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Response of a hypersaline salt marsh to a large flood and rainfall event along the west coast of southern Africa

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ABSTRACT

The Orange Estuary lost 27% (276 ha) of its wetland area near the mouth as a result of bad management practices during the 1980s. The salt marsh has been unable to recover over the last 20 years because of the persistently high soil and groundwater salinity. In 2006, a 1 in 5 year flood occurred that completely covered the desertified salt marsh and floodplain with freshwater. The flood was followed by an above average (>45 mm) winter rainfall. Soil and groundwater sampled in April and August 2004 were compared with 2006 data to quantify the impact of the flood and rainfall event. It was hypothesised that the two freshwater events would significantly reduce the soil and groundwater salinity. However, the results showed no significant difference in sediment electrical conductivity throughout the soil profile over the four sampling periods. Soil moisture and organic content however increased significantly after these events in the surface soil layer. The flood deposited silt and scoured sand from the surface layers in significant quantities. The depth to groundwater in the desertified marsh retained a similar pattern after the flood despite 15 cm changes in depth in places. In 2004 a clear groundwater electrical conductivity gradient was present extending from the less saline north part of the marsh (0–15 mS cm^{-1}) to the central part (120–135 mS cm^{-1}) and decreasing again towards the south (60–75 mS cm^{-1}). The flood served to even out the groundwater salinity across the desertified marsh (60–90 mS cm^{-1}). The flood and high rainfall had a limited impact on the soil and groundwater characteristics. The few significant changes that were recorded were mostly restricted to the surface soil layers and on a small spatial scale. The rainfall did however create numerous pools of low salinity (<60 mS cm^{-1}) water on the marsh surface that provided a brief opportunity for salt marsh seeds to germinate. A further benefit of the flood was the increased tidal reach into the desertified marsh importing freshwater from the river mouth and exporting salt. Despite these responses it is unlikely that the hypersaline salt marsh will revegetate naturally. Human intervention is needed to ensure the rehabilitation of this important Ramsar site.

1. Introduction

The Orange Estuary forms part of the Orange River Mouth Transboundary Ramsar Site (ORMTRS). The ORMTRS is a coastal wetland of international importance located at the international boundary between South Africa and Namibia (Fig. 1). On the south bank of the Orange River Mouth, a large floodplain is situated that was historically covered with salt marsh vegetation. A sequence of events, most notably the construction of a causeway, building of flood control levées and the 1988 flood, led to the loss of approximately 90% of the floodplain salt marsh (Morant and O'Callaghan, 1990). In September 1995 the Ramsar site was placed on the Montreux Record (a record of Ramsar sites where changes in ecological character have occurred) as a result of a belated recognition of the severely degraded state of the salt marsh on the south bank. This implies that the ORMTRS may lose its status as a Ramsar site unless the salt marsh can be rehabilitated. South Africa is now obliged, as a signatory of the Convention, to ensure that the ecological character of the site is restored.

Bornman et al. (2002, 2004a,b) showed that the distribution and health of the dominant salt marsh plant, *Sarcocornia pillansii*, is related to the depth to the water table and the salinity of the groundwater. It was found that the salinity of the groundwater was the main limiting factor preventing the natural recolonisation of the salt marsh at the Orange Estuary (Bornman et al., 2004b). The Orange Estuary salt marsh is subject to variable hydrologic conditions, due in part to natural rainfall and streamflow extremes and in part to human modifications that alter the amount and period of streamflow that in turn reduces tidal flushing. Zedler et al. (1986)

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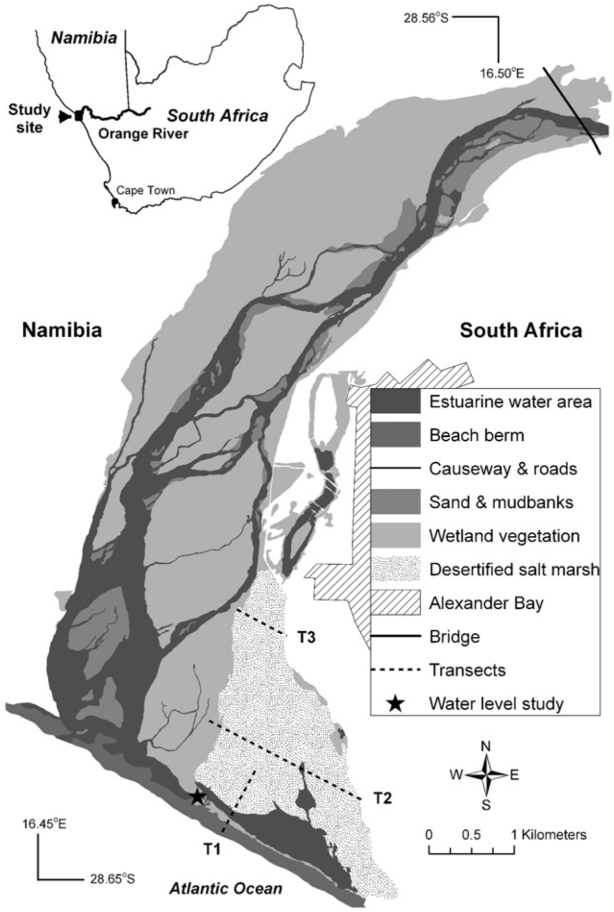

Fig. 1. Map of the Orange Estuary showing the location of the desertified marsh, the three long-term transects and the water level study site.

and Alvarez-Rogel et al. (2007) also found that when considerable changes in physical conditions occur and are maintained for more than a few months then the distribution of salt marsh vegetation will change in response to the new conditions.

Anthropogenic changes to flooding regimes in highly variable arid catchments have a severe effect on floodplain vegetation (Capon, 2005; Alexander and Dunton, 2006). Flood events are necessary to periodically leach accumulated salts from the root-zone caused by evapotranspiration (Jolly et al., 1993; Slavich et al., 1999) and to recharge the floodplain aquifer (Jolly et al., 1993). Brief periods of freshwater inundation at specific times of the year alleviate stress in hypersaline and dry soils and promote seed germination (Zedler, 1983; Callaway et al., 1990; Noe and Zedler, 2001; Alexander and Dunton, 2002; Forbes and Dunton, 2006). Catastrophic flooding on the other hand can lead to sedimentation and increased soil salinity causing widespread plant mortality, temporary reductions in productivity, and both short and long-term changes in community composition (Zedler et al., 1986; Zedler and West, 2008).

Low flows in the Orange River during 2004 and 2005 (Figs. 2 and 3) resulted in increased seawater penetration into the estuary although the extent of tidal inundation of the desertified marsh was not affected. This was believed to be the direct cause of the die-back of less salt-tolerant species such as *Phragmites australis* and *Schoenoplectus scirpoideus* in the lower reaches. Increased salinisation of the estuary further reduced the chances of natural recovery and anthropogenic intervention appeared to be the only solution to rehabilitate the degraded salt marsh. Re-establishing plant cover is essential for restoring ecosystem functions, but revegetation can be difficult in severe sites, such as arid and semi-arid salt marshes that experience hypersalinity, episodic sedimentation, depauperate seedbanks and low seed dispersal from distant reference sites (Zedler et al., 2003; O'Brien and Zedler, 2006). Early in 2006, the Orange River flooded in response to heavy rainfall in its catchment and the floodwaters covered the floodplain regions of the estuary for several days. The water column salinity of the estuary remained fresh to brackish (<15) for a further five months.

The hypothesis tested was that the floodwaters over the desertified floodplain were sufficient to significantly reduce the soil and groundwater salinity. The flood was followed by above average rainfall (Fig. 3) at the estuary during winter and it was further hypothesised that the additional freshwater input from the rain would reduce the salinity of the soil and groundwater further. The effect of the two freshwater events on the soil and groundwater was investigated and compared to the dry period of 2004. The results from the study will indicate whether the system can revegetate naturally or if anthropogenic intervention is required.

2. Materials and methods

2.1. Study site

The Orange Estuary is situated at the mouth of South Africa's largest river on the Atlantic coast and forms the border with Namibia (Fig. 1). The wetland supports a large number of migratory waterbirds and is one of a limited number of wetlands along the arid Atlantic coastline of southern Africa (Anderson et al., 2003). The Ramsar site covers an area of approximately 2298 ha (Fig. 1), of which 1842 ha can be considered estuarine wetland. The largest salt marsh area (south of Alexander Bay) comprises an area of approximately 300 ha, of which at present more than 276 ha is desertified (27% of the total estuarine wetland area).

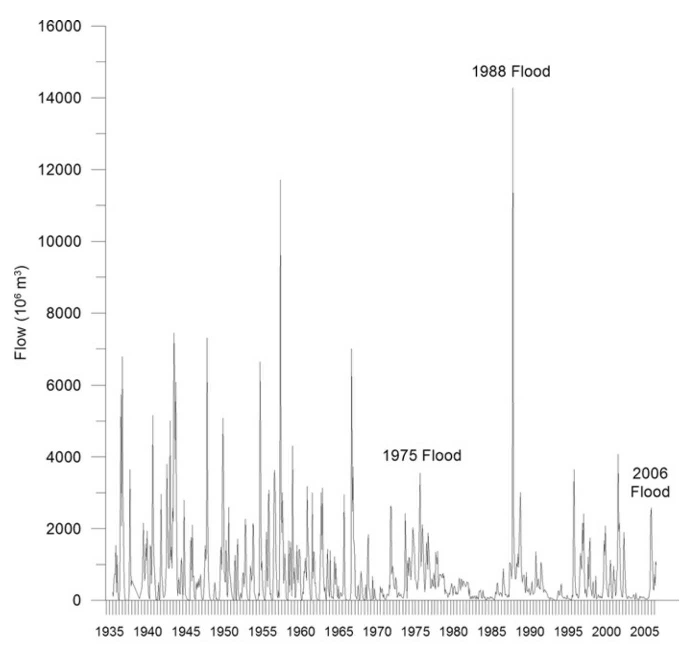

Fig. 2. Monthly river flow from 1935 to 2006 (data from the Vioolsdrif gauging station provided by the Department of Water Affairs and Forestry).