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# The use of a non-destructive method to estimate the abundance of brachyuran crabs (Crustacea, Decapoda) in coastal islands of a marine protected area

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**Abstract.** This study aimed to quantify brachyuran crabs at the coastal islands of Santa Catarina state, in two consecutive summers (2008 and 2009) and to discuss the efficiency of a visual census methodology for long-term monitoring. Sampling was conducted at five islands, including in the Arvoredo Marine Biological Reserve. Crabs were sought in 4 m² quadracts during autonomous dives at two depth layers, both shallower than 15 meters. *Stenorhyncus seticornis* and *Mithraculus forceps* were the dominant species, followed by *Mithrax hispidus*, *Mithrax tortugae*, *Cronius ruber* and *Menippe nodifrons*. There were no significant differences between depths, except for *M. forceps* that concentrated in the shallow layer. *S. seticornis* and *M. forceps* shifted their dominance among sites and years. Further census efforts should be concentrated at depths of less than 10 meters, thereby increasing time available for sampling during dives and also include spatial bottom heterogeneity to access the causes of crab abundance variability. The visual census method seems to be a good alternative for quantifying the dominant species without causing environmental disturbance and therefore it is appropriate in marine protected areas.

**Key words:** Marine Protected Areas (MPA), marine reserves, visual census, scuba dive, crustaceans

**Resumo. A utilização de um método não destrutivo para estimar a abundância de caranguejos braquiúros (Crustacea, Decapoda) em ilhas costeiras de uma area marinha protegida.** Este estudo visa quantificar os caranguejos braquiúros nas ilhas costeiras de Santa Catarina em dois verões consecutivos (2008 e 2009) e discutir a eficiência do monitoramento a longo prazo através da metodologia de censo visual. Amostragens foram realizadas em cinco ilhas, incluindo a Reserva Biológica Marinha do Arvoredo (REBIO). Os caranguejos foram procurados, através de mergulhos autônomos, em quadrados de 4 $m^2$, por dois mergulhadores e foram amostradas duas profundidades acima de 15 metros. *Stenorhyncus seticornis* e *Mithraculus forceps* foram as espécies dominantes, seguidos por *Mithrax hispidus, Mithrax tortugae, Cronius ruber e Menippe nodifrons*. Não foi detectada diferença significativa entre as profundidades, com exceção de *Mithraculus forceps* que se concentrou em águas mais rasas. *S. seticornis* e *M forceps* alternaram a dominância entre locais e anos. Censos futuros devem se concentrar em profundidades mais rasas que 10 metros, permitindo mais tempo de amostragem para os mergulhadores registrando as características do substrato para avaliar as causas da variabilidade da abundância dos caranguejos. O censo visual se apresenta como uma boa alternativa para quantificar espécies dominantes sem perturbar o ambiente e assim apropriado para ser aplicado em áreas marinhas protegidas.

**Palavras chave:** Áreas Marinhas Protegidas (AMP), reservas marinhas, censo visual, mergulho autônomo, crustáceos

## Introduction

Biodiversity assessment provides information that is essential in the current age of environmental changes (Duffy & Stachowicz 2006) and has often focused on 'species' measures such as richness and relative abundance. Most of the biodiversity assessments of Decapoda that have been conducted along the Brazilian coast have employed standard fishing methods such as net trawling and underwater traps over soft bottom (e.g. Mantelato & Franzoso 2000, Calado & Sousa 2003, Bertini *et al*. 2004, Braga *et al.* 2005, Almeida *et al*. 2007). However, rocky reefs are very common in the south-eastern/southern coast of Brazil, having their southern limit at 29°20' S, 49°43' W. In theses habitats, decapod crustaceans represent one of the most important groups of the sublittoral benthic macrofauna (Alves *et al.* 2006). Decapods studies in rocky reef have been limited to the coast of São Paulo state at 23°25' S, 46°38' W (Mantelatto *et al.* 2003, Braga *et al.* 2005, Alves *et al.* 2006, Mantelatto *et al.* 2007, Alves 2009, Camargo *et al.* 2010) and of Paraná state at 25° 25' S , 49° 16' W (Dubiaski-Silva & Masunari 1998, 2008). In rocky reefs, small crabs and other decapods inhabit crevices and deep caves, where trawling is ineffective and traps usually work only for larger species.

Sampling by scuba diving seems to be ideal to find cryptic species and have recently been used for decapods surveys (Bouzon & Freire 2007) and counts (Alves 2009, Teixeira 2010). The first scientific report about decapods on the rocky bottom in the Arvoredo Biological Marine Reserve (ABMR) showed that scuba diving was a very good option for sampling the sea bottom without destroying the entire environment and for searching for animals hidden in micro-habitats; the rate at which the study identified decapod species in the area was almost one new record per dive (Bouzon & Freire 2007). Besides, diving to count crabs by manual capture (Alves 2009) and by visual censuses (Teschima *et al.* 2009) or associated to manually collected rodoliths (Silva- Karam 2008) equally have pointed out the importance to the rocky bottom community of *Stenorhynchus seticornis* (Herbst, 1788), *Mithraculus forceps* (A. Milne Edwards, 1875) and *Mithrax tortugae* Rathbun, 1920.

Visual censuses employing scuba diving are a well-established and routine practice for investigating reef fishes (Edgar *et al.* 2004, Ferreira & Gonçalves 2006, Floeter *et al.* 2006). The method has also been used for lobster studies in marine areas with varying degrees of protection, especially in the Caribbean, Australia and New Zealand (Eggleston *et al.* 2003, 2008, Shears *et al.* 2006). This methodology is also used in coral environments to study invertebrates, fishes and substrates worldwide in the Reef Check protocol (Ferreira & Maida 2006) but counting crabs has not a well-established methodology.

Brachyuran crabs are important food items for both reef fishes that are of economic interest and for top chain fishes such as whiting and groupers (Dubiaski-Silva & Masunari 2008, Machado *et al.* 2008). The diets of other invertebrates, such as octopuses, are also based on brachyuran crabs (Leite *et al.* 2009). Crabs have a wide range of feeding habits; many species are detritivores, recycling organic matter up to higher levels of the food chains. Moreover, they are one of the main predators of phytal ecosystems (Dubiaski-Silva & Masunari 2008). The production of planktonic larvae also couple crabs with the pelagic habitat. Due to all these interactions with the demersal and pelagic habitats, local repetitions of crabs counting are useful for the ecosystem monitoring in marine protected areas.

The aim of this study was to quantify the brachyuran crabs at the rocky bottom of Santa Catarina's coastal islands using the non-destructive methodology of visual census in two consecutive summers. We discuss the method ´s power and its viability for monitoring actions in marine protected areas.

## Materials and Methods

*Study area*

This research was conducted at five coastal islands located along the shelf that connects two major adjacent areas of the Brazilian coast, namely, the 'South Brazilian Shelf' and the 'South Brazilian Bight' (Pimenta *et al.* 2004). All of the islands are situated within a 73 km range and their names and locations are as follows: Arvoredo (27º17'S 48º23'W), Galés (27º10'38"S 48º25'02"W), Deserta (27º16'23"S 48º19'53"W), Campeche (27º42'03"S 48º27'57"W) and Moleques do Sul (27º51'S 48º26'W) (Fig. 1). During spring and summer, there is an upwelling of the cold South Atlantic Central Water (SACW) along the Santa Catarina inner shelf that originates at the Subtropical Convergence, while tropical warm waters dominate at the surface (Carvalho *et al.* 1998). The region is considered a faunal transition zone; there is a certain affinity between decapods species from the Argentinean coast up to 23º S along the central Brazilian coast (Boschi 2000). However the survival of the tropical species can be compromised during harsh years with very low temperatures (Barneche *et al.* 2009).

The islands Arvoredo, Galés and Deserta are inside the Arvoredo Marine Biological Reserve (AMBR). The AMBR was established in 1990, has an area of 17,600 hectares and is located 11 km off the coast. Apart from the southern area, Arvoredo Island is a no-take Marine Protected Area (MPA). The reserve is under great pressure, both by lobbying for the right to conduct underwater tourism and from illegal fisheries. Campeche Island is located 1.7 km from the island of Santa Catarina and is approximately 50 hectares in area. The emerged area has been designated an archaeological heritage site by the Institute for Historical and Artistic Heritage (IPHAN). However, there are no local fishing restrictions, although the island is within the Right Whale Marine Protected Area. The Moleques do Sul Archipelago is located 12 km from the island of Santa Catarina, within the range of the Serra do Tabuleiro State Park. There are no restrictions on utilization of the submerged area. The biological habitats at the shallow rocky bottoms are typical of moderately exposed sites along the southern Atlantic shore, with many patches of gravel and sandy sediments extending down in soft slopes to depths of 20 m (Oliveira *et al.* 2008).

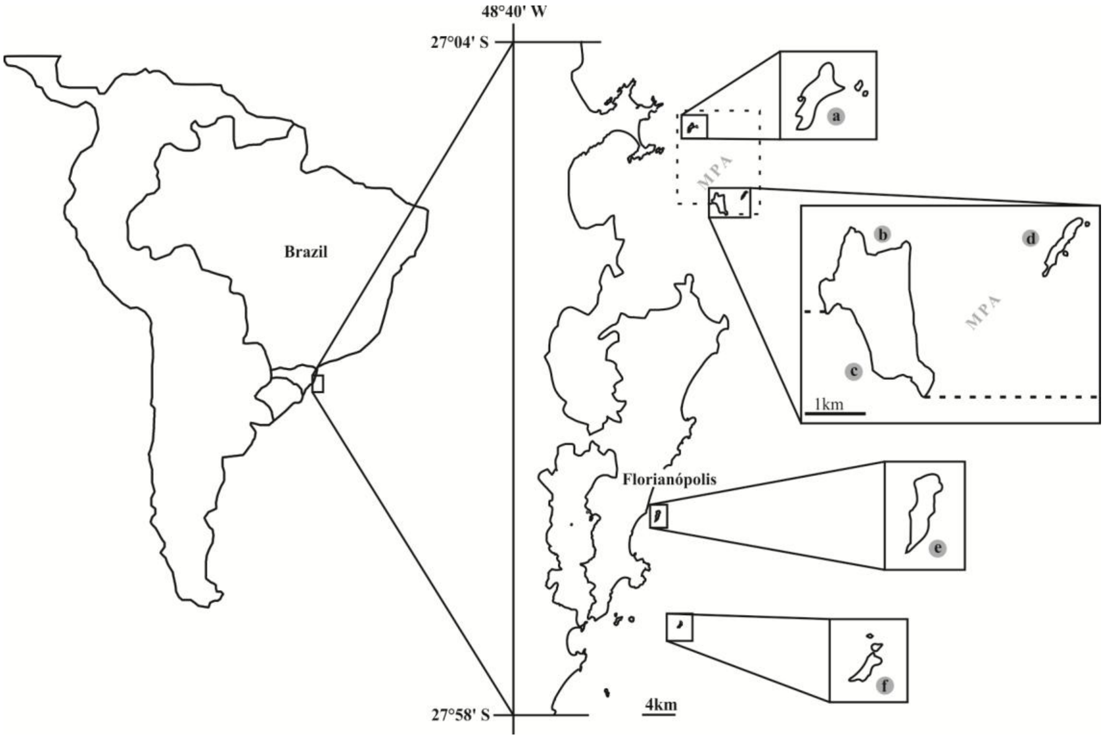


**Figure 1**. Study area showing the six sites at Southern Brazilian coast. a) Galés Island, b) Saco d'água and c) Baia do Engenho in Arvoredo Island d) Deserta Island, e) Campeche Island, f) Moleques do Sul Island. MPA = Marine Protected Area.

*Experimental design and data analysis*

Visual censuses were conducted by scuba diving during the summer, when weather conditions allow underwater field work, in 2008 (January to April) and 2009 (January to March), at six sampling points (Fig.1). The sampling sites were: Deserta, Galés, Saco d'água (27º16'27"S 48º22'01"W) and Baia do Engenho (27º17'36"S 48º22'02"W) (both at Arvoredo Island), Campeche and Moleques do Sul. Crabs larger than 15 mm of carapaces width (CW) were actively sought in small crevices and under rocks in a square of 4 m² by two divers. Eight squares were randomly sampled at two depths; between 5 and 10 meters and deeper than 10 meters. The >10 meters depth at Baia do Engenho in 2008 and Moleques do Sul in 2009 were not sampled due to logistic problems. Considering the need to optimize the sampling time underwater, the data for crab abundance and dominant species abundance were analyzed using the ***t*** test in order to verify differences between depths. Where no significant difference were detected between depths, we applied a two-way analysis of variance (ANOVA) to detect differences in crab abundance and dominant species between sites (n = 6) and years (n = 2). If significant differences between depths were detected, the two-way ANOVA was performed for depth (n = 2) against site (n = 6 or 5) for each year. The Tukey test was applied *a posteriori*. The Bartlett test was applied *a priori* and data were log-transformed (x +1) in order to fulfil the assumptions for ANOVA (Zar 1996).

## Results

Seven species were recorded: *Stenorhynchus seticornis* (Herbst, 1788), *Mithraculus forceps* (A. Milne-Edwards, 1875), *Mithrax hispidus* (Herbst, 1790), *Mithrax tortugae* Rathbun, 1920, *Menippe nodifrons* Stimpson, 1859, *Cronius ruber* (Lamarck, 1818) and *Platypodiella spectabilis* (Herbst, 1794). *S.seticornis* and *M. forceps* were the dominant species in both years; the other species contributed with less than 5 % of crabs, *P. spectabilis* was registered only once in 2009 (Table I).

**Table I**. Total abundance (n°. ind. $4m^{-2}$), percentage of abundance (%), abundance mean and standard deviation (SD) of crab species in 2008 and 2009.

| | *S. seticornis* | *M. forceps* | *M. tortugae* | *M. hispidus* | *M. nodifrons* | *C.ruber* | Total |
|---|---|---|---|---|---|---|---|
| **2008** | | | | | | | |
| Total | 341 | 152 | 17 | 6 | 1 | 1 | 518 |
| % | 66 | 29 | 3 | 1 | < 1 | < 1 | |
| Mean | 4.45 | 2.02 | 0.19 | 0.10 | 0.01 | 0.02 | 6.79 |
| SD | 2.09 | 1.80 | 0.26 | 0.31 | 0.11 | 0.12 | 2.41 |
| **2009** | | | | | | | |
| Total | 219 | 354 | 11 | 5 | 2 | 5 | 596 |
| % | 37 | 59 | 2 | 1 | < 1 | 1 | |
| Mean | 2.74 | 4.43 | 0.14 | 0.06 | 0.03 | 0.06 | 7.45 |
| SD | 1.35 | 1.83 | 0.35 | 0.25 | 0.15 | 0.20 | 3.25 |

*S. seticornis* was dominant in Deserta and Campeche Islands in both years, Baia do Engenho and Moleques do Sul Island in 2008, while *M. forceps* was dominant in Saco d´Água in both years and in Gales Island in 2009 (Table II).

**Table II**. Relative abundance (%) of *S. seticornis* and *M. forceps* in the six sites in 2008 and 2009.

| Site | Species | 2008 | 2009 |
|---|---|---|---|
| Deserta | *S. seticornis* | 41 | 67 |
| | *M. forceps* | 25 | 30 |
| Galés | *S. seticornis* | 53 | 8 |
| | *M. forceps* | 43 | 91 |
| Campeche | *S. seticornis* | 88 | 79 |
| | *M. forceps* | 11 | 17 |
| Saco d´água | *S. seticornis* | 29 | 30 |
| | *M. forceps* | 71 | 64 |
| Baia do Engenho | *S. seticornis* | 52 | 47 |
| | *M. forceps* | 19 | 49 |
| Moleques do sul | *S. seticornis* | 65 | |
| | *M. forceps* | 26 | |

Abundance of total crabs was slightly higher in 2009, unless in Campeche Island (Fig. 2), due to the raised counts of *S. seticornis*. There was no significant differences ($p < 0.01$) in total crab and *S. seticornis* between the two depth strata (Table III) and the analysis of variance conducted with total crabs and *S. seticornis* showed an interaction of years and sites (Tab. III) for both. This interaction was also explained by the high numbers of *S. seticornis* in Campeche Island. The less common species *M.hispidus*, *M. nodifrons* and *C. ruber* were equally distributed in the two depths, years and sites (Table III) and *Mithrax tortugae* was significantly more abundant at Campeche and Galés islands.

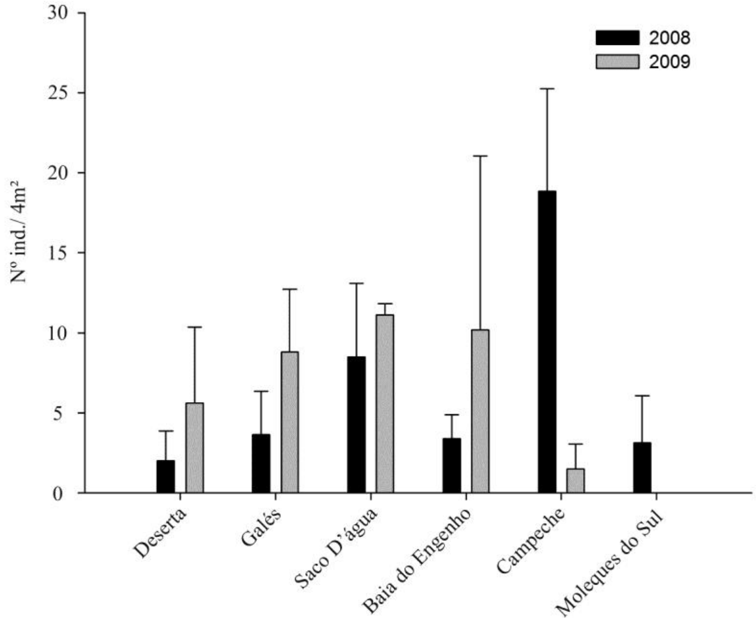


**Figure 2**. Abundance (mean ± sd) of crabs in the two depths (5- 10 m and > 10 m) at the six sites sampled in 2008 and 2009.

**Table III.** Results of ***t*** test between 5-10 m and > 10 m sampling and the two-way ANOVA to test the effects of factors year and site and their interaction on crab species abundance, showing F values. * p < 0.01; ns non significant. Error degrees of freedom ANOVA: 150

| | ***t*** test | two-way ANOVA | | |
|---|---|---|---|---|
| | Depth | Year | Site | Year x Site |
| Degrees of freedom | 158 | 1 | 4 | 4 |
| Total crabs | 1.2ns | 6.9* | 5.2* | 17.8* |
| *Stenorhynchus seticornis* | 0.4ns | 1.2ns | 13.7* | 34.7* |
| *Mithraculus forceps* | 2.3* | -- | -- | -- |
| *Mithrax tortugae* | 0.7ns | 1.7ns | 4.3*1 | 2.2ns |
| *Mithrax hispidus* | 0.4ns | 0.0ns | 2.4ns | 2.2ns |
| *Menippe nodifrons* | 0.6ns | 0.3ns | 1.4ns | 2.1ns |
| *Cronius ruber* | 0.8ns | 2.1ns | 0.8ns | 0.8ns |

(1) Tukey test: Campeche = Galés < Deserta = Saco D´água = Baia do Engenho.

*Mithraculus forceps* was significantly more abundant at 5-10 m depth (Table III) and was analyzed separately. Their counts were very high at 5-10 m depth in Campeche Island in 2008 (Fig. 3) and in Baia do Engenho in 2009 (Fig. 4) compared to depths greater than 10 m at the same site. These peak values in the shallow depth explained the significant interaction between depth and site for both years (Table IV), since in the other sites, abundance was similar or slightly higher in the shallow.

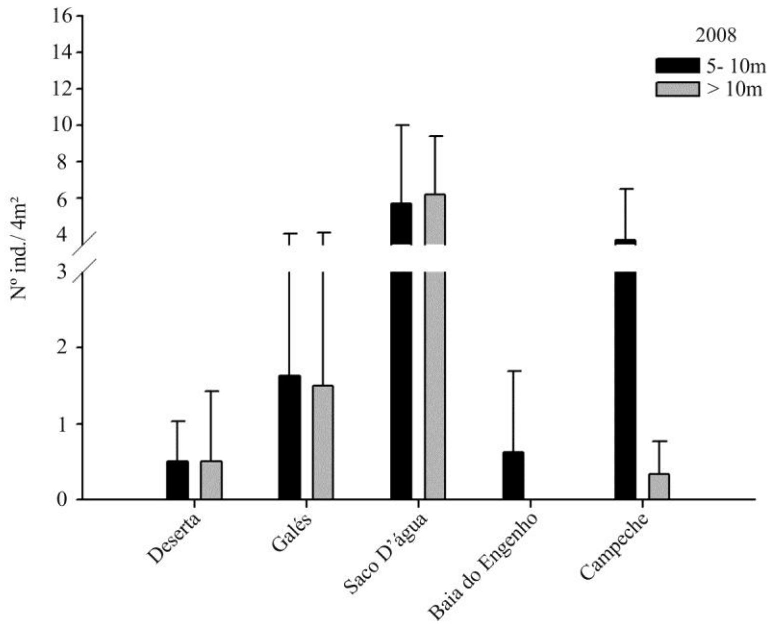


**Figure 3.** Abundance (mean ± sd) of *Mithraculus forceps* by site in 2008 at depths of 5-10 m and >10 m.

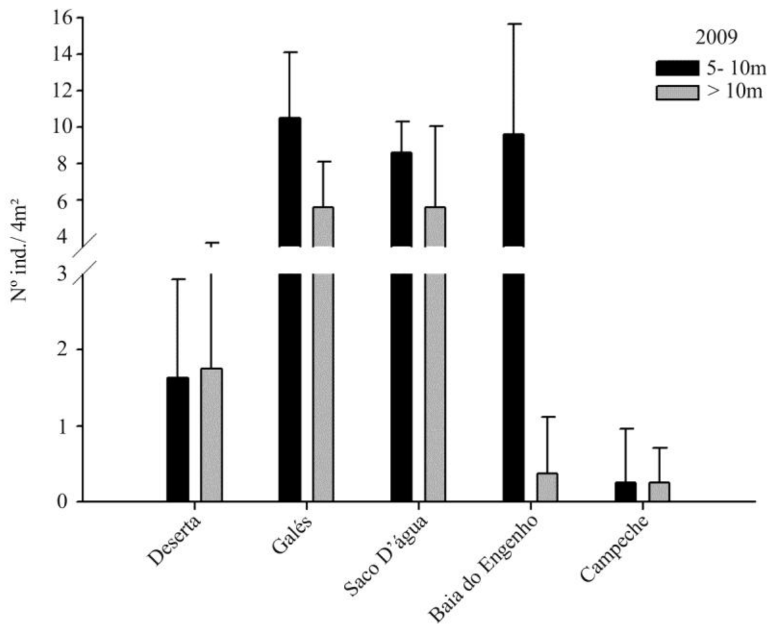


**Figure 4.** Abundance (mean ± sd) of *Mithraculus forceps* by site in 2009 at depths of 5-10 m and >10 m.

**Discussion**

Using the visual census method, we observed just seven of the 25 species recorded in the previous faunal survey conducted in 2002 (Bouzon & Freire 2007). The previous survey was conducted with manual capture and also corer samples of the sediment in the boundary rocky/sandy bottom, which enabled the capture of small crabs from 0.78 to 18.00 mm of carapace width (CW) that are very difficult to sight. It means that the visual census alone does not fit for crab surveys. However the results for counting crabs are promising since the dominant species *Mithraculus forceps* and/or *Stenorhyncus seticornis* were the same in other works that used different sampling methodology as corer samples in Silva-Karam (2008) and manual capture in Alves (2009).

**Table IV.** ANOVA results for *Mithraculus forceps* in 2008 (without Baia do Engenho) and 2009 (with Baia do Engenho), showing F values. * p<0.01

| | 2008 | | | 2009 | | |
|---|---|---|---|---|---|---|
| | Depth | Site | Interaction | Depth | Site | Interaction |
| *Mithraculus forceps* | 4.6* | 17.0* | 2.8* | 25.7* | 39.4* | 9.0* |

The dominance of these two species in the subtidal rocky bottom of Brazilian south and south-eastern coast seems to be a pattern. The continuous reproductive periods of *M. forceps* (Mantelatto *et al*. 2003) and *S. seticornis* (Okamori & Cobo 2003, Teixeira 2010) provide the foundation for their dominance. The difference in methodology limits the assessment of abundance comparison. Only proportional data is available in Alves (2009) and Teixeira (2010) that used the number of crabs/time spent diving as the effort unit. Abundance of *M. forceps* captured in an 850 $m^2$ area (Mantelatto *et al*. 2003) are much lower than the present work probably due to the difficulty to make a detailed search in a big area (Table V). Besides, corer and rodolith samples abundance in the calcareous bed are much higher than our results (Table V), probably due to the availability of the rodolith as microhabitats for the benthic species (Blankensteyn *et al*. 2003) and to the capture of crabs smaller than 15 mm of CW.

**Table V.** Abundance of *Mithraculus forceps* using varying methods.

| Site | Methodology | Abundance (ind.4$m^{-2}$) | Reference |
|---|---|---|---|
| Anchieta Island | Manual capture | 0.014 to 0.061 | Mantelatto *et al*. 2003 |
| Arvoredo Island (calcareous algal bed) | Corer samples<br>Rodolith samples | 220 to 444<br>40 to 240 | Bouzon 2002<br>Silva-Karam 2008 |
| Arvoredo Reserve (4 sites) | Visual samples | 0.25 to 10.5 | Present study |

The facts that *S. seticornis* was equally distributed in both depth layers and that *M. forceps* was more abundant at 5-10 meters indicate that future visual census could concentrate at depths of less than 10 meters to optimize underwater time. *M. forceps* and *S .seticornis* shifted their dominance in sites and years, but some sites seemed to have better conditions for crabs, as Campeche Island, Baia do Engenho at Arvoredo Island, outside of the AMBR and Galés Island inside the AMBR, where *Mithrax tortugae* was also concentrated. Coverage of sessile zoobenthos and macroalgae in the islands also exhibited great variability between the same sites (Bouzon 2011). Besides, another crab sampling within a range of just 3.8 km at Victoria Island suggested that even in a restricted area there are specific structures and dynamics in the crab community (Alves 2009). Therefore, further crab census should include studies of the degree of spatial bottom heterogeneity, biological interaction and plankton-benthos coupling to explain adult crab abundance variability.

Visual census seems to be a good option to access the occurrence of the dominant species *M. forceps* and *S. seticornis* without disturbing the environment and should concentrate at depths of less than 10 meters. Sampling should be continued at Campeche Island, Galés Island and Baia do Engenho to access the factors causing the interannual variability. Sustained repetition of visual census analyses at the Arvoredo area will demonstrate the method's power.

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