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Coastal saltmarsh vulnerability to climate change in SE Australia

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Keywords

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Introduction: the Ecological Significance of Saltmarsh

Until recently Australian saltmarsh was the least studied of all marine habitats in spite of their occupying as much as sixteen thousand square kilometres of the Australian coastline and supporting more than three times the number of vascular plant species found in mangrove forests. Ignorance of the ecological values of saltmarsh has been reflected in the relative lack of protection afforded to the habitat compared to other ecosystems. The loss of saltmarsh from the estuaries of eastern Australia following

European colonisation began with the reclamation of saltmarsh for agricultural, industrial, transport and residential development (Kratochvil *et al*. 1972; Saenger *et al*. 1977; Davis and Froend 1999; Finlayson and Rea 1999). Significant alterations to the hydrology of saltmarshes have followed the imposition of levees, culverts and floodgates, leading to the loss of ecological function and the replacement of saltmarsh with glycophytes.

On the evidence of historical aerial photography, recent decades (1950's and following) mangroves have began replacing saltmarsh from the seaward edge, a trend likely to continue with elevated sea-levels as a result of global climate change (Saintilan and Williams 1999; 2000) This trend is consistent between geomorphic settings and biogeographic regions. In recognition of the consistent decline of saltmarsh and the vulnerability of saltmarsh to further losses as a response to sea-level rise, coastal saltmarsh was declared an Endangered Ecological Community under the NSW Threatened Species Conservation Act in 2004.

Fortunately the growing awareness of the vulnerability of coastal saltmarsh has prompted more than a decade of research by a number of university and government scientists. While there is still much to be discovered about Australian saltmarshes the time is ripe to dispel the myth that we know virtually nothing. The picture which emerges is one of a vulnerable habitat–which makes a unique and important contribution to the ecology of the coastal zone.

(i) Migratory Shorebirds and Saltmarsh

Trans-equatorial migrant Charadrii (whimbrel, godwits, plovers, sandpipers) of the East-Asian-Australasian flyway use intertidal mud and sand flats of estuaries as feeding and roosting habitat (Marchant and Higgins 1994, Higgins and Davies 1996). These birds breed in the high latitudes of northern Asia, and migrate south in August as the arctic summer cools. The journey may span 13 000 kilometres (Barker *et al.* 1995), with the birds stopping and feeding on productive temperate and tropical coastal wetlands (Parish *et al.* 1987). The East Asian-Australasian flyway is considered the world's most threatened flyway (Gill *et al.* 1994, Melville 1996).

Within Australia, while some subpopulations of migratory birds may make use of riparian wetlands (Kingsford *et al.* 1994), most flock to the consistently reliable coastal wetlands (Watkins 1993) to which they may return season after season (Driscoll 1995). In temperate southeastern Australia, it is the estuaries which provide most of the soft, intermittently flooded feeding grounds needed, and it is here that the great majority of shorebirds are found (Smith 1991).

The saltmarshes of eastern Australia are also an important habitat for several species of migratory shorebird (Lane 1987; Lawler 1996). In the Hunter estuary, migratory birds feed in the invertebrate-rich mudflats of Fullerton Cove at low tide, and at high tide roost along estuarine beachfronts and coastal saltmarsh. Open roost sites are preferred for the early detection of avian predators (Lawler 1996; Luis *et al.* 2001; Rogers *et al.* 2006). Species utilising the saltmarsh as a roost include the Curlew Sandpiper, Marsh Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper, Eastern Curlew and Pacific Golden Plover (Geering 1995, Spencer et al 2009). Within the Hunter, large flocks of Sharp-tailed sandpiper, Eastern Curlew and Bar-tailed Godwits utilise saltmarsh on the north-western portion of Kooragang Island as a night-time roost. The site is characterised by sparse vegetation and large shallow pools where birds continue to feed on Chironomids while roosting (Spencer *et al.* 2009).

(ii) Fish and Crustacean use of saltmarsh and saltmarsh exports

Subtropical saltmarshes may also support a diverse fish assemblage during spring tides (Morton *et al.* 1988, Thomas and Connolly 2001), including species of commercial importance. Mazumder *et al.* (2005) have found concentrations of juvenile and other small fish to be similar between temperate mangrove and saltmarsh environments at Towra Point, Botany Bay during spring tides. Crinall and Hindell (2004) found a similarly diverse fish assemblage in the saltmarshes of Victoria, including a number of commercially important species. In addition, the Towra Point saltmarsh was found to be a highly productive source of crab larvae, predominantly sourced from the genus *Paragrapsus*, which occupies mid to upper-intertidal situations (Mazumder *et al.* 2006).

Multiple regression analyses of variables relating to the catch of individual species suggest that saltmarsh area may contribute to the catch of a range of species, in particular the mud crab *Scylla serrata* (Saintilan 2004). The data indicate that the diversity of habitat types is of more significance in supporting healthy fish stocks than mangrove or seagrass alone. Mangrove proliferation at the expense of saltmarsh and seagrass is therefore of concern.

(iii) Bats and other mammals

The open vegetation structure of saltmarsh in southeastern Australia is unique in the coastal zone. The absence of trees and the presence of the grass *Sporobolus virginicus* make saltmarsh a habitat for swamp wallabies, kangaroos (Laedsgaard 2002) and the rare water mouse *Xeromys myoides* (Van Dyke 1997, Spencer *et al.* 2009). Monamy *et al.* (2004) have demonstrated the utilisation of saltmarshes by insectivorous bats, in New South Wales and Victoria. Two bat species identified in the survey are listed as vulnerable under the NSW Threatened Species Act (1995). Belbase (2005) reported bats feeding over the saltmarsh of Kooragang Island at times coinciding with the emergence of mosquitoes, possibly an important food source for microbats.

Saltmarsh increases in floristic diversity with increasing latitude, as mangrove diversity decreases (Saenger *et al.* 1977). Over 40 species have been identified in temperate Australian saltmarsh (Underwood and Chapman 1993). The southern bioregion is of particular interest floristically, as saltmarshes of the region are more species rich than further north, with *Austrostipa stipoides*, *Gahnia filum*, *Limonium australe* and *Sclerostegia arbuscula* forming a characteristic southern suite of species (Hughes 2004). A number of other species with restricted distribution in coastal saltmarsh include *Distichlis distichophylla* (endangered), *Halosarcia pergranulata* subsp. *pergranulata, Wilsonia backhousei* (vulnerable) and *Wilsonia rotundifolia* (endangered) (Hughes 2004). Coastal saltmarshes are a storehouse of halophytic plants that may be of potential benefit in developing species to be used to revegetate inland areas suffering from salinisation.

Threats to saltmarsh

Estuaries in southeastern Australia have been modified in such a way that the proliferation of mangroves has been promoted. Increased silt loads and nutrient levels, caused by the development of catchments, have created new and highly fertile mangrove environments. Over the previous five decades, increases in sea-level and rainfall have exposed upper-intertidal environments to mangrove colonisation. Of 31 case studies reviewed by Saintilan (2003) only four reported a decline in mangrove area. These were in association with the construction of Brisbane airport (Hyland and Butler 1988), the construction of flood-gates at Throsby Creek (Williams *et al.* 1999) and Ironbark Creek (Morrison 2001) on the Hunter River, and development works within Port Jackson (Thorogood 1985). In the latter case, McLoughlin (2000) reports an overall increase in mangrove area in the Parramatta River-Port Jackson system since European colonisation. Unfortunately, there are few data describing the distribution of estuarine macrophytes prior to the use of aerial photography.

This trend of mangrove proliferation has placed pressure on other estuarine habitats. In a review of 29 photogrammetric surveys covering over 20 estuaries in Queensland, New South Wales, Victoria and South Australia, Saintilan and Williams (1999, 2001) described an increase in the area of mangroves, and a corresponding decrease in the saltmarsh habitat. In 70% of estuaries surveyed, saltmarsh losses to mangrove incursion have exceeded 30%, and in some situations losses have approached 100%. These impacts have placed heightened pressure on saltmarsh already impacted by agricultural and urban developments (Kratochvil *et al.* 1972, Saenger *et al.* 1977, Zann 1997, Finlayson and Rea 1999).

Wilton (2002) demonstrated that while saltmarsh losses in recent decades have been greatest in urbanised estuaries, the component of loss due to mangrove encroachment is relatively constant between estuaries, at a median figure of 30%. The overall sea-level rise in the period 1940-2000 (70 mm at the Fort Dennison datum in Sydney Harbour) represents approximately 30% of the vertical range of the saltmarsh. The consistency of the trend between estuaries, the approximation of the degree of loss with the degree of sea-level rise, and the pattern of encroachment along drainage lines (Saintilan and Williams 1999) all suggest that at least some component of saltmarsh loss is related to sea-level trends.

More recently Rogers et al. (2006) compared the extent of mangrove encroachment to relative sea-level rise. By using a network of 96 Surface Elevation Tables (SETs) installed at twelve sites in New South Wales and Victoria, Rogers et al. (2006) were able to measure subsidence and sedimentation in wetlands over a 4-year period following 2000. By comparing the rate of subsidence with oceanic (eustatic) sea-level trends, they calculated the relative sea-level trends for each site, which was then compared to rates of mangrove encroachment. The correlation was strongly significant. For many of the same sites Wilton (2002) demonstrated no significant correlations between mangrove encroachment and the degree of catchment modification, rainfall or eustatic sea-level trends. The suggestion is that a large component of mangrove encroachment can be accounted for by relative sea-level trends, but these are site-specific, and may be influenced by local factors including groundwater levels (Rogers et al 2005; Rogers and Saintilan 2008).

Sea-level rise is not the only potential impact of climate change on Australian saltmarshes. The increase in saltmarsh diversity with latitude is strongly correlated with minimum monthly air temperature (Saintilan in press). The germination of several species of saltmarsh may be inhibited by higher temperatures, explaining the depauperate tropical saltmarsh flora, in spite of the extensive area of intertidal habitat available for colonisation in these latitudes. The southward translation of climatic zones in Australia would threaten the diversity hotspots of the southern mainland coastline and Tasmania.

Management of sea-level rise for Coastal Wetlands

The rate of sea-level rise is expected to accelerate over the coming century to reach 18-59cm above present levels by 2100 (CSIRO and BOM 2007). A major problem in coastal wetland conservation is the lack of knowledge on ecosystem response to sea-level and the absence of planning tools for estuarine managers to incorporate anticipated responses in planning for ecosystem protection in the future. To preserve or enhance ecologically desirable habitat, planning agencies must make appropriate zoning decisions now in anticipation of climate trends.

Understanding how particular coastal wetlands respond to sea-level change is contingent on an understanding of factors which influence surface elevation of the wetland. Within Australia a number of factors are of significance in controlling surface elevation of coastal wetlands, including sedimentation rate, groundwater flow and biological productivity (Rogers et al 2006; Rogers and Saintilan 2008). For a wetland to survive under moderate rates of sea-level rise, it is important that flows of sediment and groundwater continue to the wetland. The impacts of groundwater removal on coastal wetlands deserve research attention, as does the management of sediment flows through catchments and onto estuarine deltaic wetlands. Doubtless wetlands will be forced to recede landward, and buffer planning should consider local gradients in determining the extent of land required by coastal wetlands in the immediate future.

The development of landscape-scale models of coastal wetland responses to sea-level rise has to date been limited by the lack of good elevation data at this scale. Recent advances in the development of LiDAR as a means of capturing elevation over wide areas has ushered a new era of coastal wetland response modelling. LiDAR-based elevation models now exist over several segments of the NSW coast, including the NSW central coast (J. Hudson pers. comm). At a basic level of analysis, sea-level rise can be extrapolated onto the elevation models, and the altered distribution of mangrove and saltmarsh vegetation communities be modelled using the approximate elevation preferences of each community type. The Surface Elevation Table data provides the opportunity to factor into this analysis the dynamic relationship between sea-level rise and marsh surface elevation, which can offset a sizable proportion of sea-level rise, particularly in mangrove. A further level of accuracy would be gained from the hydrodynamic modelling of coastal wetland environments and their hinterlands, so that the models considered the attenuation of tides as they propagate through the marsh. The application of these modelling techniques will over the coming few years allow the development of maps forecasting the distribution of mangrove and saltmarsh under a range of IPCC sea-level rise scenarios, allowing coastal planners to maintain or enhance accommodation space in anticipation of the shoreward translation of vegetation communities.

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