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The role of wrack deposits for supralittoral arthropods: An example using Atlantic sandy beaches of Brazil and Spain

Mª Carmen Ruiz-Delgado [a,*], Jenyffer Vierheller Vieira [b], Valéria Gomes Veloso [e], Mª José Reyes-Martínez [a], Ilana Azevedo Sallorenzo [c], Carlos Alberto Borzone [b], Juan Emilio Sánchez-Moyano [d], Francisco José García García [a]

[a] *Departamento de Sistemas Físicos, Químicos y Naturales, Universidad Pablo de Olavide, Carretera Utrera Km 1, 41013 Sevilla, Spain*
[b] *Centro de Estudos do Mar, Departamento de Ciências da Terra, Universidade Federal do Paraná, Av. Beira Mar, s/n CEP 83255-000, Pontal do Sul, Pontal do Paraná, PR, Brazil*
[c] *Instituto de Biologia, Departamento de Biologia Marinha, Universidade Federal Fluminense, Outeiro de São João Batista s/n, Campus do Valonguinho Centro, Niterói, CEP 24020-140 Rio de Janeiro, RJ, Brazil*
[d] *Departamento de Zoología, Universidad de Sevilla, Av Reina Mercedes 6; 41012, Sevilla, Spain*
[e] *Laboratório de Ecologia Bêntica, Departamento de Ciências Naturais, Universidade Federal do Estado do Rio de Janeiro, Avenida Pasteur, 458, CP 22290-240 Rio de Janeiro, RJ, Brazil*

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A B S T R A C T

Wrack deposits, as accumulated detritus, are a common feature on beaches worldwide and significantly contribute to the shaping of supralittoral arthropod communities. The composition and relative age of upper-shore deposits influence the structure and taxonomic composition of invertebrate assemblages. Moreover, these influences may vary geographically, depending on the locally prevailing climatic and hydrodynamic conditions. The amount and composition of wrack deposits as well as community attributes (total density, species richness and diversity) were determined on sandy beaches in three distinct geographical regions: South (Paraná) and Southeast (Rio de Janeiro) of Brazil and SW Spain. These parameters were compared between upper and lower wrack bands on each beach and between beaches in each region. Wrack deposits were composed of mangrove propagules in the Paraná region, by macrophytes, dead invertebrates and macroalgae in Rio de Janeiro region and by seagrass and macroalgae in the SW Spain region. In all regions, the total amount of stranded wrack differed between beaches, but the amount accumulated between bands (i.e upper and lower band) was similar between beaches. Wrack bands shaped the density of common taxa (Talitridae, Tenebrionidae, and Staphylinidae), with consequences for community structures. This result could be due to their preference for specific microhabitats and food sources, which might differ according to the relative age of the wrack deposits. The results suggest that, independent of wrack composition, the distribution of wrack deposits in bands and their relative ages seems to play a role on the structure of supralittoral arthropod assemblages.

1. Introduction

Stranding organic allochthonous materials is a common feature on sandy beaches around the world. These systems are generally characterized by the action of strong hydrodynamic forces that create unconsolidated sands devoid of large primary producers (McLachlan, 1981; Griffiths et al., 1983). Beach food webs in these environments are supported primarily by allochthonous resources. Organic materials come from adjacent coastal ecosystems (rocky intertidal, rocky shores, seagrass meadows, mangroves) associated with offshore dynamics and physical factors such as currents, prevailing winds, waves and tides, which transport organic materials and leave accumulation of them along shores to form wrack deposits (e.g. Ochieng and Erftemeijer, 1999; Orr et al., 2005). In many temperate regions, these wrack deposits are composed mainly of marine macrophytes and macroalgae, but mangrove propagules and carrion represent other major organic components of beach cast. The former are common in tropical areas while the latter become important on beaches with very low allochthonous inputs (Colombini and Chelazzi, 2003).

The amount and spatial distribution of allochthonous materials at a given beach may vary according to the production of the

* Corresponding author.
E-mail address: mcruidel@upo.es (M.C. Ruiz-Delgado).

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adjacent habitats; the physical environment of beaches (e.g. rate of exposure, beach slope, wave height, type of substratum and swash environment) and the composition and buoyancy of the drifting wrack (Ochieng and Erftemeijer, 1999; Orr et al., 2005; Barreiro et al., 2011; Duong and Fairweather, 2011). Over the entire beach, wracks can be distributed into patches from the extremely high water of spring tide to mean tidal levels or can be deposited along one or more drift lines, usually at high water spring line and in bands or in a band down to the level of the most recent high tide (Marsden 1991; Ochieng and Erftemeijer, 1999; Colombini et al., 2000). Such distribution patterns affect the abundance and distribution of invertebrate assemblages, particularly supralittoral invertebrates (e.g. Stenton-Dozey and Griffiths, 1983; Jaramillo et al., 2006; Olabarria et al., 2007). Several authors reported higher abundances and species richness of invertebrates in wrack patches than in bare sediments (Dugan et al., 2003; Jaramillo et al., 2006; Ince et al., 2007; Rodil et al., 2008; MacMillan and Quijón, 2012). In addition, the position of wrack deposits over the beach surface determines the beach inhabitants that can colonize them (Colombini et al., 2009). Wrack deposits in the middle and lower-shore are more likely to be colonised by marine taxa, whereas upper-shore deposits are likely to be dominated by terrestrial taxa, mainly insects and their larvae (Egglishaw, 1965). Furthermore, upper-shore deposits are subject to dehydration, ageing and sand covering, encouraging their decomposition and remineralization (Griffiths and Stenton-Dozey, 1981; Inglis, 1989; Jedrzejczak, 2002a). These processes are complex and depend on the amount and composition of wrack (Jedrzejczak, 2002a; Rossi and Underwood, 2002).

Different types of wrack such as macroalgae and propagules may vary in their physical characteristics, which could determine their decomposition rates, nutritional values and also microclimatic conditions (i.e. temperature and humidity) (Rodil et al., 2008). Therefore, the composition and the age of wrack might influence the structure and taxonomic composition of invertebrate assemblages, depending on the preference for specific microhabitat and food sources that differ according to species (Valiela and Reitsma, 1995; Colombini et al., 2000; Pennings et al., 2000). Talitrid amphipods as well as tylid and oniscoid isopods are considered primary colonizers of newly deposited wrack, while different insect species, mainly dipterans and coleopterans, colonize the deposits when these dry out (e.g. Griffiths and Stenton-Dozey, 1981; Behbehani and Croker, 1982; Inglis, 1989; Colombini et al., 2000). In addition to their use as refuges, wrack deposits represent the main food resource for supralittoral invertebrates. The distribution pattern of wrack-associated fauna is related to feeding preference of individual species for a type of resource as a food (Colombini and Chelazzi, 2003). Because many of these organisms form the base of coastal food chains, their abundance and the availability of food resource to support their biomass are important factors in the abundance and diversity of beach ecosystems (Dugan et al., 2003; Ince et al., 2007).

Large amounts of wrack (mostly macroalgae) have been quantified worldwide (Stenton-Dozey and Griffiths, 1983; Polis et al., 1997; Ochieng and Erftemeijer, 1999, Dugan et al. 2003; Orr et al. 2005; Barreiro et al., 2011) with important effects for the macrofaunal community (Colombini and Chelazzi, 2003). However, few studies have evaluated wrack biomass of different types of allochthonous materials such as macroalgae, seagrass and mangrove propagules and their associated invertebrate assemblages. Apart from the amount and composition of stranded wrack, the position and the relative age of upper-wrack deposits influence the composition and structure of wrack-associated fauna (Colombini et al., 2000; Jaramillo et al., 2006; Rodil et al., 2008). Moreover, most studies have been conducted on a local scale, so that it remains unknown whether the ecological role of the composition and relative age of wrack deposits on the supralittoral assemblages could be generalized beyond a local context.

This study aimed to investigate response patterns of supralittoral arthropods associated with wrack deposits over several sandy beaches. For this, we evaluated the standing crop of wrack and their associated fauna on six sandy beaches, which differ in wrack composition and morphodynamic characteristics, located on Brazilian and Spanish Atlantic coasts. We predicted that: (1) differences would be found between beaches with respect to total amount and their relative deposition on tide lines (i.e. bands); (2) differences would be found between wrack deposits in which relative ages vary with respect to density, diversity, and structure of invertebrate assemblages; (3) disregarding species differences, there would be similar patterns of the distribution of supralittoral assemblages as a response of the relative age of wrack deposits of sandy beaches located on both sides of the Atlantic Ocean.

2. Materials and methods

2.1. Study area

This study was conducted on six sandy beaches located in three geographical regions (Fig. 1): South (Paraná – PR) and Southeast (Rio de Janeiro – RJ) of Brazil and SW Spain (SW Spain), in order to obtain, in a general way, similar patterns of wrack accumulation and distribution of arthropods assemblages inhabiting upper-wrack deposits. These regions were selected according to the type of allochthonous subsidies. The beaches of the Paraná region were subsidized mainly by mangrove propagules, while the beaches of Rio de Janeiro and the SW Spain were subsidized mainly by macrophytes and macroalgae.

The coast of the Paraná region (PR) has a humid subtropical climate with a mean annual temperature of 22.2 °C and mean annual precipitation of 1890 mm. Tides on the Paraná coast are semidiurnal and microtidal, with a tidal range between 0.5 and 2 m (Knoppers et al., 1987). Cem (25°34′24″S; 48°20′13″W) located near to the mouth of the Paranaguá bay estuary, is a low-energy reflective beach, modified by tides. It has fine sands, a gentle slope and a low wave height. Assenodi (25°35′24″S; 42°22′04″W) located at Leste coastal plain, is an intermediate to dissipative, wave-dominated beach with medium sands and a gentle slope (Table A1). Both beaches are bordered by *restinga* (i.e. coastal sand dune vegetation).

The coast of Rio de Janeiro (RJ) has a semi-humid tropical with an annual average temperature of 22.2 °C and average annual precipitation of 1890 mm. This region has microtidal, mixed semidiurnal tides, with a range between 0.3 and 0.7 m (Dias and Kjerfve, 2009). Grumari (23°02′52″S; 43°31′18″W), located in the west of the Rio de Janeiro coast, is a dune-backed, high-energy reflective beach, classified as wave-dominated, with coarse sands and a steep slope. Una (22°43′02″S; 41°59′07″W), protected by Cape Búzios, classified as dissipative and wave-dominated beach, has fine sands with a gentle slope and is bordered for much of its length by restinga (Table A1).

The southwest of Spain (SW Spain) coast has a dry-summer subtropical climate with a mean annual temperature of 18.4 °C and mean annual precipitation of 546.1 mm. The Gulf of Cadiz is a semidiurnal mesotidal environment with a tidal range between 3.2 and 1.1 m (Benavente et al., 2002). Levante (36°33′37″N; 6°13′27″W) located in the outer zone of Cadiz Bay, is a dune-backed, dissipative beach. It is characterized by medium sand, gentle slope and low wave heights. Peginas (36°39′43″N; 6°24′15″W) located at north of the Cadiz Bay, is classified as intermediate beach, backed by low cliffs and faced by rocky shore