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Talitrus saltator as a biomonitor: An assessment of trace element contamination on an urban coastline gradient

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ABSTRACT

This study reports the first ever application of the trace element pollution index (TEPI) along a coastal, urban gradient using trace element concentrations (Ti, Mn, Co, Cu, As, Mo, Ag, Cd, Pb, Cr, Fe, Zn and Se) in the amphipod crustacean *Talitrus saltator*. Samples were collected from 10 sites in Galway Bay (Ireland) and concentrations of Pb showed the greatest spatial variation, likely due to the proximity of some sites to a former landfill and busy harbour. The TEPI used alongside the quartile method allowed for the assigning of sites to contamination level categories. Mapping these class levels allowed for straightforward visualisation of trace element contamination along the urban gradient. In addition, this study presents trace elements levels in *T. saltator* form the Atlantic Coast of Europe for the first time and the concentrations observed were comparatively lower than previously reported for *T. saltator* from the Baltic and Mediterranean seas.

1. Introduction

The sandhopper *Talitrus saltator* (Montagu) inhabits sandy beaches of European coastal seas, from the central and western Baltic to the north west Atlantic and Mediterranean (Scapini et al., 1996; Fialkowski and Rainbow, 2016). Sandy beaches are of considerable socio-economic importance but also of great ecological importance as they are transitional or 'ecotonal' areas between the land and sea (Ugolini et al., 2004; Conti et al., 2016). *T. saltator* occupies the supralittoral of sandy beaches (Nourisson and Scapini, 2015), and represents the greatest component in terms of animal biomass (Griffiths et al., 1983).

The balance of energy transfer and nutrient cycling in sandy beach ecosystems is regulated by the exchanges that occur along the supralittoral belt (Conti et al., 2016). These exchanges primarily compose of detrital processing by beach-dwelling organisms such as *T. saltator* (McLachlan and Brown, 2006; Colombini and Chelazzi, 2003). Due to limited of primary production in sandy beach ecosystems, there is a dependence on allochthonous organic debris (Colombini and Chelazzi, 2003) such as, marine angiosperms and macroalgae (Adin and Riera, 2003). As grazers, detritivores and scavengers living between land and sea; sandhoppers feed on plant and animal organic matter of both marine and terrestrial origin (Wildish, 1988). Therefore, as both the majority of animal biomass in the supralittoral and, as an important food source for many invertebrates, *T. saltator* occupies an extremely important niche in sandy beach ecosystems (Evans, 1988; Griffiths et al., 1983).

Sandy beaches and particularly urban beaches, are vital to coastal economies, providing amenities, recreation and tourism in urban settings (Wood and Hoagland-Grey, 1996). Sandy beaches house diverse communities and support biodiversity in the intertidal; however, they are vulnerable to a variety of pollution sources due to anthropogenic activities that can threaten their delicate nature (Conti et al., 2016). Contamination from anthropogenic practices can arise from land and sea, from oils spills and debris from ships (Schiel et al., 2016), to land-based human activities which result in the accumulation of nutrients, pesticides, trace elements (TEs) and persistent organic pollutants (POPs) (Conti et al., 2016). As opposed to contaminants such as pesticides and POPs which only originate from human activates, TEs are also present naturally in the environment. Thus, TEs can become bioavailable to biota through atmospheric deposition and by erosion of the geological matrix (Nair et al., 2006) as well as through anthropogenic activities. Some TEs are essential micro-nutrients such as Se, Fe and Zn (Avelar et al., 2013) and others can be toxic even at low concentrations (Pb, As), although, at a bioavailability above a certain threshold concentration all TEs have the potential to become toxic to biota (Rainbow, 1995). Most TEs are also persistent in the marine environment (Bargagli, 1998), accumulating in biota and transferring within trophic levels.

Biomonitors accumulate TEs relative to their ambient bioavailability (Rainbow, 2006). Accumulated concentrations are time-integrated measures of exposure of the given biomonitor, to all bioavailable sources of trace metal over time (Rainbow, 1995; Morrison et al.,

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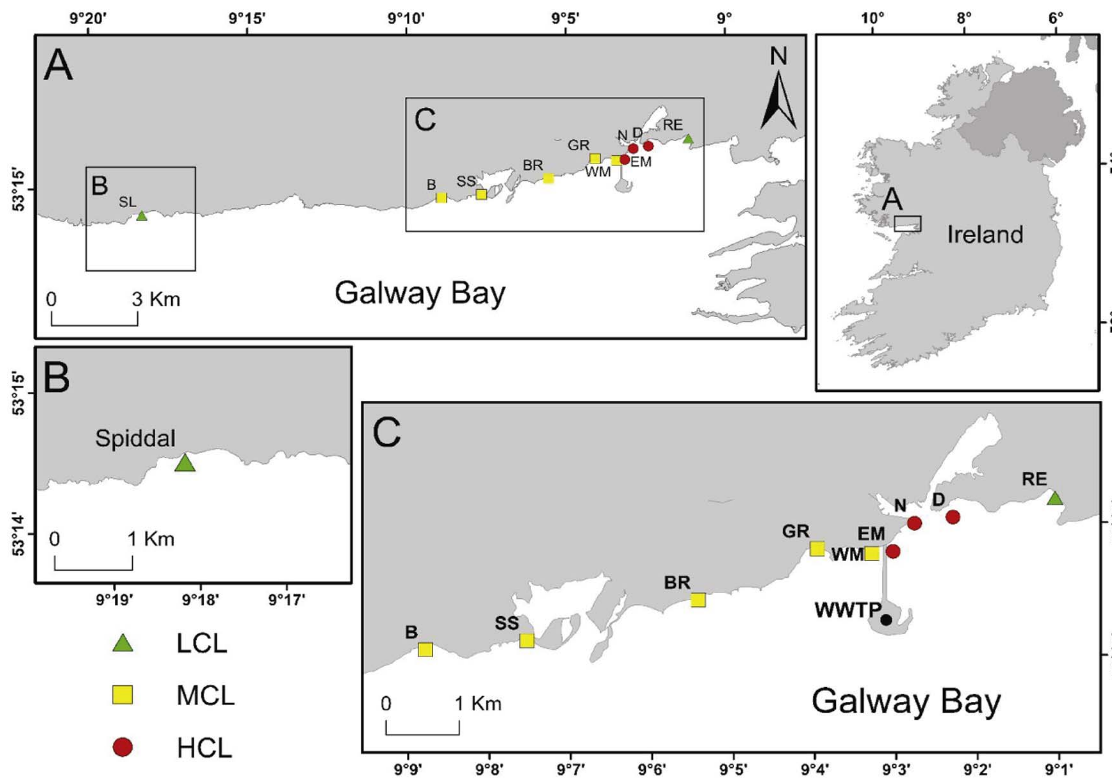

Fig. 1. Sampling sites of *T. saltator* in Galway Bay. LCL is the low contamination level (< 0.80), MCL: medium contamination level (> 0.08 but, < 1.14) and HCL: high contamination level (> 1.14). WWTP: Mutton Island waste water treatment plant. Locations; B: Barna SS: Silverstrand, BR: Blackrock, GR: Grattan road, WM: West mutton, EM: East mutton, N: Nimmo's pier, D: Docks beach, RE: Renmore Beach and SL: Spiddal.

2008). As such, accumulated TE concentration in a biomonitor is a measure of total integrated bioavailability of any given TE to the examined biota at the examined site over a given time (Fialkowski et al., 2009). A number of trans-national strategies aimed at assessing and monitoring ecological quality of aquatic environments have promoted the use of biotic indices namely, the Water Framework Directive (WFD) (EC, 2000) and the OSPAR Co-ordinated Environmental Monitoring Programme (CEMP) (OSPAR, 2008). Biomonitors have been suggested over typical measures of TE contamination i.e. environmental matrices of water and sediment (Richir and Gobert, 2014b), as most importantly, biomonitors give a measure of the bioavailability of a given TE or other contaminant (Rainbow, 2006; Rainbow, 1995; Conti et al., 2010), which is of much greater ecotoxicological relevance than typical measurements (Rainbow and Phillips, 1993).

Talitrid amphipods and specifically *T. saltator* satisfy the criteria which constitute a ‘good’ biomonitor, outlined in Rainbow (1995) and Rainbow and Phillips (1993). Biomonitoring programmes utilising *T. saltator* could potentially be advantageous because, among other reasons, sandhoppers are easily and cost-effectively sampled and have a wide geographic distribution; allowing the possibility of comparison of coastal TE contamination on a local and international scale (Ugolini et al., 2012a; Fialkowski et al., 2009). Finally, talitrid amphipods can accumulate TEs from both marine and terrestrial sources (Wildish, 1988) integrating two routes of contamination (Ugolini et al., 2008) and retain metals from both solution and food (Conti et al., 2016; Ugolini et al., 2004; Weeks and Rainbow, 1991).

Detritus, macroalgae and marine angiosperms such as *Zostera* spp. constitute the majority of the talitrid diet (Fialkowski and Rainbow, 2016). As algae uptake metals from solution, *T. saltator* can, in turn, be considered as a biomonitor of trace metals present in the water (Rainbow, 2006; Rainbow, 1995). In the same way that primary producers such as angiosperms can be used as biomonitors, giving early warning of TE contamination at higher trophic levels (Govers et al., 2014; Ferrat et al., 2003); potentially so too can sandhoppers, filling the important niche they do in an ecotone between land and sea. Laboratory-based experiments have also shown that *T. saltator* has the capacity to swallow microplastic debris (Ugolini et al., 2013). Therefore, *T. saltator* act as a vector of pollutants on sandy beaches (Ungherese et al., 2012) due to the large role they play in energy transfer in sandy beach ecosystems (Evans, 1988; Griffiths et al., 1983).

Sandy beach crustaceans have been employed in biomonitoring programmes at an increasing rate worldwide (Fialkowski and Rainbow, 2016). Talitrid amphipods, have been suggested and employed as biomonitors of a number of contaminants, particularly trace elements (Fialkowski and Rainbow, 2016; Fialkowski et al., 2009; Ungherese et al., 2010a; Ugolini et al., 2004), polybrominated diphenyl ethers (PBDEs) (Ungherese et al., 2012), polycyclic aromatic hydrocarbons (PAHs) (Ugolini et al., 2012b) and most recently polychlorinated biphenyls (PCBs) (Ungherese et al., 2016). TE concentrations in talitrid amphipods have been studied across several European coastal seas; from the UK (North and Irish seas) (Fialkowski et al., 2009; Rainbow et al., 1989) to the Baltic (Fialkowski and Rainbow, 2016; Fialkowski et al., 2009) and Mediterranean seas (Ungherese et al., 2010b; Fialkowski et al., 2009).

However, to date no study has examined the effectiveness of *T. saltator* as a biomonitor of coastal TE contamination along an urban coastal gradient. The principal aims of this study are: i) to show the potential use of the talitrid amphipod *Talitrus saltator* as a biomonitor of trace element contamination on an urban gradient; ii) providing an initial assessment of TE contamination in Galway Bay using the TESVI and TEPI; iii) on a local scale, the potential affect which an urban waste water treatment plant (WWTP) and commercial harbour and leisure marina could be having on the distribution of TE contamination in Galway Bay will also be explored. The data gathered in this study will provide an initial record of TE contamination in the north Atlantic and along an urban coastal gradient using the biomonitor *T. saltator*.