Impacts of drainage disposal on biodiversity in wetlands of the Western Australian wheatbelt.

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Abstract: The Western Australian wheatbelt has rich wetland associated plant and animal communities. Most of them occur in or around freshwater wetlands but a significant proportion of species, especially plants, are found at naturally saline sites where the level of endemism is high. Some naturally, as well as many secondarily, saline wetlands are likely to be used as receiving bodies for saline drainage water from agricultural land. Principles of sustainable development and environmental responsibility require that there is assessment of the likely impacts on plants and animals at these wetlands. These impacts are not easily predicted but increased hydroperiod may be at least as important a cause of impact as increased salinity. The relationship between species occurrence and salinity is comparatively well documented; there is very limited information on the relationship with acidity, which may increase as a result of deep drainage, and the relationship between species occurrence and hydroperiod is poorly understood. Little is known about trophic cascades that may occur as a result of loss of species. In this paper, I summarise the biodiversity values of wetlands in the wheatbelt, as well as existing information on species responses to changes in salinity, acidity and hydroperiod to indicate the possible impacts of drainage. In association with this information, a scheme to evaluate the suitability of wetlands for receiving drainage is presented.

Keywords: salinity, hydroperiod, invertebrates, waterbirds, plants

1. INTRODUCTION

Rivers in the wheatbelt of south-west Western Australia arise in an old landscape with low rainfall and very little topographic relief. As a result, natural drainage systems east of the Meckering Line are poorly defined and river valleys can be tens of kilometres wide. Prior to clearing of natural vegetation for agriculture, there was stream flow only after major storm events in either summer or winter and the flow was usually of short duration [Hatton and Ruprecht, 2002]. Wetlands east of the Meckering Line were ephemeral.

West of the Meckering Line, rainfall is higher and gradients increase slightly. Rivers are channelised and, prior to clearing, many would have flowed seasonally but permanent water occurred in only a few pools. Wetlands varied from ephemeral to seasonal. The extensive stands of trees (or dead trees) across the beds of many wheatbelt lakes is evidence of this seasonality [Froend et al., 1997; Halse et al., 1993a].

The result of agricultural clearing has been to increase run-off [George and Conacher, 1993] and to raise water-tables and water salinities via the process of secondary salinisation [Clarke et al., 2002]. There has been approximately a 10-fold increase in the spatial extent of salinity since clearing [Hatton and Ruprecht, 2002] and the combination of more water in the landscape and greater water salinity has lead to a significant amount of drainage on farmland to control both ground and surface water [Ali and Coles, 2002].

Broadscale drainage in dryland agricultural areas is unusual [Ali and Coles, 2002] but is occurring in the wheatbelt because the region has an almost unique level of secondary salinisation [NLWA, 2001]. Lack of comparable drainage elsewhere, and a unique biota, mean studies from outside Western Australia are of little help predicting the likely effect of drainage disposal water on aquatic biodiversity in the wheatbelt. Many of the aquatic systems, especially in the eastern wheatbelt, that are potential receiving bodies for drainage are naturally saline. While intuitively it may seem that drainage waters would have little adverse impact on saline systems, evidence from studies of salinity tolerance and habitat preference of many species suggest this is not true [Halse et al., 2003].

This paper reviews what is known of the tolerance of wheatbelt wetland animals and plants to increased salinity and altered flood regimes, uses this information to infer some ways in which both surface and deep drainage may be detrimental to receiving bodies, and describes a possible system for assessing biodiversity impacts of drainage. For the purposes of the paper, it is assumed drainage will be directed into natural waterbodies, although it may also be sent to evaporating basins, dams constructed for aquaculture or other disposal options [George and Coleman, 2002]. The potential, although poorly defined, indirect benefits of drainage to terrestrial and wetland biodiversity as a result of reducing effects of salinisation in the catchment as a whole [Ali and Coles, 2002; Hatton and Ruprecht, 2003] are not considered.

In common with many biological studies, the term fresh is used herein for water with salinity < 3 g L^{-1} Total Dissolved Solids, subsaline for 3–10 g L^{-1} and saline for water > 10 g L^{-1}. Occasionally salinity is expressed in terms of electrical conductivity (1000 µS cm^{-1} ≈ 0.6 g L^{-1} until above 50 g L^{-1} when the conversion factor begins to approximate 1 g L^{-1}). Wetlands are defined in the Western Australian Wetlands Conservation Policy to include bodies of both still and flowing water, i.e. lakes, swamps, pans, creeks and rivers.

2 WETLAND VALUES

Wheatbelt wetlands have considerable biological value. In a global context, south-west Western Australia has a rich and highly endemic flora [Hopper et al., 1996] and a recent survey of wheatbelt wetlands recorded 986 wetland-associated plant species [Halse et al., 2004]. The same survey recorded 957 species of aquatic invertebrates, 58 waterbird species and 21 frog species. The wheatbelt, along with the rest of the south-west, appears to be one of the most important regions in Australia for radiation of invertebrates with a drought-resistant life-stage [Halse et al., 2003].

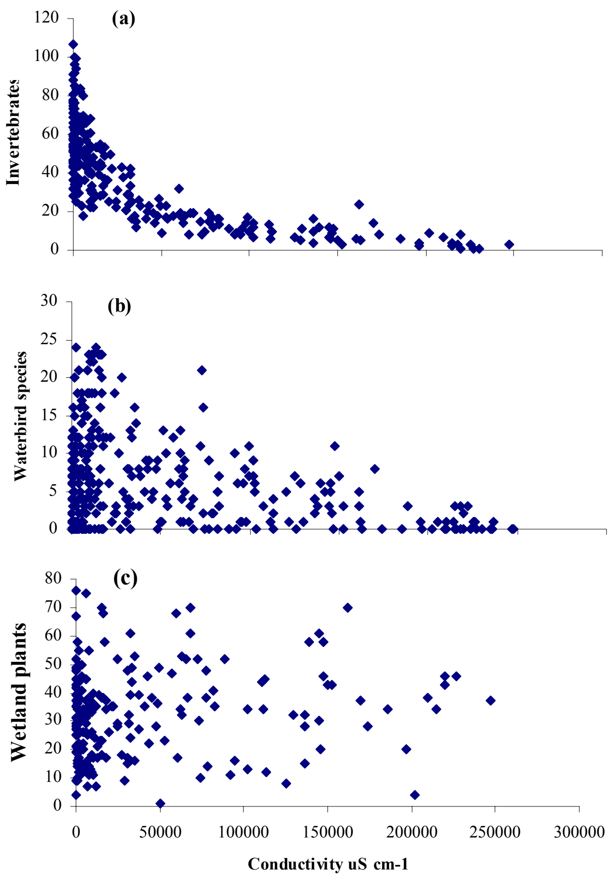

Figure 1. Relationship between salinity and species richness for (a) aquatic invertebrates, (b) waterbirds, and (c) wetland-associated plants [Cale et al., 2004; Lyons et al., 2004; Pinder et al., 2004].

Most invertebrate species occur in freshwater wetlands but about 15%, including *Parartemia* brine shrimps, many smaller species of crustaceans and many species of dipteran larvae, are more-or-less restricted to naturally saline wetlands [Pinder et al., 2002]. Most of these naturally saline wetlands are playas, often associated with extensive braided drainage lines covered in plants tolerant of salt and water-logging. About 60% of the wetland-associated flora of the wheatbelt occurs in, or around, these naturally saline systems, which are particularly important for chenopods (Salicornioideae), daisies (Asteraceae) and strapweeds (Juncaginaceae) [Lyons et al., 2004].

The wheatbelt is a highly fragmented landscape and relatively few wetlands, even in nature reserves, are in natural condition, free of significant weed invasion and hydrological change. As a result, all undisturbed wetlands have important nature conservation values. This applies as much to large naturally saline playas as to small freshwater wetlands, although faunal species richness is higher at fresh wetlands.

3. SALINITY TOLERANCE

Invertebrate species richness in wheatbelt wetlands starts declining at salinities > 4.1 g L^{-1} (6800 µS cm^{-1}; Fig. 1). To some extent, loss of freshwater species is offset by an increase in number of halophilic ones and, in fact, richness of predominantly freshwater species begins declining at salinities > 2.6 g L^{-1} [Pinder et al., 2004]. Most waterbirds are more tolerant of salinity, which acts as a constraint on species richness rather than a determinant of it. Nevertheless, all but two wheatbelt wetlands surveyed in recent years with ≥ 15 waterbird species had salinities ≤ 10 g L^{-1} (Fig. 1; see also [Halse et al., 1993b]). As with invertebrates, some waterbirds are salt-lake specialists: Banded Stilts *Cladorhynchus leucocephalus* and Hooded Plovers *Charadrius rubicollis* are obvious examples.

Most submerged or emergent aquatic plants (i.e. those growing in the waterbody) are salt-sensitive, although *Ruppia* persists until about 50 g L^{-1}. Riparian plant richness is independent of wetland salinity in hydrologically undisturbed situations (Fig. 1) but is inversely related at secondarily salinised wetlands and streams [Halse et al., 1993a; Lymbery et al., 2003]. This is principally the result of increased salinity and waterlogging around plant roots caused by secondary salinisation [Cramer and Hobbs, 2002]. Depending on piezometric head, it is likely that over long time periods other species of salt tolerant plants, with the same life-forms as those killed, may establish at the sites but there is no evidence of this occurring in the wheatbelt yet.

An important consideration for the persistence of ecological communities in salinized landscapes is that salinity often detrimentally affects plant and animal reproduction at lower concentrations than adults withstand [Nielsen et al., 2004]. Halophilic species of invertebrates and aquatic plants in saline wetlands often require a pulse of fresh or subsaline water to trigger reproduction [Geddes, 1981].

4. DURATION OF FLOODING

Annual rainfall in the wheatbelt varies between 600 and 300 mm and evaporation ranges from 1000 mm to 2000, depending on distance from the coast. Prior to land clearing, few wheatbelt wetlands held water for long periods and their aquatic invertebrates and plants have evolved with seasonal or episodic flood regimes. The distributions of trees in, and around, wheatbelt wetlands show that *Melaleuca*, *Eucalyptus* and *Casuarina* do not tolerate permanent inundation. Emergent sedges exhibit similar a similar response [Halse et al., 2004].

Many invertebrate groups with drought-resistant life-stages have higher species richness in seasonal waterbodies than permanent ones. Halse [2002] found all wetlands with high numbers of ostracod species (9–12) were seasonal. More recently, Halse and McRae [2004] showed that five of the six species of the giant ostracod *Australocypris* in Western Australia appear to be restricted to seasonal, naturally saline wetlands experiencing relatively little hydrological disturbance.

The information above, based on biological survey, suggests it is likely that changing the hydroperiod of a wetland will alter its aquatic invertebrate fauna and its flora. Likely causes of change include altered cues for hatching and germination of spores and seeds, and altered time periods available for grazing animals and predators to establish populations. In the case of naturally hypersaline playas, changes to the seasonal pattern of salinity as a result of altered hydroperiod (Figure 2) may affect key triggers in plant and animal life-cycles.

5. IMPACTS OF DRAINAGE DISPOSAL

As various forms of drainage are implemented on secondarily salinised land, the amount of water discharged will increase beyond that attributable to clearing alone [Hatton and Ruprecht, 2002] and will further exacerbate a situation where wetlands already contain more water than they should. In the case of freshwater wetlands, both salinity and hydroperiod will increase. For naturally saline wetlands, hydroperiod and the pattern of seasonal variation in salinity (rather than maximum salinity) are likely to change (Fig. 2).

Depending on discharge volume and salinity, it is likely that impacts of drainage on biodiversity will range from negligible to severe. The greatest impact of discharge will usually be on the immediate receiving body but sometimes impacts on downstream wetlands, as a result of overflow from the primary receiving body, may be more ecologically important. It should be stressed, however, that descriptions of potential impacts provided here are based on inference from distributional data and species habitat associations, rather than studies of wetlands that have received drainage. The descriptions are provided to warn proponents of drainage of the types of outcomes to avoid, rather than as an evaluation of drainage design. The situation where impact will be most likely is a large quantity of saline drainage water discharged into a freshwater stream or wetland. Even at relatively low final salinities in the receiving body, riparian and emergent plants will die [Lymbery et al., 2002] and aquatic invertebrate richness will decline [Pinder et al., 2005].

In some cases, drainage water may contain heavy metals, nutrients or other contaminants that cause biodiversity changes beyond the effects of salinity [Kefford, 2000]. Another potential problem is the transport of nutrients past primary receiving bodies through to coastal estuaries during large floods, such as occurred in the Avon River and Swan Estuary in 2000 [Hatton and Ruprecht, 2002]. Increased surface drainage is likely to make such events more frequent and widespread fish kills may occur, depending on conditions in the estuary.

Acidic saline groundwater is widespread in the wheatbelt [Mann, 1983] and deep drainage is likely to increase the frequency of acidic surface waters. While naturally acidic saline playas occur in the Belka Valley and around Scaddon [Lane and Munro, 1983], they comprise a relatively unusual wetland type to which few species are adapted. They are the most species-poor wetlands found in Western Australia. Furthermore, the species occurring in acidic saline water mostly avoid permanent wetlands [Halse and McRae, 2004], so it seems highly probable that turning seasonal alkaline salt lakes into acidic permanent ones will cause significant loss of biodiversity. How fast acidic drainage will turn wetlands acidic is unknown; most wheatbelt wetlands are alkaline and apparently well buffered [e.g. Lake Coyrecup, Cale et al., 2004].

Yet another agent of change is siltation. Poorly designed drains erode [Ali and Coles, 2002] and, if silt is carried into natural creeks, it may lead to loss of deeper pools in creeks and the smothering of woody debris and other habitat important for invertebrate species. Loss of river pools in the wheatbelt has already been pronounced [see Kendrick, 1976]. Some drainage proposals include a commitment to remove silt that has accumulated in creeks as a result of the long-term erosion on farmland [Coleman and Meney, 2000]. This has potential biodiversity benefit.

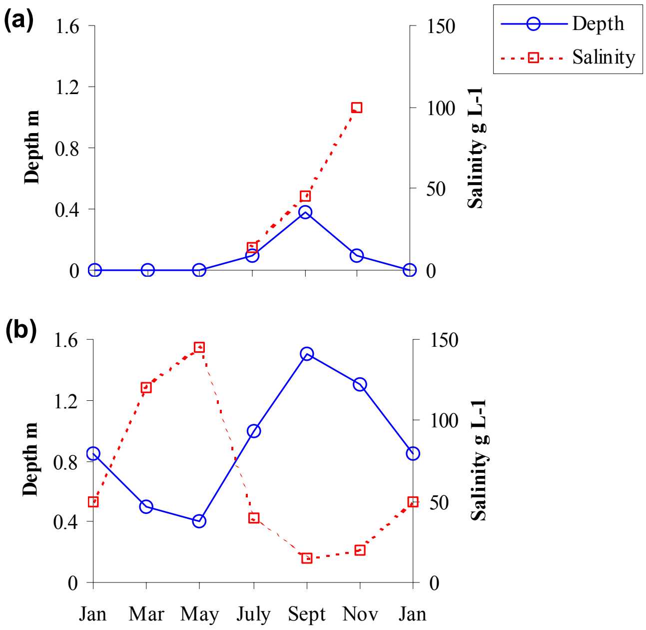

Figure 2. Hydroperiod and salinity patterns in a naturally saline wheatbelt playa (a) hydrologically undisturbed, and (b) receiving drainage. After Halse et al. [2003].

It has been emphasised that substantially increased hydroperiod is likely to have deleterious effects on emergent and riparian plants. Most of the equally important effects in the water column will be recognised only through biological survey. Hydroperiod affects biodiversity directly through effects on individual species (e.g. water-logging, changed triggers for reproduction) and indirectly by altering the way in which components of the wetland system interact and through cascading trophic effects. For example, the nutrient accumulation and changed salinity patterns that accompany permanent inundation may change the ecological character of a waterbody, in particular the balance between phytoplankton, submerged macrophytes and benthic mats as main primary producers [Davis et al., 2002]. This will result in different animal species using the wetland [Strehlow et al., 2005].

6. ASSESSING IMPACTS

Assessing likely impact of drainage requires three kinds of information: (1) quantity and quality of discharged water and its physical behaviour in the receiving body, (2) biodiversity or conservation values of the receiving body, and (3) whether the values are threatened by discharge. This paper has dealt mostly with the latter two types of information, although water quantity and quality are crucial to assessment. There are currently three schemes for identifying conservation values of wetlands in the wheatbelt and the threats posed to them by drainage. In the Moore River catchment, SKM [2001] assessed wetland suitability for receiving drainage principally on vegetation condition, although presence of fresh water and threatened species were also used as criteria. They rejected an earlier scheme of Coleman et al. [2000] as too complex for landholders to apply. Coleman et al.'s scheme largely used physico-chemical measurements as surrogates for biodiversity and then defined the amount of variation in physico-chemical parameters that was acceptable, although vegetation condition was scored as well. More recently, the Wetlands Coordinating Committee, an inter-agency committee responsible for implementation of the State Wetlands Policy, proposed a third scheme (Fig. 3).

Pre-assessment
Check wetland category
Collect technical data

Assessment process
Cat 1 → EPA assessment
Cat 2 → Approved by Expert Panel if impact unlikely otherwise referred to EPA
Cat 3 → Approved by Expert Panel unless downstream impact likely

Indicators for assessment
Current vegetation condition
Current vs natural salinity regime
Lakebed plants, benthic mats and salt crystalisation
Level of human disturbance in and around lake
Likely change to current hydoperiod and salinity

Figure 3. Outline of scheme proposed by Wetlands Coordinating Committee for evaluation of impacts of drainage on biodiversity.

In summary, wheatbelt wetlands will be assigned to three categories according to suitability for receiving drainage, as determined by existing data and expert assessment. This categorisation will let drainage proponents know in advance the scope of assessment required if a wetland is to receive drainage. Applications to drain into Category 1 wetlands will be referred to the EPA and the proposal will receive a high level of scrutiny. Category 2 wetlands will be assessed by an inter-agency committee and may be referred to the EPA; proponents will be expected to provide technical information in support of their proposal. Category 3 wetlands will be assessed but it is anticipated that drainage will usually be approved, subject to no adverse downstream effects beyond the Category 3 wetland in flood years. Both surface and deep drainage will be assessed.

7. CONCLUSIONS

Despite a considerable amount of surface and deep drainage already having been implemented in the wheatbelt, the effect of receiving drainage on the ecology of wetlands is poorly understood, although the direction of impact on biodiversity is clear. Only for salinity have response thresholds been quantified.

Naturally saline wetlands have important biodiversity values that may be threatened by surface, as well as deep drainage, so that choice of receiving body for any drainage scheme requires careful investigation. The streamed approach for assessment of biodiversity impacts proposed by the Wetlands Coordinating Committee should help protect wetland biodiversity while providing proponents with a clearer indication of the outcome of assessment prior to lodgement of drainage applications.

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