

Trends in wetland salinity: auditing the condition of wetlands relative to baseline

Peter A Gell¹

¹School of Science and Engineering, University of Ballarat, Mt Helen, Vic

Introduction

Wetlands are often the hydrological and sedimentary sink in the Australian landscape and so they can integrate evidence for the impacts of anthropogenic natural system change higher in a catchment. Due to their capacity to amplify hydrological and geomorphic responses to human impacts they are often critical repositories of catchment and climate change. Wetlands can archive this record of change through time by accumulating in their sediments biological and chemical indicators of water salinity. This paleoecological record can provide evidence of salinity change that does not rely on memory or technology.

Wetlands are subjected to a wide range of drivers of change. Prehistorically, their condition has largely been driven by climate driven factors that are mediated through the surface and groundwater hydrology of the catchment. The interplay of surface vegetative cover, surface runoff, precipitation:evaporation ratios and ground-surface water interactions makes complex the understanding of the long term hydrological balance of any open system wetland. Simpler systems exist in closed lake systems, particularly those rain gauge crater lakes in western Victoria. Here the salinity of the wetland is largely a consequence of positive or negative water balance with relatively dry conditions leading to shallower, more saline systems and long term pluvial surpluses leading to lake level rise, to overflow point in some cases, and to a freshening in water condition. Understanding the record of salinity available from the sedimentary archives of these systems, coupled with modelling of the hydrogeomorphology, can reveal quantitative estimates of past climates. Similar records from open systems are influenced by the same climate drivers, however these are distilled by catchment scale factors. Reduced rainfall may dry catchments but coincident reduced temperatures may have a greater hydrological effect through reduced evaporation (e.g. Williams *et al.*, 2001), allowing water to gather at the surface despite reduced precipitation. Wetlands in fluvial contexts provide another order of complexity in terms of interpretation as their condition at any time reflects an integration of local, endogenic effects and evidence of conditions transported from higher in the catchment. At the end of catchments estuaries are more complex again; their salinity a function of local, catchment transported and marine inputs.

There is a widespread focus on wetland ecosystem restoration and rehabilitation with programs at local and continental scale. The EU Water Framework Directive for example, seeks to understand good ecological condition to guide its restoration process although it is uncertain whether the derogation clause will render these lofty aims redundant in many cases. In Australia the National Water Initiative aims to recover water from inefficient users and to reallocate it to the River Murray to restore its ecological functioning. At the same time a programme supporting decentralised wetland management has lead to a local scale management regime (Lane *et al.*, 2004). The dialogue encircling these frameworks do not directly seek to understand good or natural ecological condition, but faced with the realities of management, agencies and individuals are often equally faced with the task of understanding the past condition of a wetland to evaluate its present status. Here, palaeoecological evidence can be particularly instructive, and, where available, can direct managers to identify target conditions that are achievable, realistic and have an historical precedent. In their absence, on ground works can drive a wetland into states that have no precedent in the long term.

Methods

A wide range of wetlands across south-eastern Australia have been analysed palaeolimnologically, with the principal indicator of salinity history being diatoms. These siliceous algae are sensitive to water quality, in particular water salinity (Gell, 1997). Their abundance allows for the development of statistical models or transfer functions that allow for

the reconstruction of lake salinity from the fossil assemblages archived in lake or wetland sediment sequences (Gell, 1998). Coupled with precise radiometric dating techniques, these approaches allow for the reconstruction of wetland salinity histories over centuries and millennia, with increasing resolution towards the present.

The Australian Research Council funded Environmental Futures Network has supported a working group, OZPACS, to collate century scale records of ecosystem change across Australia with a view to presenting the record of change to natural resource managers. One of the outcomes of this program is to assemble multiple data bases of records of proxies of environmental change (e.g. pollen, archaeology, charcoal, geochronology). This data base has been assembled (Fitzsimmons *et al.*, 2008) and is available on the Australian Quaternary Association website (<http://www.aqua.org.au/Archive/OZPACS/OZPACS.html>). Part of this data base includes the assembled diatom records of wetland change. This paper reviews evidence from over 100 palaeolimnological records across south-east Australia, assembled under the mantle of OZPACS. It focuses on several key sites that reflect the nature of wetland salinity change from closed, fluvial and coastal contexts and draws conclusions from the sedimentary lessons that may better guide wetland ecosystem management measures.

Results

An analysis of the database of over 100 wetlands analysed for fossil diatom assemblages reveals that wetland salinisation has been a symptom of catchment change from very early in European settlement. While it is difficult to ascribe direct cause, heavy stocking rates and early attempts at irrigation and abstraction are the most likely drivers of the increases in salinity determined from the 19th century. More recently inter-basin transfers, large scale engineering and water abstraction, wetland and dryland salinisation and climate change can all be implicated in the salinisation of lowland wetland systems. Internationally significant wetlands are 10-50 times more saline than their pre-European baseline condition.

The closed lakes of the volcanic plains of western Victoria have, for many years, provided evidence of climate driven salinity change. More recent, fine resolution records, coupled with lake basin modelling, have revealed a sustained period of increasing salinity due to a reduced precipitation:evaporation ratio from the mid-1800s (Jones *et al.*, 2001). The recent drought has diminished surface water availability across western Victoria to an extent that is probably unusual at a century scale although it is not yet possible to attribute this to human-induced climate change or natural variability (Gell *et al.*, 2007a).

The floodplains wetlands of the Murray-Darling basin have provided for the production of over 40 diatom-based palaeolimnological records of water quality change. The complexities driven by the interaction between river, floodplain and wetland make for a diverse array of wetland changes. At Tareena Billabong, downstream of the Murray- Darling junction, a period of relative limnological stability for 3000 years was followed by increases to wetland salinity from the late 1800s attributable to intensive pastoral activity from the 1840s (Gell *et al.*, 2005a, 2005b). In the South Australian Riverland Loveday Wetland reveals a pre-European history where high salinity was a natural phenomenon. The nearby Loch Luna, originally shallow and fresh has now a permanently maintained water levels and has increased in salinity tenfold since settlement (Gell *et al.*, 2007b).

The provision of a number of salinity records from coastal contexts is providing clear evidence of the impact of hydrological and land development on the salinity of these wetlands. Of note is the narrative from Lake Ainsworth on the northern NSW coast where an analysis of anecdotal opinion strongly supported a long term freshwater history of the lake, which informed the management plan. The palaeolimnological record however, revealed a marine connection and a saline past (Tibby *et al.*, in press) that ultimately prompted recollections at odds with the management direction. The effect of surface water diversions are evident from the Lower Snowy River floodplain where MacGregor *et al.* (2005) document a 50-fold increase in salinity post settlement, mostly post the interbasin transfer. In contrast the lakes of south-east South Australia, thought naturally fresh, were in fact natural

brackishsaline and were freshened after the implementation of drainage channels from the mid-1800s to rid the dunes swales of surface water (Haynes *et al.*, 2007). One of the strongest exemplars of the critical contribution of palaeoecological evidence comes in the protracted dispute over the nature of the Coorong, at the mouth of the River Murray, and the call for the allocation of River environmental flows to restore its *Ruppia*, fish and waterbird stocks. The long term evidence reveals that both Coorong lagoons were strongly influenced by tidal input and largely disconnected from the River system for the last 7000 years, and that the system was not a reverse estuary but subsaline and homogeneous sustained by freshwater inputs from the hinterland (Fluin *et al.*, 2007). Management directions based in short terms views have held up its restoration and lead to artificially elevated salinity levels that have induced a cascade effect to deoxygenate the surface sediments leading to sulphide production (Krull *et al.*, submitted) that impacts negatively on *Ruppia* (Heijs *et al.*, 2000).

The salinity of the wetlands of south east Australia has increased, or decreased in some instances, largely on account of direct catchment change and hydrological manipulation. While the rain gauge lakes of western Victoria attest to a century scale desiccation, most riparian and coastal lakes have proven to be particularly resilient to these changes. The identification of southeast Australia as a global climate hotspot due to future drying (Giorgi, 2006), the modelling of flows from the Murray Darling basin suggesting 25-50% decreases this century (Gell *et al.*, 2007b), and the prospects for metre (Rahmsdorf, 2007), to multiple metre (Hansen, 2007) sea level rise all call for a radical rethink on how Australians manage water resources to manage their wetlands. By way of example, the call for environmental river flows to restore the Coorong is both folly and futile as:

- It has historically been independent of river inputs,
- It is in a Basin that is vastly overallocated in terms of surface and ground water
- The yield from the catchment is likely to decrease substantially
- The southern ocean will rise rapidly recasting the regional hydrogeomorphology.

The most accessible and realistic source of water capable of ‘freshening’ the hypersaline Coorong is the Southern Ocean and management measures to harness sea level rise to re-oxygenate the system may provide the best prospect for its ailing ecosystem.

Conclusion

The short term appreciation of wetland condition misrepresents the magnitude of salinity change many wetlands have experienced. Increasingly this short term memory is being used to define the salinity, and ecological, targets for wetland restoration measures. An understanding of an earlier baseline provides a clearer understanding of the opportunity cost of such intensive water resource development and catchment change and allows society to better evaluate the costs and benefits of industry. Recent climate change has driven wetland condition into states unprecedented at the millennial time scale. Forecast climate change will exacerbate the effect of the drivers of salinisation already experienced and make the challenge of wetland ecosystem restoration even more acute.

References

- Fitzsimmons, K.E, Gell, P.A., Bickford, S., Barrows, T.T., Mooney, S.P., Denham, T.P. & OZPACS contributors. 2008. The OZPACS database: a resource for understanding recent impacts on Australian ecosystems. *Quat. Austr.*, 24: 2-6.
- Fluin, J., Gell, P., Haynes, D. & Tibby, J. 2007. Paleolimnological evidence for the independent evolution of neighbouring terminal lakes, the Murray Darling Basin, Australia. *Hydrobiol.*, 591: 117-134.
- Gell, P.A. 1997. The development of a diatom data base for inferring lake salinity: towards a quantitative approach for reconstructing past climates. *A. J. Bot.*, 45: 389-423.
- Gell, P.A. 1998. Quantitative reconstructions of the Holocene palaeosalinity of paired crater lakes based on a diatom transfer function. *Palaeoclimates*, 4: 1-14.

- Gell, P., Baldwin, D., Little, F. & Tibby, J. & Hancock, G. 2007b. The impact of regulation and salinisation on floodplain lakes: the lower River Murray, Australia. *Hydrobiol.*, 591: 135-146.
- Gell, P., Bulpin, S., Wallbrink, P., Bickford, S. & Hancock, G. 2005a. Tareena Billabong – A palaeolimnological history of an everchanging wetland, Chowilla Floodplain, lower Murray- Darling Basin. *Mar & Freshw Res.* 56: 441-456.
- Gell, P., Fluin, J., Tibby, J., Haynes, D., Khanum, S., Walsh, B., Hancock, G., Harrison, J., Zawecki, A. & Little, F. 2006. *Changing Fluxes of Sediments and Salts as Recorded in lower River Murray wetlands, Australia.* IAHS, 306: 416-424.
- Gell, P., Jones, R. & MacGregor, A. 2007a. The sensitivity of wetlands and water resources to climate and catchment change, south-eastern Australia. *PAGES News*, 15 (1): 13-15.
- Gell, P., Tibby, J., Fluin, J., Leahy, P., Reid, M., Adamson, K., Bulpin, S., MacGregor, A., Wallbrink, P., Hancock, G. & Walsh, B. 2005b. Accessing limnological change and variability using fossil diatom assemblages, south-east Australia. *River Res. & Appl.*, 21: 257-269.
- Giorgi, F. 2006. Climate change hotspots. *Geophys. Res. Lett.* 33: 1-4
- Hansen, J. 2007. Climate catastrophe. *New Scientist*, 28 July: 30-34.
- Haynes, D., Gell, P., Tibby, J., Hancock, G. & Goonan, P. 2007. Against the tide: the freshening of naturally saline coastal lakes, south east South Australia. *Hydrobiol.*, 591: 165-183.
- Heijs, S.K., Azzoni, R., Giordani, G., Jonkers, H.M., Nizzoli, D., Viaroli, P & van gemerden, H. 2000. Sulphide-induced release of phosphate from sediments of coastal lagoons and the possible relation to the disappearance of *Ruppia* sp. *Aq. Microb. Ecol.*, 23: 85-95.
- Jones, R.N., McMahan, T.A., & Bowler, J.M. 2001. Modelling historical lake levels and recent climate change at three closed lakes, Western Victoria, Australia (c.1840 – 1990), *J. Hydrol.*, 246: 159-180.
- Krull, E., Haynes, D., Gell, P., McGowan, J. & Lamontagne, S. (submitted). Changes in organic matter chemistry in the Coorong Lagoons over space and time. *Org. Geochem.*
- Lane, M.B., McDonald, G.T. & Morrison, T.H. 2004. Decentralisation and environmental management in Australia: A comment on the prescriptions of The Wentworth Group', *Austr. Geogr. Stud.* 42:103-115.
- MacGregor, A.J., Gell, P.A., Wallbrink, P.J. & Hancock, G. 2005. Natural and post-disturbance variability in water quality of the lower Snowy River floodplain, Eastern Victoria, Australia. *River Res. & Appl.*, 21: 201-213.
- Rahmsdorf, S. 2007. A semi-empirical approach to projecting future sea level rise. *Science*, 315: 368- 370.
- Tibby, J., Lane, M. & Gell, P.A. in press. Local knowledge as a basis for environmental management: a cautionary tale from Lake Ainsworth, northern New South Wales. *Env Cons.*
- Williams, M., Prescott, J.R., Chappell, J., Adamson, D., Cock, B., Walker, K. & Gell, P. 2001. The enigma of a late Pleistocene wetland in the Flinders Ranges, South Australia. *Quat. Int.* 83-85: 129-144.