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Variation in rocky shore assemblages and abundances of key taxa along gradients of stormwater input

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ABSTRACT

Stormwater brings freshwater and terrestrially derived contaminants into coastal systems and is predicted to increase with climate change. This study aimed to characterise variation in rocky shore assemblages in relation to stormwater pollution. Intertidal assemblages were sampled in similar habitats at a range of distances (0 m, 10 m, 20 m, 60 m, and 100 m) from stormwater outfalls on three rocky shores north of Dublin. In general, taxon richness and algal cover increased after 20 m from a stormwater outfall. Limpet population structure and condition index showed no consistent patterns among shores. Assemblage structure at or near stormwater sites differed from that at sites 100 m away. These findings, ideally supplemented by experimental research, may be used to inform stormwater management and remediation approaches.

1. Introduction

Society relies on marine ecosystems for a range of ecosystem services, such as provision of food, nutrient recycling and climate regulation (Millenium Ecosystem Assessment, 2003; TEEB, 2010; Liquete et al. 2013). Multiple anthropogenic stressors can alter the functioning of coastal ecosystems, reducing biodiversity and the provision of services to society (Johnston and Roberts, 2009; Bulling et al. 2010). Increased urbanization has led to an increase in a wide range of pollutants deposited on catchment surfaces which are transported with stormwater during wet weather periods and ultimately enter aquatic systems (Aryal et al. 2010). Significant changes are projected to occur in climate over this century, with an expected increase of 10–25% for Ireland's winter precipitation (McGrath et al. 2005). The generation of stormwater and its associated pollutants is determined by the level of precipitation that occurs (Patz et al. 2008), and is also affected by rainfall-related flooding (Dierkes et al. 2002).

Stormwater is an important uncontrolled and unregulated source of pollution. The creation of stormwater pollutants in urban environments is complex and the pollutants arise from a large number of urban activities (Duncan, 1999). It can degrade water quality by introducing a combination of contaminants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), heavy metals, freshwater, pesticides, sediment, nutrients, bacteria and sewerage (Makepeace et al. 1995). Stormwater can alter the quality, turbidity, salinity, temperature and pH of the water it enters (Corcoran et al. 2010) causing significant effects on marine biota (Pratt et al. 1981). The impact of stormwater pollutants on organisms depends on a number of factors such as total load of pollutants, their nature and concentration. Anthropogenic stressors such as this have the potential to alter the diversity and structure of natural assemblages.

To date the ecological effects of stormwater run-off in marine ecosystems remains uncertain. Many stormwater studies have focused on the toxicity of stormwater on individual organisms (Schiff et al. 2003; Greenstein et al. 2004; Grapentine et al. 2008). Multiple interacting species in an assemblage serve as a better representation of an ecosystem as the contaminants may act as a stressor on any of the complex dynamics that affect assemblage integrity (Maher and Norris, 1990). A number of studies have explored the relationship between stormwater pollution and marine assemblage structure (Willemsen et al. 1990; Morrissey et al. 2003; Schiff and Bay, 2003; Ghedini et al. 2011) yet only weak biological effects have been observed. Many of these studies have looked at short term effects (i.e. single rainfall events). Further study is needed of the longer term changes associated with chronic

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inputs of stormwater and its cumulative effects. Benthic communities provide a useful model for marine pollution assessment as they reflect not only conditions at the time of sampling but also conditions to which the community has previously been exposed (Reish, 1986). Some taxa, such as perennial algae and some grazing gastropods are particularly influential and may be sensitive to pollution (Borowitkza, 1972; Philips, 1977; Evans-White and Lamberti, 2009). Furthermore, the ratio of ephemeral to perennial algae can be used as an indicator of ecological status (Cusack et al. 2008) and it can be informative to characterise the effects on these groups of species. Changes in populations of these taxa would have potentially important indirect effects for the wider community and ecosystem processes (e.g. Menge, 1995; O'Connor and Crowe, 2005; Crowe et al. 2013).

The aim of this study was to relate the distance from a stormwater outfall with the structure and taxon richness of rocky shore assemblages as well as with the abundance of selected taxa and with size structure and condition of limpets.

2. Materials and methods

2.1. Study sites and sampling design

Assemblages were sampled on three rocky shores in north County Dublin, Ireland: Malahide (53°26′N 42.42″, 6 °26′ 37.74″W), Portmarnock (53 °26′ 08.20″, 6°07′17.71″) and Rush (53 °31′ 02.57″, 6 °05′15.48″) (Fig. 1). All three shores featured man made shoreline stormwater outfall points that run into Dublin Bay. The three shores were classed as having high ecological status with water quality ranging from potentially eutrophic to unpolluted (McGarrigle et al. 2010). The shores comprised large slabs of limestone bedrock and each contained fucoid alga and associated fauna and had similar shore aspect, catchment activities (mixture of urban and low intensity agriculture), wave exposure, and background salinity (fully marine). All sampling took place on the lower mid shore, which was dominated by *Fucus serratus*. This alga is a host to a diverse range of epibiota including molluscs, crustaceans and epiphytic algae (Boaden et al. 1975) and components of these assemblages have previously been found to be potential indicators of pollution (Atalah and Crowe, 2012).

Intertidal assemblages of algae and invertebrates from the three rocky shores were compared to test whether patterns of assemblage structure matched current predictions about the effects of stormwater. As the spatial extent of the stormwater flows was not known, sampling was carried out using a 'gradient' design (Bayne et al. 1988; Wiens and Parker, 1995). Stormwater outfalls were located a minimum of 200 m apart on each shore. As the concentration of pollutants usually decreases with increasing distance from a point source (Bishop et al. 2002), sampling distances were chosen at a number of intervals between 0 m (source of pollution) and 100 m (maximum possible distance from pollution). Studies have shown that the effects of pollution have been localised and assemblages located 100 m from pollution serve as adequate controls (Terlizzi et al. 2002). Five distances from the stormwater outfall point were randomly selected on the lower mid shore (0 m, 10 m, 20 m, 60 m, 100 m), with five replicates at each distance (i.e. 25 replicates in total at each shore).

2.2. Sampling

Sampling was performed over 5 days in April 2012 during low tide. All sites were sampled during the same weather event, dry and cloudy. Preceding the survey there were no extreme precipitation events. This ensured that data collected were not affected by short term stormwater flows, but by any impacts that may have accumulated over time. Sampling consisted of four different methods to cover the range of species on the shore: Quadrat survey (large species), algal epibiota collection (organisms living on *F. serratus*), scrapings (small and cryptic species) and *Patella vulgata* collection (size and condition of key species).

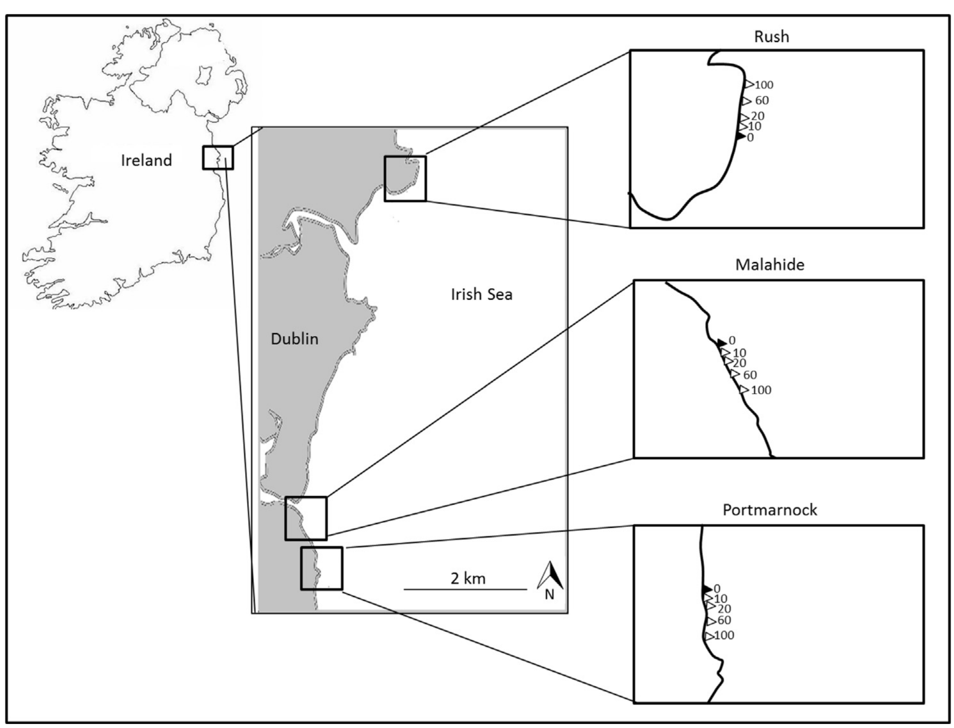

Fig. 1. Location of stormwater outfalls (0 m = closed triangle) and sampling sites (triangles; 0, 10, 20, 60 and 100 m distance) along the North Dublin coastline.