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Home advantage? Decomposition across the freshwater-estuarine transition zone varies with litter origin and local salinity

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ABSTRACT

Expected increases in the frequency and intensity of storm surges and river flooding may greatly affect the relative salinity of estuarine environments over the coming decades. In this experiment we used detritus from three contrasting environments (marine *Fucus vesiculosus*; estuarine *Spartina anglica*; terrestrial *Quercus robur*) to test the prediction that the decomposition of the different types of litter would be highest in the environment with which they are associated. Patterns of decomposition broadly fitted our prediction: *Quercus* detritus decomposed more rapidly in freshwater compared with saline conditions while *Fucus* showed the opposite trend; *Spartina* showed an intermediate response. Variation in macro-invertebrate assemblages was detected along the salinity gradient but with different patterns between estuaries, suggesting that breakdown rates may be linked in part to local invertebrate assemblages. Nonetheless, our results suggest that perturbation of salinity gradients through climate change could affect the process of litter decomposition and thus alter nutrient cycling in estuarine transition zones. Understanding the vulnerability of estuaries to changes in local abiotic conditions is important given the need to better integrate coastal proceses into a wider management framework at a time when coastlines are increasingly threatened by human activities.

1. Introduction

Coastal ecosystems, including estuaries and salt marshes, face threats from various environmental stressors associated with global climate change (Nicholls, 2004; IPCC, 2012; Zappa et al., 2013; Wong et al., 2015). Increased sea level and more intense and frequent storm surge events are likely to cause extensive shoreline erosion as well as saltwater intrusion into coastal rivers (Bear et al., 1999; IPCC, 2012). However, coastal protection is unlikely to be efficiently achieved simply by ‘hard armouring’ (Zanuttigh, 2011; Pontee and Parsons, 2010, 2012; Esteves, 2014). The innovative approaches for a sustainable coastal flood management incorporate natural processes and include the inundation of some coastal areas (Zanuttigh, 2011; Esteves, 2014; Hanley et al., 2014; Hoggart et al., 2014). Adopting integrated coastal defence approaches such as ‘managed retreat’ and ‘no active intervention’, however, requires an understanding of the ecological impact of floodings or other changes in flow regimes on recipient ecosystems and their functions (Pontee and Parsons, 2010; Bouma et al., 2014; Hoggart et al., 2014).

Decomposition is a fundamental process in the functioning of the estuarine ecosystem (McLusky and Elliott, 2004), facilitating the recycling of nutrients and chemical elements, and thereby sustaining important food chains and primary production (Cummins et al., 1989; Graça, 2001; Quintino et al., 2009). The decomposition of organic material in aquatic ecosystems proceeds in three sequential stages: leaching, conditioning, and then fragmentation (Petersen and Cummins, 1974). Shortly after falling into the water, leaf-litter rapidly loses mass due to the leaching of soluble organic and inorganic constituents. This stage is followed by microbial colonization, causing numerous modifications to leaf condition and enhancing acceptability and colonization by macroinvertebrate detritivores responsible for the leaf fragmentation. The rate of this process depends on the physico-chemical characteristics of the leaf material, the local composition of both microbial and

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macrofaunal communities, and the abiotic environmental conditions of the environment (e.g. salinity, nutrients, water temperature, oxygen concentration, pH) (see Lopes et al., 2011 and references therein).

In estuaries, where salinity represents the main ecological factor defining habitat boundaries (Telesh and Khlebovich, 2010), the abiotic conditions gradually change along a gradient from marine to freshwater. Any significant changes in the intensity and frequency of seawater inflows into estuaries and rainfalls into rivers of the kind expected through climate change, are likely to modify the overall local abiotic conditions, with possible alteration of the decomposition process (Mendelssohn et al., 1999). Detritus from marine sources could be moved further inland and upstream through catchments (see Tate and Battaglia, 2013 for an example), whilst estuarine and marine systems might be expected to receive increased quantities of terrestrial leaf litter. The consequence of such perturbation could be that detritus processing is due to local mismatch between the salinity regime. Such mismatch would lead to direct effects on breakdown rates, or indirectly affect decomposition via changes in the associated detritivore assemblage, or a combination of both. To date, only few studies have explicitly examined how changes in local salinity and macrofauna affects detritus breakdown although those that do (Lettice et al., 2011; Lopes et al., 2011; Bierschenk et al., 2012) report that decomposition rates varied according to salinity gradients and that detritus originating from without the local system decomposed more slowly. Moreover, the composition of the associated detritivore community changed along the salinity gradient (but see Lopes et al., 2013). These results suggest that detritus decomposes more effectively in the environmental conditions of its native habitat. Nevertheless, there has been no comparison of the decomposition of terrestrial, saltmarsh, and marine litters across the range of salinities found in a typical estuary.

Here we report the results of a field experiment to investigate the breakdown rates of terrestrial, saltmarsh, and marine derived detritus (respectively *Quercus robur*, *Spartina anglica* and *Fucus vesiculosus*) across the salinity gradient in two neighbouring estuaries in southern England. We also surveyed the composition of invertebrate assemblages associated with the detritus in each habitat. In so doing, we provide the first insights into the potential vulnerability of estuarine systems to shifts in local conditions expected from climate-related changes in freshwater flooding and seawater inundation events.

2. Materials and methods

2.1. Study sites

The experiment was undertaken in the estuaries of the rivers Yealm (50°18.6′N, 04°4.2′W) and Erme (50°18.3′N, 03°57.0′W), in South Devon, UK (Fig. 1). Both rivers rise on Dartmoor flowing south for 16 and 20 km respectively before discharging into Wembury and Bigbury bays. The estuaries of both rivers are characterized by similar physical features: extension (about 6 km); catchment area (Yealm = 55 km^2, Erme = 43 km^2); mean river flow discharge (Yealm = 1.7 m^3/s, Erme = 1.9 m^3/s); large tidal range (4.7 m) and a full salinity range from marine to freshwater (Sheehan et al., 2010). In both rivers, saltwater ingress into the freshwater zone is strongly limited by the presence of weirs.

At each estuary, three habitats were selected along the salinity gradient, according to the Venice System (1959) for the Classification of Estuarine Waters: ‘freshwater’(limnetic); ‘low salinity’water (mesohaline); ‘high salinity’water (polyhaline). In the Yealm the three habitats were located along 800 m stretch of estuary, whilst in the Erme the passage from freshwater to high salinity occurred over a 2 km distance. The two ‘freshwater’habitats (Fw) were located at 600 m and 300 m upstream of a weir in the Yealm and Erme respectively (above the normal tidal limit – NTL), and were characterized by wooded banksides dominated by broad-leaved trees. The two ‘low salinity’ habitats (Lo) were located in areas equidistant between the NTL weirs and the open coast, in sites where euryhaline species such as *Ulva* spp. indicated a brackish regime. The riparian vegetation in these habitats were characterised by species typical of upper saltmarsh vegetation. The two ‘high salinity’ habitats (Hi) were located in areas dominated by marine macro-algae, and banksides featuring scattered trees and open terrestrial vegetation.

Salinity was recorded continuously by loggers submerged and anchored to the river bed for 4 weeks, from end of May to June 2010 (i.e. during the decomposition experiment). The mean salinity values (expressed as Practical Salinity Unit, ± standard deviation), at the three habitats in each river (from freshwater to low salinity and high salinity) were: 0.0 (±0.0), 17.6 (±2.2), 23.0 (±1.8), in the Yealm; and 0.0 (±0.0), 12.4 (±3.0), 20.1 (±3.1) in the Erme.

2.2. Experimental procedure

The decomposition experiment was run using 3 species particularly abundant in the three study habitats (Fw, Lo, Hi): these were (respectively) the tree *Q. robur* L. (Fagaceae); the grass *S. anglica* C. E. Hubb. (Poaceae), and the fucoid alga *F. vesiculosus* L. (Fucaceae). Naturally dehisced leaves or laminae from the three species were collected in May 2010 from woods adjacent to the freshwater sites (*Quercus*), salt marshes near the low salinity sites (*Spartina*), and the inter-tidal in the area of high salinity sites (*Fucus*) within the catchment of both rivers. The leaf material for the experiment was randomly selected from the collection sites and subsequently oven-dried to constant weight (60 °C for 72 h).

Since detritus from the three sources had different dry densities, we prepared litter bags with different weights but similar volumes in order to offer comparable surfaces for detritivore colonization. The litter bags (nylon cloth, 100 × 100 mm, 5 mm mesh size; Bärlocher, 2005) were half filled with dried detritus, (corresponding to 5 g of *Quercus*, 8 g of *Spartina* and 12 g of *Fucus*). In the case of *Spartina* the leaves were cut into 8 cm long fragments (excluding the basal and apical parts). The 5 mm mesh size was chosen to allow colonization by macroinvertebrates yet at the same time reduce the potential for detritus loss due to fragmented litter falling out of the bags (Quintino et al., 2009). Four replicate bags for each species were deployed at each of the three habitats (Fw, Lo, Hi) at each of the two estuaries (Yealm, Erme). The bags were attached to ropes anchored to the river bed by bags of pebbles and steel pegs hammered into the sediment, to prevent occasional emersion in low tides and limit abrasion. We exposed the detritus for 38 days (late May to late June 2010), based on decomposition rates estimated from previous studies (Sangiorgio et al., 2008; Quintino et al., 2009). After this time, the litter bags were retrieved and preserved in plastic bags containing 70% alcohol. The detritus was washed to remove sediment, dried in an oven at 60 °C for 72 h and reweighed. Macro-invertebrates were separated from the sediment with a 500 μm mesh size, identified at the lowest possible taxonomic level and counted.

2.3. Data analyses

Weight loss for each litter species was calculated as percentage according to the following equation: $\%L = (W_0 - W_t)/W_0 \times 100$, where W_0 is the original dry weight of the litter and W_t was the dry weight remaining after 38 days (Petersen and Cummins, 1974). Furthermore, in order to compare the decomposition rates for