

*Research Articles*

## The anomuran and brachyuran communities (Crustacea: Decapoda) in sheltered and exposed rocky shores from Anchieta and Guarapari regions (Espírito Santo), Brazil

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**ABSTRACT.** Rocky shores are ecosystems susceptible to anthropic impact, and the absence of information in Brazil about their biota hampers characterization and conservation measures. Thus, this study analyzed the abundance, richness, diversity and dominance of anomuran and brachyuran communities in sheltered and exposed rocky shores in Anchieta and Guarapari on the coast of Espírito Santo State. It was also studied the community variation concerning the types of rocky shores during the rainy and dry seasons. The organisms were collected manually in the mediolittoral zone of the rocky shores from October 2014 to September 2015. Additionally, temperature and salinity of the water were measured and the rainfall recorded from a meteorological station. In this study, 3,156 individuals were collected, comprising 14 species. The hermit crabs *Clibanarius antillensis* and *Calcinus tibicen* were the most abundant species. The three-way ANOVA analysis revealed that there was no interaction between ecological indices and the study locations, rocky shores and seasons. The abundance of the decapod community was statistically different between locations. The richness and diversity indices were higher on the sheltered rocky shore because of the presence of rock fragments and heterogeneous sediments, they are providing higher availability of microhabitats in these areas. There was no relationship between the decapod community and environmental factors, possibly because of a small variation of these factors registered between rainy and dry seasons. It is concluded that the anomuran and brachyuran communities are probably more influenced by biological interactions and physiographic features of rocky shores than by environmental factors.

**Keywords:** mediolittoral zone; abundance; richness; diversity; decapods

### INTRODUCTION

Rocky shores are highly heterogeneous environments typically formed by rocks of varying sizes, steep walls, flat areas and tidal pools (Ghilardi *et al.*, 2008). This heterogeneity is one of the main factors influencing the distribution and abundance of biotic communities living in these areas (Araújo *et al.*, 2005; Ahmad *et al.*, 2011).

Several species found in rocky shores are often unique to this ecosystem, since these organisms must be able to withstand numerous physical factors, such as luminosity, salinity variation, temperature, wave hydrodynamics, topography and substrate type (Ghilardi *et al.*, 2008; Moreno & Rocha, 2012; Coutinho *et al.*, 2016). In addition, they are also subjected to biological factors, especially predation and competition (Wilson, 1991; Moreno & Rocha, 2012).

Macroinvertebrates (>0.5 cm) are considered the most abundant and diverse organisms found on the rocky shores (Abushaala *et al.*, 2014). Crustacean decapods are an essential part of this fauna, and are fundamental to the maintenance and balance of this ecosystem since they contribute to the recycling of nutrients and organic matter, besides of serving as food for other organisms such as fish and birds, and, in some cases also for humans (Fransozo *et al.*, 2011; Abushaala *et al.*, 2014).

Information related to the species composition, richness, abundance and distribution patterns provides an important tool for understanding the functioning of the coastal ecosystems (Bertini *et al.*, 2004; Nanami *et al.*, 2005). Knowledge of species composition and abundance is a fundamental parameter for comparing communities under the influence of natural and anthropogenic disturbances (Olawusi-Peters & Ajibare, 2014). In this sense, studies focusing on rocky coastal ecosystems are important since they are susceptible to anthropic impacts (Crowe *et al.*, 2000; Thompson *et al.*, 2002). The detection of impacts and the possible consequences on the environment, however, are often hampered by an absence of basic information on the species inhabiting these sites, preventing the implementation of measures for their conservation and restoration (Ghilardi *et al.*, 2008; Pohle *et al.*, 2011).

The coast of Espírito Santo (ES), southeastern Brazil, has been subjected to several anthropic activities, such as fishing and shellfishing, recreation, tourism, urbanization, mining and industrial and port activities. All of these activities may change the biota of coastal environments. Barbosa *et al.* (2008) suggested tourism as the main impact factor for the algal communities of the mediolittoral zone in Jacaraípe Beach (ES), and Zalmon *et al.* (2011) found low macrofaunal richness in sites exposed to high influence of domestic sewage in the Vitória Harbor (ES).

Some of the studies conducted on the rocky shores of Espírito Santo State are related to floristic surveys (Nalesso *et al.*, 2005), fish communities (Floeter *et al.*, 2007; Macieira & Joyeux, 2011), overall macrofauna (Ramos *et al.*, 2010; Zamprogno *et al.*, 2012; Cruz, 2014) and mollusks (Silva & Castro, 2014). Coutinho *et al.* (2016), in a review study on the benthic community of the rocky coasts of Brazil, mentioned that among the states of the southeast, ES had the fewest published studies related to the rocky shores' benthic community. Thus, studies involving the characterization, composition and distribution of decapod crustaceans are practically non-existent, although it is well known that they are common inhabitants of this ecosystem.

Therefore, the present study aimed to analyze the structure of the anomuran and brachyuran community present in sheltered and exposed rocky shores of the municipalities of Anchieta and Guarapari, both in the coast of ES State, Brazil, with two distinct physiographic features. The study focused on abundance, species richness, diversity, dominance, as well as on the community variation relative to the types of rocky shores during rainy and dry seasons.

## MATERIALS AND METHODS

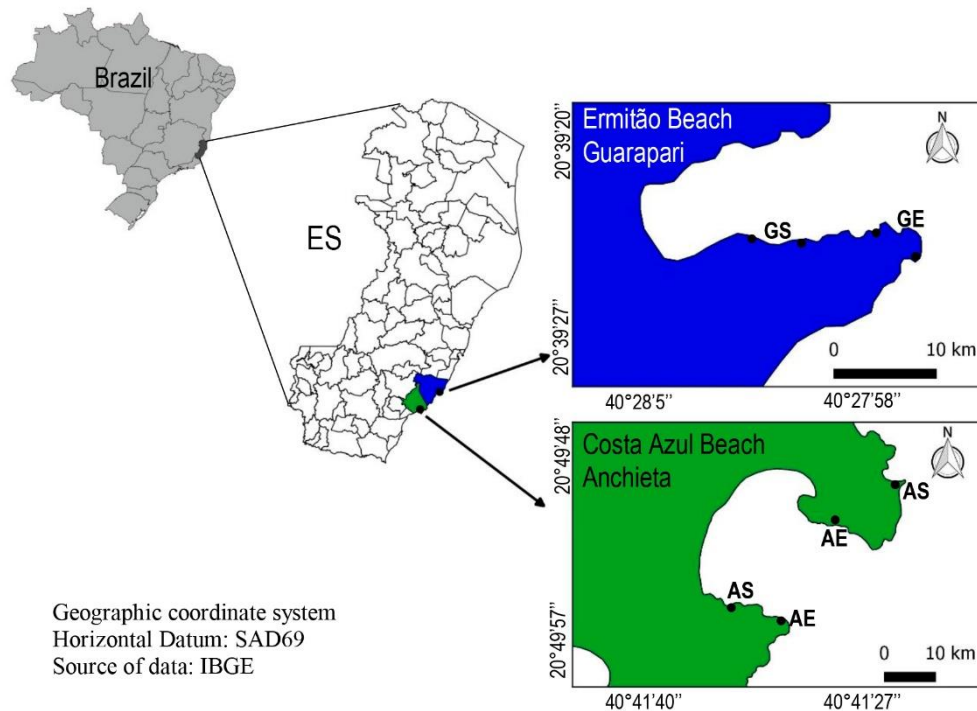
### Data collection

This study was carried out in two municipalities of ES, Brazil: Costa Azul Beach, located in the Balneario of Iriri, Anchieta, southern region of the state and Ermitão Beach in Morro da Pescaria Municipal Park, Guarapari, in the metropolitan region of ES (Fig. 1).

At both beaches, two rocky shores with distinct physiographic features based on the Széchy & Paula (2000) methodology were identified for the collection of decapods: a) sheltered rocky coast - characterized by low hydrodynamics with little wave action on the slopes. In both locations, it was a rocky-sandy beach made up of rock fragments of various sizes, entirely exposed at low tide. The presence of sand reefs, algal and bivalve banks and corals was rare, b) exposed rocky coast - characterized by a steep rocky shore and high hydrodynamism with strong wave on the slopes and continuous walls. These locations were entirely exposed at low tide with large tidal pools occupied by algae and invertebrates such as crustaceans, sea urchins, sea anemones, mollusks and corals.

Bi-monthly collections were carried out from October 2014 through September 2015 with three collections in the rainy season (October to March) and three in the dry season (April to September). The determination of the rainy and dry seasons of the state of ES was based on Ramos *et al.* (2016).

The collection effort was defined in pilot collections, and sampling efforts with two persons during 20 min and another one with one person for 10 min were tested. We noticed that the number of hermit crabs increased considerably in the 20 min collection, mainly in Guarapari, known as hermit crab beach. Thus, to avoid impacting the hermit crab population, the sampling was standardized as a one-person collection for 10 min during low tide in two areas of the mediolittoral zone approximately 15 m apart. A manual sampling at the sheltered rocky shore was performed on the sediment and through rock displacement to uncover decapods present since, in this environment, there was no other type of biogenic substrate. In the exposed



**Figure 1.** Map of Espírito Santo indicating the two municipalities with the sampling areas: Costa Azul Beach (Anchieta) and Ermitão Beach (Guarapari), Brazil. The dots indicate sheltered (AS, GS) and exposed (AE, GE) the rocky shores sampled at each beach.

rocky coast the collections were carried out inside the tidal pools.

Water temperature and salinity were measured at each site using a mercury column thermometer and a specific optical refractometer, respectively. At the sheltered rocky shore, the water was collected on the sea surface and inside the tidal pool at the exposed rocky shore. Rainfall data covering the week before each sampling until the day of the collection were obtained from the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (INCAPER). The collected decapods were bagged, labeled and stored in a styrofoam box containing ice, and transported to the Zoology Laboratory in Alegre-ES where they were kept frozen until analysis.

The decapods were identified according to the literature (Melo, 1996, 1999), and the taxonomic classification was based on that of De Grave *et al.* (2009). After the analyses, all specimens or a sample of 10 individuals of each species were stored in vials containing 70% alcohol and deposited in the scientific collection of the Universidade Federal do Espírito Santo, Alegre.

#### Data analysis

Before applying the ANOVA tests, the data were checked for normality (Kolmogorov-Smirnov) and

homogeneity (Levene test). In the absence of homogeneity, data were log-transformed before the ANOVA test; results were considered significant when  $P < 0.05$ . Small deviations from normality or homogeneity after transformation were accepted because ANOVA is considered to be robust to such violations (Zar, 1999). A two-way ANOVA was used to evaluate the differences of environmental factors (water temperature, salinity and rainfall) between regions and seasons.

The decapod community was analyzed in relation to the type of rocky shore (sheltered and exposed) and to the sampling location (Anchieta and Guarapari), being AS (Anchieta: rocky shore sheltered), AE (Anchieta: rocky shore exposed), GS (Guarapari: rocky shore sheltered) and GE (Guarapari: rocky shore exposed). The two sampled areas in each rocky shore were considered as replicates, totalizing six samples in AS, AE, GS and GE in each season.

The following ecological indices were calculated: 1) species richness as the number of species obtained in a sampling unit (Krebs, 1998), 2) species diversity by using the Shannon-Weaver index ( $H'$ :  $\log_2$ ; bits  $\text{ind}^{-1}$ ), 3) equitability index ( $J'$ ) by Pielou (1966), and 4) dominance index:  $dN_{\max}/N$ , where  $N_{\max}$  is the number of individuals in the most abundant species (Berger & Parker, 1970).

The total abundance, richness of species ( $S$ ), species diversity ( $H'$ ), equitability ( $J'$ ) and dominance index ( $d$ ) were contrasted using a three-way factorial ANOVA to test the null hypothesis of no differences in ecological indices associated with the factors "regions", "rocky shores" and "seasons".

Rarefaction curves were constructed for each rocky shore (sheltered and exposed) to compare taxonomical diversity in samples of different sizes. For this calculation, species absolute abundance data were used to estimate the number of taxa that would be expected in a sample with a few individuals. The algorithm described by Krebs (1998) was adopted for this analysis. The standard errors were converted to 95% confidence intervals in the graphical plot (Colwell *et al.*, 2004).

The frequency of species occurrence (%) was calculated by the percentage of occurrence of a species in relation to the total number of collections in each type of rocky shore (12), calculated as:  $Fa = (Pa/P) \times 100$ , where:  $Fa$  is species frequency,  $Pa$  number of collections in which the species was present and  $P$  total number of collections (48). According to the results, the species were classified as: constant ( $75\% < Fa \leq 100\%$ ); very common ( $50\% < Fa \leq 75\%$ ); common ( $25\% < Fa \leq 50\%$ ); occasional ( $10\% < Fa \leq 25\%$ ), and rare ( $\leq 10\%$ ) (Dajoz, 2005; Odum & Barrett, 2007).

Correspondence analyses (CA) were used to evaluate the relationship between the abundance of decapods and types of rocky shores. In these analyses, absolute abundance was used, considering each species as a group of independent data, minimizing the influence of sampling design (Leps & Smilauer, 2003). The data were ordered by canonical correlation analysis (CCA) (Gittins, 1985) to reveal possible patterns among environmental factors and decapods abundance.

Prior to multivariate analysis (CA and CCA), the data were simplified by eliminating species with a frequency less than or equal to 25% (Bertini *et al.*, 2010; Barros-Alves *et al.*, 2017).

## RESULTS

### Environmental factors

The average surface water temperature was statistically different between the regions ( $F = 5.76$ ,  $P = 0.021$ ): Anchieta showed a higher mean temperature ( $25.2 \pm 1.9^\circ\text{C}$ ) compared to Guarapari ( $23.9 \pm 1.7^\circ\text{C}$ ). No statistical difference ( $F = 0.46$ ,  $P = 0.503$ ) was detected between dry and rainy seasons. There was, however, an interaction between regions and season, showing that the temperature in the rainy season in Anchieta ( $25.9 \pm$

$1.9^\circ\text{C}$ ) was significantly higher than in Guarapari ( $23.5 \pm 1.9^\circ\text{C}$ ) (Fig. 2).

For environmental salinity factor, no statistical difference between regions and seasons was detected ( $P > 0.05$ ). The mean water salinity in the rainy and dry season in Anchieta was  $37.1 \pm 2.5$  and  $35.7 \pm 2.9$ , respectively, while in Guarapari the average salinity in the rainy season was  $37.5 \pm 2.5$  and  $36.7 \pm 0.8$  in the dry season (Fig. 2).

Rainfall recorded in the Anchieta and Guarapari regions during the study period was atypical for the region, with a low rainfall index during the rainy season. A two-way ANOVA detected a statistical difference between regions and seasons, but there was no interaction between the factors. Guarapari showed higher average rainfall ( $3.69 \pm 2.91$  mm) in the week prior to collection compared to Anchieta ( $2.31 \pm 2.53$  mm) ( $F = 4.34$ ;  $P = 0.04$ ). In the dry season ( $4.53 \pm 3.02$  mm) in Anchieta, it rained more in the week before the collection than in the rainy season ( $1.46 \pm 1.34$  mm) ( $F = 21.78$ ;  $P = 0.000$ ) (Fig. 2).

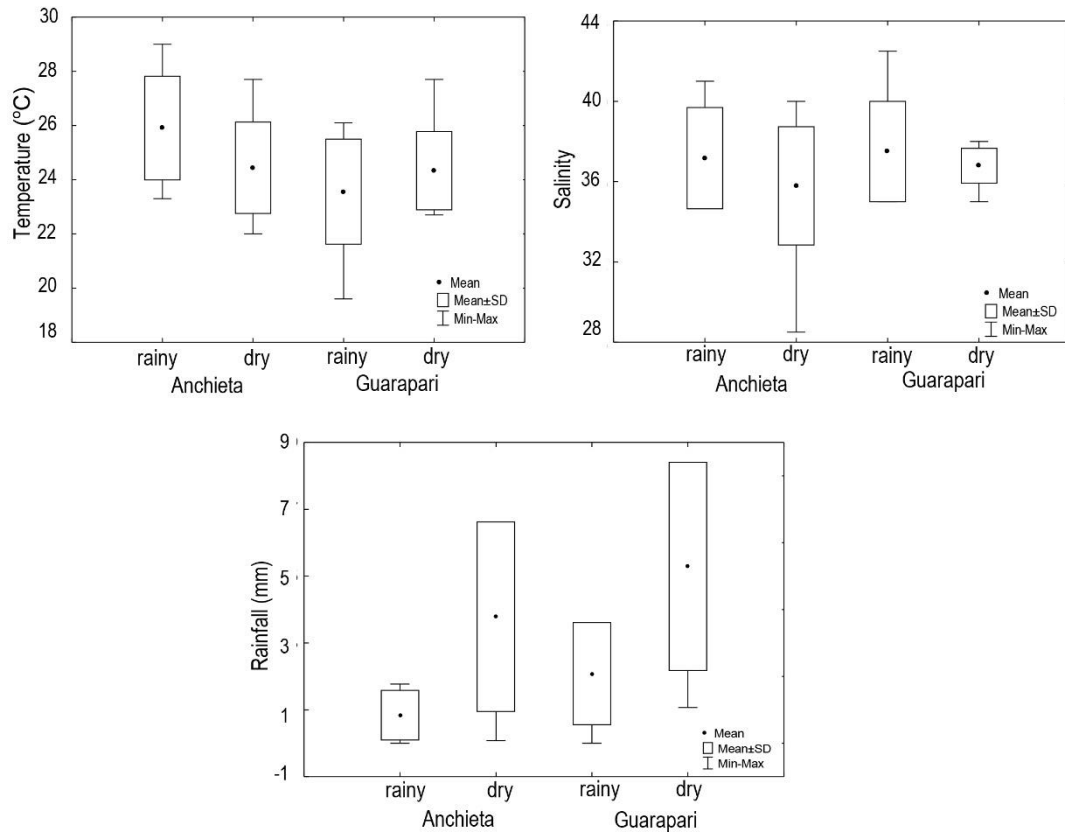
### Community structure

A total of 3,156 anomuran and brachyuran individuals was collected, comprising 14 decapod species (7 Anomura and 7 Brachyura); 11 species were collected in both regions. The Guarapari region had the highest abundance with 2,134 individuals, and Anchieta was represented by 1,022 individuals (Table 1).

Among the Anomura, the family Diogenidae had the highest number of species (four), followed by Paguridae (two) and Porcellanidae (one). The Brachyura was represented by families Epialtidae, Eriphiidae, Grapsidae, Majidae and Menippidae with one species each and by Panopeidae family with two species (Table 1).

Anomura was represented by 2,946 specimens, with *Clibanarius antillensis* being the most abundant species ( $n = 1,766$ ) followed by *Calcinus tibicen* ( $n = 1,029$ ). A total of 210 individuals of brachyuran crabs was collected, with *Eurypanopeus abbreviatus* being the most abundant crab ( $n = 115$ ) (Table 1). Most decapod species collected in Guarapari and Anchieta were present in both seasons (Table 2).

The average values of abundance, species richness, diversity, equitability, and the dominance indices at the Anchieta and Guarapari rocky shores are shown in Figure 3. The three-way factorial ANOVA revealed that ecological indices did not show an interaction with the factors "regions", "rocky shores", and "seasons" (Table 3). Significant differences, however, were observed between regions concerning abundance, with statistically higher values in Guarapari (88.92 ind) than



**Figure 2.** Box plot of the temperature, salinity and rainfall during the seasons (rainy and dry) in Anchieta and Guarapari, Espírito Santo, southeastern Brazil.

in Anchieta (42.58 ind). The species richness ( $S$ ) and the diversity ( $H'$ ) showed significant differences between the “rocky shores” factor, where sheltered rocky shores showed the higher richness ( $S = 4.9$ ) and diversity ( $H' = 1.30$ ) compared to exposed rocky shores ( $S = 3.0$ ;  $H' = 0.78$ ) (Table 3). In addition, the diversity index was statistically higher in the Anchieta ( $H' = 1.23$ ) than in Guarapari ( $H' = 0.85$ ).

The rarefaction curves performed for 200 individuals showed a higher species richness in the sheltered rocky shores of both regions (Anchieta and Guarapari), indicating a tendency of stabilization of the number of species collected in the environments sampled (Fig. 4).

The relationships among the decapod's abundance and rocky shores were analyzed with the correspondence analysis (CA) (Fig. 5). The species *Acantholobulus schmitti*, *Pachygrapsus transversus*, *Petrolisthes armatus*, and *E. abbreviatus* showed high correspondence with sheltered rocky shores (AS and GS), whereas *C. tibicen* was associated mainly with GE. The species *C. antillensis* was abundant in all rocky shores, but with a high correspondence with GS and AE, whereas *Pagurus brevidactylus*, *Pagurus*

*criniticornis* and *Omalacantha antillensis* showed high correspondence preferentially with AE and AS.

The canonical correlation analysis of species abundance and environmental factors revealed that there was no significant correlation ( $R = 0.64$ ;  $P = 0.07$ ), suggesting that temperature, salinity and rainfall did not influence species distribution.

### Frequency of occurrence

The frequency of occurrence of species differed between the rocky shores. The hermit crab *C. antillensis* was constant (>75% of the frequency of occurrence) in all of the rocky shores sampled and *C. tibicen* was constant only in Guarapari.

At Anchieta rocky shores, the hermit crabs *P. criniticornis* and *P. brevidactylus* showed a frequency ranging from common to occasional, whereas in Guarapari these hermits ranged from occasional to rare. In the sheltered rocky shores of both regions, the frequency of *P. armatus*, *E. abbreviatus*, *A. schmitti*, and *P. transversus* varied between from common to constant. The species *Menippe nodifrons*, *Eriphia* and *Epiialtus bituberculatus* were rare for all rocky shore (Table 1).

**Table 1.** Number of individuals (n) and frequency of occurrence (FO) of decapod species in each type of rocky shore (sheltered and exposed) in Anchieta and Guarapari, Espírito Santo, southeastern Brazil. She: sheltered, Exp: exposed, ct: constant, vc: very common, cm: common, oc: occasional, ra: rare.

Infraorder/Family/Species	Anchieta					Guarapari				
	She		Exp		Total	She		Exp		Total
	n	FO	n	FO	n	n	FO	n	FO	n
<b>Anomura</b>										
<b>Diogenidae</b>										
<i>Calcinus tibicen</i> (Herbst, 1791)	25	cm	72	vc	97	112	ct	820	ct	932
<i>Clibanarius antillensis</i> Stimpson, 1859	292	ct	418	ct	710	667	ct	389	ct	1,056
<i>Clibanarius scolopetarius</i> (Herbst, 1796)	3	oc	2	oc	5	0	-	0	-	0
<i>Paguristes tortugae</i> Schmitt, 1933	3	oc	2	oc	5	0	-	1	ra	1
<b>Paguridae</b>										
<i>Pagurus brevidactylus</i> (Stimpson, 1859)	7	oc	3	oc	10	1	ra	2	ra	3
<i>Pagurus criniticornis</i> (Dana, 1852)	10	cm	13	cm	23	0	-	2	oc	2
<b>Porcellanidae</b>										
<i>Petrolisthes armatus</i> (Gibbes, 1850)	54	vc	1	ra	55	47	vc	0	-	47
<b>Brachyura</b>										
<b>Epiplatidae</b>										
<i>Epiplatys bituberculatus</i> H. Milne Edwards, 1834	0	-	0	-	0	0	-	1	ra	1
<b>Eriphiidae</b>										
<i>Eriphia gonagra</i> (Fabricius, 1781)	1	ra	0	-	1	1	ra	0	-	1
<b>Grapsidae</b>										
<i>Pachygrapsus transversus</i> (Gibbes, 1850)	22	vc	0	-	22	23	ct	1	ra	24
<b>Majidae</b>										
<i>Omalacantha antillensis</i> (Rathbun, 1920)	1	ra	23	cm	24	1	ra	2	oc	3
<b>Menippidae</b>										
<i>Menippe nodifrons</i> Stimpson, 1859	1	ra	0	-	1	0	-	0	-	0
<b>Panopeidae</b>										
<i>Acantholobulus schmitti</i> (Rathbun, 1930)	11	cm	1	ra	12	6	cm	0	-	6
<i>Eurypanopeus abbreviatus</i> (Stimpson, 1860)	53	vc	4	oc	57	58	ct	0	-	58
Number of individuals	483		539		1,022	916		1,218		2,134
Species richness	13		10		13	9		8		12
Diversity index (bits ind <sup>-1</sup> )	2.04		1.18		1.75	1.39		0.98		1.44
Equitability index	0.55		0.35		0.47	0.43		0.32		0.40
Dominance index	0.60		0.77		0.69	0.73		0.67		0.49

## DISCUSSION

The brachyuran and anomuran species that inhabit the rocky shores of the coast of ES were studied for the first time. Such information is highly relevant for future studies about the fauna because these ecosystems can change the species composition caused by anthropic activities. Coutinho *et al.* (2016) emphasized the importance of surveys of benthic communities in the rocky coasts in Brazil, which can be used as a basis for future studies on the effects of environmental changes on the respective biota and may help, for example, to develop a better and more accurate prediction of climate change impacts on this environment and its biota.

The community structure of anomuran and brachyuran crabs showed differences concerning the regions (Anchieta and Guarapari) and types of rocky shores. Sheltered rocky shores, regardless of location, showed higher diversity and species richness (13 species in total), whereas species abundance was significantly higher in Guarapari.

Differences in faunal composition among coastal marine ecosystems have been reported in the literature, and are related to the adaptation of the species to each type of environment, with more complex environments providing more refuge for invertebrate survival from predators and environmental stress (Bruno & Bertness, 2001; Nucci *et al.*, 2001; Araújo *et al.*, 2005; Zamprogno *et al.*, 2012; Abushaala *et al.*, 2014; Morais & Lee, 2014; Barros-Alves *et al.*, 2017). Thus, species

**Table 2.** Number of individuals of decapod species for rainy and dry seasons in Anchieta and Guarapari, Espírito Santo, southeastern Brazil.

Infraorder/Family/Species	Anchieta			Guarapari		
	Rainy	Dry	Total	Rainy	Dry	Total
<b>Anomura</b>						
<b>Diogenidae</b>						
<i>Calcinus tibicen</i>	54	43	97	445	487	932
<i>Clibanarius antillensis</i>	360	350	710	493	563	1056
<i>Clibanarius scolopetarius</i>	2	3	5	0	0	0
<i>Paguristes tortugae</i>	2	3	5	0	1	1
<b>Paguridae</b>						
<i>Pagurus brevidactylus</i>	4	6	10	0	3	3
<i>Pagurus criniticornis</i>	7	16	23	1	1	2
<b>Porcellanidae</b>						
<i>Petrolisthes armatus</i>	41	14	55	24	23	47
<b>Brachyura</b>						
<b>Epialtidae</b>						
<i>Epialtus bituberculatus</i>	0	0	0	1	0	1
<b>Eriphiidae</b>						
<i>Eriphia gonagra</i>	1	0	1	0	1	1
<b>Grapsidae</b>						
<i>Pachygrapsus transversus</i>	6	16	22	16	8	24
<b>Majidae</b>						
<i>Omalacantha antillensis</i>	6	18	24	2	1	3
<b>Menippidae</b>						
<i>Menippe nodifrons</i>	1	0	1	0	0	0
<b>Panopeidae</b>						
<i>Acantholobulus schmitti</i>	11	1	12	3	3	6
<i>Eurypanopeus abbreviatus</i>	45	12	57	38	20	58
Number of individuals	540	482	1022	1023	1111	2134
Species richness	13	11	13	9	11	12

richness and abundance may increase in habitats with increased complexity or roughness (Kawasaki *et al.*, 2003). Therefore, the higher diversity and species richness of anomurans and brachyurans obtained in the sheltered coastlines of both regions are possibly related to the lower impact of the waves and the formation of complex microhabitats, composed of fragments of rocks of varied sizes and heterogeneous sediment, providing favorable conditions for the presence of many species.

A higher diversity of decapod species has also been observed in coastal reef environments with low hydrodynamics on the coast of Pernambuco (Brazil) by Giraldes *et al.* (2012). These results were related to the association of individuals in substrate formed by algae, sponges and corals, whereas the open areas of the reefs with higher exposure to the wave action presented lower diversity, displaying few species adapted to live only in caves and cracks of the corals where they protect themselves from the action of the waves.

According to Flores & Paula (2001), within a single marine habitat, such as rocky shores, the number of substrates available for the decapod crustaceans is usually variable, and differences in diversity may depend more on the area where each substrate occurs. Therefore, the diversity of species in each ecosystem may differ according to the environment available in

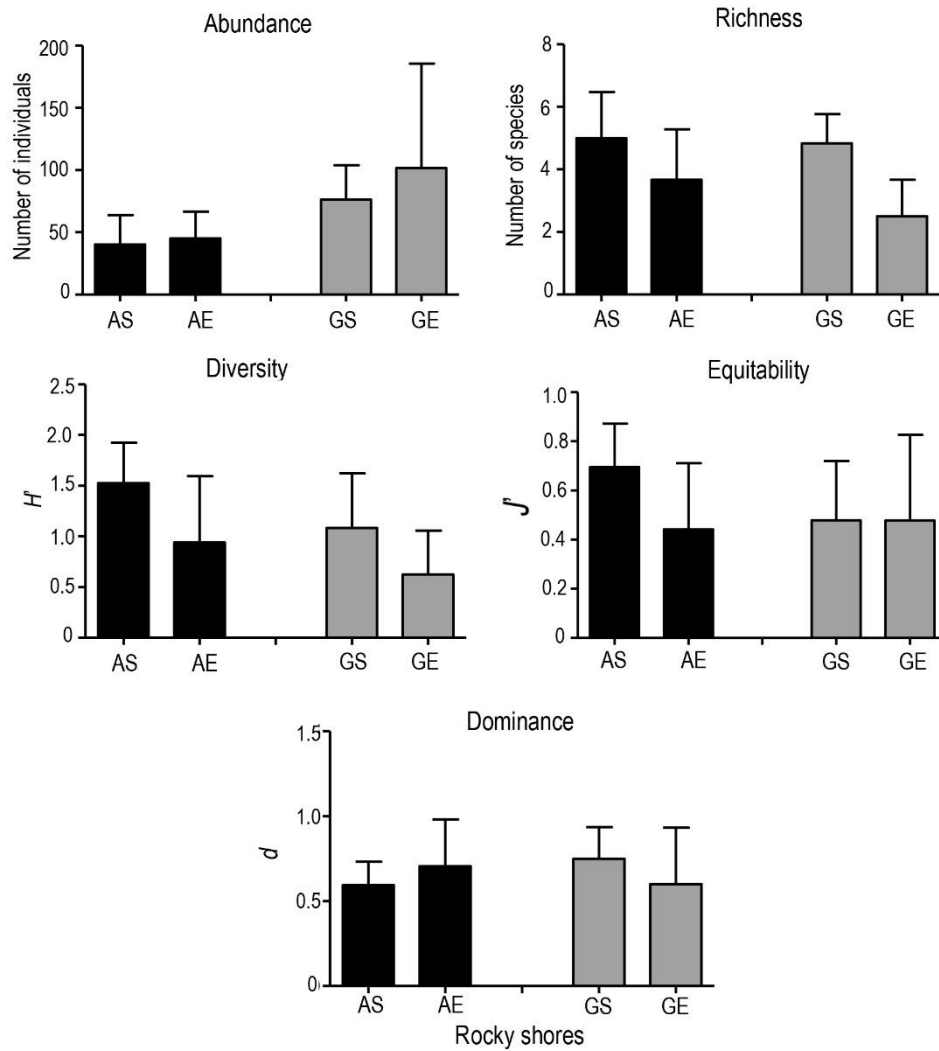
each region, as observed in the present study, and by Masunari & Dubiaski-Silva (1998) who registered 17 species of anomurans and brachyurans in Ilha do Farol (PR), southern Brazil, of which four were frequent in the present study. Other studies have focused only on brachyurans: Nóbrega & Martinelli-Lemos (2016) found 14 species of crabs in a rocky substrate at an estuary of the Brazilian Amazonian coast. Leite *et al.* (1998), on the other hand, focused on anomurans and found nine hermit crab species in the rocky shores of the São Sebastião Channel, northern coast of the state of São Paulo.

The diversity and richness of species of Anomura and Brachyura found in the present study can be considered high when compared to the study of Giraldes *et al.* (2012) at the coastal reef of Porto de Galinhas Beach, northeastern Brazil. In addition, the results of the rarefaction curves (Fig. 4) obtained for the sheltered and exposed shores of both locations, indicated a stabilization tendency of the species number, which suggests that the species number obtained is close to the accurate richness of the region, and that the sampling effort was adequate for the decapod species inhabiting these rocky shores (Schilling & Bastista, 2008; Gotelli & Colwell, 2010).

The high number of decapods in Guarapari is related to the presence of two species of hermit crabs (*Clibanarius antillensis* and *Calcinus tibicen*). *C. antillensis* was the most abundant species in this study and showed a frequency of occurrence above 75% (constant) in all rocky shores, but particularly in GS. According to Osawa & Fujita (2008), species of the genus *Clibanarius* are frequent inhabitants of shallow waters and intertidal zones, where they inhabit rocky shores, coral reefs and estuarine areas, and they show high resistance to environmental variations. Moreover, to inhabit the intertidal regions, the hermit crabs must have physiological and behavioral adaptations to deal with water loss (Bertness, 1981; Taylor, 1981; Gherardi & Vannini, 1993). Therefore, in all the field collections, *C. antillensis* showed a grouping behavior and was able to occupy cracks during periods of low tide to reduce water loss (see also Leite *et al.*, 1998).

The second most abundant species was the hermit crab *C. tibicen*, found in the exposed coast of Guarapari and frequently collected inside tidal pools, which coincides with similar observations made by Almeida *et al.* (2010) in the south of Bahia. Conversely, Leite *et al.* (1998) collected *C. tibicen* mainly in the sublittoral zone and rarely in the tidal pools of the northern coast of the state of São Paulo.

The high frequency of these hermit crabs (*C. antillensis* and *C. tibicen*) in Guarapari may be related to the availability of gastropod shells in this environ-



**Figure 3.** Mean values and standard deviations of decapod abundance, species richness, diversity, equitability and dominance indices for each rocky shore studied in southeastern Brazil. AS: Anchieta sheltered rocky shore, AE: Anchieta exposed rocky shore, GS: Guarapari sheltered rocky shore and GE: Guarapari exposed rocky shore.

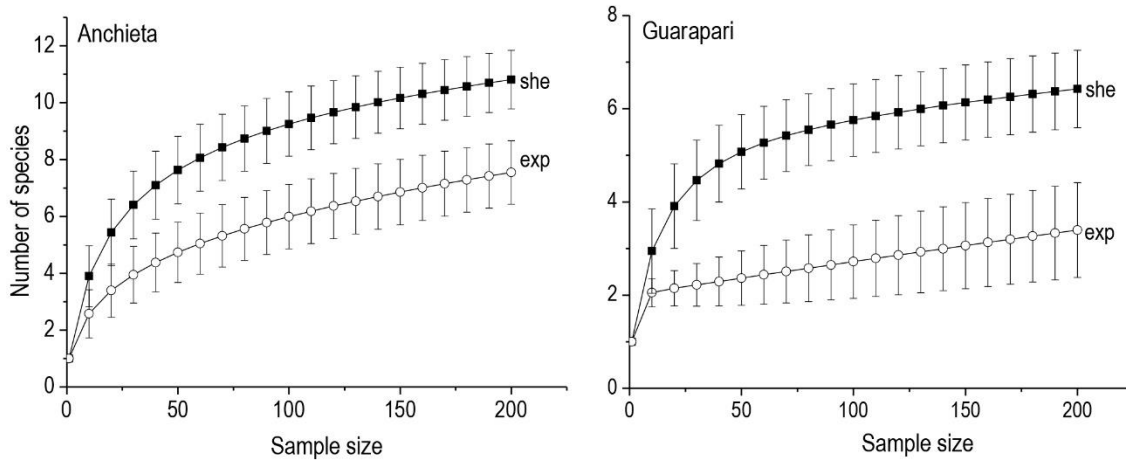
**Table 3.** Summary of results of three-way analysis of variance (ANOVA) on effects of the sampling location (Anchieta and Guarapari, southeastern Brazil), rocky shores (sheltered and exposed) and seasons (rainy and dry) in the abundance, richness, diversity, equitability and dominance indices of the decapod community. F: variance ratio, P: significance.

Sources of variation	Abundance		Richness		Diversity		Equitability		Dominance	
	F	P	F	P	F	P	F	P	F	P
Regions	8.637	0.005	2.506	0.121	6.091	0.018	1.276	0.265	0.117	0.734
Rocky shores	0.071	0.792	22.55	0.000	11.566	0.002	2.521	0.120	0.068	0.795
Seasons	0.021	0.885	0.011	0.916	0.184	0.671	0.02	0.889	0.808	0.374
Regions × rocky shores	0.463	0.500	1.347	0.253	0.170	0.682	2.488	0.123	3.252	0.079
Regions × seasons	0.837	0.366	0.100	0.753	0.047	0.829	0.001	0.971	0.767	0.386
Rocky shores × seasons	0.593	0.446	0.011	0.916	1.107	0.299	0.161	0.691	0.003	0.959
Regions × rocky shores × seasons	0.596	0.445	0.278	0.601	0.000	0.996	0.276	0.602	0.872	0.356

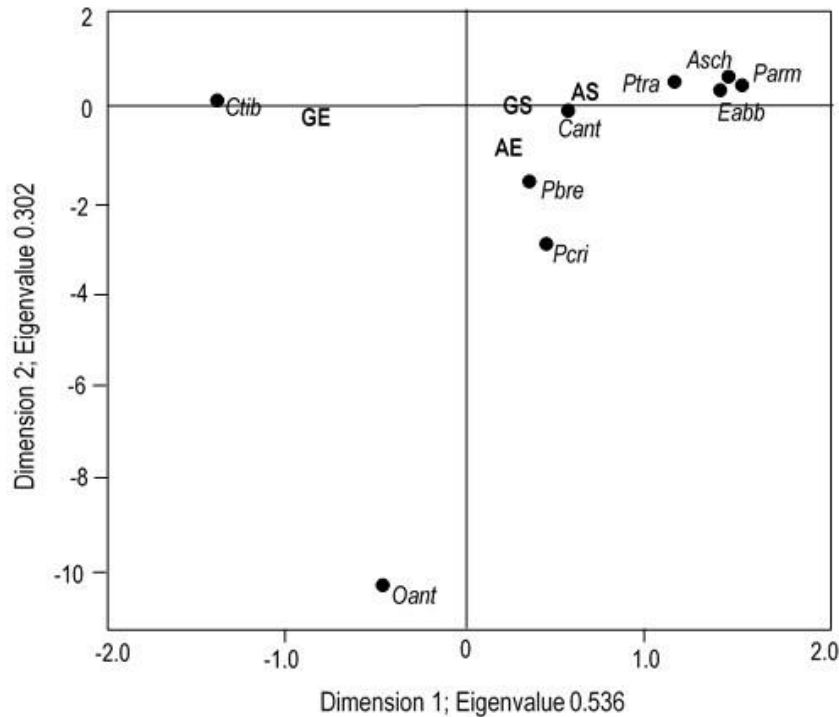
ment, since it was found a greater diversity of gastropods shells in Guarapari (20 species) than in Anchieta (15 species) (C.C. Ribeiro, *unpubl. data*).

According to Ayres-Peres *et al.* (2008), the availability of gastropod shells may directly affect the biology of hermit crabs, and the shortage of these shells may hinder





**Figure 4.** Rarefaction curves observed for decapod species in sheltered (she) and exposed (exp) rocky shores of Anchieta and Guarapari, southeastern Brazil.



**Figure 5.** Correspondence analysis evaluating the spatial abundance of decapod species based on Bray-Curtis similarity matrices concerning rocky shores (sheltered and exposed) in Anchieta and Guapari. AS: Anchieta sheltered rocky shore, AE: Anchieta exposed rocky shore, GS: Guarapari sheltered rocky shore, GE: Guarapari exposed rocky shore, southeastern Brazil. Cti: *Calcinus tibicen*, Cant: *Clibanarius antillensis*, Parm: *Petrolisthes armatus*, Asch: *Acantholobulus schmitti*, Eabb: *Eurypanopeus abbreviatus*, Ptra: *Pachygrapsus transversus*, Pbre: *Pagurus brevidactylus*, Pcri: *Pagurus criniticornis*, Oant: *Omalacantha antillensis*.

the growth and reproduction of these anomurans. Thus, studies regarding these topics are essential for a better understanding of the habitat preference of decapods and their ecological role in a given environment.

Other species of hermit crabs such as *Pagurus criniticornis* and *Pagurus brevidactylus* were more

abundant in Anchieta than in Guarapari. According to Almeida *et al.* (2010), these species can live in many habitats, like sand and mud bottoms, reefs, among rocks, algae and in fragments of shells and corals. Thus, the available resources at the rocky shores of Anchieta possibly allowed a high abundance of these species in this area.

The group of species composed by *Eurypanopeus abbreviatus*, *Acantholobulus schmitti*, *Pachygrapsus transversus* and the porcelain crab *Petrolisthes armatus* showed a high correspondence to protected coasts at both localities (AS and GS), since they were present almost exclusively in these places, and their occurrence varied from common to constant. Their biology explains the occurrence of these species in sheltered environments: e.g., *P. transversus* lives in any mediolittoral zone offering shelter like cracks and holes to relieve thermal stress and dehydration during low tide (Abele *et al.*, 1986; Agnew & Taylor, 1986; Masunari & Dubiaski-Silva, 1998). Similarly, other species such as *E. abbreviatus* and *A. schmitti* are protected in the spaces between rocks during low tide periods and are usually found buried in the substrate formed by mud, sand or gravel (Masunari & Dubiaski-Silva, 1998; Fransozo *et al.*, 2013), whereas *P. armatus* occupies any hiding place, under stones, corals, sponges or bank of mussels (Veloso & Melo, 1993).

The spider crab *Omalacantha antillensis* showed high correspondence with AE, demonstrating a high frequency in this rocky shore, especially within tidal pools with large amounts of algae. The crabs of the genus *Omalacantha* and *Acanthonyx* are known for their herbivorous habit and for using algae for camouflage as a defensive strategy against predators (Stachowicz & Hay, 2000; Blanco *et al.*, 2011; Carvalho *et al.*, 2016). Therefore, their occurrence in this area allows the use of algae for camouflage, besides contributing to their feeding.

The other species collected (*Clibanarius sclopetarius*, *Paguristes tortugae*, *Epialtus bituberculatus*, *Eriphia gonagra*, and *Menippe nodifrons*) were less frequent, varying from occasional to rare. This low abundance of these decapod species may be related to sampling difficulties as observed for *E. gonagra* and *M. nodifrons*, which occupy rock cracks during low tides (Masunari & Dubiaski-Silva, 1998). Future studies with a collection effort directed to the more agile and cryptic brachyurans may help to provide more accurate information about the presence and abundance of these crabs in the region.

Regarding the rainy and dry seasons, no relationships were detected in the association of the decapod fauna and environmental factors, since the values of temperature, salinity and rainfall among the collection sites varied very little between seasons. Rainfall could be a preponderant factor for the presence of intertidal decapods, however, according to Ramos *et al.* (2016), the hydrological year of 2014-2015 was considered atypical in the state of ES, being drier than the historical average recorded in the state, with a rainfall deficit of up to 75%, and classified as "extremely dry". Thus, despite the differences observed

between rainy and dry seasons in the average volume of rainfall in the week before the collection, the amount of rainfall was low, showing no correlation with the decapods present in these environments.

The physical characteristics of the intertidal zone are the primary factors influencing the habitat partitioning by decapods (Masunari & Dubiaski-Silva, 1998). Considering that, the present study was carried out in the mediolittoral zone and the environmental factors were homogeneous in the studied periods, it is assumed that the species distribution was possibly related to their biological characteristics and the physical differences of each type of rocky shore rather than to environmental factors. However, in studies that considered a more extensive range of intertidal areas, it was possible to detect seasonal differences: Masunari *et al.* (1998) in Ilha do Farol (Paraná) and Morais & Lee (2014) in intertidal rare rocky fragments in the Brazilian Amazonian coast.

In conclusion, the information generated in this study is relevant to improving the knowledge about the fauna of anomurans and brachyurans of the rocky shores located in the State of Espírito Santo. This faunal study was carried out before the disruption of a mining dam in November 2015, which reached the coast of Espírito Santo and caused one of the biggest environmental catastrophes in Brazil. Therefore, these data can be used for future monitoring strategies, environmental conservation measures and the sustainable use of natural resources of the region.

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