Preface

Papers in this Special Issue of the *Australian Journal of Botany* refer to salinising landscapes in Australia where salt is accumulating at toxic concentrations in soils, rivers and wetlands. This process of salinisation was begun, unknowingly, by European settlers in the 18th century when they removed native vegetation from the Australian landscapes to establish agriculture. After a century of land clearing, concern was expressed that it was causing rivers and soils to become salty (Beresford *et al.* 2001). However, land clearing continued and Western Australia could claim, for example, that in the 1960s more than “one million acres a year” (400 000 ha per year) was being cleared for agriculture. Land clearing continues today at about 400 000 ha per year, mainly in the state of Queensland, despite evidence that it causes salinisation (ANZECC Task Force 2001).

On a massive scale, agriculture has replaced native vegetation with annual species of crops and pastures. The annual species transpire less water per year than the mix of annuals and perennials they have replaced and, as a consequence, the drainage component of the landscape’s water balance has increased. Drainage-water has moved through the landscape and carries with it some of the salt that has accumulated over geological time. The movement of subterranean salty water has been described as a “silent flood” (Sexton 2003). This transported salt has been concentrated at evaporation sites and in rivers and wetlands.

Salt has accumulated in the Australian landscape primarily in the valley floors. These low-lying areas of more inherently fertile soils were those selected initially for farming. It is a major concern that prime agricultural land is being lost to salinity. Awareness of the “salinity crisis” (Beresford *et al.* 2001) as a result of land clearing is now widespread (Sexton 2003). However, the crisis is predicted to deepen before our best efforts can make a difference. For example, it has been estimated that the land affected and at risk from dryland salinity in Australia will increase from 5.7 million hectares currently to 17 million hectares by 2050 (National Land and Water Resources Audit 2001). However, these estimates are based upon predictions of salinity concentrations in groundwater and future depths to water table, and are imprecise.

Coupled with early agriculture in the valley floors was the establishment of rural towns and infrastructure (roads; railways; buildings; water supplies). Infrastructure also is seriously affected by salinity. Thus, the direct effects of salinity are felt more widely than by farmers alone. It is estimated that the costs to protect and restore infrastructure in Western Australia could exceed agricultural losses (National Land and Water Resources Audit 2001).

Wetlands, rivers and the remaining fragments of riparian vegetation are located in the most seriously affected, low-lying parts of the salinised landscapes. It is now recognised that the loss of species and functioning ecosystems (biodiversity) is a significant part of the salinity crisis. However, a national task force reported recently that “our knowledge of the effects of salinity on biodiversity urgently needs to be improved” (ANZECC Task Force 2001).

A National Action Plan for Salinity and Water Quality (NAPSWQ 2002) has become a priority in Australia as a reaction to the many facets of the salinity crisis. Catchment and regional groups nominated in the NAPSWQ are expected to take planned action to protect and restore the natural resources of their designated areas with the assistance of national and local funding (NAPSWQ 2002). A National strategic plan for biodiversity conservation is in place (National Objectives and Targets for Biodiversity Conservation 2001–2005, 2001).

The 13 papers in this volume were among 30 papers, and a similar number of posters, presented to a recent conference on the ‘Prospects for biodiversity and rivers in salinising landscapes’ (http://crc.vivid.global.net.au/pages/publications.asp). The Conference was convened jointly by two new Australian research centres: the Cooperative Research Centre for Plant-based Management of Dryland Salinity (http://www1.crcsalinity.com/) and the Centre of Excellence for Natural Resource Management (http://www.cenrm.uwa.edu.au/). The Conference provided a timely opportunity for more than 200 delegates to review progress and influence the priorities of the two research centres.

The Conference was held at Albany in the south-west of Western Australia. The south-west of Western Australia has several features of the landscape that are internationally recognised for the importance of their biodiversity and, as such, require the custodians to protect, conserve and restore them, namely:

- It is one of five Mediterranean ecosystems designated as a world hotspot for biodiversity conservation (Myers *et al.* 1999). Hotspot designation is based upon the concentration of unique (endemic) species that a region contains and the significant impact on them by human activities.
- A number of wetlands of high conservation-value that are listed in the Ramsar International Treaty as a priority for restoration and protection (Lake Warden system; Toolibin Lake—shown in the cover figure).
- Shark Bay at the north-western tip of the WA Hotspot for Biodiversity was declared a World Heritage Area in 1991 since it satisfies all four natural criteria for listing (major stages of the world’s evolutionary history; geological and biological processes; natural beauty; threatened species).
- Clearing of land and salinity continue to threaten these areas with irreversible damage to ecosystems and species extinction (ANZECC Task Force 2001).

Salinising landscapes are, predominantly, privately owned and Cocks (this volume) emphasises the need to change to profitable farming systems that ‘leak’ less water than the current systems based upon annual plants. The cover picture of this volume shows an agricultural landscape that is being

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revegetated to leak less water and nutrients to protect Toolibin Lake, one of the last freshwater inland lakes in the south-west of Western Australia and that is listed under the Ramsar Convention as a 'wetland of international importance' for biodiversity. Emergency action to prevent salinisation of the lake includes the use of ground-water pumps to keep the saline water table 1.5 m beneath the lake and diversion of saline surface-water to the salinised Lake Taarblin. Revegetation includes alley farming with *Eucalyptus* species suitable for the production of oil and activated charcoal, and for carbon sequestration (*E. occidentalis, E. astringens, E. loxophleba* subsp. *loxophleba, E. loxophleba* subsp. *lissophloia* and *E. vergrandis*), and *Acacia saligna*, *Acacia accuminata* and *Casuarina obesa*. The evaluation of suitable perennials continues and Woodall *et al*. (this volume) report on the culture of sandalwood (*Santalum spicatum*), a woody perennial that is native to the south-west of Western Australia that has high economic value. On a limited scale the authors conclude that this hemi-parasite of a wide range of species may contribute to the profitability of farming systems as well as to the biodiversity of the region.

Cocks (this volume) argues that governments are more likely to allocate funds to the protection and restoration of biodiversity if it has an assessed economic value and he proposes the use of non-market methods, such as contingent valuing, to value biodiversity. Such valuations need to include considerations of the 'ecosystem services' provided by biodiversity (clean air and water; healthy soils; biological control of pests; degradation of wastes; and other services: PMSEIC 2002). Presently, we reward those who degrade the environment and not those who practice good stewardship and "we have to stop seeing biodiversity as a museum-collection of cute and interesting creatures and start recognising that it underpins the so-called free ecosystem services on which our entire agricultural sector depends" (Morton *et al.* 2002).

A group of concerned scientists has recommended that farmers be paid to maintain biodiversity, beyond an expected duty of care, so that ecosystem services are provided (Wentworth Group 2002). Who pays for this extra care in land management by farmers that in the short-term may not be profitable for them to do so? The Wentworth Group recommends a number of options. One option is to increase the prices of food, fibre and quality water to include the costs of maintaining biodiversity in a healthy state. Currently, a deteriorating environment, in the form of lost biodiversity, subsidises food prices, defers costs to future generations and fails triple bottom line accountability (economic; social and environmental). This is not only a local issue since world markets increasingly expect produce to come from production-systems that comply with the triple bottom line and threaten to impose non-tariff trade barriers for non-compliance. Hence, the promotion of 'environmental management systems' and Ridley *et al*. (this volume) report on methods of assisting farmers to evaluate and adopt systems of management that will give substance to the claim of 'clean and green' systems of production.

Difficulties arise in allocating water to the environment. Goss (this volume) reminds us that the water of the Murray–Darling Basin is over-allocated to agriculture yet substantial 'environmental flows' are necessary to sustain the biodiversity of floodplains, rivers and wetlands. Goss points out that the adoption of farming systems that use rainfall where it falls (less leakage) will have the benefit of improved water quality for biodiversity and people. However, in the Murray–Darling Basin, and elsewhere (Cocks, this volume), there will be decreases in the yield of water from the changed catchments and, therefore, less water to allocate among the competing claims.

It is being argued (Wentworth Group 2002) that the environment needs to be represented in the market when the allocation of water is being negotiated to ensure that environmental flows are allocated to rivers, lakes and wetlands. As an example, the Group recommends that negotiators for the environment be funded with AU$300 million to secure the environmental flow of 425 GL per year that is needed to prevent the mouth of the Murray River from closing.

The need to allocate water to the environment is being acknowledged increasingly by governments. Recently (14 November 2003), the Murray–Darling Basin Ministerial Council announced that an additional 500 GL per year would be released into the Murray to improve the health of designated areas of biodiversity (http://www.thelivingmurray.mdbc.gov.au/). It will take five years for this extra environmental flow to be achieved by means of irrigation efficiencies and purchases of water from irrigators for the environment. However, this commitment by the Ministerial Council is considered to be only one-third of the environmental flows needed for the health of the biodiversity of the Murray River. Environmental flows will be targeted at high-priority sites while other sites will deteriorate further – the trade-offs considered necessary to sustain 'working rivers' and 'working landscapes' (see the cover picture of this volume for an example). The Ministerial Council made an earlier commitment, in 2002, to restore the upper reaches of the Snowy River to good health over the next 10 years with an environmental flow of 212 GL per year; this is 21% of the original flow in the upper reaches of the River (White 1997). The allocation of scarce resources among competing claims, including the environment, requires a rational basis for doing so. Hobbs *et al*. (this volume) advocate the methods used in health care for setting priorities for limiting loss, or damage, to biodiversity. These methods are based upon considerations of the degree of threat, relative values and the likelihood of successful intervention.

Authors in this volume document the severe losses in biodiversity that have taken place and they predict further losses. Two papers report on data from the recent biological survey of the south-west of Western Australia and show that populations of both vascular plants and invertebrates have been severely reduced as a result of salinity and predict further losses in species and numbers (Halse *et al.* this volume; McKenzie *et al.* this volume). Other data coming from the Western Australia survey support the opinion that "450 endemic vascular plant species are in grave danger of extinction as a result of increasing salinity, and that a further 400–500 taxa will be subject to major genetic erosion as salinity wipes out many of their populations" (ANZECC Task Force 2001). A comparison of three catchments of the Collie River in the south-west of Western Australia (Lymbery *et al.* this volume) provided an opportunity to show that as the salinity of the riparian zone increased with the intensity of land clearing in the catchment there was a reduction in richness and diversity of plant species. These deleterious effects of salinity are superimposed upon riparian vegetation that is, usually, highly fragmented because of land clearing and in poor condition because of access by grazing animals and invasion by weeds. Yet, this poor-quality, fragmented riparian vegetation that is subject to further decline from salinity may be the most important vegetation remaining in a landscape to provide habitats for animals and birds.

There has been an insidious decline in the health of woodlands of eastern Australia as a result of salinisation (Briggs *et al.* this volume). Reasons for the slow recognition of the impact of salinity on biodiversity decline include institutional barriers to the management of biodiversity at the scale of the landscape. Community and Regional Groups, National Councils, and Action Plans aim to overcome these barriers and ensure that funding for protection and restoration is directed at agreed priorities with defined methods for monitoring progress (National Objectives and Targets for Biodiversity Conservation 2001–2005, 2001; NAPSWQ 2002). Briggs *et al.* (this volume) warn of the positive feedback loop between the loss of native vegetation and the rate of salinisation (ANZECC Task Force 2001). However, the long delay between causal events and observable effects make it difficult to convince the sceptics of the relationship between cause and effect and can generate a false sense of immunity. The vicious cycle of a positive feedback loop that generates exponential change should sound alarms for those who devise and implement Action Plans.

Managers of water in salinising landscapes need to know the response of species to the saline environment. For example, a 1999 audit of salinity in the Murray–Darling Basin predicted that, if no further actions were taken, then within 20 years the salinity concentrations in the River Murray upstream from where Adelaide takes its water will exceed the World Health Organisation standard for drinking water (800 µS per cm) 40% of the time (Murray–Darling Basin Ministerial Council 1999; K. F. Goss, pers. comm.). In salinising landscapes, freshwater aquatic systems are exposed to increasing concentrations of salt that may decrease suddenly when flushed with seasonal inundations of fresh water. Three papers in this volume review the response of freshwater ecosystems to salinisation. Nielsen *et al*. (this volume) conclude that while 1000 mg per L (1500 µS per cm) may be considered a critical concentration of salt for many freshwater species, there is uncertainty about how this critical concentration may affect the different life-stages of a species. They conclude, also, that it is not possible with present knowledge to predict how salinity affects the structure and function of freshwater ecosystems. With the progress of salinisation, Davis *et al*. (this volume) identified changes in the state of aquatic systems from freshwater macrophytes to microbial mat-dominated systems and conclude that such changes in state may be difficult to reverse in restoration programs. James *et al.* (this volume) review the response of aquatic species to salinity and point out that it is difficult to predict the response of mobile aquatic species that are able to acclimatise to a changing environment and, consequently, they advocate adaptive systems of management and risk assessment as methods for the management of saline water. In assessing the risk of damage to aquatic ecosystems by salinity, Hart *et al*. (this volume) emphasise the importance of two factors: location in the salinising landscape and the current condition of the ecosystem. Limitations to the use of risk assessment in decision-making for the management of salinising landscapes include better descriptions of the response–dose relationships and how to include uncertainties. Hart *et al*. (this volume) believe that the resilience of ecosystems to disturbances (Gunderson and Holling 2002) is a useful concept that, with further knowledge, may be incorporated into risk assessment. While these four papers review a substantial body of knowledge and experience, they support the conclusion that our ability to improve the prospects for biodiversity in salinising landscapes is limited by a lack of knowledge on how species and ecosystems respond to saline environments (ANZECC Task Force 2001).

What are the prospects for biodiversity in salinising landscapes of Australia? On the final day of the Conference, delegates were engaged in workshops to express their views on how the prospects for biodiversity could be improved. The Workshop-Groups contained people with a diversity of interests, including researchers and those who manage private and public land. The Groups proposed 44 Strategies to achieve 17 Objectives that they considered would improve the prospects for biodiversity in salinising landscapes (http://crc.vivid.global.net.au/pages/publications.asp). Some of the Strategies could be implemented now (30) while the remainder (14) were priorities for research. In general, the Groups identified the need for the following: a widely supported cultural change in the ways we manage our landscapes; packages of best-bet practices for landscape managers to implement now that will enable them to balance the private and public needs from healthy natural and agricultural systems; and increased knowledge about the ecology of salinising landscapes so that practices of landscape management are supported by valid, sustainable methods.

The importance of a "cultural change" in the management of our landscapes was listed as a priority by the Conference. In part, this cultural change is to value and protect biodiversity but a deeper cultural change is needed (Flannery 1994) if the prospects for biodiversity are to be improved. Much of the land cleared for agriculture in Australia is of an ancient, weathered, flat landscape with low and highly variable rainfall and sluggish internal drainage. The hydrological and nutrient cycles of the landscape were in balance with the native vegetation that had evolved over geological time without recent rejuvenation by glaciation and vulcanism. Salt from the sea, and redistribution from ancient internal drainage, accumulated in the landscape but was kept at depth because native vegetation used water where it fell. The landscape is prone to salinisation and desertification when native vegetation is removed (White 1997, 2000). The culture of Europeans who established agriculture in the Australian landscape was shaped by an empathy with a geologically young landscape supporting an established agriculture. The Australian landscape was to be rapidly settled and domesticated in the image of Europe (White 1997, 2000; Beresford *et al.* 2001). The imposition of a foreign culture on the Australian landscape persists today by a highly urbanised society and a diminishing number of people practicing unsustainable agriculture for short-term economic necessities to the great disadvantage of biodiversity; a situation described by Flannery (1994) as "cultural maladaptation". Management of the many facets of the salinity crisis requires manipulation of the hydrological balance of the Australian landscape through plant-based and engineering methods by people with empathy for their unique environment. It will require practices based on good science and technology, the implementation of strategic plans adequately resourced through the political will of the urban majority and carefully monitored for progress. Some of these requirements are in place (NAPSWQ 2002; National Objectives and Targets for Biodiversity Conservation 2001–2005, 2001) and the results that flow from them will offer hope for biodiversity identified as high-value that can be realistically protected in a salinising environment.

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