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THE SEA URCHIN *ECHINOMETRA LUCUNTER* (ECHINODERMATA, ECHINOIDEA) AS A REFUGE FOR THE BARBER GOBY *ELACATINUS FIGARO* (PERCIFORMES, GOBIIDAE)[1]

(With 3 figures)

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ABSTRACT: *Elacatinus* are small bright colored reef fish that have the habit of cleaning fishes and invertebrates. *Elacatinus figaro* are often found near the sea urchin *Echinometra lucunter*, suggesting a possible relationship between them. The addressed questions of this study are: (1) is the territory occupied by *E. figaro* related to the proximity of *E. lucunter*?; (2) does *E. figaro* show a refuge preference for *E. lucunter* spines?; and (3) are the densities of the two organisms correlated in the studied rocky reefs? Quadrats (1.0m^2) were randomly sampled in three rocky reefs in Arraial do Cabo, RJ, Brazil. Before placing each quadrat on the substrate, the distances between each of the 89 *E. figaro* individuals observed and their nearest urchins were registered. While placing each quadrat, the escape behavior and the chosen refuge were observed. Furthermore, the densities of *E. lucunter* and *E. figaro* in each quadrat were quantified. From all observed *E. figaro*, around 57% were inside the perimeter of the urchins' spines, 21% were less than 10cm far from them, 17% were between 10cm and 20cm away from them and less than 5% were more than 20cm away from the urchins. Most of the *E. figaro* (around 95%) that were out of the urchins spines' perimeter promptly moved to the nearest urchin during the quadrat location. A positive correlation was observed between the densities of *E. lucunter* and *E. figaro*, suggesting a strict association between them, probably due to the use of the spines of the sea urchin as a refuge by this goby.

Key words: Micro-habitat. Spatial distribution. Reef fish. Arraial do Cabo. Conservation.

RESUMO: O ouriço *Echinometra lucunter* (Echinodermata, Echinoidea) como refúgio para o gobiídeo *Elacatinus figaro* (Perciformes, Gobiidae).
Elacatinus são pequenos peixes recifais de colorido brilhante que possuem hábito de limpar peixes e invertebrados. *Elacatinus figaro* são freqüentemente encontrados junto aos ouriços *Echinometra lucunter*, sugerindo uma possível relação entre eles. As questões abordadas no presente estudo são: (1) o território ocupado por *E. figaro* está relacionado à proximidade com *E. lucunter*?; (2) *E. figaro* mostra preferência de refúgio pelos espinhos de *E. lucunter*?; e (3) as densidades dos dois organismos estão correlacionadas nos recifes estudados? Quadrados (1.0m^2) foram aleatoriamente amostrados em três costões rochosos em Arraial do Cabo, RJ, Brasil. Antes do posicionamento de cada quadrado no substrato, a distância entre cada um dos 89 indivíduos de *E. figaro* observados e o ouriço mais próximo foi registrada. Durante a colocação de cada quadrado, o comportamento de fuga e o refúgio escolhido foram observados. Além disso, foram quantificadas as densidades de *E. lucunter* e de *E. figaro* em cada quadrado. Do total de *E. figaro* observados, aproximadamente 57% estavam dentro do perímetro dos espinhos do ouriço, 21% estavam a menos de 10cm de distância, 17% estavam entre 10cm e 20cm de distância, e menos de 5% a mais de 20cm de distância dos ouriços. A maioria dos *E. figaro* (aproximadamente 95%) que não se encontravam no perímetro dos espinhos do ouriço se deslocaram rapidamente para o ouriço mais próximo durante a colocação do quadrado. Uma correlação positiva foi observada entre as densidades de *E. lucunter* e *E. figaro*, sugerindo uma associação entre eles, provavelmente devido à utilização dos espinhos do ouriço como refúgio por este gobiídeo.

Palavras chave: Micro hábitat. Distribuição espacial. Peixes recifais. Arraial do Cabo. Conservação.

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INTRODUCTION

Gobiidae is the largest teleost family, with a worldwide distribution (NELSON, 2006). The gobiid genus *Elacatinus* Jordan, 1904 has 33 valid species, 25 of which distributed in the tropical western North Atlantic (COLIN, 2010) and three of which originally described for the Brazilian Coast: *Elacatinus figaro* Sazima, Moura & Rosa, 1997, *E. pridisi* Guimarães, Gasparini & Rocha, 2004, and *E. phthirophagus* Sazima, Carvalho-Filho & Sazima, 2008. *Elacatinus* are small reef inhabitants that feed mainly on parasites by engaging in cleaning symbiosis with other fish and invertebrates (JOHNSON, 1982; PEZOLD, 1993, SAZIMA & MOURA, 2000).

Some *Elacatinus* species use sponges, coral heads, chiton burrows and limestone encrusted with coralline red algae as microhabitats (TAYLOR & VAN TASSELL, 2002). However, there are very few studies showing exactly how those reef microhabitats are used (GREENFIELD & JOHNSON, 1999; LEVENBACH, 2008). Understanding microhabitat use by gobies can provide critical insights into how high goby diversity is maintained in coral reefs and may also reveal clues to processes leading to the origin of those species (TAYLOR & VAN TASSELL, 2002). In addition, the preservation of these cleaners may greatly help the conservation of reef ecosystems (LIMBAUGH, 1961; POULIN & GRUTTER, 1996; GRUTTER *et al.*, 2003), since the removal of disease causing ectoparasites can have significant impacts on the fitness of their hosts (CUSACK & CONE, 1986; POULIN & GRUTTER, 1996), through decreased reproductive output (ADLARD & LESTER, 1995; MØLLER *et al.*, 1999), increased predation on weakened hosts (LAFFERTY & MORRIS, 1996), and deleterious behavioral effects (POULIN, 1994). Also, these cleaners have strong influence on the movement patterns, habitat choice, activity, local diversity and abundance of a wide variety of reef fish species (GRUTTER, *et al.*, 2003).

Some authors (PATZNER, 1999; ALVARADO, 2008) observed that sea urchin aggregations were used as a refuge by several fish species and HARTNEY & GRORUD (2002) observed a very strict relation between the goby *Lythrypnus dalli* (Gilbert, 1890) and the sea urchin *Centrostephanus coronatus* (Verrill, 1867) at a Californian island. Some reports about the habitat of *E. figaro* and a first report of a possible relation between *E. figaro* and *Echinometra lucunter* have been made by SAZIMA *et al.* (2000).

The objective of this study is to verify whether (1) the territory occupied by the goby *E. figaro* is related to *E. lucunter* proximity; (2) *E. figaro* shows a refuge preference for *E. lucunter* spines and (3) the densities of *E. lucunter* and *E. figaro* are correlated in the studied rocky reefs. Additionally, conservation notes based on the present and reported results are made.

MATERIAL AND METHODS

The study took place at Arraial do Cabo (Rio de Janeiro), a small rocky cape in southeast Brazil (22°57' S, 42°01' W) under the influence of an upwelling that creates a strong temperature gradient and a high primary production due to increased nutrient concentration (VALENTIN, 1974). Arraial do Cabo is biogeographically important because it represents the southern limit of many tropical marine species (YONESHIGUE & VALENTIN, 1988; CASTRO *et al.*, 1995), including fishes (BRIGGS, 1974; MOYLE & CECH JR., 1982; MENNI, 1983).

Three rocky reefs with differences in topographic complexity and hydrodynamic exposure (CALDERON *et al.*, 2007; CALDERON, 2008) were chosen for this study (Fig.1): a) Ponta D'água (PD) which is situated in a small open bay and has an intermediate topographic complexity and moderate hydrodynamic exposure (CALDERON, 2008); b) the southwest part of Ilha dos Porcos island (IP) has an intermediate topographic complexity and low hydrodynamic exposure (CALDERON *et al.*, 2007; CALDERON, 2008); c) Saco do Cherne (SC) is located outside the cape, has a lower degree of topographic complexity (mostly a vertical rock wall) and a high level of hydrodynamic exposure (CALDERON *et al.*, 2007; CALDERON, 2008) (Fig.1).

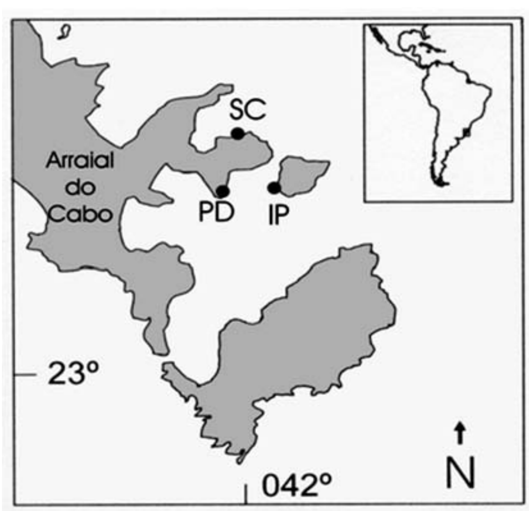

Fig.1- Map of Arraial do Cabo, RJ, Brazil. Studied sites marked with dots. SC, Saco do Cherne; PD, Ponta D'água; IP, Ilha dos Porcos.

The densities of *Elacatinus figaro* and *Echinometra lucunter* were quantified through *in situ* observations by SCUBA diving. At each reef, 15 to 21 one square meter quadrats were randomly placed along transects at depths ranging from four to seven meters and the numbers of *E. lucunter* and *E. figaro* individuals in each one were registered. In order to randomize the quadrat placement along transects, the numbers referring to the meters along the transect were haphazardly selected on the boat before each scuba dive.

Before placing each quadrat frame over the hard substrate, landscape marks were taken at the substrate surfaces based on its morphology and sessile organisms (*e. g.* algae, or sessile invertebrates) where each *E. figaro* was seen. The landscape marks were taken from a secure distance (around 1.5-2m) to ensure that the fish were observed prior to their escape move. After the approach, the distances between each landscape mark and the nearest *E. lucunter* were registered.

Up to a 1.5 meter distance, the fish did not show any sign of disturbance in response to the divers' presence. Four distance classes between gobies and sea urchins were established: a) inside the perimeter of the sea urchin spines (0); b) less than or equal to 10cm distance (<10); c) less than or equal to 20cm distance (<20); d) over 20cm distance (>20). During placement of the quadrat on the substratum, the escape behavior and the chosen refuge of each *E. figaro* were recorded.

Linear correlations were performed to test the relationship between the densities of *E. figaro* and *E. lucunter* in IP and PD. The densities of *E. lucunter* among sites were compared with a Welch ANOVA (Lomax, 2007), as data were not homocedastic (Levene's test; Levene, 1960), followed by a Games-Howell post hoc test (Lomax, 2007). The densities of *E. figaro* among IP and PD were compared with a T Test after log transformation (Sokal & Rohlf, 1995).

RESULTS

One of the locations (SC) was marked by a lower density of the two organisms, with the presence of only one *E. figaro* individual, found inside the perimeter of the spines of an *E. lucunter*. In the two other sampled rocky reefs, a total of 88 *E. figaro* were observed. Most fish were inside or very close to the perimeter of the urchins' spines (Fig.2).

Elacatinus figaro was mainly observed using *Echinometra lucunter* as a refuge. Furthermore, 95% (36 out of 38) of the fish that were not inside the perimeter of the urchins spines promptly moved to the nearest urchin during the placement of the quadrat on the substrate. The only two *E. figaro* individuals that did not seek refuge in *E. lucunter* moved to different areas of refuge: one swam to crevices in the substrate, and the other quickly moved to different areas on the rocky substrate with short and erratic movements, however keeping around the initial point.

Densities of *E. figaro* and *E. lucunter* were highly correlated at PD ($r=0.780$; $N=20$; $P<0.0001$; Fig.3) but not at IP ($r=0.144$; $N=21$; $p=0.5335$). Densities of *E. figaro* differed significantly among IP and PD ($t=2.832$; $df=39$; $p<0.01$). The largest density was observed at IP ($2.95\pm0.71m^2$; mean±standard error) followed by PD with an intermediate density ($1.30\pm0.56m^2$) and finally SC, with just one individual being observed. A similar distribution pattern was observed for *E. lucunter* (Welch ANOVA; $F=24.820$; $df=55$; $p<0.0001$), showing a higher density at IP ($14.42\pm1.30m^2$), followed by PD ($5.05\pm1.03m^2$) and SC ($2.53\pm0.85m^2$). Parwise Game-Howell post tests showed were significant differences in *E. lucunter* densities of IP and PD (1.75; $P<0.0001$) and between IP and SC (2.495; $P<0.0001$), but were not significant between PD and SC.

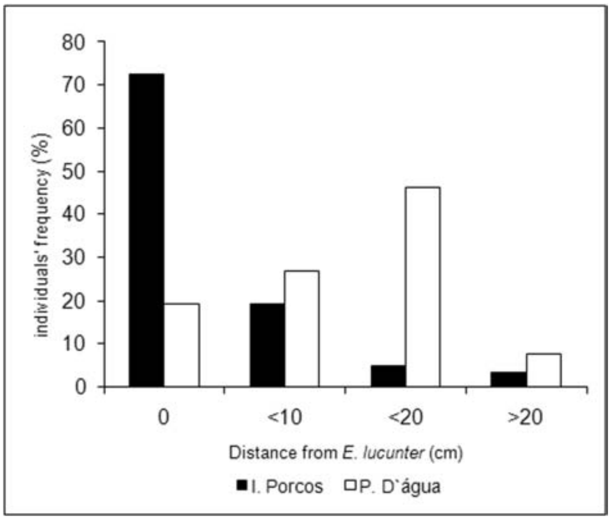

Fig.2- Categorized distances between *E. figaro* and the nearest *E. lucunter* in proportion to the total number of observed individuals in IP (Ilha dos Porcos; N=62) and PD (Ponta D'água; N=26).

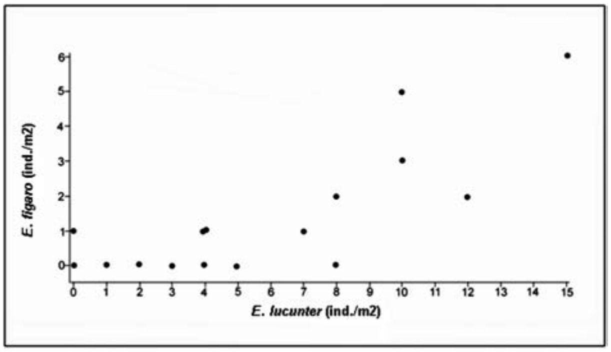

Fig.3- Correlation between densities of *E. figaro* and *E. lucunter* in PD, Ponta D´água (r=0.780); N=20; P<0.0001).

DISCUSSION

The main observation of this work was the close association between the goby *Elacatinus figaro* and the sea urchin *Echinometra lucunter* in the reefs of Southeast Brazil. The main evidences of that association were the strong correlation between the population densities of the two species, the spatial distribution of the gobiid in relation to the position of the urchins, and the clear escape behavior displayed by the fish, which almost invariably sought refuge amidst the urchin's spines. Our results statistically corroborate the observations made by Sazima *et al.* (2000) who also registered that barber gobies were frequently sheltering under urchins. Many fishes on coral reefs are known to associate with particular microhabitats (Munday *et al.*, 1997) and are capable of selecting them even at the time of settlement (Jones, 1984a; Breitburg, 1991; Levin, 1991; Carr, 1994) or may relocate to them later on (Jones, 1984b; Levin 1994; Ault & Johnson, 1998). However, little attention has been paid to the use of organisms as refuges, despite their potential for maintaining species diversity and supporting higher trophic levels (Levenbach, 2008). The results show that most *E. figaro* keep very close to *E. lucunter*, since most of them were found inside the perimeter of the urchins' spines (around 57%) and only 4 individuals (less than 5%) were further than 20cm away from the urchin. According to these results, a close relationship between these two organisms is evidenced.

Habitat structure can mediate predation effects by supplying refuges, which can be a significant determinant of reef fish abundance on local scales (Carr & Hixon, 1995; Beets, 1997; Steele, 1999; Anderson, 2001). Consequently, it is possible that the main cause of the strong fish-urchin association observed here is the protection conferred by the urchins' spines to the goby.

Six other sea urchin species are found in the Arraial do Cabo rocky reefs: *Arbacia lixula* (Linnaeus, 1758), *Diadema antillarum* (Philippi, 1845), *Eucidaris tribuloides* (Lamarck, 1816), *Lytechinus variegates* (Lamarck, 1816), *Paracentrotus gaimardi* (Blainville, 1825), *Tripneustes ventricosus* (Lamarck, 1816) (Tommasi, 1966; Castro *et al.*, 1995; Smith, 2005), all of which might potentially be used as refuges by *E. figaro.* During our underwater sampling, two of those species, *L. variegatus* and *P. gaimardi*, were observed alongside *E. lucunter* at the three rocky reefs. However, *E. figaro* was only found close or inside *E. lucunter*'s spines perimeter, demonstrating the specificity of the relationship. This may be related to spine size, since spines of *L. variegatus* and of *P. gaimardi* are shorter than those of *E. lucunter* (Smith, 2005; Lawrence, 2007), so that the size and the space among their spines may not be enough to protect the goby from predators. The same specificity between *Elacatinus* and *Echinometra* was found in other sites along the Brazilian coast, like Ilhabela (São Paulo State), Ilha Grande, Cabo Frio and Rio de Janeiro (Rio de Janeiro State) (personal observations). A similar correlation between spine size and usefulness as a refuge was observed for the relationship between the goby *Lythrypnus dalli* (Gilbert, 1890) and the urchin *C. coronatus* (Hartney & Grorud, 2002).

Densities of *Elacatinus figaro* and *Echinometra lucunter* were highly correlated, except at IP, where *E. figaro* did not follow the density increase of *E. lucunter.* At that site there was an extremely high density of *E. lucunter* (more than twice that of PD and tree times that of SC). It is possible that the refuge availability (*i.e. E. lucunter* density) may be not a restrictive factor influencing the maximum density of *E. figaro* at IP so that other factors, like food availability, territorialism and/or interactions with other species may be prominent in determining its densities, once the refuge is no longer a limiting factor. Another factor to be considered is the size of sample quadrat. It is possible that the use of a different quadrat size could have shown the relationship between these two organisms at IP. Thus, the lack of correlation in IP may be due to the spatial scale considered ($1m^2$).

Our results support those of Sammarco (1982) and Hartney & Grorud (2002) on the direct positive effects of a sea urchin on the local abundance of specific reef fish, with a very important ecological role for habitat structure. This view is at odds with the usual view of sea urchins as destructive grazers of reef communities (LAWRENCE, 1975; DAYTON, 1985; SCHIEL & FOSTER, 1986; JONES & ANDREW, 1990).

Cleaner fishes may increase fish diversity on reefs (GRUTTER, *et al.*, 2003). Also, since some fish travel long distances to be cleaned, the cleaners' effects may extend much further than the vicinity of the reef (RANDALL, 1958; GRUTTER, *et al.*, 2003) making *E. figaro* an important species for the conservation of many fish species and the reef environment. SAZIMA *et al.* (2000) reported a large number of species being cleaned by *E. figaro* in the southeast Atlantic coasts, including among them, commercial fishes with great value for the aquarium trade and fisheries. The fact that this goby is one of the main specialized cleaners at Brazilian costal reefs (SAZIMA *et al.*, 1999; TAYLOR & HELLBERG, 2005), allied with the observations that *E. lucunter* is used as a refuge by *E. figaro* makes these two species extremely important for reef fish conservation.

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