*, 2006; Macpherson, 1994; Sasal *et al.*, 1996). Prochazka (1998) discussed data of similar reductions in the density of small fishes at the Tsitsikamma National Park in South Africa, a marine protected area.

When looking at the relative density of each species, it's noteworthy that almost all species have their densities lowered with depth, with the exception of *C. glaucofraenum*, *E. signifera* and *P.*

*marmoreus*, all of them carnivorous or onivorous with tendency to be carnivora. The cause of this correlation for *C. glaucofraenum* is probably due the apperance of sand habitats on deeper areas, since the common habitat of this species is the interface between rocks and sand (Santos, 2005; Rangel, 2007). For *E. signifera*, the cause of this correlation is unknown and needs further research. However, note the fact that, for being a microcarnivorous species, it would have more freedom on depth choice.

The positive correlation with depht found for *P. marmoreus* on Xavier Island could be a result of the sympatric high frequency of occurrence of a closely related fish (*P. pilicornis*) with putative similar ecological demands that may cause interspecific competition and a consequent depth segregation (Larson, 1980; Lombarte *et al.*, 2000). Moreover, on Costão da Barra, site where *P. pilicornis* is very abundant, *P. marmoreus* frequency of occurrence was low. Rangel (2007) also encountered very distinct patterns of distribution and abundance for the blennies *P. pilicornis* and *P. marmoreus* on Arraial do Cabo (Brazil). Santos (2005) analyzed the diet of *P. marmoreus* and *P. pilicornis* and concluded that the first is onivorous with tendecy to be carnivory and the latter is a classic onivorous. This demonstrated a discrete segregation on food habits. On Farol bay, the species density did not increase with depht, but the frequency of occurrence did. This could be due to the positive relation between the species and the sea urchins, considering that sea urchins density reached the peak at Farol 3m. On Capim bay, the *P. marmoreus* density descreased with depht, but also, on this site, the species showed a negative correlation with predators (*Mycteroperca* spp) density, what could influence its lower density there. Other studies also documented that *P. marmoreus* abundance increases with depth (Rauch, 1996; 2003).

*P. pilicornis* was very abundant at Costão da Barra and common at Xavier island. However, it almost desapeared on Arvoredo Island. Rangel (2007) also founded similar patterns of dominance for this species, being the most abundant (90%) on some sites and almost absent on others. Beldade and Gonçalves (2007) observed a decreasing number of settlers and consequent lower adults of *P. pilicornis*, from one year to another, suggesting that the low input, *i.e.* number of settlers, may be the strongest factor in determining adult density. This species is an exception among most cryptobenthic fishes, because it presented a relatively long time living on plancton (32 days) (Beldade & Gonçalves, 2007). This is consistent with the idea that this species may disperse offshore. In fact, only newly hatched larvae have been captured near

shore (Olivar, 1986), what corroborates this idea.

Like encountered by Nieder *et al.* (2000), neighboring sites were more similar to each other than to distant ones, suggesting that a broader scale pattern exists (Sale 1998), *e.g.* currents or upwelling. The area (28°45'S) is characterized by locally upwelling events, mainly during spring and summer (Emilsson, 1961; Matsuura, 1986; Castello, 1990). That could create variations on the water temperature on the distinct islands. In fact, on summer, the water on Xavier-Costão da Barra is colder than on Farol-Capim (personal observation). This could explain part of the similarities among sites. *M. delalandii*, seems to reproduce in the summer (personal observation of many young individuals), maybe needing a minimum surface water temperature to reproduce with success, and maybe this minimum would not be frequently reached on Xavier Island. Indeed, it is possible that smaller scale processes generate patterns detectable on a larger scale (Sale, 1998).

The biology and behavior characteristics of many cryptobenthic fishes works together for them to stay near the coast they were born. They hatch from benthic eggs, typically presenting functional eyes, fins and guts, shows better swimming abilities than pelagic species and spend relatively short periods in the plankton as larvae (Hickford & Schiel, 2003; Fisher, 2005; Watson, 2009). By remaining close to high relief substrates, and avoiding areas with laminar currents intertidal fishes might be able to reduce offshore dispersal (Marliave, 1986). Beldade *et al.* (2007) recorded the presence of all larval stages close to shore in many species of cryptobenthic fishes. These facts suggest they may be able to remain close to shore in coastal shallow subtidal areas colonizing the area with the same species always, *i.e.* self-recruitment.

The presence of conspecifics may also influence recruitment (Sweatman, 1983; Webster, 2004). Preferential settlement of larvae into habitat occupied by conspecifics has been demonstrated for a number of coral reef fish species (Sweatman, 1983, 1985 and 1988; Fowler, 1990; Sweatman & St. John, 1990; Booth, 1991, 1992 and 1995). The presence of conspecifics could be an indicator of habitat quality to the settling larvae (Levin 1993) and if resources are not limited, growth and/or survival may be enhanced by settling among adult conspecifics (Jones, 1987; Forrester, 1990; Booth, 1995). Indeed, the risk for an individual from a predator might be lessened if it places another potential prey individual between itself and the predator (Hamilton, 1971).

## MICROHABITAT FEATURES AND BIOTIC INTERACTIONS

Like expected, cryptobenthic fish assemblage was positively correlated with microhabitat features. *M. delalandii*, the dominant species on Farol inlet, site where the samplings of microhabitat features were made, showed a significant positive correlation with 10-20cm holes, and a positive tendency with 20-30cm holes. Silveira (2010) also reported a positive correlation between *M. delalandii* and numbers of holes bigger than 10cm. For bridled gobies, a manipulation of population density and crevice availability showed that intraspecific competition for refuges is a key agent of mortality (Forrester & Steele, 2004).

This study failed to detect a consistent correlation pattern between potential predators (*Mycteroperca* spp) and cryptobenthic fish assemblage total density. Indeed, when looking individually for each species, *M. delalandii* showed a positive correlation with *Mycteroperca* spp densities at Farol 3m, what could be related to a similarity of habitat between the two groups. Silveira (2010) founded a positive correlation between both groups and number of holes (refuges) bigger than 10 cm. In addition, at Capim inlet 10m, *M. delalandii* and *P. marmoratus* showed a negative correlation between densities of the two species and *Mycteroperca* spp, maybe related with predation pressure. The difference on patterns founded between Farol and Capim inlet, could be due to variations in habitat complexity, since it has been suggested that the mechanism causing higher densities of fish in more physically complex habitats is a reduction in predation pressure, brought about by the availability of refuges (Hixon & Beets, 1993; Caley & St John, 1996; Willis & Anderson, 2003). Indeed, it cannot be excluded a sampling error effect, since this pattern was only encountered on the place with smaller sampling size.

A stronger correlation between groups, was not found maybe due to different habitat scales used between groupers and cryptobenthic fishes (Sale, 1998), or either it was not considered all possible predators (*e.g.* Pulps, Morays, Sand diver, between others). Another reason could be a low level of predation, the investigated species being a secondary prey for groupers, or so abundant as to make any predation related effect negligible.

The pattern of interaction between cryptobenthic and territorial fishes (*Stegastes* spp) was clear. Looking to the whole community, on shallow water (3m) the cryptobenthic fish density increased with the decrease of *Stegastes* spp density and the pattern appeared to hold on all

sites with exception of Farol inlet. These may be another reflection of higher habitat complexity on Farol inlet, decreasing the interspecific competition, allowing more individuals to live on the same area (Begon *et al.*, 2006).

When looking at the individual density of each species, it is interesting to note, that the negative correlations always occurred at shallow water (3m) what could be due the higher abundance of cryptobenthic fishes and *Stegastes* spp on this depth, increasing the chance for competition (Forrester, 1995). The positive correlation between species and *Stegastes* spp at deeper waters (10m) maybe is demonstrating a similar habitat preference, and because the densities of both groups are low, there is no competition. Silveira (2010) founded a positive correlation between *Stegastes fuscus* and number of holes bigger than 10cm.

The relationship between sea urchins and cryptobenthic fishes showed distinct patterns dependent of the site. *M. delalandii* was frequently observed behind sea urchins, and presented the higher densities on Arvoredo island, also the place with higher sea urchins densities. Santos (2005) reported affinities between *M. delalandii* and the black sea urchin (*Echinometra lucunter*). However, *M. delalandii* density did not show a positive correlation with sea urchins. Indeed, at Xavier 3m it showed a negative correlation. These may be due that the fact that the use of sea urchins by *M. delalandii* does not means that it will settle or even survive better with the sea urchins density increase. However, it cannot be excluded the possibility that the used method cannot efficiently count *M. delalandii* individuals, confusing the results. Farol inlet was the place with higher sea urchins densities, this could result in a higher number of hiding fishes, that could masked the results. The negative correlation on Xavier island, could be due the lower density of both groups, making that where it is sea urchin its more difficult to see *M. delalandii*. *S. brasiliensis* was seeing only at Arvoredo Island commonly behind black sea urchins, what was statistically corroborated with Spearman correlation. At Santa Catalina Island (southern California, USA) manipulative experiments confirm a casual relationship between the local abundance of a small temperate reef fish, *L. dalli*, and the presence of sea urchin (*C. coronatus*) (Hartney & Grorud, 2002). Two gobiesocids and two cryptobenthic gobies were associated with sea urchins as juveniles.

The inverse correlation showed by *L. nuchipinnis* with sea urchins on Capim (less complexity) and at Xavier may be due to this fish-urchin association may be site dependent, varying with substratum



type, host density, and predation risk (*e.g.* Elliott, 1992), or either affected by several attributes of the sea urchin relative to the habitat it occupies (Hartney & Grorud, 2002). Patzner (1999) also registered the effect of sea urchins as a hiding-place for juvenile benthic teleosts.

## CONCLUSIONS

Present results provide the first insight into the cryptobenthic fish assemblage of the north-east islands of Santa Catarina Island, including the depth preferences of some species, giving useful starting point for future research. Now with the present work, cryptobenthic fish community inhabiting the coastal rocky shores of North Santa Catarina state is better known, so that is possible to approximately predict which species will be encountered in a given area. On contrary, the dominance pattern of the different species is still hardly predictable, owing to the variety of factors, biotics and abiotics, which regulate the structure of these coastal fish assemblages. Looking at such variability in the assemblage structure, a comparison among patterns observed in different localities demonstrated to be important to improve the knowledge of the general dynamics that regulate fish populations.

The general variability found on the community parameters is related to specific species responses. Manipulative experiments are necessary for further understanding of the mechanisms involved.

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## CONCLUSÕES GERAIS

Os resultados do presente trabalho representam os primeiros dados relativos a comunidade de peixes criptobênticos da região da Ilha de Santa Catarina. A partir dos resultados obtidos pôde-se conhecer a densidade relativa das espécies em cada área de estudo e seus respectivos padrões de distribuição vertical, os quais algumas vezes se mantiveram entre os locais amostrados. Por outro lado, os padrões de dominância das diferentes espécies ainda é difícil de prever devido a grande variedade de fatores, bióticos e abióticos, os quais regulam a estrutura de comunidades desses peixes. No entanto, para que se possa melhor conhecer as densidades relativas das espécies de hábitos mais crípticos e menores tamanhos, sugere-se o uso de metodologias que envolvem coleta (ictiocidas ou anestésicos). Durante o presente trabalho notou-se que as principais diferenças referentes a estrutura de comunidade ocorreram na zona dos 3m de profundidade, ao contrário da zona dos 10m onde a estrutura de comunidade manteve-se homogênea entre os locais amostrados.

Com relação aos possíveis mecanismos responsáveis (complexidade de habitat, predação e competição) pela distribuição de peixes criptobênticos na área de estudo, os resultados mostraram uma grande variabilidade, as quais estão provavelmente correlatadas a respostas individuais de cada espécie. Além disso, por não envolver experimentos manipulativos, os dados não provam causa-consequência, mas levantam algumas hipóteses que poderiam ser testadas para melhor compreender sobre os mecanismos envolvidos na distribuição de peixes criptobênticos (*e.g.* a interferência de *Stegastes* spp sobre peixes criptobênticos pode depender da densidade de ambos os grupos; relação entre crípticos e ouriço; efeito da predação em ambientes com diferentes níveis de complexidade). Com relação ao efeito dos predadores sobre os peixes criptobênticos, sugere-se a inclusão de outras espécies que poderiam preda os peixes criptobênticos em suas diferentes fases de vida (*e.g.* *Holocentrus adscensionis*, *Muraena* spp e *Synodus* spp).

## Anexo 1. Peixes criptobênticos mais abundantes na área de estudo



*Malacoctenus delalandii*  
Tamanho máximo: 8cm



*Parablennius pilicornis*  
Tamanho máximo: 12.7cm



*Parablennius marmoreus*  
Tamanho máximo: 8.5cm



*Hyleurochilus fissicornis*  
Tamanho máximo: 8.7cm



*Labrisomus nuchipinnis*  
Tamanho máximo: 23 cm



*Coryphopterus glaucofraenum*  
Tamanho máximo: 8 cm

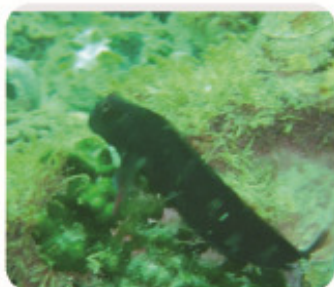
## Anexo 1. Peixes criptobênticos mais abundantes na área de estudo



*Emblemariopsis signifera*  
Tamanho máximo: 2.5cm



*Starksia brasiliensis*  
Tamanho máximo: 3.5cm



*Ophioblennius trinitatis*  
Tamanho máximo: 15cm



*Hypsoblennius invemar*  
Tamanho máximo: 5.8cm



*Scartella cristata*  
Tamanho máximo: 12cm



*Gobiesox barbatulus*  
Tamanho máximo: 8cm