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Detecting benthic community responses to pollution in estuaries: A field mesocosm approach

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ABSTRACT

Biological stress responses in individuals are used as indicators of pollution in aquatic ecosystems, but detecting ecologically relevant responses in whole communities remains a challenge. We developed an experimental approach to detect the effects of pollution on estuarine communities using field-based mesocosms. Mesocosms containing defaunated sediments from four estuaries in southeastern Australia that varied in sediment contamination were transplanted and buried in sediments of the same four estuaries for six weeks. Mesocosm sediment properties and metal concentrations remained representative of their source locations. In each estuary, fauna communities associated with sediments derived from the site with the highest metal concentrations were significantly different from other communities. This pattern was evident for some of the individual taxa, in particular the polychaete *Capitella* sp. Consistent responses across estuaries suggest numbers of individuals, and especially *Capitella* sp., could be used to identify contaminated sediments in estuaries with similar fauna and site characteristics.

1. Introduction

Developing new approaches to identify the effects of pollution on communities at large spatial scales is at the forefront of current ecotoxicological research (Artigas et al., 2012; Grimm et al., 2009). The challenge in developing these approaches is that they need to be biologically and chemically relevant and at appropriate scales for detecting significant impacts within complex and often highly variable ecosystems (Batley et al., 2002). New approaches need to be cost-effective and adaptable so outcomes can be utilized by environmental practitioners in the design of monitoring and management programs that encompass whole ecosystems (Beketov and Liess, 2012). This requires a broad range of information about how pollutants enter a system, *in situ* interactions between pollutants, individual and community stress responses as well as the dynamics and relative influence of other environmental processes.

Single-species toxicity tests are no longer accepted as a sufficient approach to assess the effects of pollution and determine environmental risk (Van Straalen, 2003). Multiple weight-of-evidence approaches that link stress responses in individuals to populations and community structure and function are needed to capture the complexity of toxicant–biological interactions under natural and predicted ranges of environmental conditions. Recent developments of genetic and morphological biomarkers means that stress responses to pollution in individual organisms and populations are relatively well studied (e.g. Carew et al., 2007; Long et al., 2003). Comparatively few studies have developed methods for identifying community-level responses and understanding ecological implications of pollution. The aim of this study was to address this knowledge gap by developing an approach that can be used (1) to identify the effects of pollution on communities and (2) as part of a multiple weight-of-evidence approach for assessing environmental risk.

Our approach used field-based mesocosms to identify changes in benthic invertebrate communities in response to sediment-bound pollution in estuaries. We defined mesocosms as experimental units used to transport and relocate defaunated sediments between estuaries. Several studies have used similar experimental approaches using defaunated sediments to identify the effects of pollution on benthic communities in estuaries (Chariton et al., 2011; Roach et al., 2001). The designs of these experiments have involved the translocation of sediment from sites with different levels of contamination into one or two reference or 'clean' sites. These studies demonstrate how benthic fauna found at those one or two reference sites respond to contamination. We suggest

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understanding how different communities respond to contamination by undertaking experiments at more than two sites that have different contamination levels, physical and biological characteristics is a key component to the development of adaptable and biologically relevant tools for assessing pollution impacts. Furthermore, contaminated sites are increasingly being exposed to more sources of pollutants so experiments need to be replicated at contaminated as well as clean sites. This study is the first experimental approach investigating the effects of pollution at replicate sites that had different types and levels of contaminants.

Here, we present data from a reciprocal transplant experiment at four estuaries in Port Phillip Bay and Western Port, two large urbanized embayments in southeastern Australia. Mesocosms that contained defaunated sediments collected from the four estuaries were buried in the intertidal areas of the same four estuaries. We tested the hypothesis that colonization of the mesocosm sediments would depend on the source of the sediment. We predicted if the same patterns of colonization between mesocosms occurred at each site then it was a general response to the source sediments. If the colonization patterns between sites were different then the responses could not be generalized and were specific to the community composition and physical characteristics in each estuary. The estuaries had similar sediment types, area of intertidal habitat and macrofauna community composition but were influenced by different land use practices and had varying levels of sediment contamination. Therefore, sediment contamination could be among the explanations for biological responses to the source sediments.

2. Methods

2.1. Sites and experimental design

Four estuaries were selected for this experiment; Little River, Werribee River, Kororoit Creek and Merricks Creek (Fig. 1). These estuaries were continuously open with fine sands (average grain size ranged from 108 μm ± 13 std error at Kororoit Creek to 189 μm ± 8.6 std error at Merricks Creek), flowed into large semi-enclosed bays and had similar taxonomic diversity. They are influenced by different land use practices that are reflected in varying levels of metals, nitrogen, phosphorus and total petroleum hydrocarbons between estuaries (Table 1). Merricks Creek was in a different bay and over 60 km away from the other estuaries but it was selected because it met these selection criteria.

Mesocosms were plastic trays (25 × 15 × 6 cm deep), with most of the sides cut away and the open spaces covered with mesh (mesh size = 2 mm), which was held in place using cable ties. Mesh sides prevented horizontal, subsurface migration of macrofauna while allowing porewater movement and water drainage. The mesocosms were buried in the sediment so the surface was level with the surrounding sediment. Target organisms that were expected to colonize the mesocosms included mobile adult infauna that can leave the sediment (amphipods and mobile polychaetes such as *Simplisetia aequistis*), mobile epifauna moving across the sediment surface (mostly gastropods), and recruits of these and other taxa.

Sediment for the mesocosms was collected from each site approximately one month prior to the commencement of the experiment. Plastic spades were used to carefully lift sections of sediment of the same dimensions (25 × 15 × 6 cm deep) into the mesocosms, so the sediment maintained as close a representation of the actual sediment profile and characteristics as possible. Each mesocosm was transported back to the laboratory and stored in a −20 °C freezer.

Once sediments from all sites were collected and had been frozen for at least two days, they were placed back into the field. Mesocosms with source sediments from each estuary (hereafter referred to as KC = Kororoit Creek source sediments, LR = Little River source sediments, MC = Merricks Creek source sediments, and WR = Werribee River source sediments) were randomly allocated positions within a 30 m × 10 m experimental areas in the mid-littoral zone at each estuary. Five

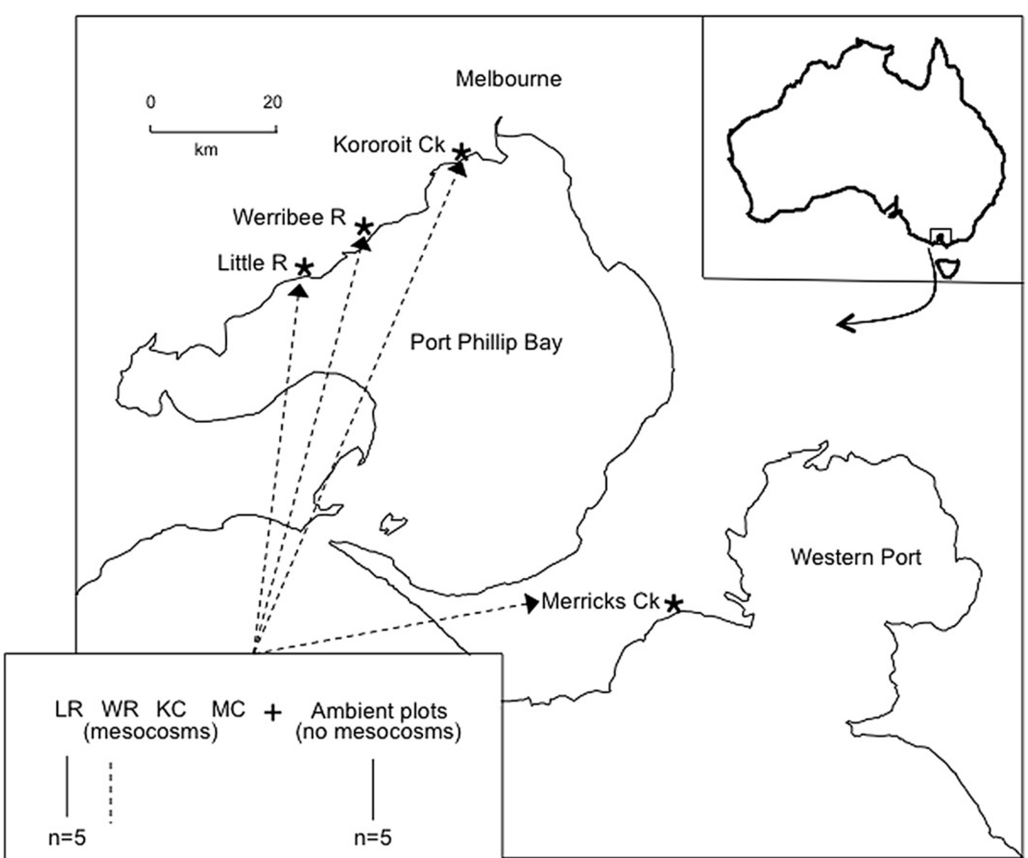

Fig. 1. Location of estuaries and set-up of mesocosms and ambient plots within each estuary (KC = Kororoit Creek, LR = Little River, WR = Werribee River, MC = Merricks Creek).