performance, measured by T_oR_{GR}, diverged from T_o for germination and there was typically a lower optimum temperature for germination than for seedling performance (Table 1). As a result, climate change may have a greater impact on seed germination than on relative seedling performance for these species.

Although southern WA has experienced climate variation in the past and its native species may have a broad tolerance to extreme climate conditions, we have little knowledge of climate thresholds for southern WA's flora. It is therefore vital that we begin to gather accurate data on species requirements for recruitment as just one small piece of the jigsaw puzzle that will assist our understanding of climate change impacts on native flora.

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Threats facing coastal saltmarsh in urban areas

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Introduction

Coastal saltmarshes are intertidal ecosystems generally vegetated by herbs, grasses or low shrubs (Adam 1990). These systems are vulnerable to sea level rise and mangrove incursion as well as more direct human disturbance including physical, chemical and biological modification. Of concern is fragmentation of habitat that may be occurring unchecked either because the presence of saltmarsh is unknown, or because steps have not been taken to conserve saltmarsh. In a study of the saltmarsh of the Parramatta River/Sydney Harbour (Kelleway *et al.* 2007), these factors led to the categorisation of more than half of the estuary's saltmarsh patches to be in 'poor' condition.

Physico-chemical Threats Facing Saltmarsh Ecosystems

Reclamation

Saltmarshes around Australia have been 'reclaimed' as part of agricultural, industrial, port and residential development. In Parramatta River / Sydney Harbour, for example, the downstream portion of the estuary is now generally devoid of saltmarsh, with seawalls, stormwater canals, residential or industrial development and sporting fields in their place. Historical sources of early settlers in the same estuary show that saltmarshes were extensive in many of the embayments, creeks and intertidal flats during the early years of settlement (Kelleway *et al.* 2007 and references therein). For the most part, little is known of the extent of historical loss in other estuaries.

Fragmentation

The construction of levees, seawalls, jetties, tracks and roads, combined with the proliferation of mangroves has fragmented many of the remaining patches of urban saltmarsh into smaller units. The ecological composition and function of smaller, fragmented patches is likely to be altered (Laegdsgaard 2006), especially in terms of habitat connectivity and overall saltmarsh productivity.

Inappropriate access

Many urban saltmarshes, particularly those accessible from residential areas are subject to inappropriate access and use. Human trampling can cause significant reduction in the number and cover of saltmarsh plants, and continued passage by recreational vehicles (4WD, trail bikes, BMX) has been responsible for the degradation of saltmarsh ecosystems at a number of locations, including within national parks (see Kelleway 2005).

Low-growing, soft herbs such as *Wilsonia backhousei* (Vulnerable, NSW *Threatened Species Conservation Act* 1994) and *Sarcocornia quinqueflora* are particularly susceptible to damage by trampling and vehicles. One of the largest remaining stands of *W. backhousei* in Sydney has been extensively damaged by trail bike use (Kelleway *et al*. 2007). Vehicle use has also been shown to alter saltmarsh hydrology and cause large reductions in the numbers of saltmarsh fauna such as crabs and molluscs (Kelleway 2005).

Dumped materials are often observed in and around urban saltmarshes, particularly at sites that are easily accessible but which are out of public view. Commonly dumped items

Saltmarsh degraded by recreational vehicle use, Georges River estuary, Sydney. Photo: Jeff Kelleway

include garden waste (which has the potential to introduce weeds) and construction materials. Saltmarsh bordering residential properties and council parklands may be subjected to mowing. This can destroy important succulent plant species and disrupt the flowering of grasses.

Rise of sea level

The vulnerability of plants living in and around estuaries to sea level rise has long been recognised (Kelleway *et al*. 2007 and references therein). Saltmarsh and mangrove will be forced further upslope and upriver from their present locations. However, the continued survival of saltmarsh is likely to be limited by local geomorphology, and by anthropogenic structures such as seawalls, roads and buildings. If space is unavailable due to the presence of such structures or steep topography then saltmarsh will disappear. Buffer zones that allow for expansion of saltmarsh should be included in state regional and local planning documents, as well as in the design of new developments adjacent to saltmarsh habitat.

Stormwater discharge

Stormwater discharge into saltmarsh can alter the salinity and nutrient regimes of the wetlands. Direct discharge onto saltmarsh appears to have promoted mangrove colonisation of the saltmarsh in several urban locations (Saintilan pers. obs.). Incursion by freshwater and brackish species such as *Phragmites australis* and *Typha* spp. and exotic weeds may also be facilitated (e.g. Kelleway *et al*. 2007).

Biological Threats Facing Saltmarsh Ecosystems

Mangrove incursion

Evidence of mangrove incursion into saltmarsh exists across the whole of southeastern Australia (Saintilan and Williams 1999) but the causes are as yet unknown. Urban saltmarshes are particularly susceptible, especially where development works appear to have enhanced sedimentation and provided new substrata for mangrove growth. As with sea level rise, the presence of anthropogenic structures greatly limits the ability of saltmarsh to respond to mangrove incursion in urban estuaries.

Exotic species

In southeastern Australia there are a few specialised exotic plant species which can tolerate the waterlogging and/or salinity conditions of saltmarshes. The invasive rush *Juncus acutus*, which is widespread and often abundant in saltmarshes of the Sydney region (Kelleway *et al*. 2007), is of particular concern as it aggressively displaces native saltmarsh species, including the native rush *Juncus kraussii.* Control is difficult and can require a combination of physical removal, herbicide application and mulch covering.

Managing the Threats

The protection of saltmarsh wetlands requires a range of approaches. First and foremost, their distribution needs to be known. A recent estuary-wide field survey of the Parramatta River/Sydney Harbour (Kelleway *et al*. 2007) highlighted the limitations of aerial photograph interpretation in identifying saltmarsh patches under canopy and/or small in size. This showed that previous mapping efforts had missed more than 70% of the estuary's saltmarsh by area. If the threats facing urban saltmarshes are to be identified and managed, then appropriate mapping and assessment protocols need to be employed in the first instance.

Secondly, strong legislative and planning measures which adequately define this ecosystem are required to minimise threats and provide for rehabilitation and continued management. In all states and territories, the highest level of protection will be offered by inclusion in the conservation reserve system (e.g. national parks, marine reserves), provided that adequate resources are supplied for their ongoing management. Legislative protection, such as that afforded saltmarsh as an Endangered Ecological Community under the NSW *Threatened Species Conservation Act* 1994, will provide another tool in addressing threats faced by this ecosystem.

Active, on-ground management options will be best assessed on a site-by-site basis. Controlling access and/or the installation of interpretive and warning signage is recommended for sites undergoing physical disturbance. Education programs for landholders, land managers and the broader community will be part of the solution to many of the management threats discussed above, while community involvement in rehabilitation and maintenance efforts will encourage the long-term protection of coastal saltmarsh in urban areas.

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