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Michel do Rosário Almeida

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Dissertação apresentada ao curso de Pós-Graduação em Biodiversidade Neotropical da Universidade Federal do Estado do Rio de Janeiro como requisito parcial para a obtenção do Grau de Mestre em Ciências Biológicas

Orientador: Dr. Ricardo Silva Cardoso

Coorientadora: Dra. Tatiana Fabricio Maria

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Banca Examinadora

Prof. Dr. Ricardo Silva Cardoso
Departamento de Ecologia e Recursos Marinhos - UNIRIO (Orientador)

Prof. Dr. Carlos Henrique Soares Caetano
Departamento de Zoologia - UNIRIO

Prof. Dr. Paulo Cesar de Paiva
Departamento de Zoologia – UFRJ

Dra. Tatiana Medeiros Barbosa Cabrini
Departamento de Ecologia e Recursos Marinhos – UNIRIO (Suplente)

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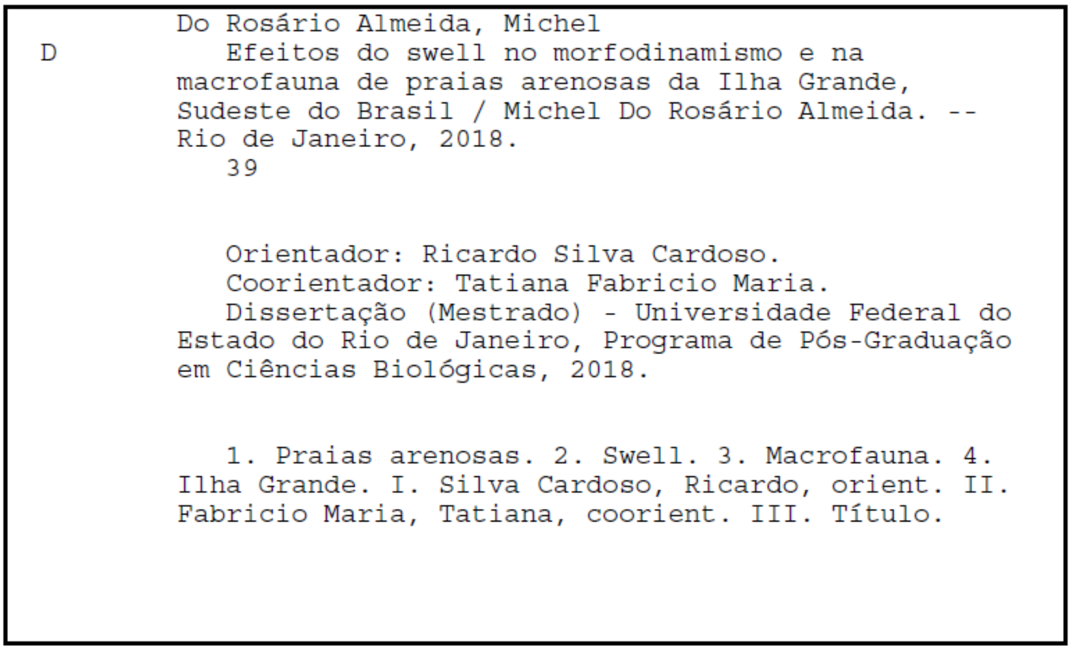

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Sumário

Introdução Geral

Esta dissertação apresentada como requisito para obtenção do grau de Mestre em Ciências Biológicas é um manuscrito e, portanto, encontra-se no formato do periódico Scientia Marina onde será submetido.

As praias arenosas são ambientes dinâmicos, cuja estrutura física é determinada pela interação entre sedimento, ondas e marés. Esse ecossistema responde à energia das ondas, que transporta a areia para o mar durante as tempestades e a move de volta para a costa durante calmarias (Short 1999). Assim, as praias arenosas constituem um dos tipos mais resilientes de linha costeira. Esse dinamismo na transferência de energia resulta em mudanças da morfologia por acreção ou erosão, o que determina o tipo morfodinâmico do sistema de praial, (Wright & Short 1984). No entanto, alguns tipos de praia, como *pocket beaches*, apresentam características peculiares. Estas praias são curtas (com menos de 2 km de extensão) e encontram-se entre costões rochosos, sendo comuns ao longo de costas rochosas em todo o mundo (Brazeiro 1999, Dehouck et al. 2009, Vousdoukas et al. 2009, Bowman et al. 2014). Nesse caso, os costões rochosos afetam a face da praia e a zona de surfe através de sua influência na refração e atenuação das ondas, limitando o desenvolvimento das correntes (McLachlan & Brown 2006, Lercari & Defeo 2015a). Portanto, as *pocket beaches* apresentam ambientes singulares, com grande variabilidade em termos de exposição às ondas, morfologia e sedimentologia, mesmo quando próximas umas das outras (Dingler 1981, Wiegel 2006).

As comunidades de praias arenosas são estruturadas por respostas individuais das espécies macrofaunais em relação ao ambiente físico (McLachlan et al. 1993). De acordo com a Hipótese de Exclusão pelo espraiamento c há um aumento nos descritores da comunidade de praias reflectivas (que apresentam grãos mais grossos, declives mais acentuados e nenhuma zona de surfe) para praias dissipativas que são mais benignas (apresentando grãos finos, declives suaves e amplas zonas de surfe). O ambiente de espraiamento mais severo, que aumenta em condições reflectivas, exclui as espécies intermareais, onde apenas os organismos que habitam supralitoral permanecem (McLachlan et al. 1995). Além disso, esses organismos do supralitoral (por exemplo, anfípodes), tendem a atingir maiores abundâncias em estados reflectivos, quando a presença de bermas torna o supralitoral mais estável (Defeo & Gómez 2005).

O regime de ondas é uma das variáveis mais importantes na estruturação do ambiente físico das praias arenosas. A influência da ondulação no nas praias arenosas pode variar de acordo com o estado morfodinâmico das mesmas, pois praias dissipativas podem apresentar uma diminuição da declividade em frente a uma maior ondulação, enquanto praias reflectivas exibem o padrão inverso (Codignotto et al. 2012, Ortega et al. 2013). No Sudeste do Oceano Atlântico, a costa do sudeste do Brasil, frentes frias com fortes ventos oriundos do sul produzem ondas de alta energia que se propagam do Leste e do Sudeste (Codignotto et al. 2012). Isso é importante para as praias arenosas do Rio de Janeiro, que estão expostas à ondulação do Sudeste. A influência da posição geográfica, da orientação da face das praias arenosas e do swell vindo do mar na morfologia da praia tem sido pouco estudadas. A orientação da face praial e a influência do swell foram analisadas em estudos temporais sobre mudanças climáticas em praias do Uruguai (Codignotto et al. 2012, Ortega et al. 2013) e em estudos sobre geologia de *pocket beaches* (Vousdoukas et al. 2009, Bowman et al. 2014). Já a posição geográfica das praias foi relacionada com o morfodinamismo em praias de ilhas da baía de Sepetiba, Rio de Janeiro (Cardoso et al. 2012). Entretanto, não foram realizados estudos que avaliassem a influência de todas essas variáveis sobre a comunidade macrofaunal de praias arenosas até o momento.

Assim, o objetivo do presente estudo é descrever a composição e a estrutura macrofaunal de 13 praias arenosas da Ilha Grande (Brasil) e testar a influência de variáveis físicas e geográficas (por exemplo, posição geográfica da praia, orientação da face da praia, orientação dos costões em relação à entrada do swell) nos descritores biológicos da comunidade, como riqueza de espécies, índice de diversidade de Shannon, equitabilidade, abundância total e biomassa. Testamos a hipótese de que as praias arenosas expostas ao swell (no Sul e Sudeste) devem apresentar areia mais fina e declive mais suave, possuindo valores maiores para os descritores da comunidade (riqueza de espécies, diversidade, equitabilidade, densidade e biomassa) em comparação com praias no Norte e Nordeste, que devem apresentar o padrão oposto, mais apresentando um estado reflectivo.

Resumo

Praias arenosas são ambientes dinâmicos que tem sua estrutura física determinada pela interação entre ondas, areia e marés. Os descritores da comunidade aumentam de praias severamente reflectivas para praias benignas e dissipativas, como descrito pela hipótese de exclusão pelo swash. Na costa do Sudeste brasileiro, frentes frias com fortes ventos do sul produzem ondas de alta energia que propagam para leste e sudeste. Isso é importante para as praias do litoral do Estado do Rio de Janeiro, que estão expostas ao swell vindo do sudeste. Entretanto, a influência da posição geográfica, da orientação das praias arenosas e do swell na morfologia das praias e, por consequência, na macrofauna existente, tem sido pouco estudada. O objetivo deste estudo é descrever a composição macrofaunal de 13 praias da Ilha Grande (Brasil) e testar a influência de variáveis geográficas (e.g. posição geográfica da praia, orientação da face da praia, orientação dos costões) nos descritores biológicos. Treze praias arenosas de micromarés foram amostradas no verão e inverno de 2011 e 2012 durante marés baixas de sizígia. Amostras biológicas foram amostradas ao longo de 5 transectos. Em cada transecto, 10 unidades de amostragem foram estabelecidas, a primeira na linha d’água, a penúltima na linha de deixa, e a última, 3 m acima da linha de deixa (supralitoral). Os crustáceos foram o grupo dominante, seguidos por poliquetos e moluscos. Parâmetros físicos foram influenciados pela posição geográfica das praias, sendo a areia mais fina, o declive mais suave e a quantidade de matéria orgânica no sedimento maior em praias orientadas para o sul e sudeste. O isópode *E. braziliensis* e o anfípode *A. brasiliensis* ocorreram em todas as praias estudadas. A riqueza e a abundância apresentaram maiores valores em praias expostas ao swell, vindo de S e SE. A variabilidade da macrofauna da Ilha Grande foi explicada principalmente pelas diferenças do morfodinamismo das praias, que teve grande influência da posição geográfica das praias em relação ao swell. O tamanho do grão, a declividade e o tamanho da praia estiveram associados com a orientação geográfica das praias, com a orientação da face das praias e com a orientação dos costões, estando as praias de maior largura, de menor tamanho de grão e menor declividade localizadas no setor sul.

Abstract

Sandy beaches are dynamic environments which its physical structure is determined by the interaction among sand, waves and tides. Community descriptors increase from harsh reflective to benign dissipative beaches, as described by the Swash Exclusion Hypothesis. In Southern Brazilian coast, cold fronts with strong southern winds produce high-energy waves that propagate from E and ESE. This is important for Rio de Janeiro sandy beaches, which are exposed to the swell coming from the SE. Nevertheless, the influence of geographic position, orientation of sandy beaches and upcoming swell on the beach morphology and, therefore, on the composition of the existing macrofauna has been poorly studied. The aim of the present study is to describe the macrofaunal composition and structure from 13 sandy beaches of Ilha Grande (Brazil) and test the influence of geographic variables (*e.g.* beach geographic position, beach face orientation, orientation of headlines) in biological descriptors. Thirteen microtidal sandy beaches were sampled in summers and winters of 2011 and 2012 during spring low tides. Biological samples were taken along five transects. On each transect, 10 equally spaced sampling units were established, the first, at the waterline, second last on the drift line, and the last, 3 m above the drift line (supralittoral). Crustaceans were the dominant group, followed by polychaetes and mollusks. Physical parameters were influenced by geographic position of beaches as sand was finer, slope was gentler and sediment organic matter was higher on beaches facing south and southeast. The cirolanid *E. braziliensis* and the amphipod *A. brasiliensis* were found at all sampled beaches. Richness and abundance were higher on beaches exposed to the swell. The variability of the macrofauna at Grande Island beaches is mainly explained by morphodynamic differences, which had high influence of the geographic position of the beaches in relation to the swell. Grain size, slope and beach length were associated with beach geographic orientation, beach face orientation and headland orientation, as larger beaches and lower grain size and slope values were found on south sector beaches.

Introduction

Sandy beaches are dynamic environments which its physical structure is determined by the interaction among sand, waves and tides. This ecosystem responds to wave energy, which carries sand offshore during storms and moves it back onshore during calms (Short 1999). Thus, sandy beaches constitute one of the most resilient types of coastlines. This determines the morphodynamic type of the beach system, from flat dissipative to steeper reflective states (Wright & Short 1984). However, some beach types, as pocket beaches, present peculiar characteristics. These beaches are constrained and short (with less than 2km in length) coastal sandy shores nested between rocky headlands and they are common along rocky coasts throughout the world (Brazeiro 1999, Dehouck et al. 2009, Vousdoukas et al. 2009, Bowman et al. 2014). In this case, headlands impact beach face and surf zone through their influence on wave refraction and attenuation, and by limiting the development of longshore currents, rips, and rip feeder currents (McLachlan & Brown 2006, Lercari & Defeo 2015). Therefore, pocket beaches show singular environments with great variability in terms of wave exposure, morphology and sedimentology even when close to each other (Dingler 1981, Wiegel 2006).

Sandy beach communities are structured by individual responses of macrofaunal species to the physical environment (McLachlan et al. 1993). This is well known and explained by the increase in community descriptors from harsh reflective (with coarser sands, steep slopes and no surf zone) to benign dissipative beaches (with fine sands, flatter slopes and a wide surf zone), as described by the Swash Exclusion Hypothesis, SEH, (McLachlan et al. 1993). The harsher swash climate increasing towards reflective conditions excludes intertidal species at the extreme reflective situation, which only supralittoral organisms remain (McLachlan et al. 1995). Also, these supralittoral organisms (e.g. amphipods), tend to reach higher abundances at reflective states, were the presence of berms makes the supralittoral more stable (Defeo & Gómez 2005) while polychaetes and mollusks reach highest abundances at dissipative conditions as these species have distinct abilities to occupy different beach morphodynamic types (McLachlan & Brown 2006).

Wave regime is one of the most important variables structuring the physical environment of sandy beaches. The influence of the swell on sandy beaches may vary according to beach type, because dissipative beaches may present a decrease in slope due to a higher ondulation, while reflective beaches show the opposite pattern (Codignotto et al. 2012, Ortega et al. 2013). The orientation of beach face and the headlands may be a significant factor behind the physical ecosystem (Calliari et al. 1996), influencing on sand composition, wave action and rip currents alongshore on pocket beaches (Dehouck et al. 2009). In SW Atlantic Ocean (SAO), Southeast Brazilian coast, cold fronts with strong southern winds produce high-energy waves that propagate from E and ESE (Codignotto et al. 2012). This is important for Rio de Janeiro sandy beaches, which are exposed to the swell coming from the SE. The influence of geographic position, the orientation of beach face and the upcoming swell in beach morphology has been little studied. The orientation of beach face and swell influence were analyzed in climate change studies at Uruguayan beaches (Codignotto et al. 2012, Ortega et al. 2013) and in geology studies at European pocket beaches (Vousdoukas et al. 2009, Bowman et al. 2014). Geographical position and exposure of beaches was related to sandy beach morphodynamics in a study at Sepetiba Bay, Rio de Janeiro (Cardoso et al. 2012). However, to date, no studies were conducted to evaluate the influence of all these variables on the macrofaunal community of sandy beaches.

Thus, the aim of this study is to describe the macrofaunal composition and structure of 13 sandy beaches from Ilha Grande (Brazil) and test the influence of physical and geographic variables (*e.g.* beach geographic position, beach face orientation, orientation of headlines) in biological descriptors as species richness, Shannon diversity index, eveness, total abundance and biomass. We test the hypothesis that the sandy beaches exposed to the swell (on S and SE) presents finer sand, higher waves and flatter slopes and, therefore, showing higher values for community descriptors (species richness, diversity, evenness, density, and biomass of both community and most representative species) when compared with beaches on N and NW, which should be more aligned to the reflective state.

Material and Methods

Study area

Ilha Grande, the third largest Brazilian island, with 350 km of water line perimeter, is located at southeast of Angra dos Reis (44°00' to 44°45' W and 22°50' to 23°20'S), and consists of an area of 193 km². At the island is located the Ilha Grande State Park. A protected area that comprises more than half of the island and bears eleven restricted areas (Cabrini et al. 2017). The park has been reported as a reference of pristine environment. Climate is tropical with dry winters and rainy summers. The most common waves have heights between 0.3 m and 1.5 m. The southwest waves, associated to frontal systems, present larger heights, between 1.0 m and 1.5 m (Cavalcante 2010). In geographic terms, the southern coast of Ilha Grande suffers direct action from undulations of southern quadrant as the passage of waves coming from the S - SE sector is favored. Thus, the western sector of Ilha Grande Bay is more vulnerable to southeast storms (Muehe et al. 1996)

Sampling and Laboratory procedures

Thirteen microtidal sandy beaches (fig. 1) were sampled once in summers and once in winters of 2011 and 2012 during spring low tides. Biological samples were taken along five transects, equally spaced and perpendicular to the shoreline. On each transect, 10 equally spaced sampling units (SUs) were established, the first (SU1) at the waterline, second last (SU9) on the drift line, and the last (SU10) 3 m above the drift line (supralittoral). One sample was taken with a 0.04 m² quadrat sampler to a depth of 25 cm. The collected sediment was sieved through a 0.50-mm mesh, and the retained material was taken to the laboratory, where organisms were sorted by species, counted, and fixed in 5% buffered formalin. For biomass estimates, collected organisms were dried at 70ºC for 24 h and weighed on a 0.001 g precision balance to obtain dry weight values.

Sediment compaction was measured in SUs of transects 2 and 4 within each beach using a penetrometer piston (Herrick & Jones 2002). Sediment samples for particle-size analysis were collected with a 3.5-cm diameter corer to a depth of 15 cm at all SUs of transects 2 and 4 for each sandy beach. Samples were dried at 70ºC for 24 h and sediment texture was assessed by sieving for coarse fractions (Suguio 1973), and by using a laser granulometer for fine fractions. Sediment parameters were estimated according to Folk & Ward (1957). The sediment organic matter content was estimated in sub-samples of 10 g of dried sediment after calcination at 600°C for 4 h. The slope of beach face was determined by the height difference (Emery 1961) between the supralittoral and the waterline on transects 2 and 4 and expressed in meters.

The Google Earth® program was used to determine the geographic variables: beach face orientation (BFO), the Headlands orientation (HO), beach geographic orientation (BGO), headland spacing and the bay extension ("depth" of the bay) and beach length following Bowman et al. (2014).

The Beach Index (BI) was calculated for each beach as a measure of its morphodynamic state, as lower values indicates reflective states and higher values indicates dissipative states, BI = (mean grain size*tide)⁄slope (McLachlan & Dorvlo 2005).

Data analysis

Diversity (H) and evenness (J) were calculated using the Shannon–Wiener index in $\log_e$ (Begon et al. 2006) for each beach, using the total number of individuals per species. Three two-way ANOVA were made at Statistica software. The first was used to test significant differences in total abundance, biomass, evenness, diversity and species richness between beaches and stations (summer/winter). The second two-way ANOVA was used to test significant differences of total organic matter, sediment compaction, 1/slope and grain size between beaches and stations. And the third two-way ANOVA was used to test significant differences of species abundance between beaches and stations. A principal component analysis (PCA) was used to assess patterns of spatial variation in sediment features and beach slope (data was $\log_{10}$ transformed) at summer and winter on Statistica software. Correlations between orientation angles (of beach face, headlands orientation and geographical position of beaches) and biological/physical parameters were analyzed using circular-linear statistics within Oriana 4 software. Correlations between BGO, BFO and HO were analyzed using circular-circular statistics within Oriana 4 software. Linear regressions between physical variables (grain size, sediment compaction, sediment organic matter and 1/slope) were made on Statistica software.

Results

Physical characterization

Physical characteristics of studied beaches are presented on table 1. Eleven of the sampled beaches were shorter than 2km and were classified as pocket beaches (the beaches that were not classified as pocket beaches are 8 and 10). The shortest beach sampled was 3 (53.41 m) and the longest was 10 (5854.33 m). 1/Beach slope varied from 4.78 to 22.13 on 2 and 9, respectively. Mean grain size ranged from 0.16 mm on 9 to 1.03 on 13. Beach Index (BI) ranged from 15.76 (12), reflective state, to 212.80 (9), dissipative state. Sediment compaction ranged from 1.85 to 5.81 (both values were recorded on 9, on summer and winter, respectively) (See table 1).

Beaches were classified as exposed or sheltered from the swell influence according to BFO angles (table 1). Beaches located on S, SE and SW (8, 9, 10 and 11), are exposed. Beaches located on N, NE and NW (1, 2, 3, 4, 5, 6, 7, 12 and 13) are sheltered (Fig. 1).

Grain size was positively correlated with 1/slope, sediment, sediment organic matter and sediment compaction. Sediment organic matter was positively correlated with 1/slope. Sediment compaction was not correlated with 1/slope and sediment organic matter (table 2). There was no significant difference in grain size, 1/slope, sediment organic matter and sediment compaction between stations as shown by two-way ANOVA.

The first two axis of the PCA (Figures 2 and 3) explained 81.1% and 84.9% of the data variation at summer and winter, respectively. At summer, the first axis explained 46.2% and showed positive correlations with slope ($r = 0.69$), grain size ($r = 0.53$) and a negative correlation with sediment organic matter ($r = -0.95$), while the second axis had 34.9% explanation being positively correlated to grain size ($r = 0.80$) and negatively to sediment compaction ($r = -0.80$). At winter, the first axis explained 62.8% and showed positive correlation with slope ($r =0.76$) and negative correlations with sediment compaction ($r = -0.90$) and sediment organic matter ($r = -0.88$), while the second axis had 22.1% explanation being positively correlated to grain size ($r = 0.78$).

Biologic characterization

A total of 5290 individuals of 33 different taxa were collected on 13 sampled beaches, 2644 on summer and 2646 on winter. Crustaceans were the dominant group in density while polychaetes presented the highest richness. Other groups were represented by the beetle *Phaleria testacea*, which was present at almost all beaches at least at summer or winter (except Dois Rios and Preta), and the amphioxus *Branchiostoma caribaeum*. The most representative species were the amphipod *Atlantorchestoidea brasiliensis*, the cogeneric isopods *Excirolana braziliensis* and *Excirolana armata*, the mole crab *Emerita brasiliensis* and the beetle *Phaleria testacea* (table 5).

Two-way ANOVA showed significant differences of species richness between beaches and stations (winter and summer). Diversity (H') and total abundance presented different values among beaches but not among stations. *Heterodonax bimaculatus, Phaleria testacea, Excirolana armata, Atlantorchestoidea brasiliensis, Emerita brasiliensis, Hastula cinerea* and *Dispio remanei* were the species that presented differences among sampled beaches.

Most of the linear correlations between physical and biological variables were not significant. Species richness were positively related with 1/slope and grain size, while species diversity (H') were associated to1/slope and Beach Index (table 3).

Influence of geographic variables

Geographic variables (Length of the beach, Headland spacing and Bay extension) were positive and significantly related to biomass and total abundance. Geographic variables were also related to *Excirolana braziliensis*, *Atlantorchestoidea brasiliensis* and *Emerita brasiliensis* abundances as these species reached higher numbers at larger beaches (Table 4).

BGO were not correlated with BFO and HO as some beaches are located close to each other but with different orientation angles (e.g. beaches 4 and 5). BFO were highly correlated with HO (r=0.96) as the headlands were aligned with the beach face at most cases. BGO, BFO and HO were correlated with Biomass on winter samplings but not on summer. The three angular geographical variables were also correlated with sediment organic matter, Headland spacing, beach length, bay extension and with *E. braziliensis* and *E. brasiliensis*,abundances. 1/slope, diversity (H') and evenness presented stronger correlations to BGO, as beaches located at South presented higher values of these variables. BFO and HO were correlated with grain size, while BGO was related to 1/slope. *A. brasiliensis* and *P. testacea* abundances were not correlated to circular parameters, however, *E. braziliensis, E. armata* and *E. brasiliensis* were highly correlated to all of them (except for *E. armata*, which was not associated with BGO). See table 6.

The most aligned beach to swell was 9, which presented the lowest values of grain size and slope, was considered de most aligned beach to the dissipative state, as presented the highest Beach Index value. Beach 8 was also located on southern sector of the island, however its orientation was more aligned to Southwest instead of Southeast. This beach presented the second highest BI value. The highest values of grain size were present on beaches 12 and 13, located at North and Northwest, the opposite of swell direction.

Discussion

Most sandy beaches community studies showed that these ecosystems are structured mainly by waves, tides, grain size and slope (Veloso et al. 2003, Defeo & McLachlan 2013). Physical parameters were correlated with BGO, BFO and HO, as sediment was finer, slope was gentler and sediment organic matter was higher on beaches exposed to swell influence. Beaches located South and Southeast (8, 9 and 10) also presented higher Beach Index values, indicating intermediate or dissipative state characteristics (McLachlan et al. 1993). Although Provetá beach (11) was located at the exposed sector of the island, its beach face was oriented southwest, which may have prevented direct swell influence (Cavalcante 2010) and may explain lower community descriptor values when compared to the other exposed beaches.

BGO and BFO were not correlated, these variables showed significant relations with biomass and sediment organic matter. However, BGO was correlated with 1/slope and BFO was correlated with grain size, even with these two physical variables being highly associated (McLachlan & Brown 2006). This possibly means that BGO and BFO are complementary, as these two variables explains the physical structure on different ways. When BFO and BGO values are similar (beaches located near and with similar orientation to the swell), beaches are grouped with similar physical characteristics, like beaches 1 and 2, 6 and 7 and 12 and 13, as seen on the PCA (fig. 2).

Macrofauna abundance patterns, species composition and community descriptors of the beaches of Ilha Grande are affected by beach morphodynamics and geographic variables. Although the most representative species occurred in most of the beaches, richness and abundance were higher on beaches exposed to the swell as highest abundances were found at beaches 10, 9, 8 (dissipative) and 1 (intermediate). The last one is not aligned to direct swell influence though the abundance was high due to *Atlantorchestoidea brasiliensis* population, a generalist species that reaches highest abundance on beaches aligned to the reflective state, where the supralittoral is more stable and allows semi-terrestrial species to reach higher abundance, fertility and size as supports Hypothesis of Habitat Safety (Defeo & Gómez 2005). In addition, our results showed that, although crustaceans were the dominant group at all sampled beaches, polychaetes and mollusks were more abundant on 8 and 9 (beaches exposed to the swell, with more gentle slopes and finer sand), the exception was 4 beach, wich had

50% of its biological community represented by polychaets. The high proportion of polychaets at Preta beach may be explained by sediment compaction and sediment organic matter that were associated with the first axis of the PCA on winter (figure 3), which was very similar to the values presented on 9, the beach with the higher polychaets abundance. This corroborates with the swash exclusion hypothesis (McLachlan et al. 1993) and with multicausal environmental severity hypothesis (Brazeiro 2001) that predicts an increase in community descriptors from harsh reflective (coarse sands, steep slopes) to benign dissipative (fine sands, gentle slopes) beaches, also predicting a higher abundance of mollusks and polychaetes at dissipative states. Crustaceans were dominant at all beaches, especially at beaches heading North and Northwest (with coarser sands and steeper slopes). 10 beach presented the higher *Excirolana braziliensis* population. This high abundance may be due to absence of *Excirolana armata*, the cogeneric competitor of this species and know to affect negatively *E. braziliensis* densities and population aspects (Cardoso & Defeo 2004) and may be related to the fact that this beach is located in a protected area, restricted to public visitation, as this species present higher densities at more pristine conditions (Veloso et al. 2011).

Longer beaches presented higher headland spacing and bay “depth” values, this correlation corroborates with studies on pocket beaches of European islands (Vousdoukas et al. 2009, Bowman et al. 2014). Biomass and total abundance were positively correlated with all three linear geographic variables, which indicates that beach length is one of the main factors that increases community parameters, as occurred on Sepetiba bay islands (Cardoso et al. 2012). Although species richness and Shannon diversity index showed no correlation with beach length, bay “depth” and headland spacing, when the biggest sampled beaches, 8 and 10, with lengths of 2.4km and 5.8km respectively, are taken out of the analysis, significant correlations ($R^2>0.38$ and $P<0.05$) occurred. The same pattern for species richness was presented by Brazeiro (1999) for Chilean beaches, in which a positive relation between species richness and beach length occurred when beaches were lower than 2km.

Some species, as the Talitrid *Atlantorchestoidea braziliensis*, the decapod *Emerita braziliensis*, the cirolanid isopod *Excirolana braziliensis* and the coleopteran *Phaleria testacea* occurred on almost all sampled beaches. The decapod *Emerita brasiliensis* is a filter feeder that inhabits the swash zone of dissipative, intermediate and reflective beach states (Defeo et al. 1992) and, although Veloso et al. (2003) has found a relation between slope and density of *E. brasiliensis* on exposed sandy beaches of Rio de Janeiro, we found no apparent linear relations, but this species abundance was correlated with all three geographic variables (Beach Geographic Orientation, Beach Face Orientation and Headlands Orientation) as it was more abundant at the south sector, more exposed to the swell influence and more related to intermediate and dissipative states. The cirolanid *Excirolana braziliensis* is one of the most representative species inhabiting Brazilian sandy beaches (Veloso & Cardoso 2001) and in some former studies has been regarded as a species that present higher densities at fine grains (Jaramillo 1982) as well as is more abundant on coarse grains (Defeo et al. 1997). Thus, the generalist pattern hoped was already expected as the cirolanid was found on 12 out 13 sampled beaches. Even tough, *E. braziliensis* reached its highest abundance on beach 10. At the same time, a circular-linear correlation was also significant for this organism as reached its highest abundance on beach 10, an intermediate beach located at the exposed portion of the island, were *E. braziliensis* occurred with no direct competition with *Excirolana armata*, considered a superior competitor and substract specialist, preferring finner grains (Defeo et al. 1997, Veloso & Cardoso 2001). The beetle *Phaleria testacea* was present on all beaches, except for beach 9. This species is commonly encountered on supralittoral and wrack deposits on Paraná and Rio de Janeiro sandy beaches (Ruiz-Delgado et al. 2014) and was also distributed along almost all 12 beaches located on Sepetiba bay, Rio de Janeiro (Cardoso et al. 2012). This implicates that this species is not influenced by geopraphycal and physical variables, inhabiting beaches of all types.

Some species presented clear abundance patterns like *Donax hanleyanus, Heterodonax bimaculatus, Excirolana armata* and *Scolelepis goodbodyi*. The bivalve *Donax hanleyanus* and the polychaete *Scolelepis goodbodyi* were just found at beaches located at the south sector of Ilha Grande. These two species are known to occur on the infralittoral of Rio de Janeiro sandy beaches, from intermediate to dissipative morphodynamic states, reaching its maximal abundance in the latter morphodynamic state (Gomes Veloso et al. 2003, Rocha et al. 2009). The bivalve *Heterodonax bimaculatus* is a suspension feeder, typical of Sepetiba bay sandy beaches, in which responded positively to exposure degree maybe for its larval dispersion (Cardoso et al. 2012). However, this species occurred only at sandy beaches facing north, not fully exposed to the incoming swell. The cirolanid *Excirolana armata* is recognized as a subtract specialist, occurring on finer sands (Defeo et al. 1997). Thus it occurred at beaches with different morphodynamics in low numbers, reaching highest abundance at Lopes Mendes, a fine grain beach, co-occurring with *E. braziliensis* (fig. 8).

Despite seasonal variation of undulation, as for part of the year, wave regimen results from local winds action associated with the South Atlantic Subtropical Anticyclone, causing waves from the east and northeast, which reach the system. During winter, the system is exposed to south quadrant ripples (SW-S-SE), associated with southwest winds derived from extra tropical cyclones originated in southern end of the Atlantic Ocean (Cavalcante 2010). There was no significant difference of physical aspects and most of biological variables did not show any difference among seasons at sampled beaches. Only species richness had significant difference, presenting higher values on winter.

We conclude that the variability of the macrofauna of beaches at Ilha Grande is mainly explained by beaches position and location, as high influence of BGO and BFO were found. Grain size, slope and beach length were associated with beach geographic orientation, beach face orientation and headland orientation as higher values were found on south sector beaches. The seasonality of waves incidence at sampled sandy beaches was not very relevant, as only two samplings were made at each beach and more studies might be necessary to assess this hypothesis. Ours results corroborated with multicausal environmental severity (Brazeiro 2001) as higher community descriptors values were found at dissipative beaches where the environment is more stable and allows this species to reach higher abundance, fertility and reflects in the species composing the sandy beach community.

Conclusão Geral

Podemos concluir que a variabilidade da macrofauna nas praias arenosas da Ilha Grande é principalmente explicada pela posição das praias em relação à ondulação. O tamanho do grão, o declive e o comprimento da praia foram associados às variáveis geográficas: BFO, BGO e HO, já que valores maiores foram encontrados nas praias do setor sul, expostas à influência direta do swell. Não grande houve diferença do swell sazonalmente, já que apenas a riqueza de espécies foi significativamente diferente entre as coletas de verão e inverno. Apesar disso, mais estudos podem ser necessários para avaliar esta hipótese, já que apenas duas coletas foram feitas em cada praia. Resultados corroboraram com a hipótese multicausal de severidade ambiental (Brazeiro 2001) e com a hipótese da exclusão pelo espraiamento (McLachlan et al. 1993), uma vez que os maiores valores de descritores biológicos da comunidade foram encontrados em praias dissipativas. Além disso, em praias de grão mais fino, declive mais suave e ambiente mais sucetível, poliquetos foram mais abundantes em comparação com praias de características do estado morfodinâmico reflectivo. A hipótese do habitat seguro (Defeo & Gómez 2005) também foi corroborada, pois *A. brasiliensis* apresentou valores elevados de abundância em praias arenosas intermédias e reflectivas.

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Appendix

Table 1: Physical and geographic characterization of sampled beaches.

Beach	Station	Length (m)	BFO	BGO	1/Slope (m)	Grain Size (mm)	Sediment compaction (Kg/cm²)	Beach Index (BI)
Freguesia (1)	Summer	333.03	73º	7º	7.57	0.36	5.01	31.46
	Winter				8.04	0.36	3.43	33.68
Camiranga (2)	Summer	507.9	67º	42º	4.78	0.41	3.76	17.49
	Winter				5.70	0.45	3.53	18.94
Feiticeira (3)	Summer	53.41	330º	60º	12.05	0.62	2.91	29.15
	Winter				12.01	0.39	5.21	45.94
Preta (4)	Summer	268.33	48º	76º	11.78	0.53	4.31	33.60
	Winter				11.49	0.43	5.74	40.45
Abraãozinho (5)	Summer	267.69	327º	100º	11.01	0.73	4.57	22.62
	Winter				11.11	0.97	4.58	17.26
Palmas (6)	Summer	604.55	64º	90º	9.87	0.74	1.87	20.01
	Winter				8.30]	0.72	3.10	17.35
Mangue (7)	Summer	319.05	65º	96º	12.37	0.70	2.37	26.70
	Winter				11.48	0.69	3.23	24.79
Lopes Mendes (8)	Summer	2420.25	218º	101º	19.85	0.26	5.01	112.78
	Winter				16.53	0.30	4.46	82.48
Dois Rios (9)	Summer	1320.35	113º	121º	22.13	0.16	1.85	212.8
	Winter				22.24	0.14	5.81	235.08
Aventureiro (10)	Summer	5854.33	171º	238º	13.54	0.49	2.71	41.53
	Winter				7.35	0.48	2.42	22.58
Provetá (11)	Summer	689.72	198º	255º	7.86	0.41	4.04	28.75
	Winter				7.35	0.53	2.20	20.63
Araçatiba (12)	Summer	622.51	295º	275º	9.87	0.94	2.29	15.76
	Winter				10.24	0.94	2.09	16.34
Bananal (13)	Summer	449.8	265º	351º	10.62	1.03	2.81	15.53
	Winter				12.35	0.79	3.88	23.32

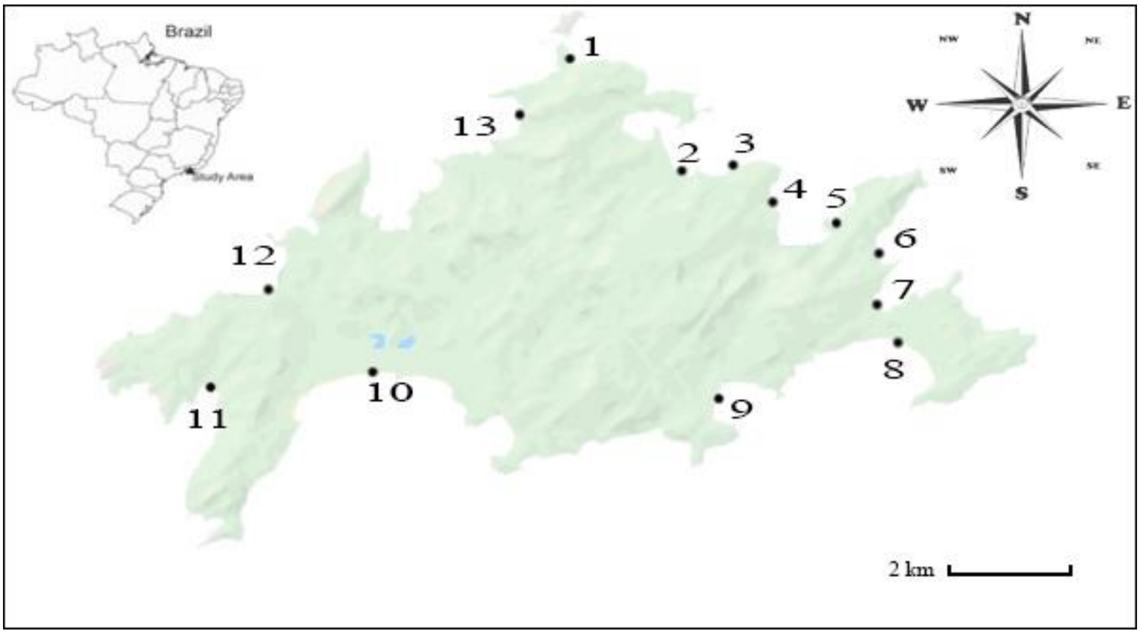

Figure 1: Location map of the 13 sampled beaches in Ilha Grande. 1: Freguesia; 2: Camiranga; 3: Feiticeira; 4: Preta; 5: Abraãozinho; 6: Palmas; 7: Mangue; 8: Lopes Mendes; 9: Dois Rios; 10: Aventureiro; 11: Provetá; 12: Araçatiba; 13: Bananal.

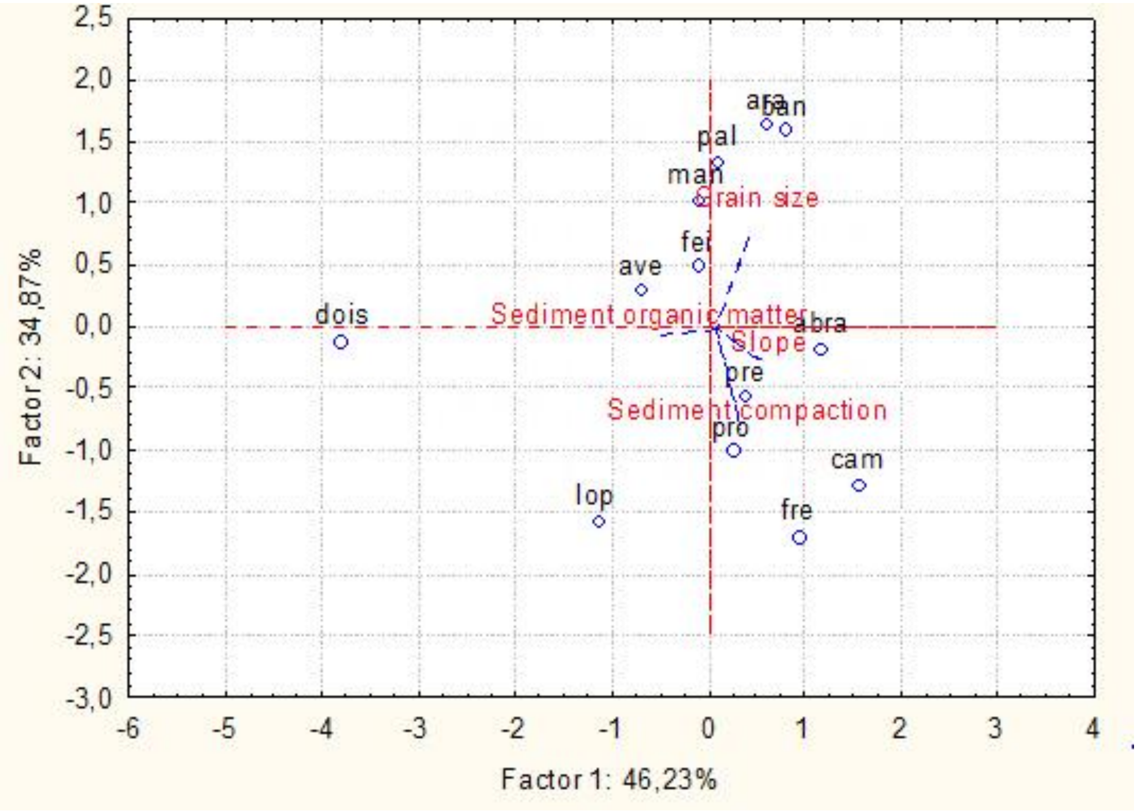

Figure 2: Ordination diagram constituted by the first two axis of the Principal Components Analysis (PCA) aplied to physical variables at Summer. dois (Dois Rios), lop (Lopes Mendes), ave (Aventureiro), fei (Feiticeira), man (Mangue), pal (Palmas), ara (Araçatiba), ban (Bananal), abra (Abraãozinho), pre (Preta), fre (Freguesia), pro (Provetá), cam (Camiranga).

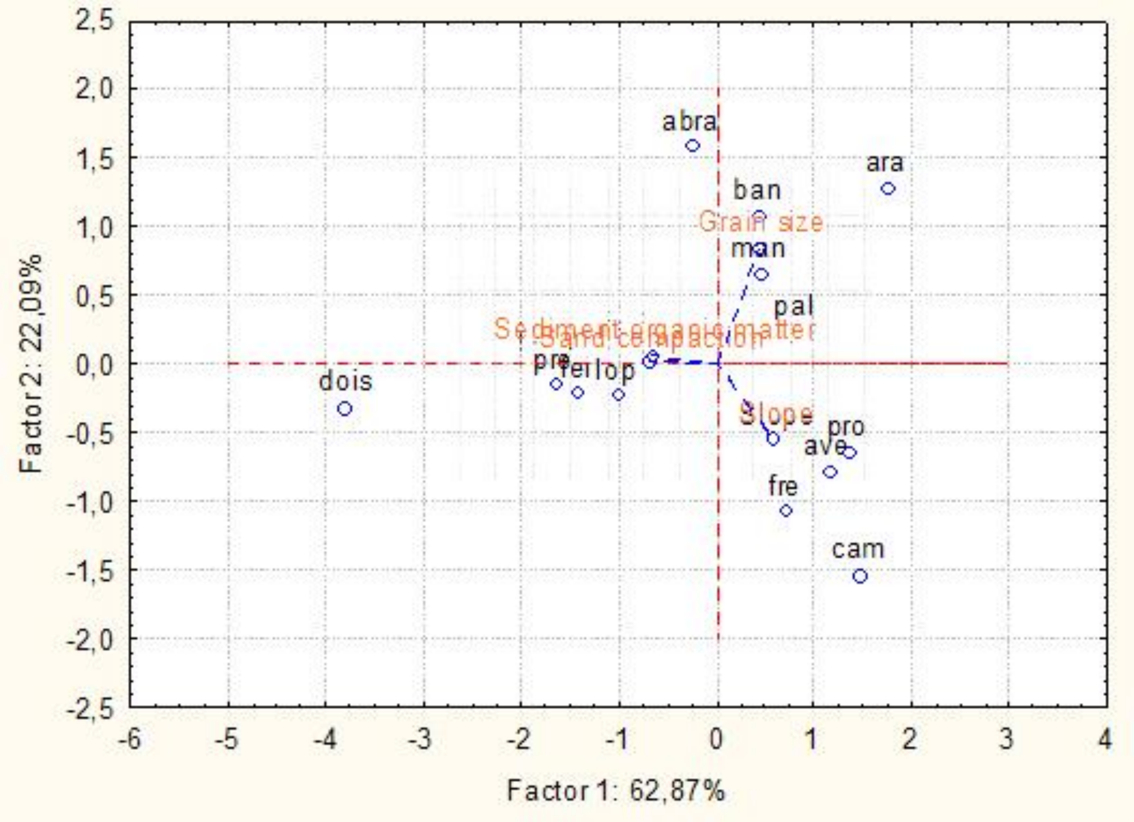

Figure 3: Ordination diagram constituted by the first two axis of the Principal Components Analysis (PCA) aplied to physical variables at Winter. dois (Dois Rios), lop (Lopes Mendes), ave (Aventureiro), fei (Feiticeira), man (Mangue), pal (Palmas), ara (Araçatiba), ban (Bananal), abra (Abraãozinho), pre (Preta), fre (Freguesia), pro (Provetá), cam (Camiranga).

Table 2: Results of linear regressions between physical variables. R values are on upper right and P values on bottom left.

Sediment compaction	0,18	0,23	0,40
0,38	**Organic Matter**	0,73	0,50
0,26	**0,00**	**1/slope**	0,39
0,04	**0,01**	**0,05**	**Grain Size**

Table 3: Results of linear regressions between physical variables and community descriptors and most abundant species

Variables	R	R²	P value
Grain Size			
Biomass	0,37	0,13	0,07
Total Abundance	0,25	0,06	0,23
Richness	0,43	0,19	**0,03**
Diversity	0,24	0,06	0,25
Eveness	0,04	0,00	0,83
P. testacea	0,01	0,00	0,98
E. braziliensis	0,11	0,01	0,58
E. armata	0,17	0,03	0,40
A. brasilienses	0,09	0,01	0,65
E. brasiliensis	0,02	0,00	0,92
Sediment compaction			
Biomass	0,00	0,00	0,96
Total Abundance	0,22	0,05	0,24
Richness	0,33	0,11	0,08
Diversity	0,32	0,10	0,10
Eveness	0,28	0,08	0,15
P. testacea	0,24	0,06	0,22
E. braziliensis	0,24	0,06	0,22
E. armata	0,20	0,04	0,28
A. brasilienses	0,10	0,01	0,53
E. brasiliensis	0,20	0,04	0,31
1/slope			
Biomass	0,20	0,04	0,31
Total Abundance	0,00	0,00	0,94
Richness	0,41	0,17	**0,03**
Diversity	0,49	0,24	**0,01**
Eveness	0,30	0,09	0,12
P. testacea	0,30	0,09	0,12
E. braziliensis	0,10	0,01	0,57
E. armata	0,32	0,10	0,10
A. brasilienses	0,20	0,04	0,29
E. brasiliensis	0,17	0,03	0,34
Beach Index			
Biomass	0,30	0,09	0,13
Total Abundance	0,00	0,00	0,81
Richness	0,36	0,13	0,06
Diversity	0,37	0,14	**0,05**
Eveness	0,20	0,04	0,30
P. testacea	0,17	0,03	0,34

E. braziliensis	0,00	0,00	0,79
E. armata	0,14	0,02	0,43
A. brasilienses	0,17	0,03	0,34
E. brasiliensis	0,20	0,04	0,28
Sediment Organic Matter			
Biomass	0,18	0,03	0,37
Total Abundance	0,05	0,00	0,83
Richness	0,23	0,06	0,25
Diversity	0,37	0,13	0,07
Eveness	0,34	0,11	0,09
P. testacea	0,15	0,02	0,46
E. braziliensis	0,02	0,00	0,93
E. armata	0,00	0,00	0,99
A. brasilienses	0,26	0,07	0,20
E. brasiliensis	0,23	0,05	0,26

Table 4: Results of linear regressions between geographic variables and community descriptors and most abundant species

	Length of the beach			**Headland Spacing**			**Bay extension**		
Variables	R	R²	P value	R	R²	P value	R	R²	P value
Biomass	0,66	0,43	**0,00**	0,56	0,32	**0,00**	0,61	0,37	**0,00**
Total Abundance	0,80	0,64	**0,00**	0,74	0,55	**0,00**	0,74	0,54	**0,00**
Richness	0,11	0,01	0,61	0,06	0,00	0,79	0,11	0,01	0,58
Diversity	0,04	0,00	0,84	0,01	0,00	0,96	0,07	0,00	0,75
Eveness	0,13	0,02	0,54	0,05	0,00	0,82	0,02	0,00	0,91
P. testacea	0,16	0,03	0,43	0,26	0,07	0,20	0,25	0,06	0,22
E. braziliensis	0,77	0,60	**0,00**	0,76	0,58	**0,00**	0,74	0,54	**0,00**
E. armata	0,19	0,04	0,36	0,13	0,02	0,53	0,15	0,02	0,47
A. brasilienses	0,52	0,27	**0,01**	0,48	0,23	**0,01**	0,42	0,18	**0,03**
E. brasiliensis	0,49	0,24	**0,01**	0,48	0,23	**0,01**	0,51	0,26	**0,01**

Table 2: Density (inds/m²) of macrofauna at sampled beaches. (C – Crustacea, M – Mollusca, A – Annelida, H – Hexapoda, CH – Cephalocordata)

	Abraãozinho		Araçatiba		Aventureiro		Bananal		Camiranga		Dois Rios		Feiticeira	
Species	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Amphinomidae (A)	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Armandia brevis (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dispio remanei (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,5	0,0	0,0	0,0
Hemipodia californiensis (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hemipodia simplex (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,0	0,0	0,0	0,0	0,0	0,0	0,0
Magelona riojai (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Orbinia riseri (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	39,5	0,0	0,5	4,5
Paraonis pygoenigmatica (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	0,0	0,0	0,0
Pisionidens indica (A)	0,0	0,0	0,0	0,0	4,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Scolelepis acuta (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Scolelepis chilensis (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Scolelepis goodbodyi (A)	0,0	0,0	0,0	0,0	0,0	3,5	0,0	0,0	0,0	0,0	68,0	0,0	0,0	0,0
Syllis spp. (A)	0,0	0,0	0,0	0,0	0,0	0,0	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphaeromopsis mourei (C)	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Spionidae (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Branchiostoma caribaeum (CH)	0,0	1,0	0,5	0,0	0,0	0,0	0,0	0,5	0,5	12,5	0,0	0,0	0,0	0,5
Olivella minuta (M)	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,5	0,0	0,0
amphipoda sp. (C)	0,0	0,0	36,0	23,0	0,0	0,0	0,0	0,5	0,0	1,0	0,0	0,0	0,0	0,0
isopoda sp. (C)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hastula cinérea (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	10,5	10,5	0,0	0,0
Lepidopa richmondi (C)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,5	0,0	0,0	0,0
Nassarius vibex (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Heterodonax bimaculatus (M)	2,5	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,0	0,0	0,0	5,5	1,5
Phaleria testacea (H)	3,0	0,5	1,5	0,5	0,0	0,5	3,0	0,0	1,5	0,5	0,0	0,0	1,0	3,0
Excirolana braziliensis (C)	0,5	4,5	1,5	1,0	113,5	439,5	12,5	4,5	7,5	12,5	39,5	25,0	5,0	11,0
Excirolana armata (C)	0,5	4,5	0,0	0,0	0,0	0,0	6,5	25,0	0,0	0,0	0,0	5,0	0,0	0,0
Metacirolana riobaldoi (C)	0,0	0,0	5,5	0,0	3,0	0,0	6,5	0,0	0,0	0,0	0,0	0,5	0,0	0,0
Atlantorchestoidea brasilienses (C)	26,0	11,0	40,5	4,0	121,0	162,0	36,5	11,0	16,5	9,0	3,5	1,0	76,0	36,0
Emerita brasiliensis (C)	0,0	0,0	0,5	1,0	5,0	3,0	1,0	1,5	1,0	0,5	0,0	0,0	0,0	0,5
Donax hanleyanus (M)	0,0	0,0	0,0	0,0	9,5	2,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Donax gemmula (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	2,0	0,0	0,0
Corbula patagônica (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0
Olivancillaria vesica vesica (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0

	Freguesia		Lopes Mendes		Mangue		Palmas		Preta		Provetá	
Species	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Amphinomidae (A)	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Armandia brevis (A)	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0
Dispio remanei (A)	0,0	0,0	6,0	0,0	0,0	0,0	0,0	0,0	13,0	8,5	1,5	0,0
Hemipodia californiensis (A)	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hemipodia simplex (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Magelona riojai (A)	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	9,0	1,5	0,0	0,0
Orbinia riseri (A)	1,5	0,0	4,5	1,0	0,0	0,0	0,0	0,0	0,0	4,0	0,0	0,0
Paraonis pygoenigmatica (A)	0,0	0,0	2,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Pisionidens indica (A)	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,5	0,5	0,5	0,0	0,0
Scolelepis acuta (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Scolelepis chilensis (A)	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	5,0	1,0	0,0	0,0
Scolelepis goodbodyi (A)	0,0	0,0	0,5	18,5	0,0	0,0	0,0	0,0	0,0	0,0	2,5	0,0
Syllis spp. (A)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphaeromopsis mourei (C)	0,0	0,0	0,0	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0
Spionidae (A)	0,0	0,0	0,0	0,5	0,5	0,0	0,0	0,0	1,5	0,0	0,0	0,0
Branchiostoma caribaeum (CH)	0,0	1,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0
Olivella minuta (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
amphipoda sp. (C)	0,0	0,0	0,0	0,0	0,5	0,0	12,0	4,5	0,0	0,0	0,0	0,0
isopoda sp. (C)	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hastula cinérea (M)	0,0	0,0	7,5	5,0	0,0	0,0	0,0	0,0	0,5	0,0	4,5	0,0
Lepidopa richmondi (C)	0,0	0,5	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Nassarius vibex (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Heterodonax bimaculatus (M)	0,5	5,5	0,0	0,0	0,0	0,0	11,0	6,5	0,0	0,0	0,0	0,0
Phaleria testacea (H)	4,5	6,0	0,0	0,5	3,0	1,0	4,5	5,0	0,0	0,0	2,5	1,0
Excirolana braziliensis (C)	27,5	23,5	17,5	39,5	17,0	3,5	40,5	69,0	12,5	7,0	53,5	25,5
Excirolana armata (C)	0,0	2,0	11,0	38,5	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,5
Metacirolana riobaldoi (C)	0,0	2,5	8,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Atlantorchestoidea brasilienses (C)	157,5	90,5	36,5	30,0	13,5	10,5	71,5	19,0	0,5	3,0	10,0	13,0
Emerita brasiliensis (C)	0,5	0,5	1,0	2,0	0,5	0,5	1,0	1,5	0,0	0,0	1,5	1,0
Donax hanleyanus (M)	0,0	0,0	7,5	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5
Donax gemmula (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Corbula patagônica (M)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Olivancillaria vesica vesica (M)	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

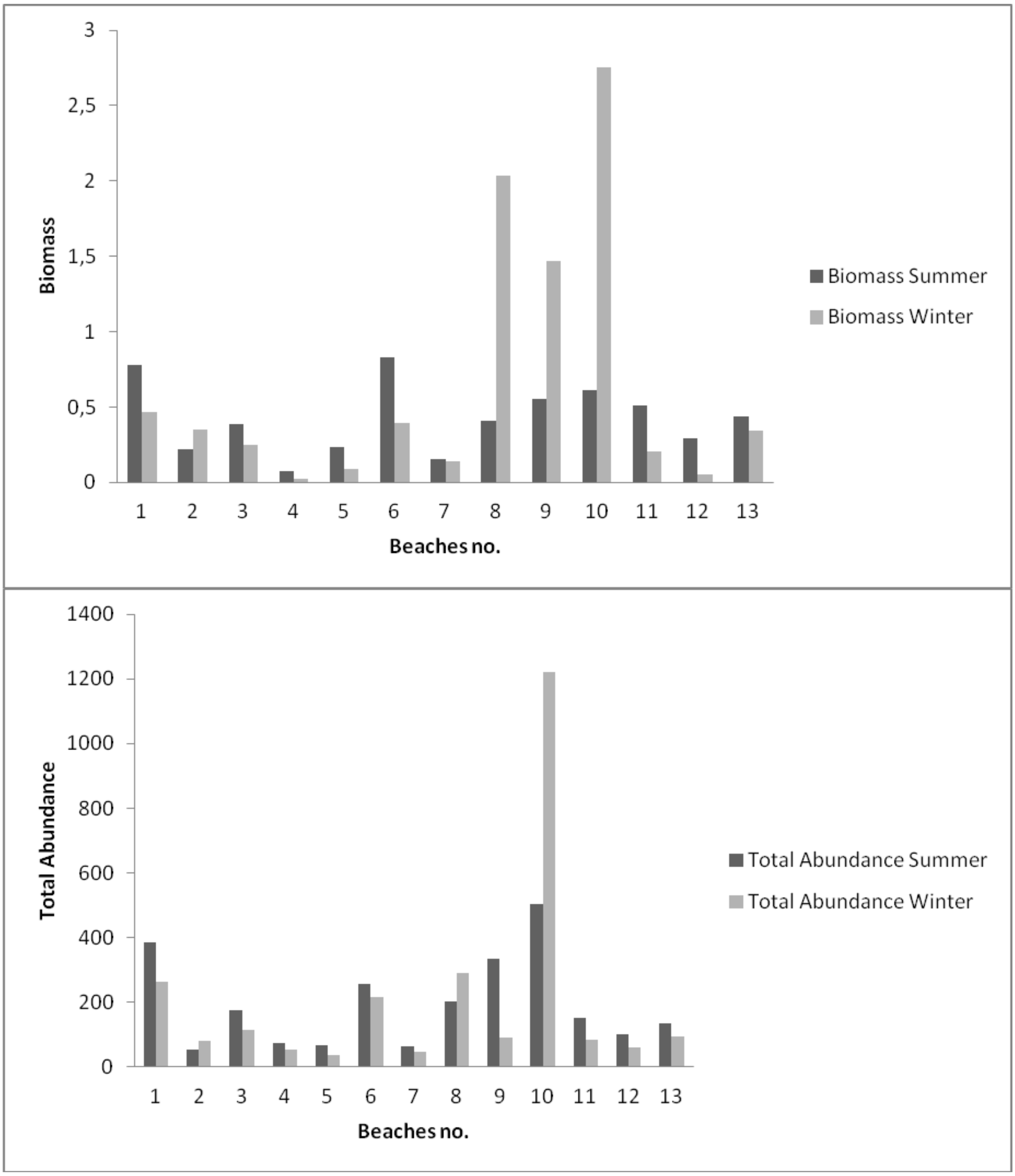

Figure 4a: Biomass of the sampled beaches on summer and winter. 4b: Total Abundance of the sampled beaches on summer and winter.

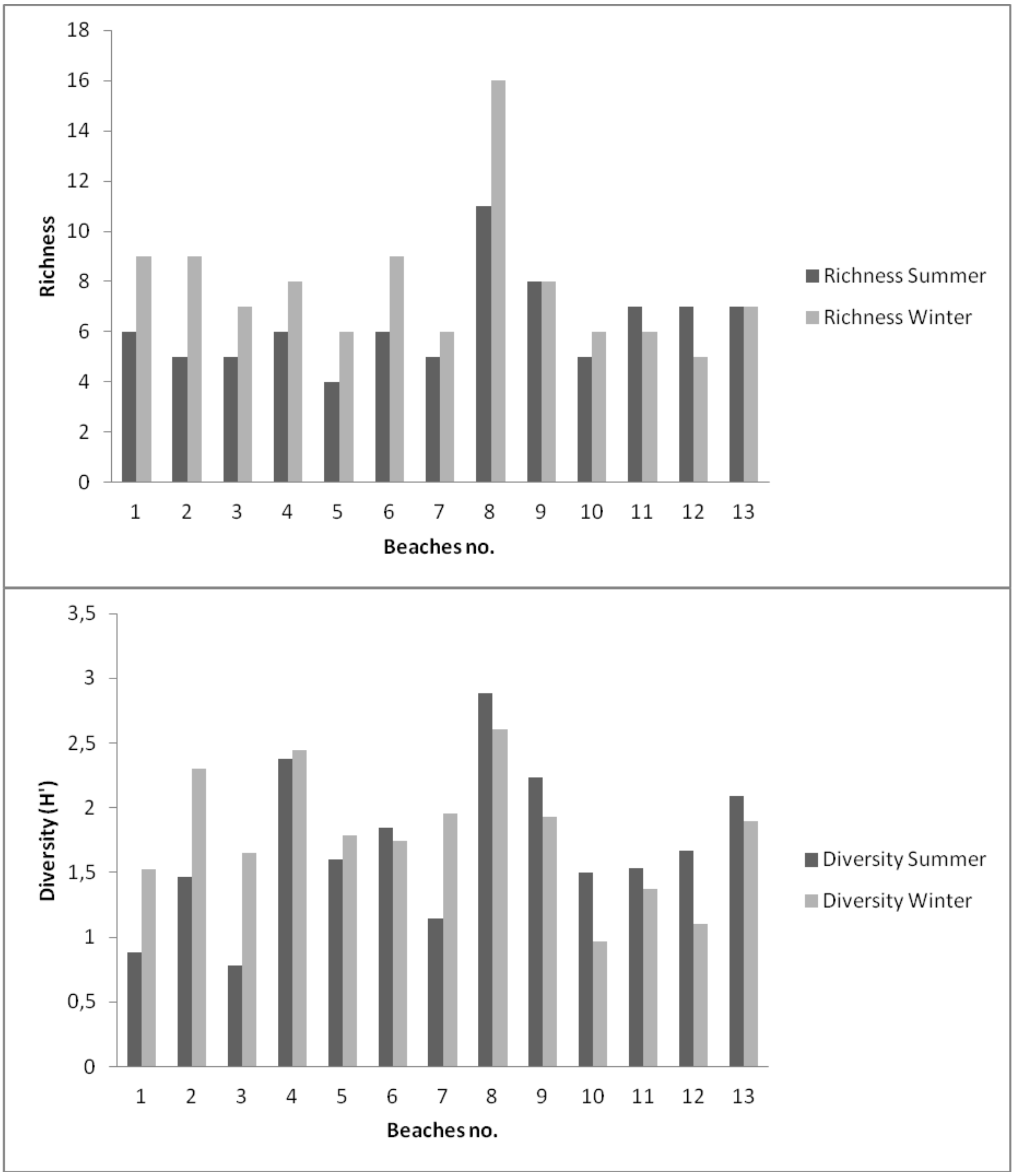

Figure 5a: Species Richness of the sampled beaches on summer and winter. 5b: Diversity (H') of sampled beaches on summer and winter.

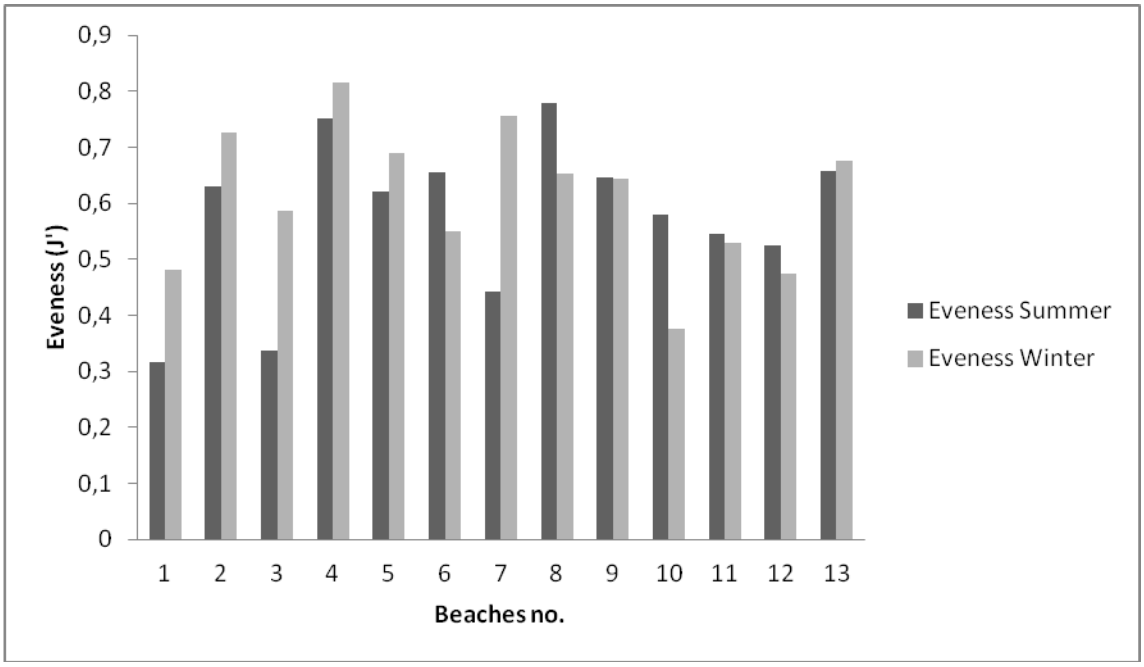

Figure 6: Eveness of the sampled beaches on summer and winter.

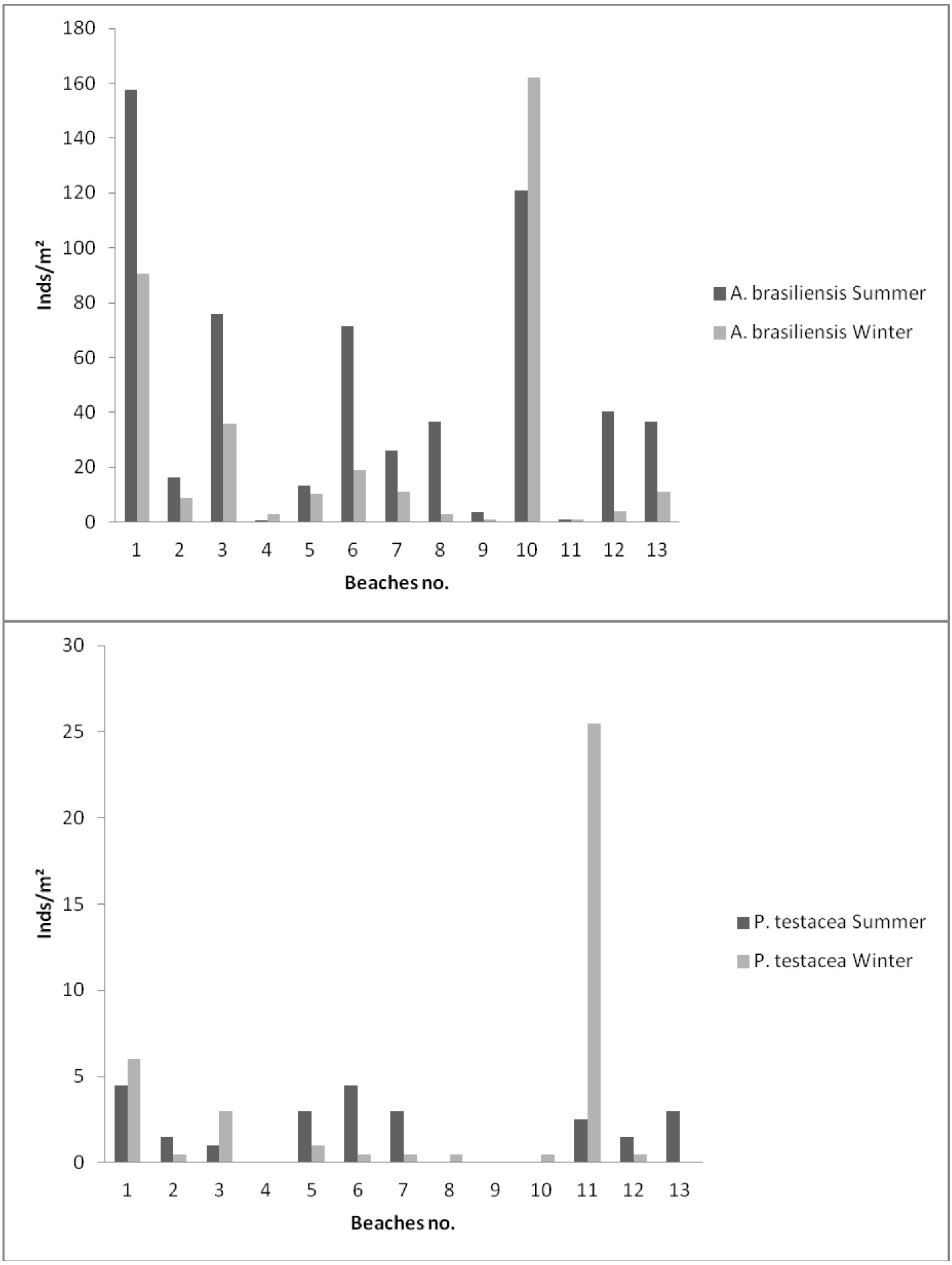

Figure 7a: *A. brasiliensis* on the sampled beaches on summer and winter. 7b: *P. testacea* abundance on sampled beaches on summer and winter.

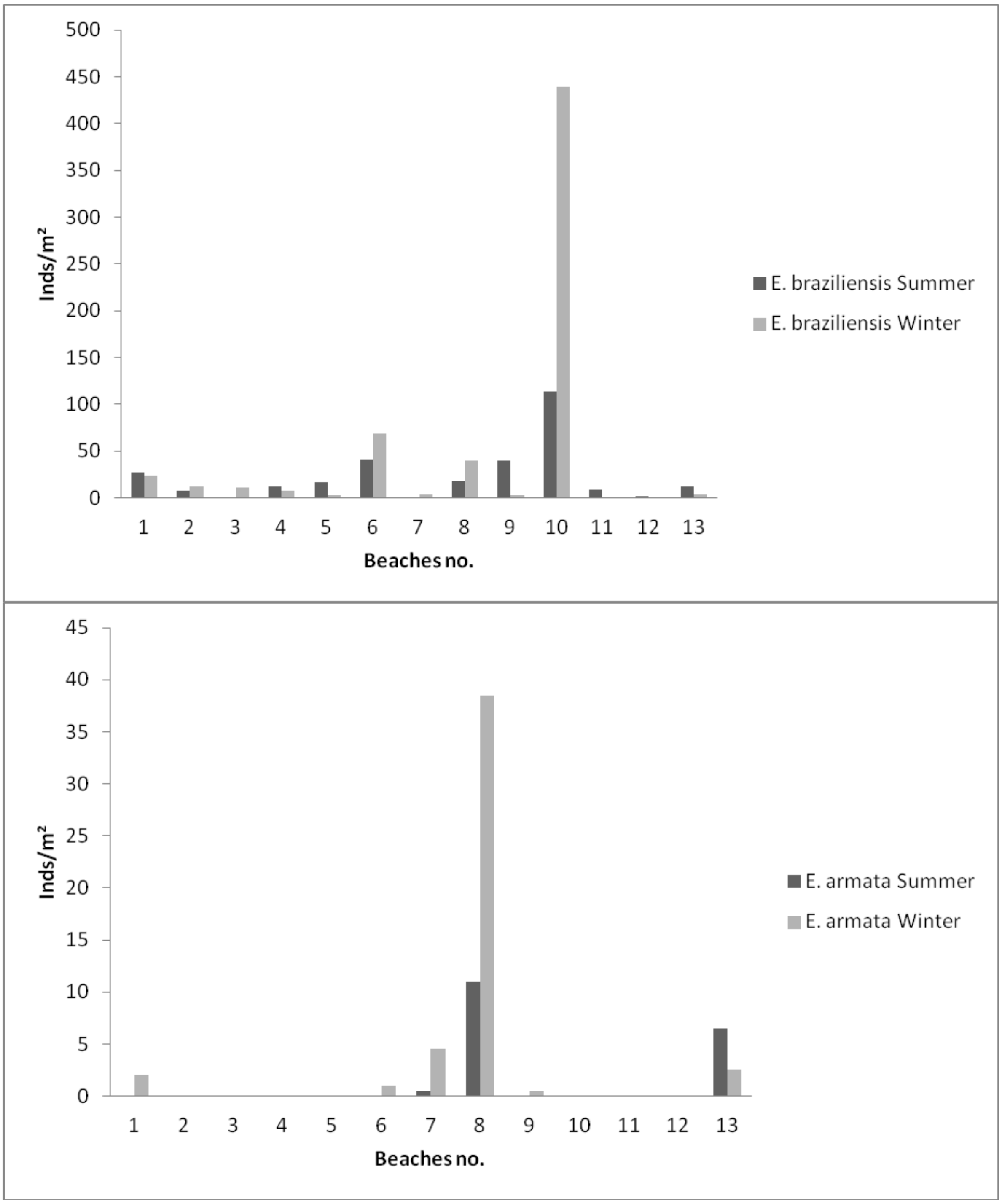

Figure 8a: *E. braziliensis* on the sampled beaches on summer and winter. 8b: *E. armata* abundance on sampled beaches on summer and winter.

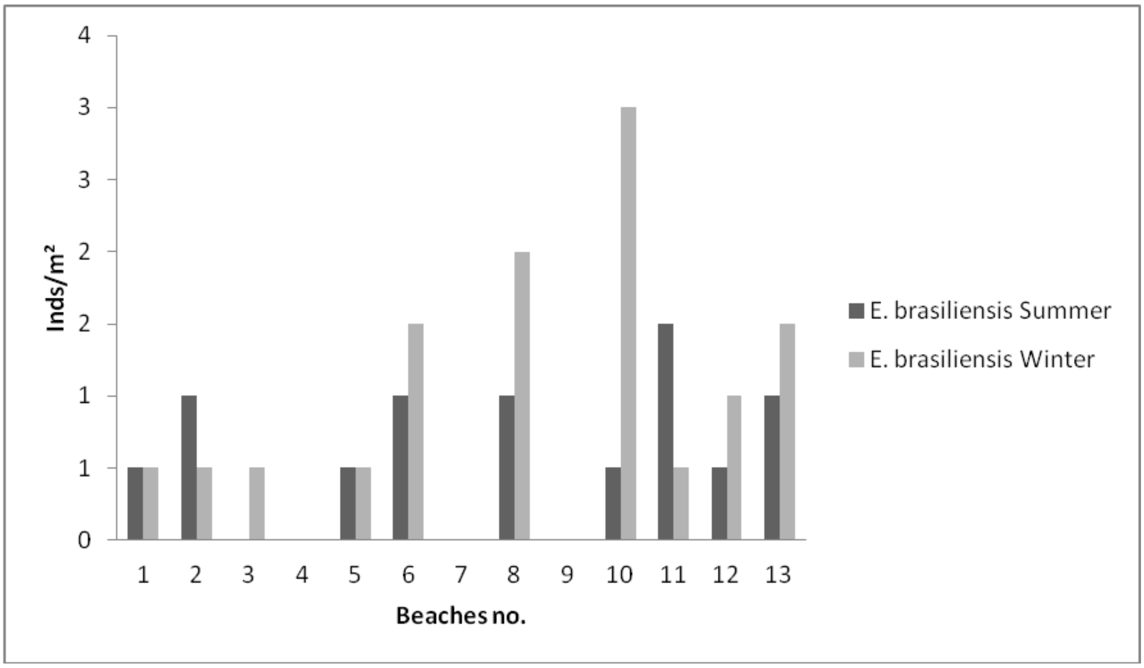

Figure 9: *E. brasiliensis* on the sampled beaches on summer and winter.

Table 6: Circular linear correlations (significant correlations in bold).

Circular-Linear correlation	Winter			Summer		
Variables	BGO	BFO	HO	BGO	BFO	HO
Biomass	**0.511**	**0.738**	**0.728**	0.237	0.490	0.429
Total Abundance	**0.506**	**0.557**	0.498	0.428	0.580	**0.534**
Species Richness	0.450	0.282	0.288	0.252	0.444	**0.519**
Diversity (H')	**0.777**	0.246	0.151	0.365	0.409	0.464
Sediment compaction	**0.733**	0.338	0.213	0.271	0.110	0.094
Organic Matter	**0.669**	0.240	0.199	**0.523**	**0.567**	**0.641**
1/Slope	**0.533**	0.151	0.294	**0.672**	0.377	0.442
Beach Index	0.481	0.392	0.445	**0.556**	0.492	**0.556**
Grain Size	0.238	**0.624**	**0.624**	0.376	**0.701**	**0.702**
Headland Spacing	**0.563**	**0.555**	**0.502**	**0.563**	**0.555**	0.503
Beach Length	**0.623**	**0.701**	**0.652**	**0.623**	**0.701**	**0.653**
Bay Extension	**0.639**	**0.620**	**0.574**	**0.639**	**0.620**	**0.575**
Eveness	**0.720**	0.454	0.351	0.375	0.383	0.431
P. testacea	0.348	0.418	0.460	0.402	0.345	0.413
E. braziliensis	**0.573**	**0.546**	0.506	**0.673**	**0.778**	**0.739**
E. armata	0.159	**0.575**	**0.614**	0.145	**0.586**	**0.609**
A. brasiliensis	0.391	0.424	0.363	0.373	0.108	0.150
E. brasiliensis	**0.522**	**0.688**	**0.581**	**0.640**	**0.659**	**0.590**