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Distributional patterns in an insect community inhabiting a sandy beach of Uruguay

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Most studies of sandy beach macrofauna have been restricted to semiterrestrial species and do not include insects when providing species richness and abundance estimates. Particularly, spatio-temporal patterns of community structure of the entomofauna inhabiting these ecosystems have been scarcely documented. This study assessed spatio-temporal distributional patterns of the night active entomofauna on a beach-dune system of Uruguay, including variations in species richness, abundance and diversity, and their relationship with environmental factors. A deconstructive taxonomic analysis was also performed, considering richness and abundance patterns separately for the most abundant insect Orders (Hymenoptera and Coleoptera) to better understand the factors which drive their patterns. We found clear temporal and across-shore patterns in the insect community inhabiting a land–ocean interface, which matched spatiotemporal variations in the environment. Abundance and species richness were highest in spring and summer, concurrently with high temperatures and low values of sediment moisture and compaction. Multivariate ordinations showed two well-defined species groups, which separated summer, autumn and spring samples from winter ones. Generalized Linear Models allowed us to describe a clear segregation in space of the most important orders of the insect community, with specific preferences for the terrestrial (Hymenoptera) and beach (Coleoptera) fringes. Hymenoptera preferred the dune zone, characterized by high elevation and low sand moisture and compaction levels, whereas Coleoptera preferred gentle slopes and fine and humid sands of the beach. Our results suggest that beach and dune ecosystems operate as two separate components in regard to their physical and biological features. The high values of species richness and abundance of insects reveal that this group has a more significant ecological role than that originally considered so far in sandy beach ecology.

1. Introduction

Exposed ocean beaches are harsh and dynamic environments primarily controlled by waves, tides, and sediment type (McLachlan and Defeo, 2013). These physical factors operating over several spatial scales are the main drivers governing macrofauna biodiversity patterns on sandy beaches. Thus, global macrofaunal patterns can be reliably predicted on the basis of these distinctive physical features of the beach environment (Defeo and McLachlan, 2005, 2013). The benthic macrofauna of sandy beaches include representatives of many phyla, but crustaceans, molluscs and polychaetes predominate, accounting for up 95% of marine species richness (McLachlan and Brown, 2006). On the other hand, insects are the most abundant terrestrial invertebrate group inhabiting coastal dunes and the supralittoral fringe of sandy shores, playing a key role in trophic webs (McLachlan and Brown, 2006). Recent deconstructive analyses based on taxonomy indicated that species richness of these four taxa increased from reflective (steep slopes, coarse sands) to dissipative (flat slopes, fine sands) beaches (Defeo and McLachlan, 2011; Barboza et al., 2012).

Most studies of sandy beach macrofauna have been restricted to marine and semiterrestrial species and do not include insects when providing species richness and abundance estimates (McLachlan and Brown, 2006). Indeed, studies describing terrestrial invertebrate communities of sandy beaches, including insects, have been relatively scarce (Giménez and Yannicelli, 2000; Colombini et al.,

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2002; Gauci et al., 2005; Costa et al., 2006; Fanini et al., 2009; Sivadas et al., 2012) or have been focused in only one insect group (Fallaci et al., 1997, 2002; Aloia et al., 1999; Fattorini and Carpaneto, 2001; Colombini et al., 2002, 2003, 2005; Chelazzi et al., 2005; Comor et al., 2008), and most of them are restricted to Mediterranean coasts. Especially, in sandy beach ecology, spatio-temporal patterns of species richness, abundance and distribution of the entomofauna belonging to both, the beach zone and the terrestrial dune ecosystem, have been mostly documented in the Adriatic coast (Chelazzi et al., 2005). These two distinct areas, along with the surf zone, comprise together a single geomorphic unit termed the Littoral Active Zone (LAZ, McGwynne and McLachlan, 1992; McLachlan and Brown, 2006). As the insect distribution extends landwards, abundance estimates are biased because sampling design commonly do not take into account the full across-shore distribution of the species, including the terrestrial dune ecosystem (Defeo and McLachlan, 2011).

Besides the need to assess spatial and temporal distributional patterns of the entomofauna in sandy beach, it is also important deconstruct these communities to discriminate patterns among distinct taxonomic groups that could respond differently to the environment, thus exhibiting contrasting patterns that would be obscured if only aggregate richness is considered (Marquet et al., 2004). By treating such species groups separately, a more complete understanding of the factors driving species richness patterns may emerge (Defeo and McLachlan, 2011). This is particularly important in temperate zones, where environmental seasonal changes tend to translate into temporal activity patterns in living organisms according to particular characteristics of the life cycle of the species. In this context, various macroclimatic and microclimatic changes and variation in the availability of food resources are important factors in triggering seasonal activity of insects (Wolda, 1988).

The aim of this paper was to assess spatial and temporal patterns of species richness, abundance and diversity of the entomofauna of the LAZ (the beach zone and the terrestrial dune ecosystem) on the dissipative beach Barra del Chuy (Uruguay), and the relationship between these ecological descriptors and environmental factors. This beach has the highest macrofauna richness (including insects) and it is the widest ocean one among all Uruguayan beaches (Barboza et al., 2012). Specifically, it is assessed whether within-year environmental changes translate into temporal differences in species richness, abundance, diversity and composition of insect community. Moreover, it is postulated that gradients in environmental factors throughout the beach-dune system generate across-shore variations in species richness and abundance of insects, which vary according to the group of species analysed.

2. Materials and methods

2.1. Study site and sampling design

The study was undertaken in Barra del Chuy (33° 45′ S, 53° 27′ W), a sandy beach on east coast of Uruguay (Department of Rocha). This is a wide (beach width ca 70 m) dissipative beach with fine to very fine (grain size = 0.20 mm) well-sorted sands, a gentle slope (2.7%), a wide surf zone and high macrofauna richness, total abundance and biomass (Defeo et al., 2001; Barboza et al., 2012). The active dunes are covered by a great abundance of the perennial herb *Panicum racemosum* (Poaceae) and some halophilous annual species such as *Blutaparon portulacoides* (Amaranthaceae), *Cakile maritima* (Brassicaceae) and *Calycera crassifolia* (Calyceraceae).

Environmental and biological samples were taken in nocturnal surveys carried out in 2012: summer (23/01–24/01), autumn (18/04–19/04), winter (22/08–23/08) and spring (13/11–14/11). Insects were collected using pitfall traps as sampling units (SU) set along three transects perpendicular to the shoreline, spaced 8 m apart from each other (10 SU per transect). Nocturnal sampling with pitfalls is an effective method to achieve a good representation of the richness and abundance of insect species in sandy beaches (Gauci et al., 2005). Traps were set during new moon days and were kept active overnight, because it has been shown that most nocturnal insects are especially active during those days (see e.g. Nag and Nath, 1991). Pitfall traps were placed every 8 m from the swash zone to 40 m inland from the beginning of the active dune. Each trap consisted of a plastic cup (12 cm diameter and 12 cm depth) filled with 150 ml of a solution of propylene glycol (50%) with a few drops of detergent. Propylene glycol is an effective killing and preservative agent, odourless, non toxic to vertebrate and slow to evaporate (Aristophanous, 2010). In the laboratory, captured insects were sorted, counted and identified to the species or genus taxonomic level or morphospecies. Some insect groups were preserved dry and others were sorted in 70% ethanol and were deposited in the Entomological Collection of Facultad de Ciencias, Universidad de la República (Montevideo). As pitfall trapping is a standard method to catch epigeic arthropods (Chen et al., 2011), all the biological data analyses included only those insect groups with well-known epigeic habits.

Sand temperature, sand compaction and elevation were measured in correspondence to each pitfall trap (SU), together with sediment samples for determination of granulometric parameters, sand moisture, and sediment organic matter content. Sand compaction was measured using a piston pocket penetrometer and the elevation was estimated according to Emery (1961). Laboratory analysis of sediment statistics was made following Folk (1980). Estimation of mean particle size and sorting were made using the GRADISTAT v.6.0 software (Blott and Pye, 2001). A fraction of the sediment sample was oven dried at 80 °C for 24 h, weighted (±0.001 g) and then burned at 460 °C for 4 h, and finally weighted again to estimate sediment moisture and organic matter content.

2.2. Statistical analyses

Between-season differences in the environmental variables were tested through one-way analyses of covariance (ANCOVA), using the distance from the dune as the covariate and season as the main factor, performing a Fisher's LSD test when significant differences were found. Non-metric multidimensional scaling (NMDS) based on Euclidean distance matrix of log transformed standardized environmental variables was used to create a two-dimensional (2D) ordination of the samples for each season. For NMDS overlays, measurements of physical parameters in each season were averaged for the three SU at same distance from the dune. Changes in environmental conditions across zones (dune and beach) were assessed by one-way Permutational Analysis of Variance (PERMANOVA; Anderson, 2001) included in the PRIMER 6.0 software package (Clarke and Gorley, 2006). One fixed factor (season) and 1000 permutations of residuals under a reduced model were considered in the design. To confirm that environmental differences between zones were due to location differences rather than to data dispersion, we used a permutational analysis of multivariate dispersions (PERMDISP; Anderson et al., 2006) included in the same software package. Abundance (mean values per transect) and species richness (number of species per transect) were used to compute the Shannon–Weiner species diversity index and Simpson's dominance index (Magurran, 1988), using the Diverse routine included in the PRIMER 6.0 software package (Clarke and Warwick, 1994).