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Gastropod growth and survival as bioindicators of stress associated with high nutrients in the intertidal of a shallow temperate estuary

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ABSTRACT

The effects of multiple stressors on estuarine organisms are not well understood. Using cage experiments we measured the survival and growth of the pulmonate gastropod *Amphibola crenata* at five locations which differed contaminant levels. Water nutrients came from a nearby sewage treatment works and the sediment contained low levels of trace metals. Over 6 weeks of exposure, sediment surface chlorophyll levels varied amongst locations. The Chl *a* values were positively correlated with sediment N and P and trace metals As, Cd, Cu, Pb and Zn. Pulmonate survival depended on location, highest mortality was from a site close to the treatment plant and mortality rate of large individuals decreased significantly with distance away from it. For four locations, medium *A. crenata* had higher survival than small (juveniles) or adults. Growth rates of small individuals exceeded those for medium and large *A. crenata*. The mean length increment/week for medium gastropods ranged between 0.49 and 1.11 mm and was negatively correlated with the amount of Chl *a* in the surface sediment, suggesting the negative effects of eutrophication on gastropod growth. Growth rate of the pulmonate was not correlated with nutrient concentration or trace metal concentrations in the sediment. The dry weight condition index (CI) did not correlate with the growth rate, and for medium individuals, was unaffected by any of the environmental variables. The CI of small individuals was negatively affected by increasing water nutrient levels and the CI of large individuals negatively affected by increasing sediment nutrients and trace metal concentrations. The results from this study suggest that gastropod growth and survival could be used as tools to monitor the effects of changing nutrient levels and recovery from eutrophication within temperate estuaries.

1. Introduction

Estuaries are amongst the most contaminated marine environments and are under threat due to increasing inputs from adjacent catchments, rivers and shallow coastal seas. The main contaminants include chemicals from industrial waste and organic materials from urban sewage treatment. Estuarine organisms are also exposed to natural stressors including salinity, temperature, varying nutrient levels and hypoxia. The responses of organisms to multiple stressors is complex (Jennerjahn and Mitchell, 2013) and little is known about the interactions between cultural eutrophication (excessive plant growth as a result of nutrient enrichment by humans) and non–nutrient contaminants such as trace metals and pathogens (Smith and Schindler, 2009).

One way to assess contaminant stress within estuarine systems is using bioindicators, species that are known to reflect contaminant conditions. Commonly burrowing organisms, polychaetes and bivalves are used for assessing contaminants in soft sediments (Byrne and O'Halloran, 2001; Zhou et al., 2003) with some species known as specific metal biomonitors because they accumulate trace metals in their tissues according to their availability in the habitat (Rainbow, 2002; Rainbow et al., 2002; Peake et al., 2006; Luoma and Rainbow, 2008; Marsden et al., 2014). More recently molecular, behavioural and physiological biomarkers have been evaluated as indicators of stress in estuarine organisms (Boldina-Coscqeric et al., 2010). One physiological measure commonly used to measure the ability of bivalves to cope with environmental stressors is the scope for growth (Widdows and Staff, 1997). While, this measure provides an estimate of the growth potential, it is not a direct growth measure and very few studies have confirmed these measurements with associated field studies. Also, there have been

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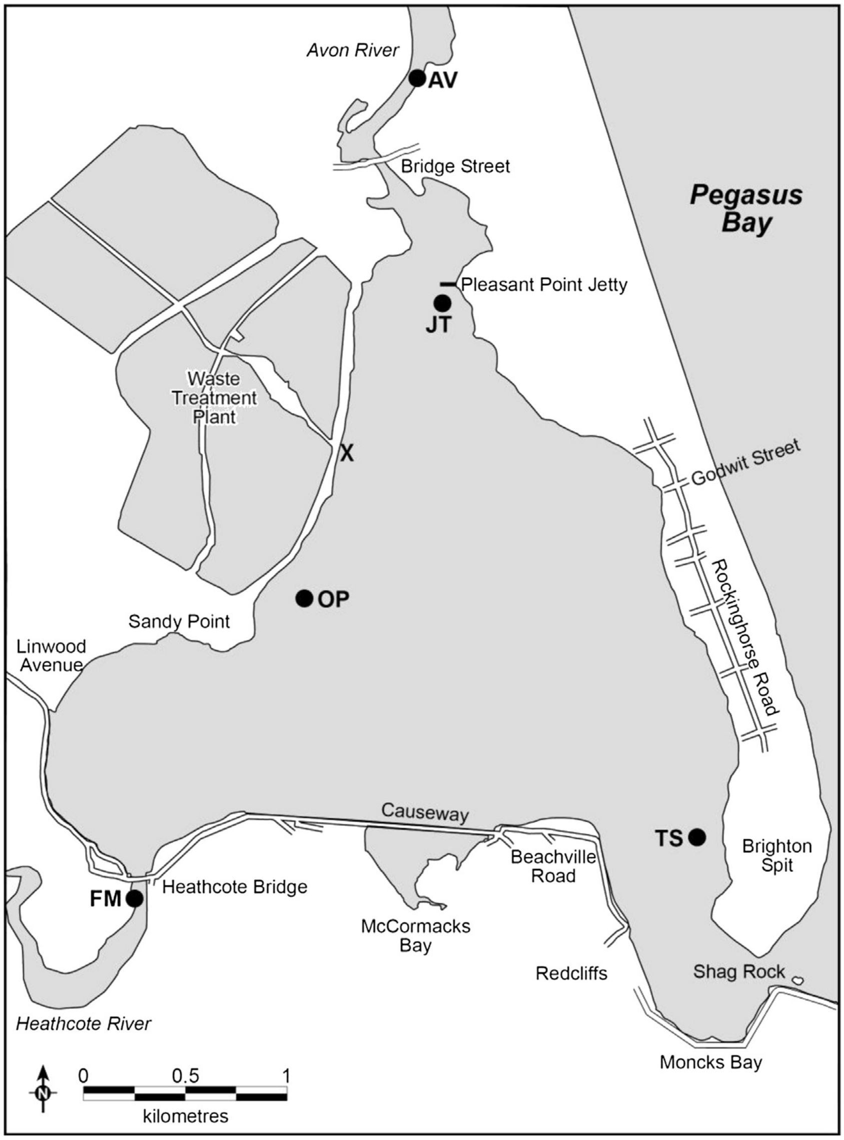

Fig. 1. Map of the locations used for *A. crenata* growth experiments in the Avon-Heathcote Estuary/Ihutai. Place names AV, Avon; FM, Ferrymead; JT, Mt Pleasant Jetty; OP, Oxidation Ponds; TS, Tern St. X marks the location of the discharge point from the treatment plant oxidation ponds.

few attempts to use growth as a response to specific contaminants in the field. There are, however, studies on bivalves (Shriver et al., 2002; Marsden, 2004) and crustaceans, exposed to specific contaminants such as trace metals (Conradi and Depledge, 1999; Marsden, 2002; Marsden and Rainbow, 2004). There are few general trends regarding the effects of eutrophication on grazing gastropods with some studies suggesting that species increase growth in response to increase in inorganic nutrients, whilst in others, there is a decrease in growth rate (Morton and Chan, 2004; Johnson, 2011) .

Deposit feeding gastropods are often successful in estuaries where they are dominant members of the macrofauna, occur in high densities and provide essential services, as a food source for estuarine predators, provide linkages between sediment microphytobenthos and bacteria and assist bioturbation (Orvain et al., 2004). The relatively large (shell length up to 35 mm) endemic pulmonate gastropod, *Amphibola crenata* is widespread throughout New Zealand, occupying a wide tidal range between high tide and low mid tide in sand and mud dominated habitats, extending into salt marshes, up rivers and mangroves (Shumway and Marsden, 1981; Pechenic et al., 2003; Alfaro, 2010). It satisfies many of the criteria required for a potential estuarine bioindicator because it is abundant, tolerant of a wide range of environmental conditions, relatively sedentary and occurs in both clean and moderately contaminated areas (Rainbow, 1995).

The Avon-Heathcote Estuary/Ihutai is a small bar-built estuary which until recently received large quantities of treated sewage and historic industrial waste, including trace elements from the city of Christchurch. There are records of the abundance of *Amphibola crenata from* the early 1960s (Marsden and Knox, 2008) and population density appears to have increased over time. With the establishment of an ocean pipeline removing more than 80% of the nutrients from the estuary benthic communities are expected to change. The reduced nutrient loads may limit primary production and microbial biomass and alter the food availability for grazing snails. Any reduction in either food availability or food quality could affect the growth, reproduction or settlement of *A. crenata.*

In this study we undertook a field cage experiment to measure survival and growth of different size *Amphibola crenata* in habitats which were exposed to a range of water and sediment contaminant