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# Effects of proximity to stormwater on the sandy-beach macrofaunal assemblages of metropolitan Adelaide, South Australia

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A B S T R A C T

Stormwater run-off often enters coastal zones but its effects on sandy beaches are unknown. This study aimed to investigate associations between macrofaunal assemblages and proximity to stormwater outlets along Adelaide's beaches, comparing semi-natural creeks with concrete drains. Five positions along an increasing-salinity gradient were sampled in the intertidal zone of six stormwater outlets and also at corresponding control sites. There was no significant difference between the two forms of stormwater (semi-natural creeks with concrete drains). Only the largest outlet (Torrens) had a significant difference in assemblage structure and taxon richness compared to its control. Total abundances at this outlet followed a convex pattern across the salinity gradient, so it appears that flow there may have a spatially-limited positive effect on the macrofauna in terms of increasing abundance and richness. Therefore, the hypothesised detrimental effects of stormwater have not been found to be evident and these observed patterns warrant further investigation.



## 1. Introduction

Stormwater run-off has become an issue for coastal habitats globally with the increase in impervious surfaces due to urbanisation, especially along coastal areas. To prevent flooding in urban areas, networks of concrete drains are constructed and natural creeks are often modified to direct water flow rapidly away from developed areas after rain events. This wet-weather run-off (referred to as stormwater) is then released out to sea carrying with it various pollutants (Schiff and Bay, 2003), nutrients (Fabricius, 2005), and suspended solids (Fox et al., 2007). Pollutants can cause eutrophication and increase turbidity of coastal waters leading to the degradation of a range of coastal habitats including seagrass meadows, reefs, rocky shores and estuaries (Inglis and Kross, 2000; Hauxwell et al., 2003; Morrisey et al., 2003; Fabricius, 2005; Lapointe and Bedford, 2011; Cox and Foster, 2013; Kinsella and Crowe, 2015). The effects of stormwater on sandy beach ecosystems and in particular the benthic macrofauna, as a considerable proportion of the biodiversity living within the sand, has received comparatively little attention in the ecological literature (but see Tew, 2001; Chaouti et al., 2008).

Studies of freshwater inputs from rivers flowing into coastal waters near sandy beaches have found either subtle (Chaouti et al., 2008) or significant (Lercari et al., 2002) negative effects on benthic biota, the major group of animals living within the sediment (McLachlan and Brown, 2006), with species abundances, richness, biomass, and diversity decreasing along the coast towards the river mouth. Stormwater does have the potential for positive effects on benthic macrofauna as it can deliver fine sediments, particulate organic matter and nutrients that could then be utilised by the macrofauna. Such positive effects were demonstrated in a study on urban wastewater run-off in an estuary near Belém, Brazil, where benthic communities showed an increased density of organisms in areas exposed to sewage run-off (Aviz et al., 2012). The effects of stormwater run-off on benthic macrofauna on sandy beaches can have important implications for the overall management of stormwater, particularly because changes in macrofauna in these systems can have significant effects on the organisms at higher trophic levels, especially as food for fish and shore birds (McLachlan and Brown, 2006).

Benthic communities can be affected differently depending on the type of watershed the stormwater drains from and whether the outlet is unmodified or modified, which is referred to here as the

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'outlet form'. These factors can determine in part the types of pollutants discharged as well as at what rate they are discharged at. For example, concrete drains, common in urban areas, can result in an increased flow rate and consequent reduction in the absorption of pollutants in transit compared with a natural creek. Conversely, natural creeks may be more likely to contain more agricultural run-off leading to higher levels of dissolved nutrients: rural watershed run-off containing higher levels of organic carbon and lower levels of pollutants compared to urban run-off in Santa Monica Bay, California led to a higher abundance and greater diversity of organisms in subtidal benthic communities compared to the urban site (Schiff and Bay, 2003). To our knowledge, the effects of run-off from concrete drains versus semi-natural creeks on sandy beach macrofauna are yet to be investigated.

The city of Adelaide, capital of the state of South Australia and situated on the east coast of Gulf St Vincent, discharges approximately 86 GL of stormwater into the gulf annually (Bryars et al., 2008; Bye and Kampf, 2008; Fox et al., 2007; Short, 2012). This stormwater run-off is thought to be, in part, responsible for the loss of >5000 ha of seagrass along this coast (Fox et al., 2007). Following a run-off event, pollutants such as nutrients, heavy metals and sediments, along with the fresh water that carries them, are held inshore of the 5 m depth contour for between 1 and 10 days (Fox et al., 2007). Such long residence times increase the exposure of inshore biota to any pollutants delivered by stormwater flows.

Plans aimed at reducing the amount of stormwater entering Adelaide's coastal zone do not currently consider the effects on sediment-dwelling animals on sandy beaches (The Office for Water Security, 2010) nor has this topic been covered well in the literature (Tew, 2001; Chaouti et al., 2008). Here, we aim to close this knowledge gap by comparing macrofaunal communities at the outlets of six stormwater drains (3 each of semi-natural creeks and concrete drains) to nearby control sites lacking any stormwater impingement. This study aimed to test the hypothesis that macrofaunal assemblages along Adelaide's metropolitan beaches are affected by proximity to stormwater outflows, as well as the type of outflow. Specifically, we tested for differences in sandy beach macrofaunal assemblages:

a) at the outflows of concrete drains, semi-natural creeks, and control areas lacking drainage; and
b) across any small-scale salinity gradients.

In addition, where differences in assemblages were found, we investigated whether macrofaunal assemblages responded in a negative or positive way to stormwater flow. The objectives not only aim to inform local stormwater management in Adelaide but also to begin filling the knowledge gap of the effects of stormwater on sandy-beach macrofauna more generally.

## 2. Materials and methods

### 2.1. Site selection

Following rain events during late winter or early spring of 2012, 65 stormwater outlets along Adelaide's metropolitan coast were mapped and characterised in terms of their size and salinity gradients (Smith, 2013; rainfall information available in Supplementary Material Fig. S1). The three largest concrete drains and semi-natural creeks (i.e. those sites where the salinity of seawater was reduced along the largest distance of shoreline were then selected for the main study. The three semi-natural creeks sampled in this study were the River Torrens, Christies Creek and Maslin Creek and the three concrete drains were located at Harrow Road, Young Street and Seaford Road (Fig. 1). These varied in size with the River Torrens at least ten times larger than the other outlets in both catchment size and freshwater plume (see Supplementary Material Table S1, Fig. S2).

Three locations (Torrens, Harrow and Young) are all situated on the same 29 km-long continuous beach (Short, 2001, 2012) and the remaining three study locations are situated on separate beaches further south (Fig. 1). This stretch of coast consists of sandy intermediate beaches with fine to medium sand, average wave height of between 0.5 and 1 m and low to moderate wave energy which

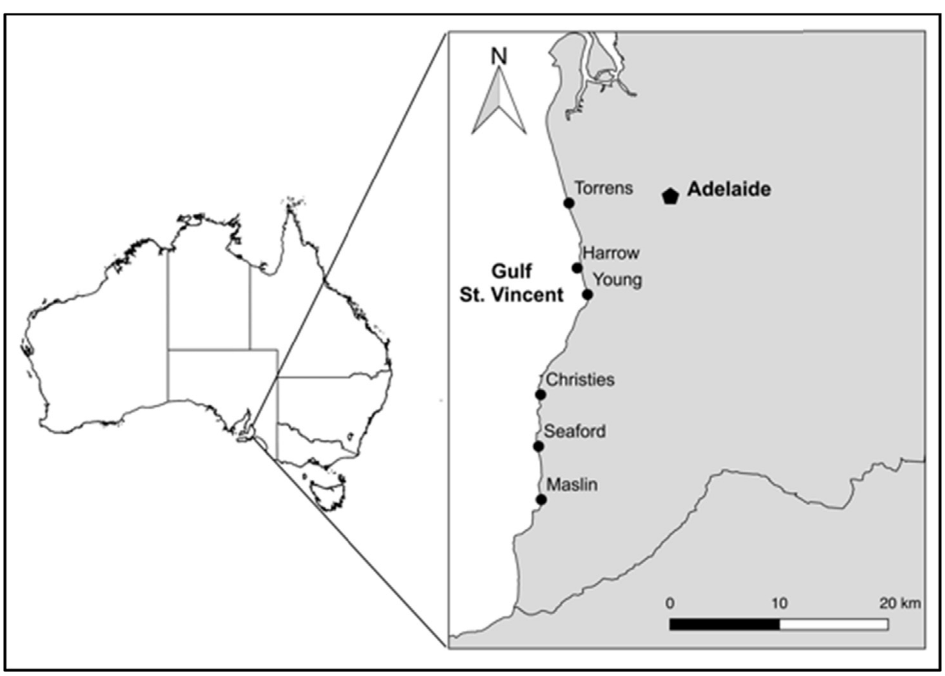


**Fig. 1.** Location of the study locations labelled: Maslin, Seaford, Christies, Young, Harrow and Torrens along the coastline of greater metropolitan Adelaide (urban area north of line). Adelaide city centre shown with pentagon and inset shows the location of Adelaide on the mainland of Australia.