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Sensitivity of a cirolanid isopod to human pressure

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ABSTRACT

Cirolanid isopods are conspicuous members of the supralittoral and intertidal fringes of sandy beaches around the world, being dominant in terms of number or biomass. *Excirolana braziliensis* is one of the most abundant species on exposed sandy beaches, both urbanized and preserved, of Rio de Janeiro in southeast Brazil. Considering the negative effects of urbanization and human pressure on sandy beaches, this study aimed to analyze the population structure and reproductive aspects of *E. braziliensis* in different stretches of Barra da Tijuca beach (Rio de Janeiro, Brazil), which differ with respect to urbanization and occupation by bathers. Monthly samplings of *E. braziliensis* were conducted throughout 12 months within urbanized and preserved stretches, including measurements of beach parameters and human pressure. The anthropogenic effect seems to be a relevant factor in explaining the variability in the population structure of this species. Negative significant correlations were found between the species density and the number of visitors, who massively occupies the urbanized stretches. Similar life history strategies were observed for different populations of *E. braziliensis*. Although high fecundity rates were reported to all stretches, the probability of eggs/embryos survival under the adverse conditions provided by the Barra da Tijuca beach is not clearly known. According to the results of this study, it could be inferred that the human pressure over Barra da Tijuca beach affects the populations: (1) directly, through human trampling and/or natural habitat jeopardizing; or (2) indirectly, by the isolation of individuals in the preserved stretch, located between environments subjected to intense disturbance. In such case, the species strategy to thrive in a protected area of restricted size, within a highly urbanized and occupied area by bathers does not appear to be the best conservation measure for peracarid species, as in *E. braziliensis*. Nevertheless, *E. braziliensis* turned out to be a good monitoring species of impacts due to its high resistance to environmental stress, persisting in highly urbanized areas dominated by bathers.

1. Introduction

The use of sandy beaches has exponentially increased in recent decades, and many beaches have undergone rapid degradation caused by increasing pollution, nourishment, grooming, exploitation, beach mining, recreation and driving of off-road vehicles (ORVs) (Defeo et al., 2009; Lucrezi et al., 2009; Schlacher and Morrison, 2008). These developments increasingly threaten the ecological integrity of beach systems, encompassing a wide range of impacts that include the destruction of dune and beach habitats by infrastructure development (Colombini and Chelazzi, 2003), destruction of birds and turtles nests (Hosier et al., 1981), and crushing of invertebrates such as crabs, isopods and bivalves (Sheppard et al., 2009).

Changes in population parameters in response to human activities have been little investigated for sandy-beach organisms (Lozoya and Defeo, 2006), except for commercially valuable ones such as sand clams of the genera *Donax*, *Mesodesma* and *Tivela* (McLachlan et al., 1996; Murray-Jones and Steffe, 2000). The removal of individuals often causes changes in spatial distribution, which can be regarded as one of the first signs of change in a population (Defeo and de Alava, 1995). Furthermore, fishing effort concentrated on individuals of a particular body size may not only affect the densities of some age brackets, but also change the size at sexual maturity and consequently the fecundity (Defeo et al., 1992). Trampling from intense recreational activities can also have a similar or worse effect than fishing, as observed by Defeo and de Alava (1995) for the species *Donax hanleyanus*, which through accidental damage, had many individuals with destroyed shells in an environment where the fishery target was *Mesodesma mactroides*, another beach-clam species. The indiscriminate removal of organisms of different sizes and in different reproductive stages was also characterized by Kingsford et al. (1991) as extremely harmful to

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the communities of rocky shores, although the precise influence of this factor on the demography of these organisms has not been investigated.

Cirolanid isopods are conspicuous members of the supralittoral and intertidal fringes of sandy beaches around the world, being dominant in terms of numbers or biomass (Defeo et al., 1992; Veloso and Cardoso, 2001; Wendt and McLachlan, 1985). *Excirolana braziliensis* Richardson, 1912 is one of the most abundant species on exposed sandy beaches, both urbanized and preserved, of Rio de Janeiro in southeast Brazil (Veloso et al., 2006). *E. braziliensis* is present even when sandhoppers (e.g. *Atlantorchestoidea brasiliensis*), considered as good bioindicators of human activities, are absent (Nardi et al., 2003; Veloso et al., 2008). Considering the negative effects of urbanization and human pressure on sandhopper populations (Barca-Bravo et al., 2008; Fanini et al., 2005; Ugolini et al., 2008), this study aimed to compare the population structure and reproductive aspects of the isopod species, *E. braziliensis* in different stretches of Barra da Tijuca Beach (city of Rio de Janeiro), which differ with respect to urbanization and occupation by bathers. The hypothesis tested in this study was that the population structure and reproductive aspects of *E. braziliensis*, such as fecundity and sexual maturity, are different between the population patches distributed along urbanized and preserved stretches of the beach.

2. Methods

2.1. Study area

For comparative purposes, we selected 3 stretches of Barra da Tijuca (23 00′10′′S; 43 12′27′′W), an exposed sandy beach of 17 km long, situated at Rio de Janeiro city, southeastern Brazil. Alvorada and Recreio are characterized by a high degree of urbanization and human occupation, with large numbers of visitors throughout the year (Veloso et al., 2008). The 1.6 km lengths of the two urbanized stretches are aided with kiosks, parking lots, and lifeguard facilities. In contrast, Reserva has no facilities; it is a marine protected area (MPA) (Marapendi's MPA – Municipal Decree No. 10308 – 15/08/91) 3 km long, situated between the two urbanized stretches. Fewer visitors (Veloso et al., 2008) visit this beach stretch, which is primarily accessed by walking.

Although all three stretches have a concrete wall shoreward of the backshore (as does the entire beach), Reserva is more pristine, with a continuous row of vegetated sand foredunes 14 m wide. The urban stretches contain sparser vegetation, in a strip no more than 9 m wide.

2.2. Physical characterization

Physical variables were measured monthly (12 months) in each beach stretch, on the sampling occasions.

To evaluate sediment characteristics, a 3.5 cm-diameter core was taken to a depth of 10 cm. A total of nine samples were randomly selected from three pre-set transverse levels, representing the water table outcrop, drift line and swash level. Immediately after collection, the samples were placed in thermal containers, until laboratory analysis. Granulometric analysis was done according to Suguio (1973), and sediment organic-matter content was measured according to Gross (1971). The granulometric parameters obtained were analyzed according to Folk and Ward (1957).

The beach slope was measured from the water table outcrop to the swash level by the height difference, after Emery (1961). Beach width (m) was measured as the distance between the base of the vegetation strip and the lower swash level.

As a measure of human pressure, the number of visitors was counted in patches (100 m × 50 m) for each hour during the day of sampling. Data were collected for a 9 h period.

2.3. Sampling and laboratory procedures

Samples of *E. braziliensis* were collected during 12 consecutive months, from August 2003 through July 2004. A 100 m total length was covered in each stretch, with 10 transects established from the water table outcrop to the swash level. Each transect was divided into 11 transverse levels of equal size, where a total of 10 samples (per level) were taken, comprising 110 samples per stretch. A stratified-random sampling design was applied, with the sampling units chosen randomly, with the aid of a pre-set grid.

Individual samples were taken with a 0.04 m^2 quadrat to a depth of 20 cm. The organisms retained after sieving through a 0.7 mm mesh were frozen, and in the laboratory were counted, sexed and measured.

Each individual was sexed by means of inspection with a stereomicroscope, according to Dexter (1977). The individuals were then measured from the beginning tip of the cephalon to the end of the telson, with the results grouped into 1 mm size classes.

To estimate fecundity, ovigerous females were measured and the eggs (per embryo, incubated in the internal brood pouches of females) were removed and counted.

2.4. Data analysis

Because our main goal was to detect differences among urban and preserved stretches only, disregarding time periods, a repeated-measures ANOVA (Underwood, 1999) was used to test for differences in physical and biological variables. Comparisons among beach stretches using mean grain size (mm), mean slope (m/m), beach width (m), percentage of organic matter, and number of visitors (ind./100 m × 50 m) were performed. Comparisons using *E. braziliensis* densities (i.e. total, juvenile, male, female, ovigerous female, eggs/embryos) and individual sizes (total and in each category) were also investigated. The post hoc Tukey's test was applied when significant differences were found (Zar, 1996). When necessary, data series was log $(x+1)$/arc-sine (x) transformed in order to fulfill the requirements of the parametric test (Zar, 1996). A chi-square test (χ^2) (Vieira, 2004) was applied to test the proportion of males to females.

Forward stepwise multiple regression analysis was used to access the effect of measured physical variables on *E. braziliensis* densities. This analysis was undertaken using F values of 0 and 1 chosen *a priori* for variable entry and removal, respectively, until the best model was obtained. Partial correlations and redundancy of independent variables were also investigated. For this analysis, only physical variables which showed significant differences among stretches were considered.

The length (mm)–fecundity (eggs/embryos per female) relationship (L–F) was estimated by the linear function: $F = a + bL$, where a and b are parameters. An analysis of covariance (ANCOVA) was used to compare the L–F relationship among beach stretches, using length as the covariate.

Estimates of the proportion of ovigerous females as a function of size were used to model a logistic maturity function and to estimate the average size at maturity, as follows (Restrepo and Watson, 1991) (Eq.): $B_L = \beta/1 + e^{(\alpha_1 - \alpha_2 L)}$ where B_L is the proportion of females bearing eggs in each size class L and α_1, α_2 and β are parameters. The non-linear fitting procedure included a penalty function in the minimization algorithm by which β was constrained to values ≤1. The average size at sexual maturity ($L_{50\%}$) was obtained by $L_{50\%} = -\alpha_1/\alpha_2$, where α_1 and α_2 were defined in