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Synthesis

# Understanding change in the ecological character of Ramsar wetlands: perspectives from a deeper time – synthesis

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**Abstract.** The Convention for Wetlands was signed in 1971 as part of a global measure to mitigate the loss and degradation of the world's wetlands. Signatory nations nominate wetlands as internationally important and commit to maintaining their 'ecological character'. In many cases the character that has been maintained was that occurring at the time of nomination with scant attention to the variability and change that occurs over longer periods. Palaeoclimate and palaeoecological research now reveals a diverse array of conditions in wetlands in the past and attests that any recently identified condition may be transient. The research further reveals the considerable magnitude and antiquity of the impact of people on wetlands. Hence the site description used by wetland managers would benefit from the provision of a longer-term perspective of change. The changing state of wetlands provides a dilemma for wetland managers. In response, a workshop on understanding change in wetlands was held in Queenscliff, Australia, in November 2013 to draw together perspectives of change from neo- and palaeoecological sources to enable the formulation of new pathways of assessment to better accommodate the dynamic nature of wetlands. A synthesis of the information provided at the workshop is provided in this paper.

**Additional keywords:** climate change, human impact, natural condition, palaeolimnology, wetland change.

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## Introduction

The Ramsar Convention on Wetlands was signed by national governments in Ramsar, Iran, in 1971 as a global measure to stem the declining state of the world's wetlands and the implications of this for resident and migratory wetland species. In so doing, the advocates for a global mechanism to exert pressure on signatory nations to mitigate the impacts of humans on wetlands acknowledged that the condition of wetlands had changed and was changing (Matthews 1993). So, from its outset, the Ramsar mechanism requiring nations to identify and maintain the 'ecological character' of wetlands listed as internationally important (also known as Ramsar Sites) (Gardner and Davidson 2011) would be an anachronism unless an appropriate reference condition or baseline ecological character was identified and inter- and intra-annual variation were considered (Finlayson 1996*a*).

The Convention also included clauses on the wise use of all wetlands and avoided the trap of advocating for the exclusion of human activities within wetlands (Finlayson *et al.* 2011). The purpose of this requirement was clearly to encourage participation and, by so doing, encourage stewardship of wetlands to arrest global trends of wetland loss and degradation. Nowadays we not only have the capacity to better measure and describe the ecological character of a wetland, for example using Earth Observation (Rosenqvist *et al.* 2007; MacKay *et al.* 2009) or ecogenomics (Gibson *et al.* 2015), but also to describe the natural assets and ecosystem services that existed well before the text of the Convention was agreed and signed in 1971 (Gell 2012).

The requirement by the Convention for Contracting Parties (signatories) to describe the ecological character of a Ramsar site at the time of listing (Finlayson 1996*a*; Ramsar Convention 1996) has been interpreted as needing to describe and maintain the ecological character as it existed at that specific point in time. This was seen as a default situation and established for administrative reasons to ensure that an ecological description was provided; sites had previously been listed without an adequate description. The ecological character description could be adjusted as more information became available, or management activities, including restoration that resulted in changes (Finlayson 1996*a*). Any interpretation that the identification of the ecological character needed to be that which existed at the time a site was listed effectively sets the perceived baseline of Ramsar wetlands to a range of points in time after 1971. This interpretation would effectively forgive all signatories their impacts on such wetlands before 1971 and relieve them of any obligation to repair the effects of most of the history of industrial development. It follows that if a wetland has changed subsequent to its designation, then it is likely that the retention of the boundary conditions associated with that change would see the wetland change further, to a condition different to that described at the time of listing. This situation was identified by Phillips and Muller (2006) when describing the ecological character of the Coorong and Lakes Alexandrina and Albert Ramsar site in south-eastern Australia.

The above describes a dilemma in the Ramsar process, but is further complicated by the variability in the trajectories of regional hydroclimate driven by a warming climate, and a lack of guidance on how the Convention processes may be affected by climate change (Finlayson 2013).

Rarely, however, have discussions about change in wetlands considered that the benefits of having a long-term view are readily available and can be obtained through palaeoecological studies. These approaches have, perhaps, not done themselves service by pursuing evidence for change over periods not readily seen to be relevant to contemporary management, nor have they always addressed key management issues (Mills *et al.* 2013). However, for several decades now, palaeoecology has dealt with shorter time frames in fine resolution, so providing clear insights into the nature of change through industrial times. Palaeoecology now deliberately addresses natural system management and those questions significant to the broader ecological community (Mills *et al.* 2013; Seddon *et al.* 2014). By requiring nations to identify the ecological character of a wetland and, more recently, limits of acceptable change to that character, the Ramsar Convention lends itself well to incorporating the lessons that accrue from a longer-term perspective of change.

The Convention has determined that change in the ecological character of a wetland 'occurs when the critical parameters of the wetland ecosystem fall outside their normal range' (Ramsar Convention 1996; Finlayson 1996*a*). However, despite calls for the Convention to provide guidance on the setting of limits of acceptable change in ecological character (Ramsar Convention Secretariat 2012) this has not been done (Ramsar Convention 2015). In the absence of such guidance it has been recommended that Contracting Parties to the Convention adopt a precautionary approach (Ramsar Convention Secretariat 2012). The Australian Government has considered this further and considers limits of acceptable change to be 'the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland' (DEWHA 2008). This implies that the range of variability that occurs in a wetland is known and that a measure or feature that moves outside the specified limits will result in an adverse change in the character of the wetland.

The uncertainty that surrounds the setting of limits has been explored in ecological character descriptions developed for several Australian Ramsar-listed wetlands (www.environment.gov.au/water/wetlands/publications#mgmt-plans, accessed 17 April 2016). Further, shortfalls in the knowledge about the components, processes and ecosystem services that constitute the ecological character can hamper the setting of such limits. In these circumstances the limits may need to be based on qualitative information or expert opinion rather than quantitative or statistical analyses.

In order to bring together perspectives from modern assessments of wetland condition and the longer-term evidence archived in sediment records, in the company of those entrusted with their management, the workshop 'Ramsar Wetlands: Understanding Change in Ecological Character' was held in Queenscliff on the margins of Australia's Port Philip and Bellarine Ramsar site in November 2013 (Finlayson *et al.* 2016). The contributions to this special issue parade the insights that can be gained from the longer-term perspective of change and reflect the discussions held over the three days of the workshop. We consider the latter to be an important outcome, since interdisciplinary discussions of this nature have not previously informed the extensive scientific and technical processes that have supported the Ramsar Convention from its inception. Whilst the Ramsar charter and its implementation remains the remit of the signatory Parties, the 2013 workshop participants urged government representatives to better recognise and appreciate the lessons the past can provide to assist in the development of solutions to the present and unrelenting dilemmas of wetland management.

## Overviews

An overview of the main points raised in the individual papers contained in this special issue of *Marine & Freshwater Research* (Gell and Finlayson 2016) is provided below as the basis for a concluding synthesis. As the synthesis focuses on the role of palaeoecological approaches as an additional tool for assessing change in wetlands not all of the managerial or monitoring issues raised in these papers are further developed. Readers are referred to the individual papers for further information about the wetlands and their management. Key points from each paper about changes in wetlands and the role of palaeoecological approaches in assessing these are summarised in Table 1.

### *Role of palaeoecology in describing the ecological character of wetlands (Finlayson et al. 2016)*

This paper explored the extent to which palaeoecological approaches could be used in concert with contemporary techniques to understand benchmark conditions, rates and direction of change. This was done within the context of the Ramsar Convention that has a focus on the conservation of internationally important wetlands as well as the wise use of all wetlands. The Convention has developed a considerable body of guidance on detecting, reporting and responding to adverse changes in the ecological character of Ramsar sites. Most of this addresses contemporary monitoring and assessment approaches, including the use of Earth Observation. There is also widespread recognition that there are gaps in the available guidance. In response, the Convention has requested its scientific and technical advisors to develop further advice on the determination of appropriate reference conditions for assessing change and establishing the range of natural variability of wetlands. This has included an analysis of how palaeoecological approaches can provide a ready means of considering the trajectories of change, and the nature and drivers of such change over time. In this respect palaeoecological approaches can be used to assist in qualifying the ecological descriptions that have

**Table 1. Key points from the papers in the special issue (Gell and Finlayson 2016) about change in ecological character in wetlands**

| Authors | Key issues |
|---|---|
| Finlayson *et al.* (2016) | Ramsar has guidance on adverse changes using contemporary ecological approaches. There are gaps in guidance, including for using palaeoecology which could improve understanding of the timing and nature of change, and provide early warnings of future change. |
| Riedinger-Whitmore (2016) | Wetlands are impacted by hydrological change, and by pollutants. Restoration is using contemporary and palaeoecology approaches to identify the causes of change and to guide the restoration. Palaeoecology suggests that nutrient management is a key to restoration. |
| Boon *et al.* (2016) | A change in character occurred when the mouth to the sea was opened. Salinity increased and freshwater vegetation declined. Increased nutrients and abstraction of river water have led to more cyanobacterial blooms. Ecological conditions have shifted from the historical baseline, and from that at the time of Ramsar listing. |
| Ralph *et al.* (2016) | Extensive geomorphic change, as well as reduced flows have caused changes in the ecological character. It is a dynamic and highly variable wetland. Difficult to identify the cause of change, and whether it is natural or not, or positive, neutral or negative. Need to determine if the boundaries of the Ramsar sites are appropriate. |
| Dong *et al.* (2016) | A palaeolimnological analysis of floodplain lakes within the lower Yangtze reveals a high historic baseline condition of 50 $\mu g\ L^{-1}$ of total phosphorus. This deeper baseline is considered to be a more robust reference condition for an assessment of limits of acceptable change. |
| Reeves *et al.* (2016) | Palaeolimnology has revealed the past state of the wetland, and increasing salinity, and identified ways to restore the wetland. The sediments now have high heavy metal concentrations that limits management. Residential development may threaten the described Ramsar values. |
| Gouramanis *et al.* (2016) | Palaeoecology has shown the high amplitude variations in the hydroecology in response to variations in the climate. Difficulties with the dating record in ephemeral systems can limit their value. Playa lakes undergo great fluctuations and a long-term perspective is needed. |
| Kermode *et al.* (2016) | Analysis of sedimentary sequences shows that the wetland has excessive heavy metal loads and that the concentrations of many were high well before the site was listed as a Ramsar site. The ecological character of the site may have been changed after it was listed. |
| Ayanlade and Proske (2016) | Heavily impacted but there has been little monitoring to establish a baseline condition or subsequent change. Remote sensing provides a way of retrieving evidence of the past and quantifying the extent of change through time. An agreed baseline condition has not been established for measuring change. |
| Newall *et al.* (2016) | Scenarios show that existing stresses will be intensified and limits of acceptable change will be exceeded. Analysis of past climatic variations questions the baseline conditions used to set these limits. The site has trajectories of change with different time-scales, magnitudes and origins. |
| Moss *et al.* (2016) | Directional change has occurred and is natural. The fens have been highly stable over recent centuries. Palaeoecological investigations suggest that the wetlands are highly resilient to a range of natural environmental factors, including frequent burning and sea level rise. |
| Clarke and Lynch (2016) | Palaeoecology is being used to develop partnerships between scientists and managers. There is scope for broadening its use to more holistic forms of management, including from narratives based on palaeoecological analyses about past changes and projected management. |
| Lynch *et al.* (2016) | Case studies identified inadequate inventory, survey and monitoring as well as significant risks to wetlands. Guidance for the wise use of wetlands could assist in addressing the loss and degradation. Innovative approaches, increased commitment and resourcing are needed. |

been developed. They can also help in two other ways: (1) improving the understanding of the timing and nature of any departure from normal conditions, and (2) providing early warnings of future change. The benefits of palaeoecological approaches have been demonstrated in many studies, especially when they have been integrated with contemporary monitoring and modelling.

### *The Everglades: an integrated approach to bring the system back from the brink (Riedinger-Whitmore 2016)*

The Florida Everglades, listed as a Ramsar site in 1987 (the largest in the USA), is a complex mosaic of sawgrass marsh, sloughs, and tree islands that relies on inflow from the Kissimmee River into Lake Okechobee, and southward sheet flow thereafter into Florida Bay. It has been impacted by hydrological modifications for human use through the constructions of an extensive network of drains and canals. This combined with the release of pollutants saw the wetland being placed on the Montreux list of Ramsar sites that were undergoing adverse change in their ecological character. Efforts to restore the Everglades commenced in the 1980s, culminating in the Comprehensive Everglades Restoration Plan, which uses contemporary and palaeoecology to identify the causes of environmental change and to guide measures to rehabilitate the system. Pollen records attest to changes in the relative proportions of plant communities, algal records to changes in water quality, including salinity and eutrophication, and the changing frequency of fossil charcoal provides evidence for historical incidence of fire. In combination they attest to the controlling influence of a variable climate including the recent advent of tree islands following extended drought events. While the palaeoecological record suggests that nutrient management is a key to restoration, it provides a greater diversity of suitable restoration targets than may have been proposed on the basis of recent evidence alone.

### *The Gippsland Lakes – an historical perspective (Boon et al. 2016)*

The Gippsland Lakes are largely dominated by freshwater influences from five major rivers with a change in the character of the system being set in place in 1889 when the present mouth to the sea was opened to improve navigation. Historical accounts attest to the system being largely fresh before opening, with the eastern lagoons occasionally influenced by tidal inflows from the natural opening east of the one that was constructed in 1889. Monitoring attests to substantial increases in lake salinity to as much as 20 mg $L^{-1}$ in even the westernmost Lake Wellington where photogrammetic analysis reveals a significant decline in the extent of freshwater reedbeds (*Phragmites australis*) and subsequent mobilisation of marginal sediments. Submerged macrophytes have declined and the grey mangrove (*Avicennia marina*) invaded from as late as the late 1980s. Increased nutrient fluxes and increasing river flow abstraction have driven the occurrence of cyanobacterial blooms, leading to closure of waterways for recreational uses. The declining light regime is thought to have impacted the condition of seagrasses (*Zostera* spp.) that represent an important nursery for fish. The Lakes are certainly continuing to depart from their pre-1889 baseline condition, and also drift past their ecological character as described at the time of listing, with recent reports of shark and ray species being caught within its waters. Although changes associated with more recent dredging of the entrance to the sea are not addressed, this historical review of ecological changes serves as a warning to the managers of this site.

### *The Macquarie Marshes – fluvial meanderings and variable wetland condition (Ralph et al. 2016)*

The wetlands and channels of the Macquarie Marshes Ramsar site lie along a major tributary in the Murray–Darling Basin, Australia, and have experienced considerable change over time on account of channel meandering and hydrogeomorphic change. Recent drying of the system due to limited river flows triggered a formal notification to the Convention of adverse change in the ecological character of the site and demanding management intervention. While listed as a Rasmar site in 1986 the hydrology of the Macquarie River system was already altered by the commissioning of a significant dam in 1967. Historical mapping and photogrammetry were used to demonstrate geomorphic change and the response of floodplain and wetland vegetation distributions. The focus of flow and the degree of inundation or drying in particular sites changed continuously, with seven phases of change identified across the last century or more. Channel avulsion is a prevailing condition within these lowland floodplain wetland and stream complexes, as much as declining flow in the main channel, challenging the implication of stasis in the Ramsar site description process. The naturally dynamic nature of lowland systems challenges efforts to identify the cause of changes in the ecological condition of the wetland, and even the appropriateness of identified boundaries to wetlands of international significance. This case study shows clearly the need for a greater understanding of natural variability in the fundamental elements of a wetland complex (where has the water gone?), and the difficulty in attributing change to either natural or human, as well as categorising it as negative, neutral or positive.

### *Ramsar wetlands of the Yangtze Floodplain (Dong et al. 2016)*

A palaeolimnological analysis of 10 floodplain lakes within the lower Yangtze River Ramsar site reveals a relatively high historic baseline condition of 50 μg $L^{-1}$ of total phosphorus based on fossil diatom–inferred conditions in sediments dated to the early to mid-1800s. Six of these sites have undergone considerable change in their inferred water quality and hence their ecological condition since the 1950s. This deeper baseline is considered to represent a more robust reference condition for an assessment of limits of acceptable change. Those sites that remain similar to the baseline have diverse aquatic macrophyte communities supporting the evidence from abundant epiphytic diatoms in lower core levels for greater macrophyte cover in the reference period. Change in the condition of the lakes appears to relate to the capacity of large catchments to deliver nutrients, and in particular to the water management actions that limit the interaction with the main river. The restoration of interactions between the river and its floodplain wetlands is one means of returning impacted sites to their reference condition, which provides for the best prospects of recovering lost macrophyte communities.

### *Abrupt changes in the Lower Barwon Ramsar site – local and catchment causes (Reeves et al. 2016)*

The Port Phillip and Bellarine Ramsar site includes wetlands associated with the terminal Barwon River after it flows through the industrial town of Geelong in south-eastern Australia. At the time of listing, Reedy Lake was described as a diverse freshwater wetland while Lake Connewarre was regarded as being naturally an open estuary. Palaeolimnological evidence has revealed that the Reedy Swamp was also a tidal system up until the point, in 1840, when the European settlers of Geelong constructed a barrage to protect freshwater flows down the river. This now well established fen has become dominated by dense emergent vegetation and managers have proposed the re-establishment of a drying regime to restore the community of diverse macrophytes that are known to have prevailed in the past. Analysis of the heavy metal content of the Reedy Lake sediments attests to concentrations that exceed trigger levels for heavy metals in sediments owing to an industrial history reaching back to a major gold rush upstream in the 1850s. The potential mobilisation of these metals, and associated acidification risk, raises concerns that this restoration measure may trigger abrupt, deleterious changes. While Lake Connewarre remains estuarine, the salinity of the system is increasing. Some efforts to mitigate this appear possible, while the legacy of industrial pollutants limits management options for Reedy Swamp. Recent intensive residential development may be the greater challenge to the site continuing to serve the values enshrined in its Ramsar listing.

### *Playa lakes and natural ecological condition (Gouramanis et al. 2016)*

Studies of the past condition of playa lakes from palaeoecological studies reveals high-amplitude variations in the hydroecology owing to variations in the prevailing climate. As an example, the salinity in Two Mile Lake in Western Australia has fluctuated between 30 g $L^{-1}$ to concentrations many times greater over millennial time-scales. It needs to be recognised that playa lakes listed under the Ramsar Convention experience great fluctuations in condition and that a long-term perspective is required to understand the full range of conditions that could be considered natural. More broadly, this record of variability invites us to recognise that, in certain hydroclimates, change in character is the prevailing condition. While there are some difficulties with the dating record in ephemeral systems that can limit the value of the data, this information can be vital for wetland managers in order to identify the change or changes that can occur over both short and long time-scales. The importance of managers having access to high-quality, high-resolution palaeodata cannot be understated in terms of being able to identify thresholds of potential concern or limits of acceptable change for managing modern lacustrine environments.

### *Industrial pollutants in an urban estuarine system (Kermode at al. 2016)*

Towra Point nature reserve is a Ramsar-listed wetland within the Botany Bay estuary close to Sydney, Australia. As a result, it is prone to receiving contaminants, largely carried by water, from the city's industrial zones. Chemical analysis of sedimentary sequences reveals that the wetland hosts heavy metal loads that exceed trigger levels for human and environmental health and this has contributed to pollutants being listed as a threat to the site's ecological character. The dated sequences reveal that the concentrations of many pollutants began to increase from the 1950s and reached maximum levels in recent decades. Clearly, the site was strongly contaminated well before it was listed as a Ramsar site. Burial of metals in sediments has the potential to reduce their bioavailability, which will limit their impact on fish and migratory waterbirds if inputs are reduced. Pollutant trigger levels are suggested as a means of flagging the risk of exceeding limits of acceptable change in the future. Management measures to date have been seen as successful and the site is seen as an example of a successful Ramsar site in an urbanised, industrialised area. As a consequence of ongoing management the site no longer satisfies all the Ramsar criteria for which it was listed, although this has been offset by meeting other criteria. This implies that the ecological character of the site has been purposefully changed since it was first listed as a Ramsar site and its ecological character described.

### *Quantification of historical change by remote sensing: changes in the Niger delta (Ayanlade and Proske 2016)*

The Niger Delta hosts the largest freshwater body in western Africa. It was suspected of being heavily impacted by the activities of the forestry and petroleum industries; however, there has been little monitoring to establish a baseline condition or subsequent change. Remote-sensing technologies provide a means of both retrieving evidence of the past and of quantifying the extent of wetland change through time. Satellite data from 1984 to 2011 show considerable loss of forest cover leading to losses in the ecosystem services the wetland provides, revealing previous management to be largely ineffective. Pressure is also developing from increased urban development. Strengthened legislation in 2007 provides hope for the mitigation of the effects of these industries on these sites which may lead to greater compliance in the notification of change under the Ramsar protocols. Effective enforcement of existing legislation and policy are seen as key to successful wetland protection in the delta. While an agreed baseline condition has not been established for measuring change this investigation has highlighted that by combining remote sensing and GIS methods it is possible to provide information on broad-scale changes in the condition of the wetlands. This information can be used to encourage the government to implement the legislation that it has at its disposal.

### *Implications of environmental trajectories for limits of acceptable change: a case study of the Riverland Ramsar site, South Australia (Newall et al. 2016)*

The limits of acceptable change that have been set for the Riverland Ramsar Site in south-eastern Australia were investigated using future scenarios for the hydrological regime and woodlands within the wetland. Projections from these indicate that the existing stress on the woodlands will be intensified and there was a high likelihood that the current limits of acceptable change would be exceeded. An analysis of past climatic variations also called into question the baseline conditions used to set these limits with the site experiencing trajectories of change with different time-scales, magnitudes and origins. While the limits of acceptable change can be reviewed and updated to more accurately reflect the natural variability experienced by the site it will also be necessary to factor in changes due to future climate change. It was further suggested that using 'Limits for Defining Change in Ecological Character' (LDCEC), as has been suggested but not adopted by the Ramsar Convention, rather than limits of acceptable change would provide a more useful approach. This would support the use of contingency planning, based on a set of LDCECs to determine the most appropriate management regime for the wetland. Planning would be based on an initial assessment of the vulnerability of the wetland to climate change with the results included in a projection of change in the site's ecological character. Site management could then be directed towards maintaining a healthy and diverse system, while enhancing adaptation to the next phase, determined by landform, hydrology and climate.

### *Long-term changes to patterned fens (Moss et al. 2016)*

The Great Sandy region in south-eastern Queensland, Australia, hosts coastal wetlands of international significance including patterned fen complexes. The fens, more typical of high-latitude systems in the Northern Hemisphere, were only identified in recent decades, enhancing the biogeographic significance of the site. These formations appear to have evolved through infilling and hydroseral evolution in two phases at 12 000 and 4000 years ago, highlighting that directional wetland change is a natural phenomenon and not unexpected over longer time frames. Further, not only are they unique in terms of their physical characteristics but they have developed in a substantially different manner to their counterparts in the Northern Hemisphere. While they appear to have been highly stable over recent centuries modern fire management practices may induce shifts in vegetation communities that risk the extent of patterned fen patches. The palaeoecological investigations suggest that the wetlands are highly resilient to a range of natural environmental factors, including frequent burning and sea level rise. At present, the wetlands appear to be stable, but evidence is starting to emerge that changes in fire management since European settlement may have promoted vegetation thickening that could threaten their extent in the future.

### *Palaeoecology to inform practical wetland conservation and management: some experiences and prospects (Clarke and Lynch 2016)*

The importance of wetlands as important social–ecological resource for human wellbeing has been increasingly recognised, partly in response to the widely publicised outcomes of the Millennium Ecosystem Assessment. Additionally, their sediments are an important source of information that can be used to help improve conservation and environmental management planning and outcomes. Case studies from the UK were used to illustrate how palaeoecology can be used to inform understanding of wetland environments and contribute to site-based conservation decisions. The broader potential of palaeoecology to inform holistic approaches to conservation, such as those based on landscape-scale actions, or focussed on ecosystem services and the natural capital associated with wetlands, is immense. Palaeoecological approaches are already being used as a basis for partnerships between scientists and wetland managers, and there is scope for broadening its use to support more holistic forms of management. Making the best of this potential will require greater communication and engagement between scientists and policy makers. Opportunities are likely to arise from the use of narratives based on palaeoecological analyses about past environmental changes and projected management scenarios, and the need for improved approaches to conservation provide opportunities for bridging the science–practitioner gap and improving wetland conservation and management.

### *Policy and planning in Ramsar wetland management in developing countries (Lynch et al. 2016)*

Similarities between issues for wetland conservation and sustainability in developing countries was explored using case studies of Ramsar sites in Tanzania, Colombia and Papua New Guinea. Key challenges identified included inadequate knowledge and data, population and development impacts, poor regulatory and planning processes, socioeconomic inequities and conflict. All three case studies identified inadequate inventory, survey and monitoring as well as significant risks to some wetland values. Mechanisms and guidance developed through the Ramsar Convention for the wise use of wetlands could assist in addressing the loss and degradation of wetlands globally. In particular, these need to incorporate effective, integrative socio-ecological approaches that involve natural resource regulation and conservation as well as development needs of local communities. Innovative approaches, increased commitment and resourcing are needed at the local level to develop and implement locally tailored plans and to effectively manage the sites and values. These must be aligned with comprehensive stakeholder engagement and programs addressing the range of stakeholder needs and perspectives. The wetlands in the case studies have a diverse range of stakeholders that require support through improved engagement, increased legislative protection and more coherent regulatory mechanisms. While the development of national policy and international commitments are apparent steps, the policies are ineffective without supporting legislation, enforcement and implementation at the jurisdictional level. It is at the local level that conservation and management initiatives need innovative approaches, increased commitment and resourcing to improve technical and financial capacity to develop and implement locally tailored catchment plans and to effectively manage the sites and their values.

## Discussion

These papers provide clear examples of the legacy of history on the present-day ecological character of wetlands. They highlight the inherent variability and a range of frequencies as well as directional change from human pollutants and lake ontogeny. Many reveal the lines of evidence of the past that have been, or are potentially, invaluable to wetland managers seeking to understand the dynamics of their systems and the forces that drive both change and stasis (see Table 1). For the purposes of understanding change for the Ramsar Convention several papers reveal considerable anthropogenic change before wetlands were listed as internationally important (Ayanlade and Proske 2016; Boon *et al.* 2016; Kermode *et al.* 2016) while others flag the risk of future change if trajectories continue or if particular remedial measures are implemented (Newall *et al.* 2016; Reeves *et al.* 2016), and one questions whether the site boundaries are appropriate (Ralph *et al.* 2016). The need for clear evidence about change prompts a discussion of how the Ramsar Convention can create more nuanced processes to deal with past and future, natural and anthropogenic, internal and imposed, change to the world's wetlands of international importance, and in doing so enhance its role in enabling wise use to support people and protect the natural values of wetlands. This is particularly important given the paradox whereby the extensive effort to develop and implement international policy, supported by a substantial and expanding information base, has not stopped and reversed the global loss and/or degradation of wetlands (Finlayson 2012; Davidson 2014). Ralph *et al.* (2016) also point out that it can be difficult to determine whether change is anthropogenic or not, or whether is it positive, negative or neutral.

The concepts of the wise use of wetlands and maintaining their ecological character have been at the core of the Convention since its inception and were redefined in 2005 to reflect the outcomes of the Millennium Ecosystem Assessment (MEA 2005; Finlayson *et al.* 2011):

> Wise use of wetlands is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development.
> Ecological character of a wetland is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.

In particular, the redefinition of ecological character now includes ecosystem services within the character of the wetland rather than as benefits that were derived from the wetland. Further, by linking wise use with ecological character in this manner it applies to all wetlands, and not just to designated

Ramsar Sites, as had previously been the case (Pittock *et al.* 2010). These are important changes as it extends the imperative of maintaining the ecological character, including the combination of the ecosystem components, processes and services, to all wetlands, and yet there is ample evidence, including from the cases shown in Table 1, that this has proven difficult for many Ramsar sites, the jewels in the crown of the Convention, let alone others (Finlayson and D'Cruz 2005; Davidson 2014).

Specific guidance for the wise use of wetlands has been provided by the Convention as part of an ongoing commitment to ensure that wetland managers have support for making effective decisions for managing and restoring wetlands. The Wise Use Handbooks provided by the Convention (Ramsar Convention Secretariat 2010) cover technical and policy issues associated with managing wetlands and have been regularly updated. While they address many of the technical issues that support wetland management they have not hitherto provided guidance on establishing baselines for determining change in ecological character, nor how to respond to variations and change due to climate change, despite requests to do so (see Finlayson 1996*a*, 2013). Being able to respond to variation and to climate change was one message from the above-mentioned papers (see Table 1).

As outlined in Finlayson *et al.* (2016), the purpose of the PAGES workshop and papers contained in this special issue (Gell and Finlayson 2016) was to provide information to wetland scientists and managers about the nature of change in wetlands, over a range of time-scales, and to improve understanding about the present condition of wetlands. This included an introduction to the concepts of ecological character and ecosystem change in wetlands (Finlayson *et al.* 2016) and the extent to which palaeoecological approaches could be combined with contemporary approaches to understand benchmarks of change, as well as the rates and direction of change and prospects for maintaining or restoring wetlands to an agreed condition, or baseline. The examples given above and summarised in Table 1 show that change has or is occurring in many Ramsar-listed wetlands, but has not been formally reported to the Convention. This seems to be the case for the examples provided by Newall *et al.* (2016) and Reeves *et al.* (2016). Such examples raise further questions about the adequacy of baseline conditions for assessing change in the described ecological character given past change. These examples and lessons are highly pertinent to managers, given the expected onset of further change as a consequence of global change and the inadequacy of many past baselines (see discussion in Kopf *et al.* 2015).

The examples also illustrate the many benefits that could arise from wetland ecologists and palaeoecologists working more closely together to combine their respective understandings of wetland dynamics in response to variable hydroclimates and human impacts, and addressing the gaps in guidance being made available to wetland managers through the Ramsar Convention and other mechanisms. This is especially opportune given a renewed interest in understanding the causes and trajectory of ecological change as the realities of global environmental change, including changes in the climate, and appropriate management responses in adapting to climate change, are considered (Finlayson 2013; Finlayson *et al.* 2015). Palaeoecological approaches provide a useful way of assessing the trajectories of change and the nature and drivers of change over time, and so can assist in qualifying established ecological descriptions, help understand the timing and nature of any departure from natural conditions, and provide early warnings of future change, especially when they are integrated with contemporary monitoring and modelling.

Contracting Parties to the Ramsar Convention would benefit from combining palaeoecological approaches with contemporary approaches for wetland assessment and monitoring in order to assess whether ecological character descriptions need revision, to understand if and when the condition of systems first departed from natural, to provide prognosis for imminent change and determine whether the drivers of change are attributable to local forces, or are extralocal and beyond the control of the managing authority.

The papers collated in Gell and Finlayson (2016) from the workshop provide examples of where such approaches have been used to help in understanding change in the ecological character of wetlands, including designated Ramsar Sites (Table 1). Building from this understanding, the provision of guidance for wetland managers on the appropriate use of palaeoecology in their management planning and preparation of ecological character descriptions would support enhanced implementation of the wise-use provisions of the Ramsar Convention, including mechanisms for determining when adverse change has occurred, or is likely to occur. Given the extent of wetland loss and degradation over recent times (Davidson 2014; Gardner *et al.* 2015) and the likelihood that many baseline or past reference conditions may not be suitable for future management purposes (Kopf *et al.* 2015), it is difficult to see how the Convention can ensure the conservation and wise use of all wetlands unless every possible step is taken to better understand the nature and trajectory of change in wetlands.

Given the situation whereby the Convention has not provided adequate guidance for setting baselines and determining when adverse change has occurred, including in the face of global climate change, it is recommended that wetland managers develop effective and integrated inventory, assessment and monitoring programs based on an appropriate mix of approaches, including contemporary ecological and palaeoecological. The appropriateness of any mix of approaches will, to a large extent, be determined by the particular features of any wetland, including the threats and relative importance of both short- and long-term pressures, but also by the capability and capacity of site managers to undertake specific technical investigations.

The Convention has supported technical initiatives to outline approaches for establishing inventory, assessment and monitoring programs, and incorporated these into an integrated framework (Fig. 1) (Finlayson *et al.* 2005; Ramsar Convention 2005). It has not, however, adopted policy measures to ensure such programs are implemented, with, for example, many countries not having completed national wetland inventories, which are seen as a foundational resource for ensuring the wise use of wetlands (Finlayson *et al.* 1999). It has also not prescribed specific technical methods for inventory, assessment and monitoring, although there is a range of technical publications in the general literature and produced by several collaborators. These include guidance provided for wetland inventory (Tomas Vives 1996; Finlayson *et al.* 2002; Rosenqvist *et al.* 2007; MacKay

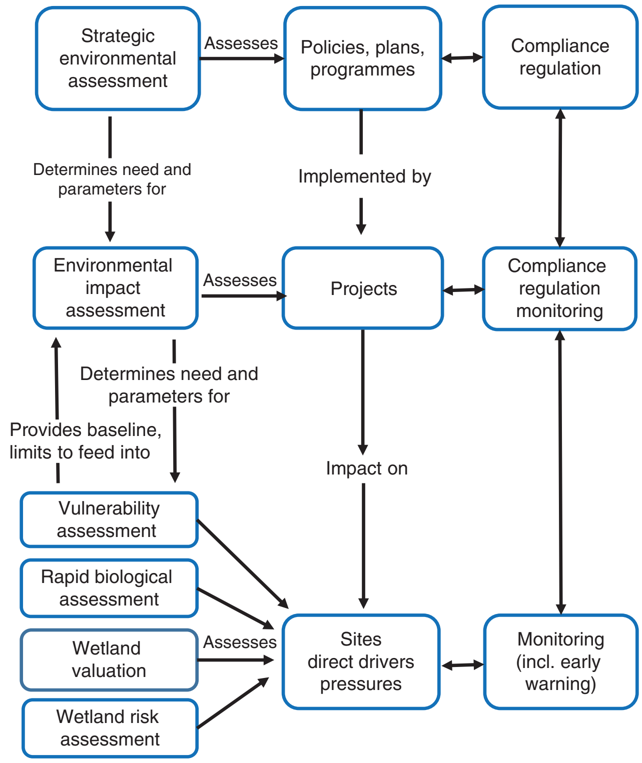


**Fig. 1.** Integrated framework for wetland inventory, assessment and monitoring (adapted from Ramsar Convention 2005).

*et al.* 2009), monitoring (Finlayson 1996*b*; Finlayson and Mitchell 1999) and assessment (van Dam *et al.* 1999; Anon. 2006; Stratford *et al.* 2011), hydrology and environmental flows (Acreman 2012; Adams 2012), water quality (Verhoeven 2014), ecosystem services (de Groot *et al.* 2006; Kumar *et al.* 2011) and restoration (Erwin 2009; Alexander *et al.* 2011; Alexander and McInnes 2012). Further, guidance for developing pictorial conceptual models of wetlands (Department of Environment and Heritage Protection 2012) could assist with incorporating information from palaeoecology into descriptions of the ecological character of wetlands.

The flow chart used by MacKay *et al.* (2009) to outline different aspects of Ramsar implementation has been adapted to show where palaeoecological approaches could fit alongside contemporary ecological approaches to provide further information about the ecological character of wetlands (Fig. 2). Given the extent of interest in palaeoecological investigations, as shown by the papers described, there is ample evidence that such approaches could contribute to general inventory to assist in the assessment of baseline conditions, the monitoring of change in wetlands, and assist with the assessment of status and trends and whether limits of acceptable change are being approached or, indeed, have been exceeded.

The papers in this Special Issue (Gell and Finlayson 2016) provide an overview of palaeoecological approaches that have been used to investigate changes in wetlands, with further information available in Gell (2012) and links to management outlined in Mills *et al.* (2013). In particular, the papers illustrate

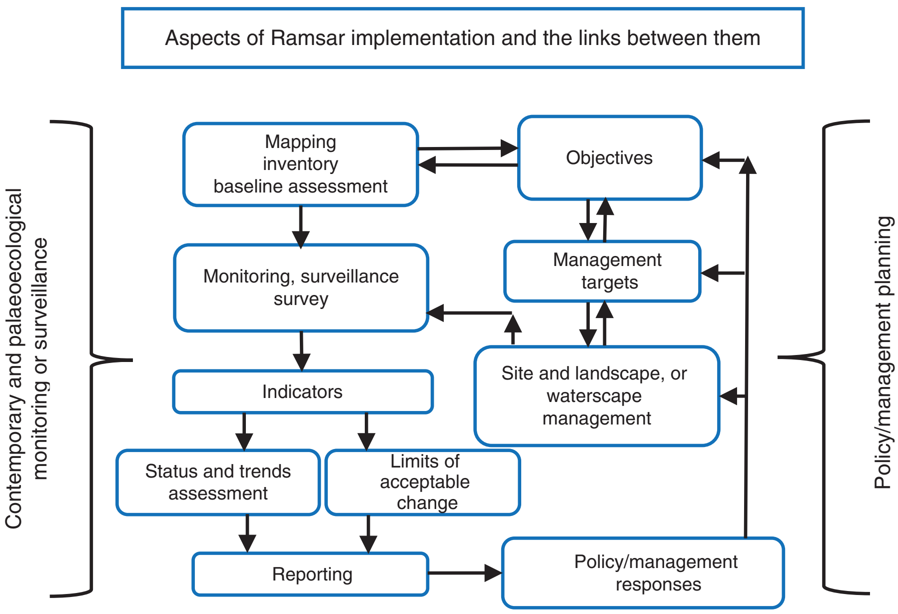


**Fig. 2.** Positioning of palaeoecological and contemporary monitoring and surveillance (left hand side) and policy and management responses (right hand side) in the different components of Ramsar implementation. The diagram has been adapted from MacKay *et al.* (2009) and the terms monitoring and surveillance have been defined according to Finlayson *et al.* (1999).

that palaeoecology can contribute to the elucidation of several general questions about change in wetlands, including:

- How has the hydrology and water quality of a wetland, and consequently the resident and migratory species, changed over time?
- How has the geomorphology of a wetland, and consequently the biodiversity, changed over time?
- What are the range of ecological states that have existed in a wetland and are there discernible trends and trajectories of change?
- Can changes in a wetland over time illustrate changes in the ecosystem services provided by a wetland?
- Can baselines for assessing change in the ecological character of a wetland be determined?
- What are the implications for wetland management in the face of climate and other environmental change?

While the above discussion has focussed on the usefulness of palaeoecology for providing information that can be used to assess change in wetlands it is recognised that not all palaeoecological approaches will be equally useful in all wetlands. This is an inherent feature of the techniques themselves, as well as variability that occurs in wetlands, especially the wider range of wetland types recognised by the Ramsar Convention, as well as the extent of contemporary disturbance. The case of ephemeral wetlands not necessarily being well suited for palaeoecological analyses has been raised by Gouramanis *et al.* (2016). However, based on the evidence provided during the workshop, and contained in this special issue, there is every expectation that palaeoecological approaches can be used to complement the information that can be collected using contemporary inventory, assessment and monitoring efforts in wetlands.

With this in mind, the workshop participants urged government representatives to make every effort to better recognise and appreciate the lessons that perspectives from a deeper time can provide to assist in the development of solutions to the present dilemmas of wetland management. If this can be done the foresight of those who constructed the text of the Ramsar Convention in 1971 may be further realised and changes in the ecological character of wetlands identified and assessed in a timely manner to ensure that wetland loss is at least reduced, if not stopped and reversed.

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