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Assessment the short-term effects of wrack removal on supralittoral arthropods using the M-BACI design on Atlantic sandy beaches of Brazil and Spain

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A B S T R A C T

Wrack removal has been adopted indiscriminately, with no previous assessment of the ecological implications for sandy beach ecosystem. This study evaluated, through an M-BACI design, the effect of wrack removal on supralittoral arthropods on Atlantic sandy beaches receiving different types of wrack: mangrove propagules (Brazil), seagrasses and macroalgae (Spain). Impacted plots were contrasted with controls in 8 successive periods before and after experimental wrack removal. After the disturbance, drastic decreases in the densities of the amphipod *Platorchestia monodi*, coleopterans Cleridae, Nitidulidae and *Phaleria testacea* (Brazilian beaches) and amphipod *Talitrus saltator* (Spanish beaches) were detected in the impacted plots. The recovery patterns of arthropods might be related to wrack features (amount, composition, and degradation) combined with density and species-specific strategies (e.g. mobility, feeding preferences) in each Atlantic region. The temporary suppression of wrack and its associated fauna can have potential effects on the wrack-derived process and food-web structure on sandy beaches.

1. Introduction

Beaches worldwide are important spaces for leisure of the local population, tourists and recreational users (Defeo et al., 2009). To satisfy this public demand, local authorities have promoted and supported actions that attract and ensure the welfare of all beach users (Davenport and Davenport, 2006). Cleaning or grooming the beach is conducted, to improve the aesthetics, amenity and utility of these systems (Fairweather and Henry, 2003; Noriega et al., 2012). This management strategy involves several approaches that range from simple manual collection (using rakes), to mechanical operations (Davenport and Davenport, 2006; Dugan and Hubbard, 2010), which remove all litter generated by human activity, as well as wrack debris (Colombini et al., 2011; Defeo et al., 2009; Dugan et al., 2003; Llewellyn and Shackley, 1996). The complete removal of wrack has attracted the interest of scientists in understanding the ecological implications inherent to this management practice (Dugan et al., 2003; Fairweather and Henry, 2003; Gilburn, 2012; Llewellyn and Shackley, 1996).

From an ecosystem perspective, wrack debris is a key element for the maintenance of biodiversity (Harris et al., 2014) and functioning of sandy beaches (Barreiro et al., 2011; Defeo et al., 2009). Wrack deposits may be composed of several types of organic materials (i.e., marine macrophytes, macroalgae, or propagules from mangroves) (Barreiro et al., 2011; Colombini and Chelazzi, 2003;

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Gonçalves and Marques, 2011; Ince et al., 2007; Ruiz-Delgado et al., 2014). Since sandy beaches have low *in situ* primary productivity, their food webs are supported by allochthonous organic debris imported from the sea and coastal areas (Colombini and Chelazzi, 2003; Nel et al., 2014). Besides being a significant food source, wrack debris provides beach fauna with a hospitable microhabitat for refuge, reproduction and growth (Colombini and Chelazzi, 2003; Ruiz-Delgado et al., 2014). However, most beach users consider wrack debris as useless debris, or as an unpleasant disturbance (Fairweather and Henry, 2003). Usually this perception is strongly influenced by the disagreeable odor from its decomposition, which attracts swarms of beach flies and buzzards (Davenport and Davenport, 2006; McLachlan and Brown, 2006).

Wrack removal may cause ecological problems by disrupting pathways of decomposition and nutrient exchange between marine and terrestrial ecosystems. This exchange forms the basis for primary production and food chains of nearshore waters (Dugan et al., 2011; Barreiro et al., 2013). Moreover, this activity can alter the composition of supralittoral invertebrates (such as crustaceans and insects), and therefore, affect beach trophic dynamics by reducing prey availability to higher trophic levels (bottom-up effects), such as shorebirds, lizards, and rodents (Dugan et al., 2003; Fairweather and Henry, 2003; Gilburn, 2012; Llewellyn and Shackley, 1996; Martin et al., 2006). Wrack removal also alters the physical characteristics of the beach environment, mainly sediment properties, beach morphology, and morphodynamics and prevents dune formation (Malm et al., 2004; Ochieng and Erftemeijer, 1999; Piriz et al., 2003). These physical modifications can cause increasing erosion of the beach profile and loss of the frontal dune (Nordstrom et al., 2000).

Most sandy beach studies related to human impacts have used 'compare and contrast' designs (e.g. Schlacher et al., 2008). In this type of design, the pre-disturbance situation is unknown, and inferences are made by simple spatial comparison between previously disturbed and undisturbed areas (Underwood, 2000). Manipulative experiments are more suitable to determine cause-effect relationships between a disturbance and biological variables (Glasby and Underwood, 1996). The M-BACI design (multivariate before and after/control and impact) is considered the most appropriate sampling strategy for evaluating planned impacts (Downes et al., 2004; Underwood, 2000). This design includes multiple control and impacted locations, which allow differentiating between the effects of impact and the background environmental variation. Moreover, the treatments are compared in multiple sampling dates before (baseline samples) and after the impacting activity. Therefore, this design ensures the correct interpretation of the interactions between locations and sampling times (Downes et al., 2004).

This study provides the first assessment of the short-term effect of wrack removal on the supralittoral arthropods assemblages using a field-based experiment, following the M-BACI design. This experimental approach was performed on four sandy beaches located on both sides of the Atlantic Ocean (southern Brazil and south-western Spain), which differ in wrack composition and morphodynamic characteristics in order to understand the effects of wrack removal on local and global scales. Moreover, the M-BACI design allowed us to evaluate the temporal patterns of arthropods (community and population level) in impacted plots after the removal of wrack debris and compare those with patterns of occurrence of fauna in adjacent control plots.

In this context, three hypotheses were experimentally tested: 1) reduction in the stranded wrack biomass by experimental removal would lower density and diversity as well as change the structure of the whole supralittoral assemblages in the impacted plots compared to control plots; 2) wrack removal would lower density of supralittoral populations, particularly those species that use wrack as food and/or shelter; 3) different recovery patterns of supralittoral arthropods in response to wrack removal are expected on sandy beaches located in both Atlantic regions (southern Brazil and south-western Spain) related to the differences in community composition of species and composition of wrack debris. This work is meant to help elucidate the effect of wrack removal at community and population scales.

2. Materials and methods

2.1. Study area

This experimental approach was conducted on four sandy beaches located in two geographical regions (Fig. 1): southern Brazil (Paraná State) and south-western Spain (Atlantic coast of Cadiz), in order to investigate, in a general way, the effect of wrack removal (i.e. mangrove propagules, seagrasses and macroalgae) on local and global scales.

The coast of Paraná has a humid subtropical climate and semidiurnal tides with spring-tide ranges up to 1.7 m (Lana et al., 2001). Along this microtidal coast, two beaches were selected for this study. Assenodi (25°35′24″ S; 48°22′04″ W) is an intermediate to dissipative, wave-dominated beach with fine sands and a gentle slope Cem (25°34′24″ S; 48°20′13″ W) is a low-energy reflective beach, modified by tides with fine sands and a steep slope (Table 1). Both beaches are bordered by typical coastal sand dune vegetation. These beaches received wrack inputs composed by mangrove propagules of *Laguncularia racemosa*, *Avicennia shaueriana* and *Rizophora mangle* from the estuarine system of Paranaguá Bay (Borzone and Rosa, 2009; Rosa et al., 2007).

The Atlantic coast of Cadiz has a dry-summer subtropical climate and semidiurnal tidal regime with a range up to 3.2 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 a wide beach, characterized by a gentle slope and fine-sized sand (Table 1). During the experiment, this beach received inputs of the seagrasses *Cymodocea nodosa* and *Zostera noltii* from seagrass beds located around Cadiz Bay. Cortadura (36°28′58″ N; 6°15′77″ W), situated in the southern part of Cadiz Bay, is an intermediate beach, backed by foredunes and low non-vegetated dune ridges. This beach is narrower than Levante beach and has a beach profile with a gentle slope and fine sand (Table 1). Cortadura beach receives inputs of brown macroalgae, such as *Dictyopteris membranacea* and *Cladostephus spongiosus*, several species of red algae, such as *Halopithys incurva* and *Chondria dasyphylla*, and green algae, such as *Codium decorticatum* and *Codium fragile* from nearby rocky shores and subtidal habitats.

2.2. Experimental design and field procedures

On two Brazilian beaches (Assenodi and Cem), a field experiment was conducted between 24 May and 4 July 2012, whereas on two Spanish beaches (Levante and Cortadura) an analogous experiment was performed between 2 October and 12 November 2012. During this period, climatic conditions were quite similar at both regions (Table 1) and we expected a great number of species associated with wrack debris (e.g. Gonçalves and Marques, 2011). Moreover, in these months of the year, the four beaches do not receive tourists and visitors. Consequently, the beaches are not exposed to other disturbances such as human trampling, vehicle