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# The state of legislation and policy protecting Australia's mangrove and salt marsh and their ecosystem services

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ABSTRACT

Saline coastal wetlands, such as mangrove and coastal salt marsh, provide many ecosystem services. In Australia, large areas have been lost since European colonization, particularly as a result of drainage, infilling and flood-mitigation works, often starting in the mid-19th century and aimed primarily towards converting land to agricultural, urban or industrial uses. These threats remain ongoing, and will be exacerbated by rapid population growth and climate change in the 21st century. Establishing the effect of wetland loss on the delivery of ecosystem services is confounded by the absence of a nationally consistent approach to mapping wetlands and defining the boundaries of different types of coastal wetland. In addition, climate change and its projected effect on mangrove and salt marsh distribution and ecosystem services is poorly, if at all, acknowledged in existing legislation and policy. Intensifying climate change means that there is little time to be complacent; indeed, there is an urgent need for proper valuation of ecosystem services and explicit recognition of ecosystem services within policy and legislation. Seven actions are identified that could improve protection of coastal wetlands and the ecosystem services they provide, including benchmarking and improving coastal wetland extent and health, reducing complexity and inconsistency in governance arrangements, and facilitating wetland adaptation and ecosystem service delivery using a range of relevant mechanisms. Actions that build upon the momentum to mitigate climate change by sequestering carbon – 'blue carbon' – could achieve multiple desirable objectives, including climate-change mitigation and adaptation, floodplain rehabilitation and habitat protection.

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## 1. Introduction

Mainland Australia has a coast 35,900 km long; islands add another 23,900 km, giving Australia a total coastline of 59,736 km [1]. Few countries – Canada and the Russian Federation, for example – have a longer coast. Not only is the coast long but the Australian mainland extends over 20° of latitude, from 22°S at Cape York in northern Queensland to nearly 44°S at South East Cape in southern Tasmania. It covers all the Köppen climate zones [2], spanning equatorial climates in the extreme north, through tropical and then subtropical climates, desert and grasslands on the western coast in particular, and to temperate zones in the south [3]. With such a long coast covering such a wide range of latitudes and an extreme of climates, it is not surprising that the marine embayments, estuaries, riverine floodplains, drowned river valleys and deltas of the Australian coast support wetlands that are simultaneously abundant and diverse, variously degraded or in good ecological condition, and protected by legislation to various degrees in different jurisdictions [4].

Mangroves are particularly extensive along northern shorelines, but stunted forms extend to the southernmost parts of the mainland. They are relatively easy to distinguish from other vegetation fringing the coast and are usually defined on the basis of

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their structure and unique position in the landscape: trees, shrubs or palms located within the upper intertidal zone and therefore subject to regular tidal inundation [5,6]. Australia has among the floristically most diverse of the Earth's mangrove systems, with 47 species, or 59% of total mangrove species [5,7,8]. Australia also has the third-largest area of mangroves in the world, after Indonesia and Brazil. They line about 18% of the coast [5].

Coastal salt marshes are more difficult to delineate, as definitions vary across jurisdictions. It is also highly variable, their vegetation including a wide range of monocots and dicots, grasses, herbs, rushes, sedges, and shrubs typically located in the upper intertidal zone, where they are subject to episodic, but recurrent, tidal inundation. Salt marshes tend to occur in the upper intertidal zone, between mean sea level (MSL) and the level of the highest astronomic tide (HAT), although plant species typical of salt marshes may occur beyond these limits, often in splash zones or in stranded and relict palaeo-wetlands. Floristically and structurally coastal salt marshes are most complex in the temperate and southern parts of the country, and northern salt marshes, while extensive, are often floristically poor [Fig. 1] [9–13]. The coastal salt marshes of southern Australia are perhaps the most diverse, on structural and floristic criteria, of any on the planet. Carr [14], for example, collated information on the floristic diversity of saline coastal wetlands in south-eastern Australia and identified 130 indigenous taxa (along with 121 exotic taxa) of vascular plants [14]. Boon et al. [13] showed there were at least seven structurally distinctive forms of coastal salt marshes in south-eastern Australia, including different types dominated by herbs, grasses, forbs and shrubs.

At higher elevations, rarely subject to tidal inundation but influenced strongly by freshwater seepage, are diverse types of freshwater or brackish water coastal wetlands, often dominated by rushes, sedges or reeds, or by trees and shrubs such as paperbarks (*Melaleuca* spp.), tea trees (*Leptospermum* spp.) and swamp oaks (*Casuarina* spp.). The very highest elevations of coastal floodplains are influenced only by freshwater flows and, in these areas, forested wetlands dominated by tall eucalypt species inter-grade with the terrestrial vegetation of the hinterland [12].

Mangroves, salt marshes and these other types of saline coastal wetlands provide a range of ecosystems services, or benefits, for which the economic value can be assessed [15,16]. Descriptions of ecosystems services typically build upon the framework developed for describing ecosystems services within the Millennium Ecosystem Assessment [17] and include provisioning, supporting, regulating and cultural services. The value of ecosystem services is increasingly quantified by resource economists and acknowledged by many policy makers [18], although the merit of ecosystem valuation is debated by some ecologists and conservationists [19]. The ecosystem services provided by tidal marshes/mangroves globally was estimated in 2011 to be in the order of US $194,000 per hectare per year [15]. This estimation constituted an increase of $180,000 per hectare per year from an earlier estimate made by Costanza et al. in 1997 [20]; the large difference was attributed by the authors to new information about mangrove and salt marsh ecosystem services and their valuation, such as storm protection, erosion control and waste treatment [15]. The rationale for the large increase in ecosystem service value has been rejected by others on the basis that cited data does not indicate better valuation methods, some components of Costanza et al. estimates are mutually exclusive, and analysis techniques do not adequately account for variation in ecosystem service values [21]. Barbier et al. [16] reviewed the published literature on the way ecosystems provide raw materials and food, coastal protection, erosion control, water purification, maintenance of fisheries, carbon sequestration, and tourism, recreation, education and research. This review demonstrated these services have been poorly valued, in large part because of spatial and temporal variability in the ecological processes that underpin their provision. Links between carbon sequestration and other ecosystems services are yet to be fully incorporated in the valuation of ecosystem services for coastal ecosystems such as mangroves and salt marshes. This is a critical omission as carbon is the building block of food webs and sustains fisheries and wildlife within coastal wetlands and in nearshore areas [22,23]. Biomass of coastal wetland vegetation constitutes approximately 50% carbon [24,25] and contributes to the vegetation complexity that acts to stabilize shorelines, buffer wave action, increase coastal protection, and create nursery grounds for fisheries.

The amount of carbon stored and the carbon-fixing process in saline coastal wetlands makes a measurable and significant contribution to global carbon flux between the atmosphere and the land/water surface. Managed properly, mangroves and coastal salt marshes could therefore play an important role in the mitigation of atmospheric climate forcing [26]. At present, however, the widespread conversion of coastal wetlands to other uses (e.g. aquaculture) contributes up to 19% of all emissions from deforestation globally [26,27]. These contributions are not accounted in any current regulatory or market mechanism [28,29]. Nor are these losses fully acknowledged in terms of the other ecosystem services foregone when coastal wetlands are cleared for agriculture or for aquaculture [30]. The increasing need to attempt to mitigate the effects of climate change has focussed research attention on carbon sequestration benefits in Australia [31–35], yet these benefits are yet to be adequately evaluated. Similarly, assessments of the economic benefit of ecosystem services provided by mangrove and salt marsh are very few and cover only a small range of wetlands, limited in terms of geographic spread, of wetland diversity, and of the range of inferred benefits.

In contrast to the case with carbon sequestration, habitat-supporting services have received some attention by Australian ecologists and policy makers, with northern-Australian mangroves estimated to generate $14,000 AUD per hectare each year to commercial fisheries [36]. Furthermore, Creighton et al. [37] have shown that returns to commercial and recreational fishing alone of rehabilitating estuaries and their associated fringing wetlands is one of the most effective investments that can be made by natural resource managers in Australia, far outweighing the returns that accrue from investment into inland wetlands. This is consistent with the economic value of ecosystem services quantified in the United Kingdom's 2011 *National Ecosystem Assessment* [38], which showed that coastal wetlands in the UK provided ecosystem services worth £1534 million each year in terms of flood control and the protection of shorelines against erosion, £1275 million annually in biodiversity value, £1245 million in water-quality improvement, £514 million in the provision of clean water, and £1081 million in amenity value. On a per-area basis, coastal wetlands were estimated to be worth £3700 per hectare per year merely for the protection they offered to coasts against flooding and erosion.

Although society is yet to fully understand – let alone value or quantify – the ecosystem services provided by saline coastal wetlands, there is little time to wait for full economic appraisals. Global increases in urbanization and industrialization, coupled with the effects of climate change on coastal wetland distribution and function, are a continuing threat and are only likely to become worse with time. A new approach to coastal management is required that adequately recognizes the dynamic nature of the fringing saline coastal wetlands and values the ecosystem services they provide, without which these systems will be subject to further decline. The deficiencies of current arrangements are particularly pertinent in Australia, where 85% of Australians live within 50 km of the coast [39], which, as noted earlier, supports extensive areas of saline coastal wetland of exceptionally high

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