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Perspective

Coastal wetlands of temperate eastern Australia: will Cinderella ever go to the ball?

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Abstract. The many sheltered embayments, riverine estuaries and drowned river valleys of temperate eastern Australia support a large area and a wide diversity of coastal wetlands. This region also supports over one-half of the country's population and includes its major tourist and industrial centres. The story of Cinderella provides an excellent simile for the status of coastal wetlands in this region of Australia: coastal wetlands provide extremely valuable ecosystem services (indeed, of considerably greater value than those provided by an equivalent area of inland wetland), yet they are undervalued by the general community, by natural-resource managers and by funding agencies. The selective investment of ecological research (including rehabilitation studies) into inland wetlands – and in particular into floodplain wetlands of the Murray–Darling Basin – has left us inadequately equipped to understand how temperate coastal wetlands function, how they will respond to climate change, and how degraded sites can be rehabilitated. Not only is an increase in research funding required, but funding has to be coordinated and focussed. The problem, however, is not only a lack of research funding; at a more fundamental level, the widespread ignorance of the value of temperate coastal wetlands needs also to be addressed.

Additional keywords: climate change, coastal lagoons, funding, ICOLLs, response envelopes, salinity, water regime, valuation, vegetation.

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Introduction

Readers of this journal would probably be aware of the story of Cinderella. For those who are not, it is a folk tale about unrecognised value, neglect and, ultimately, recognition and triumph. The parallels between it and the status of research investment and ecological understanding of coastal wetlands in temperate eastern Australia are uncanny: (1) coastal wetlands provide a wide range of highly valuable ecosystem services; (2) despite this, coastal wetlands have by-and-large been neglected by the agencies that invest into research and management of natural resources in Australia; (3) instead, they have chosen to invest increasingly into the inland 'relations' of coastal wetlands, and especially into floodplain wetlands in the Murray–Darling Basin; (4) impending threats from climate change, in particular increases in mean sea level and an increased incidence and ferocity of storms, indicate that the 'midnight' for coastal wetlands approaches quickly; and (5) a bright future is nevertheless possible, but only if coastal wetlands are recognised for their ecological, economic and social values and society decides to invest more strongly into research into their fundamental ecology and ways to improve their management, including how to rehabilitate degraded sites and those most affected by climate change.

In this Perspective article, I examine the current level of understanding of the structure, function and value of coastal wetlands in temperate eastern Australia and argue that there has been a lamentably inadequate investment in research into these systems. The geographic scope of the critique is the temperate eastern Australian coast, a region defined broadly as that part of eastern Australia south of the Tropic of Capricorn, with the acknowledgement that although this zone is dominated by classical 'temperate' climates, it includes as well, especially in south-eastern Queensland, climates that would be described as 'sub-tropical' in the Köppen climate classification. The focus is on wetland vegetation, because that is the area of my expertise, although similar arguments could likely also be mounted about our general lack of understanding of the fauna of these systems (e.g. see Saintilan 2009).

A cast of characters – the wide range of coastal wetlands in temperate eastern Australia

Mangroves and saltmarsh are the two types of environment that many readers would associate as 'coastal wetlands'. Some might include also seagrass beds, and such an inclusion would be consistent with the broad definition of 'wetland' adopted by the Ramsar Convention. There is, however, a much wider range of wetland environments along the temperate eastern Australian coast than just these three, relatively widely known types (McComb and Lake 1988; Norman and Corrick 1988; Turner *et al.* 2004; Boon *et al.* in press).

The systems that I am most familiar with are those along the coast of temperate south-eastern Australia, and those of Victoria in particular. In Victoria, native vegetation is described in terms of Ecological Vegetation Classes (EVCs); EVCs are defined as one or more of several floristic and structural types that appear to be associated with a recognisable environmental niche and can be characterised by their adaptive responses to ecological processes that operate at the landscape scale (Department of Natural Resources and Environment 2002). Table 1 shows that wetland EVCs of the Victorian coastline include not only the well recognised mangroves and saltmarsh, but also systems dominated by a floristically and structurally diverse range of other angiosperm taxa.

A similar argument about diversity can be made for coastal wetlands in New South Wales and southern Queensland. Adam *et al.* (1985), for example, identified a range of tall reedbeds, short grasslands and sedgelands, non-saltmarsh sedgelands, wet meadows, semi-aquatic and aquatic herbfields and open freshwater swamps in their inventory of New South Wales coastal wetlands. In parts of low-lying coastal floodplain along the New South Wales coast, reedbeds give way to meadows dominated by shorter sedges and grasses, including several species of *Paspalum*, *Panicum*, *Pseudoraphis*, *Eleocharis* and *Isolepis*, of which *Paspalum distichum* and *Eleocharis equisetina* are the most common (Keith and Scott 2005; Keith *et al.* 2007). These species tend to occupy the brackish backplains between the channels of larger rivers, where they receive periodic overbank flows or sheet flows from lithic slopes adjacent to the floodplain so that tidal influence is diluted, but water tables are retained close to the surface for extended periods (Boon *et al.* in press). Paperbark (*Melaleuca* spp.)-dominated swamps occur across much of the eastern Australian coast in low-lying areas adjacent to estuaries and between terrestrial and tidally inundated vegetation (Turner *et al.* 2004). Swamp oak scrubs and forests extend north from Bermagui in New South Wales and traverse substantial local gradients in soil salinity from fresh water to brackish on lower floodplains and estuaries. *Casuarina glauca* is typically the only tree species, although *Melaleuca ericifolia, M. styphelioides* and *M. quinquenervia* may co-occur (Boon *et al.* in press). In other words, there is an extremely wide range of wetland types along the temperate eastern coast of Australia, and not all of them are mangroves, saltmarshes or seagrass beds.

The value of coastal wetlands

As aquatic scientists, we all know that wetlands are valuable. The Millennium Ecosystem Assessment (2005) formalised this knowledge and listed the wide range of ecosystem services provided by inland and coastal wetlands. To some people (including many researchers), a critical component of their value is aesthetic; indeed, it is hard not to be moved by the beauty of many coastal wetlands (Fig. 1). Moreover, we have previously shown that wetlands are focal points for recreation and tourism in inland Australia (Hadwen *et al.* 2012), and the same situation likely holds just as strongly for coastal wetlands. In fact, the wetland shown in Fig. 1, at the mouth of the Thurra River in East Gippsland, is used intensively as a family camping site during school holidays, as are almost all the wetlands and estuaries along the Gippsland coast. Many estuarine wetland systems along the south-western coast of Western Australia are similarly a focal point for recreation (Brearley 2005), as are coastal wetlands in Queensland (e.g. Hadwen and Arthington 2003). The usage of such wetlands in coastal temperate Australia is controlled strongly by institutional factors such as the timing of holiday periods (Hadwen *et al.* 2011) and this, in turn, has important implications for anthropogenic impacts on these sites. Nevertheless, some wetlands, especially along the more remote coasts, are probably as close to 'pristine' (i.e. similar to an assumed pre-European condition) as is possible in this country and therefore could have significance as reference sites for ecological assessments and for setting rehabilitation targets.

Aboriginal peoples have long recognised the value of coastal wetlands. In the Sydney region, for example, various *Melaleuca* spp. and *Casuarina glauca*, all species of coastal wetlands, were used variously for bedding, to make canoes and as torches; wetlands also provided a valuable source of food by way of abundant waterbirds (Attenbrow 2010). This recognition has not always translated fully into the contemporary Australian population; the broader public has a low regard for coastal saltmarsh, even if mangroves are better regarded, mostly among the angling fraternity (Boon *et al.* 2011). Such an attitude would seem to hold increasingly too for politicians and for many senior decision makers in natural-resource management. One consolation is that coastal swamp forests in New South Wales (e.g. those dominated by *Eucalyptus robusta*, *Melaleuca* and *Casuarina* spp.) are afforded protection as endangered ecological communities. In Victoria, by contrast, there is little protection given to coastal wetlands and, indeed, in many bioregions, coastal saltmarsh is given the lowest level of protection – 'of least concern' – under the State-wide Bioregional Conservation Significance protocol (Boon *et al.* 2011).

Attempts have been made recently to quantify in economic terms the value of wetlands. Although the whole approach of economic valuation is fraught and highly controversial (e.g. see McCauley 2006), it nevertheless proceeds. Perhaps the most detailed economic valuation of natural systems has been undertaken recently in the United Kingdom as part of the National Ecosystem Assessment process (UK National Ecosystem Assessment 2011). This assessment has shown that coastal wetlands are, on average, worth three to six times as much as inland wetlands (Bateman *et al.* 2011). Coastal wetlands in the UK, for example, were estimated to be worth an average of £3730 per hectare per year in terms of flood control and storm buffering; the comparable value for inland wetlands was £608 ha^{-1} $year^{-1}$. Similarly, the average biodiversity value of coastal wetlands was far greater than that of inland wetlands (£1275 versus £273). The most telling conclusion was that the report recommended that values of £304 per hectare for inland wetlands and £1866 per hectare for coastal wetlands should be applied to any proposed change in the area of these habitats.

The value of coastal wetlands is only likely to increase as we face the onslaught of climate change, increased mean sea levels and more powerful storm surges. French (1997) and Doody (2008) have both argued for the value of coastal wetlands in protecting against shoreline erosion in the United Kingdom. Indeed, French (1997) argued that coastal saltmarsh provides valuable ecosystem services by protecting land against erosion and that many of those benefits were lost when seawalls and

Table 1. Examples of the range of coastal wetland types found in Victoria
ECV = Ecological Vegetation Class (see text for explanation)

EVC	EVC name	Characterisation	Indicator species
9	Coastal Saltmarsh Aggregate	Low, variously shrubby, herbaceous, sedgy or grassy vegetation of salinised coastal soils, in or adjacent to tidally influenced wetland. Coastal Saltmarsh can include several zones of varying structure and floristics, reflecting the regimen of tidal inundation and substrate character	Variously *Tecticornia arbuscula*, *Sarcocornia quinqueflora*, *Suaeda australis* and *Samolus repens*, often in association with *Frankenia pauciflora*, *Atriplex paludosa*, *Puccinellia stricta*, *Juncus kraussii*, *Hemichroa pentandra*, *Selliera radicans* and *Triglochin striata*. *Gahnia filum*, *Austrostipa stipoides*, *Sporobolus virginicus*, *Schoenus nitens*, *Wilsonia backhousei*, *Disphyma crassifolium* and *Distichlis distichophylla* can variously be locally prominent in more peripheral habitats.
10	Estuarine Wetland	Rushland/sedgeland vegetation, variously with component of small halophytic herbs, occurring in coastal areas where freshwater flows augment otherwise saline environments.	*Juncus kraussii*, occasionally with *Phragmites australis* or species of Cyperaceae.
13	Brackish Sedgeland	Sedgeland dominated by salt-tolerant sedges in association with a low grassy/herbaceous ground-layer with a halophytic component.	*Gahnia trifida* (sometimes *Gahnia filum*), *Baumea juncea*, with a mixture of species as for Brackish Herbland and species which are not obligate halophytes.
14	Estuarine Flats Grassland	Tussock grassland or grassy sedgeland beyond zone of normal tidal inundation but sometimes subject to seasonal water-logging or rarely brief intermittent inundation.	*Poa poiformis* with *Ficinia nodosa*, and including non-halophytic species such as *Senecio* spp., *Clematis microphylla* and *Acaena novae-zelandiae*.
53	Swamp Scrub	Dense (and potentially tall shrubby vegetation of swampy flats), dominated by Myrtaceous shrubs (to small trees), ground-layer often sparse, aquatic species conspicuous, sphagnum and/or water-logging tolerant ferns sometimes present.	*Melaleuca ericifolia*, *Leptospermum lanigerum*, with aquatic/semi-aquatic spp. (e.g. *Isolepis inundata*, *Triglochin procera s.l.*, *Villarsia* spp., *Sphagnum* spp.).
842	Saline Aquatic Meadow	Submerged ephemeral or perennial herbland of slender monocots, occurring in brackish to saline water bodies subject or not to dry periods. The vegetation is characteristically extremely species-poor, consisting of one or more species of *Lepilaena* and/or *Ruppia*.	Variously *Ruppia megacarpa*, *Ruppia polycarpa*, *Lepilaena* spp. (e.g. *L. preissii*, *L. bilocularis*, *L. cylindrocarpa*).
140	Mangrove Shrubland	Extremely species-poor shrubland vegetation of inter-tidal zone, dominated by mangroves.	Characteristically occurs as mono-specific stands of *Avicennia marina*. In some stands, species from adjacent Coastal Saltmarsh or Seagrass Meadow also present.
196	Seasonally Inundated Subsaline Herbland	Very species-poor low herbland of seasonal saline wetland within relicts of former tidal lagoons, dominated by *Wilsonia* spp.	*Wilsonia humilis* sometimes with *W. backhousei* and/or *W. rotundifolia*.
538	Brackish Herbland	Low herbland dominated by species tolerant of mildly saline conditions and rare intermittent inundation.	*Lobelia irrigua*, *Sebaea* spp., *Ranunculus* spp., *Apium annuum*, *Lachnagrostis* spp., *Isolepis cernua*, *Schoenus nitens*, *Wilsonia rotundifolia*; variously *Selliera radicans*, *Distichlis distichophylla* and/or *Samolus repens*.
656	Brackish Wetland	Collective label for the various zones of sedgy-herbaceous vegetation associated with sub-saline wetlands. Components variously include wetter versions of Brackish Sedgeland, Brackish Herbland and Saline Aquatic Meadow.	*Bolboschoenus caldwellii* and/or *Schoenoplectus pungens* and aquatic semi-aquatic species tolerant of at least moderate salinity.
821	Tall Marsh	Wetland dominated by tall emergent reeds, rushes or sedges, typically in dense, species-poor swards.	Typically *Phragmites australis*, *Typha* spp., *Schoenoplectus tabernaemontani.* Associated species are quite variable and can include *Calystegia sepium* and *Urtica incisa* and a range of aquatics.
845	Sea-grass Meadow	Sward-forming aquatic herbland of sheltered marine shallows, inter-tidal flats and lower estuarine habitats.	Dominated by *Zostera* and/or *Heterozostera* spp. (or localised variant also including *Lepilaena marina* and *Ruppia tuberosa*).
934	Brackish Grassland	Grassland on sub-saline heavy soils, including dominants of Plains Grassland (and a portion of associated herbaceous species) in association with herbaceous species indicative of saline soils.	*Poa labillardierei*/*Themeda triandra*, *Austrodanthonia* spp., *Distichlis distichophylla*, *Calocephalus lacteus*, *Selliera radicans*, *Sebaea* spp., *Wilsonia rotundifolia*, *Lobelia irrigua*; *Poa poiformis* in some coastal sites.

(*Continued*)

Table 1. (Continued)

EVC	EVC name	Characterisation	Indicator species
947	Brackish Lignum Swamp	Wetland dominated by *Muehlenbeckia florulenta* with a component or patches of salt-tolerant herbs (at least at low to moderate levels of salinity) and usually also with some species common to freshwater habitats. Can be very species-poor.	*Muehlenbeckia florulenta*, variously with *Samolus repens*, *Isolepis cernua*, *Triglochin striata*, *Chenopodium glaucum*, *Myriophyllum verrucosum*, *Selliera radicans*, *Mimulus repens*, *Distichlis distichophylla*, *Lobelia irrigua*, *Wilsonia rotundifolia*, *Lachnagrostis* spp. and/or *Gahnia filum*.
952	Estuarine Reedbed	Vegetation dominated by tall reeds (usually 2–3 m or more in height), in association with a sparse ground-layer of salt tolerant herbs. Distinguished from Estuarine Wetland by the vigour and total dominance of reeds, and from Tall Marsh by the presence of halophytes.	*Phragmites australis*, with associated species variously including *Samolus repens*, *Juncus kraussii*, *Triglochin striatum*, *Bolboschoenus caldwellii* and *Suaeda australis*.
953	Estuarine Scrub	Shrubland to scrub of Myrtaceous shrub species of sub-saline habitat, occurring in association with ground-layer including halophytic herbs.	*Melaleuca ericifolia* (in eastern Victoria), with other *Melaleuca* spp. (e.g. *Melaleuca lanceolata*, *Melaleuca gibbosa*) or *Leptospermum lanigerum* in marginal sites in western Victoria. Gound-layer includes *Samolus repens*, *Triglochin striata* and *Selliera radicans*, variously with *Sarcocornia quinqueflora*, *Gahnia filum*, *Poa poiformis*, *Juncus kraussii*, *Disphyma crassifolium*, *Distichlis distichophylla*.

Fig. 1. An example of a coastal wetland in excellent ecological condition: the mouth of the Thurra River, East Gippsland, Victoria, Australia.

Fig. 2. Coastal erosion and attempts at remediation with mangrove plantings, Lang Lang coast, eastern shore of Western Port, Victoria, Australia.

other 'sea defence' structures were employed in their place. The irony of 'protecting' hinterland by building seawalls and alienating coastal saltmarsh was explored by Doody (2008); he found that the retention of an 80-m-wide strip of coastal saltmarsh could reduce by a factor of twelve the cost of sea defences in south-east England. Two recent meta-analysis reviews (Gedan *et al.* 2011; Shepard *et al.* 2011) both show the value of coastal wetlands in shoreline protection. In Victoria, some of the most severe coastal erosion takes place along the eastern shoreline of Western Port, along the Lang Lang coast, and a program of mangrove plantings has taken place over the past decade in an attempt to halt or reverse that process (Kirkman and Boon 2012; Fig. 2).

What conclusion should we draw from these diverse points of view? It is that coastal wetlands are extremely valuable, even from the narrow perspective of economic valuation let alone from the more satisfying approach of including also intrinsic value and the provision of habitat and the protection of biodiversity. They are likely to become even more valuable with time. Given these factors, have we as a society invested sufficiently into understanding the structure and function of coastal temperate wetlands, especially with an eye to their most effective management and, if necessary, to the best way that degraded sites can be rehabilitated?

Research investment and implications for knowledge generation

The effective management of an aquatic system almost always requires that researchers and managers know what types of plants are present in it. They also need to know how those species respond to different environmental conditions.

In Australia, this means primarily understanding responses to altered hydrological conditions and to altered water quality, especially salinity and nutrients. This information can then feed into rehabilitation efforts and, ultimately, into reporting activities. I argue next that all four activities – plant identification, understanding response envelopes, rehabilitation activities, and reporting – are much better developed for inland than for almost any type of coastal wetland in Australia. This, I believe, is a direct result of the preferential funding of research and management of wetland systems in the inland over those on the coast, with the possible exception of mangrove systems in tropical northern Australia.

Field identification texts such as Sainty and Jacobs' 550-page *Water plants of New South Wales* (1981) and its related and smaller *Water plants in Australia* (2003) and, for Western Australian systems, Jane Chambers and colleagues' *A guide to emergent wetland plants of south-western Australia* (1995), provide an essential foundation for any investigation into the ecology and management of inland wetlands. With the obvious exception of mangroves, however, there is no comparable body of work for the vegetation of coastal wetlands. Mangrove identification is well catered for with the recent books by Norm Duke (2006) and Glenn Wightman (2006); in contrast, the only identification guide for Victorian saltmarsh plants is a 30-year old, 64-page booklet printed by the Botany Department of Monash University (Bridgewater *et al.* 1981). It is out-dated and, never widely distributed even when new, is now almost unobtainable. I know of no comparable field guide for saltmarshes or other estuarine wetlands in New South Wales. Queensland has the incomplete – but otherwise excellent – small booklet by Louise Johns (2006) to complement its two more substantial mangrove-identification texts (Lovelock 1993; Duke 2006). Identification guides for plants in other types of coastal wetland are even rarer.

Similarly, we know very much more about the response envelopes of plants that occur in inland wetlands than we do for the species found in coastal wetlands. Starting with the original (2000) edition of Jane Roberts and Frances Marston's *Water regime of wetland and floodplain plants in the Murray–Darling Basin*, there is now an excellent literature on the ways that wetting and drying cycles affect plant performance in wetlands of inland Australia, especially in the Murray–Darling Basin. Roberts and Marston's text has recently been updated (2011) and is complemented by Kerrylee Rogers and Timothy Ralph's excellent *Floodplain wetland biota in the Murray–Darling Basin: water and habitat requirements* (2011), which provides detailed hydrological information, not only on a wider range of taxa, but also makes hydrological recommendations for broad functional groups of plants.

In addition to such monographs that collate existing information, there is a sizeable core literature as book chapters and as peer-reviewed journal articles on inundation and plant responses for inland wetlands: recent articles by Ganf *et al.* (2010), Rogers *et al.* (2012) and Webb *et al.* (2012) are examples. In fact, the literature on devising optimal wetting and drying regimes for inland wetlands and floodplains, which extends back as far as the late 1980s (e.g. Briggs 1988), continues to the present day, with handbooks such as that outlining the Murray Flow Assessment Tool (Young *et al.* 2003) and an extensive series of review articles published under the *Waterline* banner by the National Water Commission (e.g. Capon *et al.* 2009; Alluvium Consulting 2011).

Our state of knowledge of response curves for the vegetation of temperate coastal wetlands is, in comparison, in its infancy. Aside from a rule-of-thumb that mangroves grow best with a 30 : 70 exposed : inundated water regime and the highly detailed studies undertaken on the Swan Coastal Plain in Western Australia (e.g. Froend *et al.* 1993), we have next to nothing for coastal non-tropical wetlands that could match the detailed hydrological information available for inland plant taxa. Responses to altered water quality and, in particular, to salinity are also poorly known for coastal plants, despite their occurrence in naturally salty environments. In an exhaustive review of temperate mangroves, Morrisey *et al.* (2010) referred to only one work (Ball 1988) on the salinity requirements of the grey mangrove *Avicennia marina*, the most common mangrove in southern Australia. I expect this is because it is the only paper on the topic. In contrast, in the review undertaken in 2002 of the salinity responses of the Australian freshwater biota (Bailey *et al.* 2002), we had 169 entries for the salinity tolerance of angiosperms alone (see also the review articles published around this time by Hart *et al.* 2003, James *et al.* 2003 and Nielsen *et al.* 2003, all of which dealt largely with the biota of inland, not coastal, systems).

The imbalance in fundamental ecological knowledge for inland versus coastal plant taxa is reflected in my third category: wetland rehabilitation. In his review of trends in the rehabilitation of Australian wetlands, Streever (1997) found that the plant taxa subject to most rehabilitation effort across the country were river red gum (*Eucalyptus camaldulensis*), followed by black box (*E. largiflorens*), lignum (*Muehlenbeckia florulenta*) and cumbungi (*Typha* spp.). All are plants of inland wetlands. The two coastal taxa that featured most in rehabilitation efforts were grey mangrove and salt couch (*Sporobolus virginicus*). More tellingly, Streever (1997) identified a total of 52 taxa/projects for inland wetlands but only 25 for coastal wetlands, and all of the latter were concerned with either mangroves or saltmarshes. Two points stand out in this analysis: first, two-thirds of wetland rehabilitation projects undertaken in Australia addressed inland wetlands and only one-third addressed coastal wetlands; and second, the only coastal wetlands subject to rehabilitation were mangroves and saltmarshes. As shown in Table 1, there are at least 14 other types of coastal wetland in Victoria alone and, as was noted earlier in this review, a large number of other systems (e.g. tidal freshwater marshes, *Casuarina*-dominated systems, etc.) occur in New South Wales and Queensland as well. At this stage, we do not know relative proportions of the many different types of coastal wetland across the various jurisdictions, because current inventories tend to map only seagrasses, mangroves and agglomerated saltmarsh (e.g. see Williams *et al.* 2006 for New South Wales; and Boon *et al.* 2011 mapped some – but not all – of the different types of coastal wetland in Victoria). It is quite likely that mangroves and saltmarsh do dominate in terms of total area, but this does not mean that the many other types of coastal wetland are unimportant, or that they will respond to threats or can be rehabilitated in the same way as their better-studied cousins.

The year Streever's survey was undertaken – 1996 – was just before the beginning of a drought that affected almost all of south-eastern Australia and that broke only in early 2010. (In Victoria, the drought commenced in 1997; it started later – 2002 – in New South Wales and southern Queensland; see Bureau of Meteorology 2012.) My experience, albeit only anecdotal, is that even greater efforts went into the study and rehabilitation of inland wetlands (e.g. emergency watering of river red gums along the Murray River in New South Wales and Victoria, studies into refuge habitats and low-flow responses by biota, etc) during the drought and thus after Streever's survey. Lest this be thought as a blanket criticism of such investment, it is worth re-iterating the point made by Streever (1997) that rehabilitation projects managed less than 1% of the area of existing wetlands in Australia and less than 1% of the area of wetlands that had been lost since European colonisation. My point is simply that rehabilitation effort has gone disproportionally into inland than into coastal wetlands.

It is almost certain that this selectivity in funding was a direct result of political agitation and the valid perception among politicians and other senior decision-makers that a crisis was unfolding, that 'something had to be done', and that the problem could be solved by a temporary (large) injection of research funds. The magnitude of recent expenditure, perhaps increased as a direct result of the drought and a growing recognition that the basin's water resources were over-extracted, is indeed very substantial – Price *et al.* (2009) found that over $100 million was spent annually on river rehabilitation/restoration in Australia. Despite this expenditure, there was no overarching process for project evaluation or for data management, or even for feeding quantitative results (if any) into improved policy: 'few data have been collected on evaluation and assessment of on-ground activities' (Price *et al.* 2009, page ix). Whether the level of funding enjoyed over recent years by those researching inland wetlands will be maintained now that the drought has broken – and ecosystems have clearly returned to a satisfactory state of health in the minds of senior decision-makers – will be an interesting point to follow.

The final line of evidence to support the claim for a relative neglect of coastal wetlands concerns the process of environmental reporting. It is telling that the recently released *State of the Environment report for Australia* (State of the Environment 2011 Committee 2011*a*) makes four references to wetlands in its index. All occur in the 'Inland Waters' section of the report. The section on 'Coasts' contains no specific reference to wetland condition or trend, although the summary document (State of the Environment 2011 Committee 2011*b*, page 29) does note that '…there is substantial degradation in the east, south-east and south-west [coasts]. Ecosystems near the coast, bays and estuaries in these areas are in poor to very poor condition'. The freshwater emphasis in the series of *Waterline* articles published by the National Water Commission has been commented on above and further illustrates the way that environmental reporting currently focusses on inland, rather than coastal, systems. One might argue that this distribution merely follows the difference in extent of inland versus coastal wetlands. Even if it were the case, it would not reflect the fact that coastal wetlands provide ecosystem services worth at least three times as much as those from an equivalent area of inland wetland.

Fig. 3. Housing development directly behind coastal wetlands, Hastings, western shore of Western Port, Victoria, Australia.

Current and impending threats: midnight is approaching…

Just as Cinderella's halcyon night would come to an abrupt and unpleasant end unless she took care to manage her time, the fate of coastal wetlands will be parlous unless we become better informed as to their fundamental ecology and take care to manage the manifold threats that they face in a timely way. Two threats are paramount and, if not already evident, impending: (1) climate change and the associated impacts of increased mean sea level and storm surges; and (2) population growth around the coast and the associated pressures of increased development and land claim for coastal development.

The Victorian Coastal Strategy plans for an increase in mean sea level of 0.8 m by the end of the century (Victorian Coastal Council 2008); in New South Wales the level is set at 0.9 m (Dr Neil Saintilan, pers. comm.). Increases of this magnitude are within the current projections for sea levels to rise 0.5–1.4 m above 1990 levels by the end of the century (e.g. see Rahmstorf 2007). But it is also now clear that sea levels are rising much faster than calculated by even the most pessimistic projections of the IPCC (Rahmstorf *et al.* 2007; Rahmstorf 2010). If coastal wetlands are able to retreat into the hinterland as sea levels rise, they may be able to adapt to the changed hydrological conditions. This response is unlikely along much of the coast of south-eastern Australia, given the extent to which it is already developed and likely to be 'protected' (e.g. by sea walls) into the future (Fig. 3). If, instead, coastal wetlands can increase the level of their sediments, they can maintain an ecologically sustainable relative position vis-à-vis the increasing level of the sea (FitzGerald *et al.* 2008). There are few reports of changes in surface elevation in Australian coastal wetlands, but Rogers *et al.* (2006) gave rates varying from -0.68 to $+5.27$ mm year^{-1} in various saltmarshes of south-eastern Australia.

The problem is that a global average rate of sea-level rise of 3.4 mm year^{-1} (Rahmstorf 2010) is too fast for plants in coastal wetlands to be able to respond. Even the slower rates of sea-level rise, 2.1–2.8 mm year^{-1} reported over recent decades for the south-east of the Australian continent (State of the Environment

2011 Committee 2011*b*) could be too rapid for most types of wetland vegetation to respond to in time. Mangroves probably have the best chance, but more terrestrial wetland systems of the coast have little opportunity to accrete sediments fast enough to keep pace with the increased inundation frequency and/or depth. Given the critical role that the rate of increase in sediment elevation plays in the maintenance of coastal wetlands, it is surprising that we have not invested more into accurate and geographically disparate measurements of this process. And, of course, the whole issue is made more complex and less certain by our almost complete lack of knowledge of the fundamental way in which plants in coastal wetlands respond to altered hydrological and salinity regimes, as I have discussed earlier. When the additional impacts arising from storm surges and the likely increase in severity and/or incidence of extreme events are also taken into account, it is not scaremongering to argue that coastal wetlands do, indeed, face a parlous time. Whether they can escape before midnight, as Cinderella did, is very unclear.

Linked closely with the topic of climate-change-induced sea-level rise are the growing problems created by the concentration of the Australian population along the coast and the concomitant pressures for even more urban and industrial development, all taking place in a region of Australia that has historically seen the greatest amount of resource development and of wetland alienation (Zann 2000). These factors combine to create threats that uniquely confront coastal wetlands and to which inland wetlands are largely immune.

The Australian population is concentrated in capital cities, and (with the exception of Canberra) all these are found on the coast. In fact, about one-quarter of the Australian population lives within 3 km of the coast (Zann and Dutton 2000) and a half in coastal south-eastern Queensland and New South Wales alone (Zann 2000). This seaward distribution is not a recent phenomenon: three decades ago, Pullan (1983) reported that 87% of the Australian population lived in a 50-km-wide strip between Cains and Adelaide. To further exacerbate the matter, the general movement of people from inland areas to coastal areas, which started in the early 20th century, continues to this day. Burnley and Murphy (2004), for example, noted that from 1971 to 1996, the population of the North Coast region alone of New South Wales increased by 262 296; that of the whole of inland New South Wales increased by only 57 197 over the same period.

The same story holds for other States as well. The pattern is indicated most strongly in the strip of coast between Noosa Heads and the Sunshine Coast in eastern Australia. The population in 1996 of this small strip of coast along northern New South Wales and southern Queensland was nearly 600 000; compare this with the total population of inland Queensland at the time – 41 370, or less than 10% of the population in this one coastal strip. The environmental impacts of such moves to the coast are immense (State of the Environment 2011 Committee 2011*b*), and are likely to be seen very strongly in the continued loss of wetlands and the degradation of those that remain. It is worth restating that it is the coastal zone of temperate eastern Australia that supports Australia's major tourism and industrial centres, and is a region that has historically suffered greatly from inappropriate development (Zann 2000).

And all lived happily ever after?

Despite these dark clouds, there are several developments that give hope for a positive future. One aspect of coastal wetland ecology that has progressed well in the past decade is the preparation of wetland inventories; building on earlier and, necessarily, more coarse studies (e.g. Galloway 1981; Bucher and Saenger 1991), there is now good information on the extent of different types of coastal wetlands in New South Wales (West *et al.* 2006; Williams *et al.* 2006; Creese *et al.* 2009; New South Wales Department of Primary Industries 2012) and Queensland (Queensland Environment Protection Agency 2009) and, for Victoria, finely resolved mapping for mangroves, saltmarshes and several other types of coastal wetland (Boon *et al.* 2011) as well as for most areas with seagrass beds (e.g. Roob and Ball 1997; Blake and Ball 2001; Monk *et al.* 2011). This performance contrasts strongly with the much weaker inventory efforts made elsewhere in the world, even for Ramsar-listed wetlands, for which only 37% of contracting Parties have a national wetlands inventory (Finlayson 2012).

The ecology and management of a small number of Australian coastal systems have been the subject of special issues in learned journals or in focussed studies commissioned by specific agencies. Examples include the Tuggerah Lakes and Myall Lakes, both in New South Wales, by Scott (1999) and Wilson (2008), respectively; and the seagrass beds, mangroves, saltmarshes and mud flats of Western Port, Victoria, by Keough (2011). Although they are beyond the geographic scope of this critique, the wonderful studies of coastal systems in south-western Western Australia by Brearley (2005) and Semeniuk *et al.* (2012) bear mentioning too. Even so, very many other coastal systems along the temperate Australian seaboard that are extremely important from ecological, economic and social perspectives remain very poorly known: examples include estuarine wetlands associated with the many large drowned river valleys of coastal New South Wales, including the Clarence, Manning and Hawkesbury Rivers, and the Gippsland Lakes and Corner Inlet–Nooramunga complexes in Victoria. Several syntheses of the ecology of coastal saltmarshes in Queensland, New South Wales and Victoria (Laegdsgaard 2006; Saintilan 2009; Boon *et al.* 2011) are now available, as well as a recent review of the ecology of temperate mangroves (Morrisey *et al.* 2010) to match the very large literature on tropical mangroves (e.g. Alongi 2009). Quantitative information on historical losses of coastal temperate wetlands is also becoming available (e.g. Saintilan and Williams 2000; Boon *et al.* 2008; Sinclair and Boon 2012).

Some start has been made in determining the environmental niches and ecological responses of plant species of coastal wetlands (e.g. Hickey and Bruce 2010; Prahalad *et al.* 2011) but, good as it is, the recent Australian effort lags behind what is being achieved for coastal wetlands in the Northern Hemisphere (e.g. Crain *et al.* 2004; Sala *et al.* 2008; Erfanzadeh *et al.* 2010; Alleman and Hester 2011; Schile *et al.* 2011) and, it could be argued, current efforts do not match the scope or power of the studies undertaken half a century ago by Lesley Clarke and Nola Hannon (1967, 1969, 1970, 1971) with the mangroves and saltmarshes of Botany Bay, New South Wales. Moreover, the research effort is scattered and uncoordinated; the contrast with inland systems, especially in the Murray–Darling Basin, is stark, as in the latter there are organisations such as the Murray–Darling Basin Authority, National Water Commission, and Smart Water Australia to plan research strategies and to coordinate research undertakings. Nothing comparable exists for coastal systems.

The challenge then is for the agencies that invest into ecological research and the management of natural systems to shift their focus to include coastal wetlands. After all, the coast is where the Australian population overwhelmingly lives and where it is increasingly moving to, and it is where population and development pressures are most acute and will continue to increase. Moreover, it is the coast that will be directly affected by higher sea levels and by stronger and more frequent storm surges. The problem, however, is not only a lack of research funds: at a more fundamental level, the ignorance of much of the broader public of the ecosystem services provided by coastal wetlands needs to be addressed. In our recent State-wide study of Victorian coastal wetlands, focus groups indicated unequivocally that there was little information in the public arena on coastal wetlands and that independent scientists were among the groups with most credibility when proffering advice on their ecology and management (Boon *et al.* 2011).

In principle, this matter of education could be resolved by the fuller involvement of professional ecologists in public discourse; how this could be achieved when all the indications are that reward structures for environmental scientists are skewed away from involvement in public discourse and instead towards the sole end-point of peer-reviewed publication, is unclear. At the level of research funding, it is not merely an increase in funding that is required. The funding has to be coordinated and focussed: sadly one organisation that in Australia might have been ideally suited to this role – Land and Water Australia – has been disbanded, much to the lament of those involved in practical ecology (e.g. see Lindenmayer 2011).

In 2009, Eugene Turner introduced the idea of managing natural resources on the basis of an 'ignorance-based world view' rather than under the ruling paradigm of an assumed 'knowledge-based world view' (e.g. see Ryder *et al.* 2010). Until we have the additional and targeted investment to support an appropriate level of fundamental and applied research into the ecology and management of our coastal temperate wetlands, it is difficult to see how we can do anything other than manage such areas with the ignorance-based world view that Turner outlines. One hopes that these matters can be resolved and, as in the fairy tale, it all works out for the best.

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