

Population patterns and seasonal observations on density and distribution of *Holothuria grisea* (Holothuroidea:Aspidochirotida) on the Santa Catarina Coast, Brazil

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Abstract

Seasonal population patterns of *Holothuria grisea* — the most abundant sea cucumber species on the Brazilian coast — were examined on intertidal areas in Armação do Itapocoroy Bay in southern Brazil during the winter and spring of 2003, and the summer and autumn of 2004. The study area was divided into three strata, which were defined by tide level: upper intertidal (stratum 1), lower intertidal (stratum 2) and subtidal (stratum 3). This study showed that *H. grisea* occurred more densely in subtidal stratum over all seasons, except autumn when the density was equal between subtidal and intertidal strata. Specimens were found to have an aggregated distribution pattern, but this pattern was limited to rocky sea bottoms, and this species seems to be adapted to areas with high rugosity. Finally, tide level variation seems to determine density patterns.

Introduction

Aspidochirotida are found in the intertidal zone down to the deepest trenches where, they may comprise up to 90% of the total biomass (Pawson 1970; Hendler et al. 1995; Hadel et al. 1999).

Although *Holothuria grisea* (Holothuriidae) are not commercialized in Brazil, they are the most abundant species along the Brazilian coast (Tommasi 1969) and have been consumed (in small quantities) in São Paulo State (Hadel et al. 1999) as well as in Rio de Janeiro State along with the sea cucumber, *Isostichopus badionotus* (Hadel et al. 1999; Lima et al. 2001).

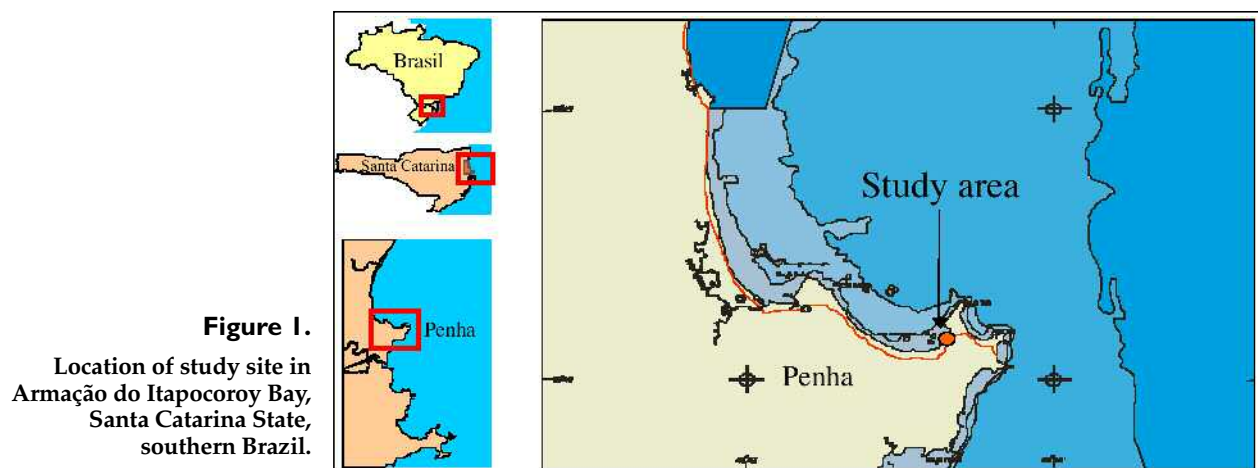
Thus, *H. grisea* could play an important role in the Brazilian economy as a new seafood resource, although few studies on this subject in Brazil have

been conducted (Lima et al. 2001). It is, therefore, important to understand the ecology and biology of this species. This study attempts to understand the density and distribution patterns of *H. grisea* along the southern Brazilian coast.

Methods

Study location

Armação do Itapocoroy Bay is in Penha (Fig. 1), on the north-central coast of Santa Catarina State in southern Brazil (26°46'10" S and 48°49'10" W). This bay is sheltered from strong southerly winds, and is exposed to easterly and northeasterly winds, the latter two being the most frequent in the area. The site is an area of low-energy wave action, gently sloping bedrock, and a sandy substrate consisting of coarse grain-sized sediment.



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The study site is an area of 1200 m² (20 m X 60 m) and is divided into three strata defined by tide level: upper intertidal (inner – stratum 1), lower intertidal (middle – stratum 2) and subtidal (outer – stratum 3), following the classification proposed by Holme and McIntyre (1971). Each stratum is 400 m² (20 m X 20 m).

Density and spatial distribution

The seasonal variation in *H. grisea* density was determined during winter and spring 2003, and summer and autumn 2004. In each stratum *H. grisea* were counted in one-meter-square (1 m²) quadrats, and 25 quadrats per stratum, per season (n = 300) were recorded. In order to establish the spatial distribution, the standardized Morisita index (I_p) of animal dispersion and aggregation was used (Krebs 1989).

Rock covering and rugosity

To better understand *H. grisea* behavior, the percentage of rock cover was measured and recorded for each quadrat in order to relate the density and distribution of the holothurians with the amount and type of substratum.

Before counting the sea cucumbers, a quadrat was divided into four parts and the percentage rock cover was estimated visually, using a scale of 0–100% with intervals of 5%.

Rock rugosity was estimated by the rugosity index d (IRd), which is a variation of the chain link method³ (Luckhurst and Luckhurst 1978), where a chain with small links was laid on the substratum. In some quadrat recorders (n = 150), constituting 5 replicates of measures (border to border), the chain was positioned to follow the contours and crevices of the substratum as closely as possible. The mean ratios of quadrats length (stretched length) to contours length (border to border)(Rg) were used as a comparative index $IRd = [1 - (1/Rg)]$.

Data analysis

In order to test significant differences in seasonal and strata density, a parametric two-factor ANOVA (Underwood 2001) was used. Data normality were verified using the Kolmogorov-Smirnov test and the homoscedasticity was tested using the Bartlett test and, when necessary, data were transformed using the square root of the density values (Zar 1984).

The absence of homogeneity in the variances was caused by the null results in stratum 1, which was subsequently excluded from the analysis. Due to the high number of samples (n = 300), the demand for normality becomes secondary to using parametric analysis (Underwood 2001).

Pearson's coefficient r (Legendre and Legendre 1998) was used to correlate the density of *H. grisea* in strata 2 (lower) and 3 (subtidal) with rock rugosity and rock covering.

Results

Density

The density values of *H. grisea* (Table 1) differed significantly between strata 2 (lower) and 3 (subtidal) ($F = 36.2373$; $p < 0.0001$) except in autumn (Fig. 2), when stratum 3 was the most abundant. Holothurian densities did not differ significantly between seasons ($F = 0.7798$; $p > 0.5$).

Table 1. Density of organisms (Dt m⁻²) in both strata over the year; EP is the standard error of the mean.

| | Stratum 2 | | Stratum 3 | |
|--------|-----------|------|-----------|------|
| | Dt | EP | Dt | EP |
| Winter | 3.32 | 1.34 | 8.04 | 1.51 |
| Spring | 3.48 | 1.44 | 7.12 | 1.58 |
| Summer | 1.60 | 0.91 | 6.68 | 1.41 |
| Fall | 3.80 | 1.25 | 4.40 | 0.74 |

Considering the season and the stratum, the two-factor ANOVA analysis showed no significant density difference during the year in strata 2 and 3 ($F = 1.5482$; $p = 0.2034$), however, analyzing each stratum separately, there was a significant density variation of *H. grisea* over the seasons when densities decreased in the stratum 2 during the summer and in stratum 3 during the autumn (Fig. 2).

Spatial distribution

The standardized Morisita index showed an aggregated spatial distribution ($I_p > 0.5$, when: $I_d > I_{mc} > 1$) on both strata during all seasons (Table 2), but highest aggregating values were always associated with the stratum 2.

3. The chain link method was proposed by Luckhurst and Luckhurst (1978) and is commonly used to determine rock complexity on reefs, where a chain with small links is laid on the substratum as closely as possible along a transect. Afterwards, an index was calculated by establishing the ratio between the contour length and the stretched length. This index, in conjunction with the number of holes and crevices counted along the transect, measures the rock complexity.

A significant ($p < 0.5$) positive linear relationship was found between the density of *H. grisea* and the amount of rock covering ($r = 0.411$; $n = 150$) (Fig. 3), and also between the density of *H. grisea* and rock rugosity ($r = 0.665$; $n = 150$) (Fig. 4). Nevertheless, the highest values of rock rugosity occurred in intermediate levels of rock covering as shown by a parabolic relationship between the rock covering and rock rugosity ($r = 0.844$; $n = 150$) (Fig. 5).

There were no differences in rock covering and rock rugosity between strata 2 and 3 (Table 3). The correlation ($p < 0.01$) found in stratum 3 between the *H. grisea* density and IRd ($r = 0.7837$; $n = 50$) was higher than the correlation ($p < 0.01$) found in stratum 2 ($r = 0.6818$; $n = 50$). No correlation ($p < 0.01$) was found between *H. grisea* density and rock covering in stratum 2 ($r = 0.3130$; $n = 50$), however, this correlation was observed in stratum 3 ($r = 0.8059$; $n = 50$) (Table 4).

Discussion

Contiguous strata are useful for determining absolute weights of any species, especially in microtidal areas. Each stratum, however, should be clearly defined to avoid confusing or mixing two or more different strata (Raffaelli and Hawkins 1996). Strata 2 (intertidal) and 3 (subtidal) in this study are clearly delineated.

To determine the density of *H. grisea* with a high degree of precision, it was necessary to record a high number of quadrats, due to its distribution pattern.

Pawson (1966) showed that holothurians are often aggregated. Thus, *H. grisea* in Armação do Itapocoroy Bay were found with the same distribution pattern, but this pattern was limited to rocky bottoms; in sandy bottom areas there was a low frequency of isolated specimens.

The highest holothurians densities were found in areas with high rock covering and in areas with high rugosity in Armação do Itapocoroy Bay. Specimens of *H. grisea* have cryptic behavior (Cutress 1996), and numerous tube feet that give a tenacious grip on hard substrates (Deichmann 1930; Hendler et al. 1995).

According to density correlations analyzed for rock rugosity and rock covering, *H. grisea* possess a strong correlation with rugosity. The highest rugosity values were found in intermediate levels of rock covering, suggesting that *H. grisea* live on rocks. However, the rock itself is not the most important factor affecting their density. Also important is a highly irregular bathymetry, with holes and crevices where *H. grisea* can find shelter and sediment with deposited organic matter.

Table 2. According to standardized Morisita index, $I_p > 0.5$ means an aggregated distribution when $I_d > M_c > 1$. How highest is the I_p value, more aggregated were the specimens

| | Stratum 2 | | | |
|-------|-----------|--------|--------|--------|
| | Winter | Spring | Summer | Autumn |
| I_d | 4.69 | 4.88 | 8.37 | 3.38 |
| M_c | 1.19 | 1.18 | 1.39 | 1.17 |
| I_p | 0.57 | 0.58 | 0.65 | 0.55 |
| | Stratum 3 | | | |
| | Winter | Spring | Summer | Autumn |
| I_d | 1.73 | 2.05 | 1.94 | 1.45 |
| M_c | 1.08 | 1.09 | 1.09 | 1.14 |
| I_p | 0.51 | 0.52 | 0.52 | 0.51 |

Table 3. Rugosity (IRd) and rock covering mean values with no significant difference between the two strata (EP = Standard error of the mean).

| | Rugosity | Rock covering |
|------------------|-----------------------|------------------------|
| | Mean (\pm EP) | Mean (\pm EP) |
| Stratum 2 | 0.044 (± 0.011) | 16.378 (± 4.531) |
| Stratum 3 | 0.049 (± 0.010) | 12.400 (± 3.458) |

Table 4. Correlation (Pearson's coefficient r) of *H. grisea* density in the strata 2 and 3 among the rock rugosity index d (IRd) and the rock covering (RC).

| | Correl IRd | Correl RC |
|------------------|------------------|-----------|
| | Stratum 2 | 0.68 |
| Stratum 3 | 0.78 | 0.81 |

Although Rogers-Bennett and Ono (2001) attributed the patchy distribution pattern of *Parastichopus californicus* without any apparent seasonal aggregating, spawning, or feeding behavior, Graham and Battaglione (2004) suspected long-term movement patterns of *Actinopyga mauritana* due to a series of directed movements in response to patchy distributions of food and shelter.

There is a positive relationship between *H. grisea* density, percentage cover of rock, and the rock rugosity index; therefore, it would be expected that the highest *H. grisea* density would be found in the

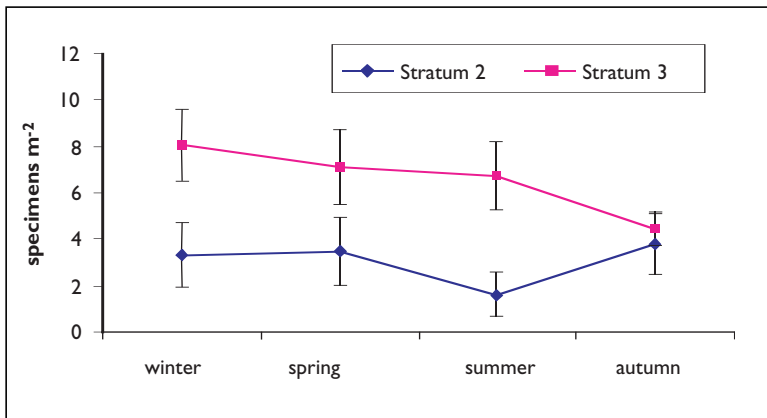


Figure 2.

Seasonal variation of *H. grisea* density (specimens m⁻²) in two strata.

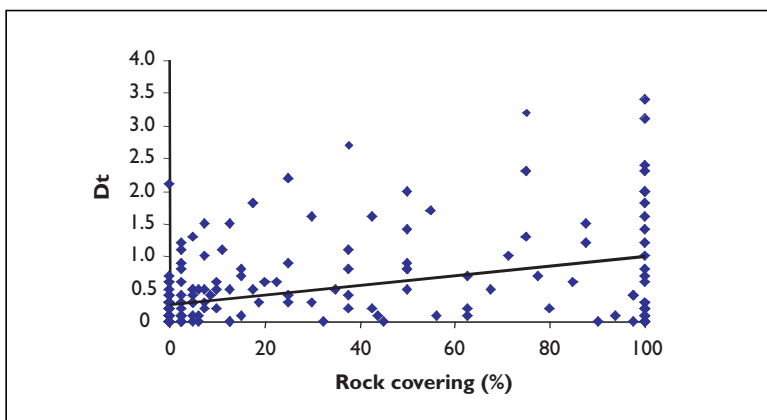


Figure 3.

Linear relationship between *H. grisea* density (Dt) and rock covering (%).

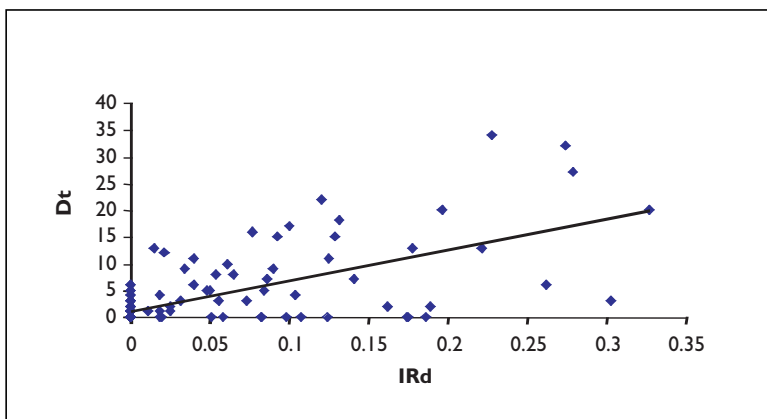


Figure 4.

Linear relationship between *H. grisea* density (Dt) and rugosity index d (IRd).

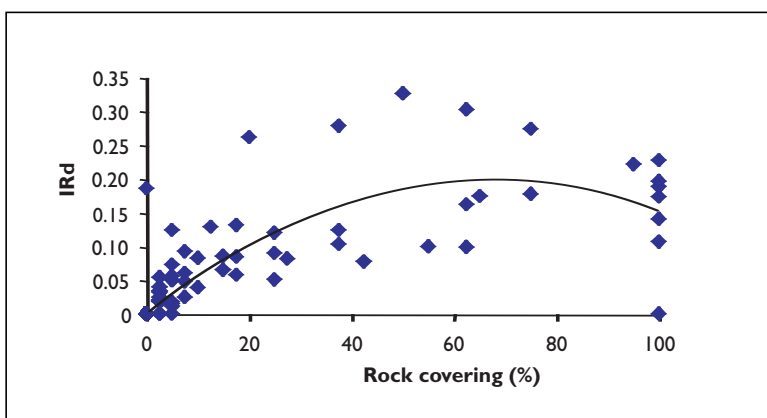


Figure 5.

Parabolic relationship between rock covering (%) and rugosity index d (IRd).

stratum with the highest rock rugosity. Rooker et al. (1997) observed that an increase in the total abundance of organisms coincides with increasing habitat rugosity. Sonnenholzner (2003) did not find *H. theeli* where the substrate was mainly sand with no shelter areas.

Zhou and Shirley (1996) divided a coastal area in Alaska into 3 strata and concluded that densities of *Parastichopus californicus* increased from the inner stratum to the outer stratum and differed significantly among the 3 strata. In Armação do Itapocoroy Bay, densities of *H. grisea* also increased from stratum 2 (middle) to stratum 3 (outer), although, between strata 2 and 3 there was no difference in rock covering or of rock rugosity, suggesting that the density variation among the two strata is determined by other ecological factors.

Tide level was the primary factor affecting density, since this species is not tolerant of long desiccation periods. Tommasi (1969) reported that *H. grisea* is the most frequently found and numerous sea cucumber species on the Brazilian coast and that it is found in high densities in subtidal zones. Sonnenholzner (2003) reported that *H. theeli* may occupy different intertidal and subtidal ecological niches and its habitat preferences may be linked to hydrodynamic characteristics such as tide level.

Significant differences in *H. grisea* densities were found among strata 2 and 3 over all the seasons, except autumn. In autumn, intense southerly winds and currents drive seawater onto the south coast of Brazil, frequently inundating the intertidal zone, and causing a mixture between strata 2 and 3. Thus, *H. grisea* were found in low aggregations in both strata during the autumn season.

This fact would also explain the significant density reduction in the autumn when analyzing only stratum 3. The intertidal zone inundation allowed a more widely spread distribution pattern of *H. grisea*, since this species occupied the two strata equally. Analyzing only stratum 2, there was a reduction in *H. grisea* density in the summer due, most likely, to the high summer temperatures (desiccate-inhibition). Highest aggregations were observed in stratum 2 suggesting an immersion response of *H. grisea* that was most concentrated in areas that had high humidity retention (e.g. tide pools) during low tide periods.

It is probable that the high summer temperatures also restricted the occupation of the most tolerant specimens to desiccation, thus forcing the least resistant ones to occupy more protected areas (subtidal). This behavior was also observed in Florida (USA) where individuals of the same species mi-

grated some distance offshore because of adverse environmental factors (Hendler 1995). An activity rhythm of *A. mauritana* related with tidal cycles was also observed in Solomons Islands by Graham and Battaglione (2004). Zhou and Shirley (1996) also aim an existence of seasonal migrations in *Stichopus variegatus* and *Cucumaria frondosa* specimens in a southeast Alaska Bay.

Generally, animals do not behave in the same way in different places. Ecological patterns can vary temporally and from place to place, so that behaviors and patterns are regulated by biotic and abiotic factors that act on the environment (Chapman, 2000). Thus, the *H. grisea* population in Armação do Itapocoroy Bay follows characteristic patterns of the species, although specific environmental factors and patterns of this habitat causes specific responses as particular behaviors.

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