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 Opinion Paper

Climate change and the wise use of wetlands: information from Australian wetlands

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Abstract This paper summarises key issues from papers included in a special issue about the impacts of climate change on Australian wetlands. The papers covered: the assessment of wetlands under climate change, adaptation and engineering responses to climate change, and restoring wetlands under a changing climate. The key issues from these papers were used to indicate areas where the Ramsar Convention could develop guidance as part of its' Handbooks for the Wise Use of Wetlands. These included: (i) assessing changes in the distribution of species and whether these constitute a change in the ecological character of the wetland; (ii) assessing the usefulness of models of wetland response to climate change; (iii) assessing the value in allocating water to protected sites where restoration would be contingent on reallocation of larger volumes of water; (iv) assessing the efficacy of engineering responses with the potential to deliver more water-efficient environmental outcomes for wetlands and (v) determining if the description of the ecological character of a Ramsar site at the time of listing is a suitable reference for management purposes. With these issues in mind it is recommended that further attention is directed towards determining and responding to the ecological consequences of climate change.

Keywords Ramsar Convention · Ecological character · Baseline · Adaptation

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Introduction

The threat of anthropogenic climate change to wetland species and ecosystems has been formally raised over the last decade through the Ramsar Convention on Wetlands (van Dam et al., 2002) and other international organisations, including the Intergovernmental Panel for Climate Change (Gitay et al., 2001, 2002) and the Convention for Biological Diversity (SCBD, 2009). The Ramsar Convention has also proposed a method for assessing the vulnerability of wetlands to climate change (Gitay et al., 2011). At the same time various global assessments have reported on the continued decline of global biodiversity, including the wide range of wetland ecosystems, despite increased responses and actions by governments and others (Darwall & Vie, 2005; Finlayson et al., 2005; Butchart et al., 2010; Loh, 2010; Armenteras & Finlayson, 2012). Further, the Millennium Ecosystem Assessment reported that the degradation and loss of wetlands was occurring more rapidly than for other ecosystems and that climate change was likely to exacerbate this situation (Finlayson et al., 2005).

In response to the impending threat of climate change to wetlands and the potential for further decline of wetland biodiversity, the Ramsar Convention has called upon Contracting Parties to the Convention to manage their wetlands so as to increase their resilience to climate change (http://www.ramsar.org/pdf/cop11/res/cop11-res14-e.pdf). The importance of wetlands for carbon sequestration and storage has also been recognised by the Convention, especially the importance of peat-based wetlands (Joosten, 2009; Joosten et al., 2012), and recently, the importance of 'blue carbon' in coastal wetlands (Crooks et al., 2011; Herr et al., 2011). As a consequence of the likely impact of climate change the Convention has also encouraged the use of wetlands listed as internationally important (known as Ramsar sites) as baseline or reference areas for monitoring, including in response to climate change (Davidson & Finlayson, 2007; Finlayson et al., 2011).

Despite the level of recognition of the likely impact of climate change on wetlands the future of wetlands under climate change has not been systematically assessed in many countries. While a systematic assessment is lacking in Australia a number of site-specific assessments have been undertaken, including those at the Ramsar-listed Macquarie Marshes (Jenkins et al., 2011), the Coorong and Lower Lakes (Gross et al., 2011) and Kakadu National Park (Eliot et al., 1999; BMT WBM, 2010). Finlayson et al. (2012) collated information from regionally distributed case studies in Australia to illustrate the extent of change and the complexity of differentiating the specific effects of climate change from those from other pressures. Further analyses of the impacts of climate change on Australian wetlands are presented in the papers contained in this special issue of the journal.

The special issue on 'Climate Change and Australian Wetlands' contains papers that consider the assessment of coastal (Eliot and Eliot 2012; Semeniuk 2012; Semeniuk and Semeniuk 2012) and inland (Wassens et al. 2011; Nielsen et al. 2012; Saintilan et al. 2011) wetlands under climate change, adaptation and engineering responses (Pittock et al. 2012), and restoring wetlands under a changing climate (Gell et al. 2012). Key points for managing ecological change in wetlands under climate change have been extracted from these papers and summarised in the text below. These points are then presented within the context of the wise use provisions of the Ramsar Convention. While the discussion is drawn from papers about Australian wetlands it is relevant to wetlands elsewhere, especially given the geographical range of wetlands covered in the papers, and the ubiquitous impact of climate change on wetlands.

Wise use of wetlands

Wise use of wetlands is an example of an 'ecosystem approach' for integrated environmental management. The Millennium Ecosystem Assessment (Finlayson et al., 2005) described ecosystem approaches in the following way 'Ecosystem approaches have been developed as an integrated alternative to sectoral approaches and specifically for promoting conservation and sustainable use in an equitable way. They focus on managing environmental resources and human needs across landscapes and trying to balance trade-offs for both human well-being and ecosystem services and are often a response to a previous tendency to manage for a single ecosystem service'. As such, wise use encompasses the many and complex linkages that exist between people and the sustainable development, including conservation, of wetlands. The concept was included in the text of the Ramsar Convention in 1971 and has been central to international efforts to conserve and restore wetlands for more than four decades (Matthews, 1993; Finlayson et al., 2011; Gardner & Davidson, 2011).

A conceptual framework for the wise use of wetlands and the maintenance of their ecological character, building on the comprehensive suite of policy and technical decisions adopted by the Convention over the past few decades, has been formalised by the Convention in recent years (Davidson & Finlayson, 2007; Finlayson et al., 2011; Gardner & Davidson, 2011). As a consequence of these decisions and the adoption of the framework, which was based on that developed for the Millennium Ecosystem Assessment, the wise use of wetlands was redefined as:

> the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development.

The definition can be divided into three components, namely, (i) the approach (ecosystem approach), (ii) the context (sustainable development) and (iii) the purpose (maintenance of ecological character). The latter is of most interest in this paper given the emphasis on ecological change in wetlands. Ecological character has been defined as:

> the combination of the ecosystem components, processes and benefits1/services that characterise the wetland at a given point in time.

Within this context, ecosystem benefits are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as 'the benefits that people receive from ecosystems' (http://www.ramsar.org/pdf/res/key_res_ix_01_annexa_e.pdf).

The previous definition of ecological character did not include ecosystem services as 'part' of the wetland, rather ecosystem services were seen as being derived from the ecological character. The change was made in response to the emphasis within the Millennium Ecosystem Assessment on the close links between the biodiversity and benefits derived by people from wetlands and hence the need to bring these closer together when talking about wetland management or the wise use of wetlands.

Issues for the wise use of wetlands

The mission of the Convention focuses on the conservation and wise use of wetlands and hence reflects the emphasis on maintaining the ecological character of wetlands, including maintenance of the ecosystem services along with the biodiversity and ecological processes that characterise the wetland. The Strategic Plan of the Convention for 2009–2015 outlines steps to implement the aim of the Convention and contains a number of actions for ensuring the wise use of wetlands (http://www.ramsar.org/pdf/key_strat_plan_2009_e.pdf).

The directions outlined in the Strategic Plan provide guidance for the wise use of wetlands and are underpinned by an increasing number of technical and policy documents that are contained in the Ramsar Toolkit of Handbooks for the Wise Use of Wetlands (http://www.ramsar.org/cda/en/ramsar-pubs-handbooks-handbooks4-e/main/ramsar/1-30-33%5E21323_4000_0). They do not, on the whole, specifically consider the ecological implications of management actions or policies, beyond general statements in support of the conservation and restoration of wetlands and their biota. Given the continued degradation of wetlands worldwide this situation raises a question about whether or not guidance that more specifically addresses the ecological consequences of wetland management is needed, particularly given the expectation that climate change will exacerbate many of the existing pressures on wetlands. Given this situation the nexus between wise use and the ecological issues identified in the papers in this special issue is explored in the text below.

A number of key issues that support the general principles of wise use of wetlands under climate change have been extracted from these papers as a basis for a general discussion on how wetland managers could respond to anticipated changes under climate change and meet their obligations under the Ramsar Convention to make wise use of all wetlands.

The absence of specific guidance through the Convention on responding to the ecological consequences of climate change has and is likely to confound efforts to ensure the wise use of wetlands. Pending the development of specific guidance from the Convention the Australian Government, for example, has responded to this situation by deciding not to report changes in wetlands as a consequence of climate change (Pittock et al., 2010). Unless the Convention prioritises the development of such guidance it may find itself in the position of not being able to provide formal advice on the maintenance of the ecological character of wetlands under climate change. The papers in this special issue provide some initial ideas that could be included in such guidance.

Assessing change in coastal wetlands

Eliot & Eliot (2012) provided a synthesis of studies from across northern Australia and identified a number of factors that needed to be considered for improved interpretation of the possible consequences of climate change in tropical estuaries. These included the need to recognise the dynamics, multiple scales and materials contributing to the estuarine structure, and specifically, the role of the underlying geological framework. They presented a conceptual framework comprising a matrix of driving processes and landform and land systems to identify those features likely to be sensitive to change, and the time scales over which change may occur, and offered a simplified interpretation of likely responses to climate changes. This approach, in combination with an understanding of landform connectivity, is seen as facilitating strategic monitoring of tropical estuaries.

Semeniuk (2012) considered wetlands along the Western Australian coast that spans tropical and temperate climates to ascertain how they would respond physically, hydrochemically and biologically to climate change over the short-term, decadal to bi-decadal, to the much longer term, extending to the recurring glacial and interglacial periods. Based on patterns in the fossil and stratigraphic record they reported that the wetlands would differentially respond to climate change depending on the latitude, coastal setting and landscape, as well as oceanography and rainfall. Further, these responses would be driven by changes in air temperatures, evaporation, rainfall patterns, freshwater influx, wind regimes and storm activity, and derivative responses, such as changes in sediment supply, maintenance of coastal forms, coastal groundwater and biota. Change in wetlands will not be simple and it may not be clear whether changes for particular species will be driven by air or sea temperature or some other climate features. Notwithstanding the complex of factors that explain the local occurrence of particular species, a change in the climate could cause a change in the ecological character of the wetland in both the short- and long-term.

Semeniuk and Semeniuk (2012) used stratigraphic, radiocarbon and pollen data from the Swan Coastal Plain in south-western Australia to provide a context for interpreting long-term changes in climate and wetlands, as well as detailed monitoring over several decades for interpreting shorter term changes. The information from both time scales was used to provide models for wetland response to bother drier and wetter climates. Not surprisingly, drier climates are likely not only to result in drier wetlands, or even the loss of some wetlands, but also to an increase in salinity and the development of carbonate deposits which may lead to changes in the vegetation. Wetter conditions are likely to result in more frequent inundation of wetlands and/or an expansion of wetland area, and fresher water, with the development of peat and/or organic matter enriched deposits. The differential response over the past 20–30 years of wetlands on the Swan Coastal Plain to climate change is attributed to heterogeneous soils, hydrological mechanisms and types of plant species. These responses raise doubts about the usefulness of single models of wetland responses to climate change.

Assessing change in inland wetlands

Wassens et al. (2011) assessed the relative responses of frog species in inland freshwater wetlands in south-eastern Australia to climate change. The dominance of generalist frog species within rain-fed wetlands rather than burrowing species indicated that characteristics such as dispersal capability, flexibility in breeding times and the ability to make use of created habitats, such as farm dams and irrigation fields, may be more important than burrowing ability and longevity when predicting vulnerability to climate change. Based on the results from the assessment it was concluded that predictive models that consider species distributions with respect to climate variability, for example variability in the duration of wet-dry periods, may be more informative when predicting the impacts of climate change on species in variable landscapes than models based on temperature shifts alone.

Nielsen et al. (2012) tested the hypothesis that increasing the hydrologic stability of freshwater wetlands in south-eastern Australia would result in reduced abundance, richness and diversity of aquatic biota emerging from wetland sediments. Their results showed that aquatic plant and microfaunal communities, that, respectively, germinated or hatched from the sediment of wetlands, had reduced biotic diversity as hydrological stability was imposed through the common management scenarios of making wetlands wetter or drier. They concluded that increased inundation or drying of wetlands could lower the resilience of the wetlands and lead to losses in diversity. Under drier climate scenario and more interventions to manage the wetting and drying of wetlands these outcomes suggest that these wetlands may become more isolated in the landscape with a consequent reduction in species dispersal to isolated wetlands, leading to a loss of biotic diversity within the landscape and potentially a change in ecological character.

Saintilan et al. (2011) assessed how the impact of climate change on the water regimes of large rivers and wetlands differ across scales from those at the scale of the high-conservation value asset, the water management unit or catchment and the entire basin. At each of these scales the conservation significance will change as climate changes, particularly as the distribution in space of wetland values is highly sensitive to alterations in flow. Based on these analyses it was concluded that the application of conservation significance to sites, including the listing and definition of sites under the Ramsar Convention, will also need to be flexible to the changing distribution of water across the landscape and the movement of biota between sites, particularly in dynamic and opportunistic settings. At the broadest scale, this may require managers to refine their conservation priorities and redistribution of water between valleys and through time. This must happen in concert with agreements regarding obligations for the protection of important wetland biodiversity, as there is little point in allocating water with diminishing returns to protected sites where restoration would be contingent on reallocation of large volumes of water, and conservation gains are greater elsewhere. These issues raise important concerns for developing management plans to ensure the wise use of wetlands through the often used allocation of environmental flows.

Adaptation and engineering responses

Pittock et al. (2012) considered the potential for using small-scale engineering works, often known as 'environmental works and measures' as alternatives to purchasing water licences in order to return water to the rivers and wetlands, in particular in the Murray-Darling Basin in south-eastern Australia. The water management authorities are hopeful that scarce water supplies can be divided further while conserving the environment and maintaining agricultural production. This is seen as an expedient way of meeting politically mandated ecological targets with insufficient water and to sustain ecological refugia for short periods in extremely dry conditions. There is a fear that the concept of environmental works and measures has morphed in ambition from a realignment of ongoing engineering works to a means of supporting landscape-scale flooding. The notion that we can take the same, limited water supply and divide it for more and more uses is beguiling. Further, it seems to have captured the imagination of political leaders as a way out of a tough dilemma, by funding projects with the potential to deliver more water-efficient environmental outcomes for the Basin's rivers and wetlands, thereby reducing the need to recover water from consumptive users. Yet the aspiration has not been matched by the performance. The implementation of management strategies that are unproven or driven more by political concerns than on-ground evidence could undermine wider efforts to ensure the wise use of wetlands.

Restoring wetlands under a changing climate

Gell et al. (2012) considered the array of challenges faced by wetland managers when restoring ecosystems at risk from changing climate and human impacts. By drawing on the palaeolimnological record from wetlands in western Victoria, in south-eastern Australia, an extended range of past climates and wetland responses to climate changes and variability were identified. Further analysis revealed that variability seen in many lakes since the expansion of European settlement in the mid-late nineteenth century was now outside the historic range of variability shown throughout the longer term record and raised the spectre that the adaptive capacity of the wetlands had been compromised. This situation is likely to be exacerbated by reductions in rainfall across south-eastern Australia and represents a major challenge for wetland managers who may need to manage for change. Further, it raises questions about the adequacy of reference conditions when restoring wetlands—what is a suitable reference condition? This applies equally, if not more so, to Ramsar-listed wetlands where the ecological character, as described at the time of listing, is generally taken as a reference condition for management purposes. If the ecological character of a wetland at the time of listing under the Convention was outside the range of historical variability for the wetland its' resilience may have been compromised and management steps to maintain this character, as required by the Convention, may prove futile or even exacerbate the change processes in place.

Climate change and the wise use of wetlands

Findings such as those outlined above are not fully addressed within the wise use guidance of the Ramsar Convention that focuses more on the management of ecosystem-related change rather than on the ecological consequences of change. Given the absence of specific guidance on the ecological consequences of climate change further guidance on the following topics, as derived from the above-mentioned papers, may be usefully considered by the Convention. Namely, guidance for: (i) assessing changes in the distribution of species and whether these constitute a change in the ecological character of the wetland; (ii) assessing the usefulness of models of wetland response to climate change; (iii) assessing the value in allocating water to protected sites where restoration would be contingent on reallocation of large volumes of water; (iv) assessing the efficacy of engineering responses with the potential to deliver more water-efficient environmental outcomes for wetlands, thereby reducing the need to recover water from consumptive users; and (v) determining if the description of the ecological character of a Ramsar site at the time of listing is a suitable reference for management purposes, and whether palaeolimnological investigations may be able to provide guidance on defining a suitable temporal reference.

The existing wise use guidance is largely oriented towards management planning, including guidance for collecting management-relevant information, but does not cover the ecological concepts outlined in the papers in this special issue. Nor does it cover the modelling approaches that have been used in Australian wetlands for considering the distribution of species and their dispersal in response to water allocation and land use management.

The key issues that have been identified (see above) can help identify the need for specific adaptation measures for wetlands under climate change. In this respect guidance on the ecological requirements for wetland species could assist managers to better target their interventions and deal with the specific ecological conditions needed for species survival in specific wetlands, or dispersal between wetlands, including restoration. While it may be possible to generate ecological information for some highly valued wetlands or wetland species, it is unlikely that specific requirements will be available for many. Consequently, managers will at times need to make decisions about wetland adaptation without having access to sufficient knowledge. While the Convention is not in a position to make such detailed ecological information available to managers it could assist managers by providing guidance on the development of adaptation measures for specific wetland types, or under some circumstances, even their biota; the emphasis in the guidance being on how to make the best decisions for local circumstances and specific wetlands and their biota.

The finding from palaeolimnological approaches that have revealed the shorter term record of change due to catchment and hydrological change, and the discharge of wastes, may underestimate the magnitude of wetland change that has important implications for the implementation of the Convention. The possibility that wetlands may be operating outside of their natural variability raises questions about their resilience and the usefulness of many baseline or reference conditions for setting management or restoration targets, especially under a changing climate. This raises questions about the legitimacy of management regulations, such as those for assessing change in the ecological character of Ramsar sites, which depend on comparing change to an established baseline. The Convention currently focuses on the description of a baseline at the time of listing of Ramsar sites as an important mechanism for determining whether or not a wetland has undergone change as a consequence of human activity—it does not contain mechanisms to ascertain if the baseline is a legitimate expression of the ecological condition of the wetland. The Convention does address the importance of establishing the range of natural variation in the ecological character of a wetland within a given time frame as a baseline against which change can be measured (Resolution IX-1, annex a, paragraph 18; http://www.ramsar.org/cda/en/ramsar-documents-resol-resolution-ix-1-annex-a/main/ramsar/1-31-107%5E23536_4000_0), but does not provide specific guidance on the bounds of a given time frame. Based on the evidence presented above, additional guidance on establishing a relevant time frame is warranted and could greatly assist wetland managers and provide a more robust basis for future management, especially where a wetland has moved beyond the previously recognised bounds of natural variability.

The absence of specific ecological information for wetland management in the Wise Use Handbooks may not be that surprising given that the Convention has primarily functioned as a policy forum for Contracting Parties and not as an ecological forum. The advent of climate change and its' implications for the implementation of the Convention may require a change in emphasis. The adoption in mid-2012 by the Convention of a further decision on climate change and wetlands (http://www.ramsar.org/pdf/cop11/res/cop11-res14-e.pdf) may herald steps in this direction given that the decision sought the development of guidance on, *inter alia*, the implications of climate change for maintaining the ecological character of wetlands, including the determination of appropriate reference conditions and specified limits of change for assessing change in ecological character. It further sought advice on ecosystem-based adaptation to climate change for coastal and inland wetlands. The information contained in the papers on 'Climate Change and Australian Wetlands' can support the request made by the Convention for further information on maintaining the ecological character of wetlands under climate change.

While the issues raised in this special issue about the ecological consequences of wetlands to climate change were based on Australian case studies there is every expectation that similar issues will arise for wetlands elsewhere. This expectation is supported by the information contained within a set of continental and sub-continental assessments of the likely impacts of climate change on wetlands recently reported and summarised by Junk et al. (2012).

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