Department of Environment

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Natural Heritage Trust

Water notes

Water notes for river management

Advisory notes for land managers on river and wetland restoration

The ecology of Wheatbelt lakes

Salt has been accumulating in the soils and salt lakes of Western Australia's Wheatbelt for tens of thousands of years.

The salt was (and still is) brought into the Wheatbelt as trace amounts in rainfall and naturally accumulated as a result of high evaporation rates and internal drainage (see Figure 1 for representation of the extent of the Wheatbelt and Water note 34 for more information on internal drainage). In most of the landscape the salt was stored well below the soil surface. However, there were and still are parts of the landscape, such as salt lakes, that have been salty since well before clearing of the Wheatbelt occurred. These areas are often referred to as sites of primary salinisation and are estimated to have occupied less than one per cent of land area in the Wheatbelt.

Land clearing and the replacement of deep-rooted perennial species with shallow-rooted annual cropping species in the Wheatbelt region of Western Australia has resulted in a reduction in water use by vegetation (evapotranspiration). This has in turn caused a rise in watertables and mobilisation of salt previously stored deep within the soil profile. These processes have had a two-fold impact on the wetlands and waterways of the Wheatbelt.

The first impact of land clearing is altered hydrology. Raised watertables have caused an increase in the area of waterlogged land and increased runoff. Waterlogging of low

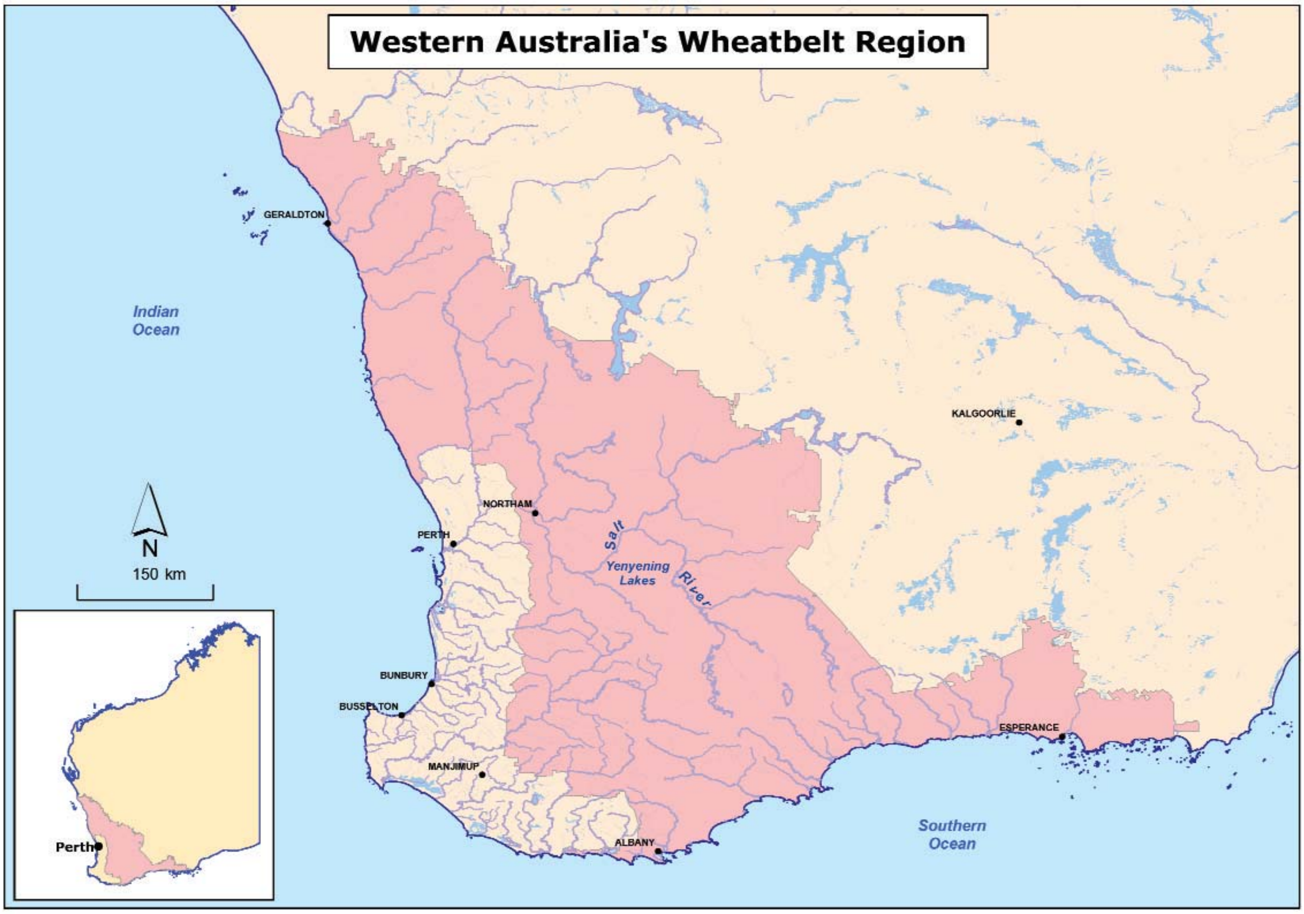

Figure 1. The extent of the Wheatbelt in Western Australia.

lying areas has affected vast areas of land in the Wheatbelt, killing vegetation not able to cope with waterlogged soils and resulting in altered ecosystems, and an accompanying loss of biodiversity. Increased runoff has also altered the nature of many waterways in the Wheatbelt. In many areas, prior to clearing there were no defined creek lines where well-developed streams now exist. These recently developed streams were originally low-lying depressions covered by native vegetation whose transpiration kept groundwaters deep. After clearing, the additional run-off eroded the clay cover on the stream base and exposed more permeable material. Other alterations to waterways include increased mobilisation of sediment, increased flow volumes, increased period of flow and increased flood magnitudes.

The second impact of clearing of native vegetation in the Wheatbelt has been the mobilisation of salt previously stored deep below the soil surface. This process, referred to as secondary salinisation, is affecting many streams, rivers and wetlands of the Wheatbelt.

Figure 2. Dead fringing vegetation at Little White Lake, part of the lakes system in the Upper Arthur River catchment (photo J Davis).

Due to the widespread occurrence of secondary salinisation in many parts of southern Australia, determining the impacts of secondary salinisation on aquatic ecosystems has become an increasingly important issue. This Water note has been prepared to provide information on how aquatic systems in the Wheatbelt of Western Australia function, their values and the impact of secondary salinisation on these systems.

Wheatbelt aquatic systems

The waterway and wetland systems of the Wheatbelt have been shaped over millions of years by the climate and geology. The Wheatbelt landscape of today is very flat and the ancient river valleys (palaeochannels) have become filled with sediment (further information on the development of palaeochannel systems in the Wheatbelt can be found in Water note 34). Today, rivers in these ancient valleys are often reduced to chains of salt lakes that only link up and flow after exceptionally high rainfall. In most years rainfall is insufficient to cause the systems to flow and the high rates of evaporation mean that the lakes and pools are dry for much of the year. These features, as discussed in the following two sections, have played very important roles in the evolution of Wheatbelt aquatic species and ecosystems.

The importance of seasonal water regimes

The seasonal wetting (or filling) and drying of lakes and rivers has two implications for aquatic flora and fauna. The most obvious of these is the fact that rivers and lakes may be dry for considerable parts of the year. The aquatic flora and fauna must be able to either tolerate drying out (desiccation) and 'return to life' once winter rains return or complete their life cycles before the pools dry out and produce seeds, eggs or other propagules that will 'survive' over summer and grow when suitable conditions return.

As a result the sediments of lakes and rivers contain a store of buried and hidden organisms, seeds (seed banks) and eggs (egg banks) of species that remain dormant when the systems are dry. Clearly, a dry lake is not a 'dead' lake. It is merely a dormant system waiting for the right conditions—usually the onset of winter rains—to return to a fully functioning aquatic system.

The second implication of wetting and drying is that whilst water is present, the salinity of the water will change through the course of the season. Typically, there will be an initial pulse of fresh water with winter rains as lakes and pools fill up. As winter ends and rainfall decreases salinities will steadily increase as water evaporates leaving behind increasingly concentrated salt. Aquatic flora and fauna have evolved to make use of this initial pulse of freshwater and be able to tolerate—to differing degrees—increasing salinity as pools shrink. For example, *Ruppia*, *Lepilaena* and *Lamprothamnium* are the main species of salt tolerant aquatic plants found in Wheatbelt lakes and rivers. Seeds and spores of these species are probably present in the sediments of almost all Wheatbelt systems however successful germination requires the right combination of conditions. Research undertaken by PhD student Lien Sim at Murdoch University has found that germination only occurs up to salinities of 45 g/L (salinity of seawater is 35 g/L). This suggests that this is an important threshold for maintaining aquatic plants in saline systems. Once germination has occurred these plants can survive in salinities up to approximately 90 g/L.

Life cycles of aquatic organisms have evolved to enable survival during seasonal fluctuations in salinity and dry phases and provide recolonisation of waterbodies on re-flooding. Although truly freshwater species have disappeared from saline systems, species must still be able to cope with seasonal changes in salinity and dry phases over summer.

The functions of complex pool and channel systems

As mentioned earlier, rivers in Wheatbelt valleys, especially in the eastern Wheatbelt, are now often reduced to series of lakes and channels that rarely link up and flow as rivers. The resulting complex geometry of the inter-linked channels and lakes (for example, Yenyening Lakes and the Salt River system) means that these systems have a high degree of retentiveness. Rather than water moving rapidly through the landscape, it may remain in pools for long periods of time. In the process suspended particles will drop to the sediments, nutrients will be taken up by aquatic plants and extensive food webs can develop. The complexity of this mixture of deep and shallow pools and long and short channels means that the system offers much potential to retain sediments and nutrients, rather than transporting them further downstream. Floodwaters will also be dispersed more slowly throughout the system rather than moving quickly through the catchment to possibly inundate farms and townships further downstream.

Figure 3. Yenyening Lakes in the Salt River palaeodrainage system in the upper Avon catchment (photo J Davis).

Often these pools form isolated microcosms of aquatic life, only mixing with other pools when the system is in flood following exceptionally heavy winter rains or episodic summer rainfall events. It is important that we identify the pools where natural values are still high. The pool-channel systems of Wheatbelt rivers indicate that the aquatic landscape is not a homogenous one. Relatively fresh systems can occur in close proximity to highly saline systems. In The Channels region upstream of Yenyening Lakes, salinities can vary from small pools containing fresh to brackish water, through to larger pools of saline to hypersaline water, depending on the location and time of year. These relatively fresh and brackish systems now have immense importance as the last remaining examples of their type. Their value in supporting current plant and animal communities fauna is still very high.

Figure 4. The small brackish pools at the south-west corner of The Channels contain fish and aquatic invertebrates that cannot exist in the hypersaline pools and channels to the north (photo J Davis).

Ecological states

Nearly all of our Wheatbelt waterbodies have already been affected by secondary salinisation. Once diverse freshwater plant and animal communities have been replaced by a smaller suite of salt tolerant forms. The effect of increasing salt on aquatic organisms follows the classic pattern of chemical pollution. Many sensitive species have disappeared to be replaced by a small number of tolerant species which occur in large numbers.

It is possible to use an alternative stable states or ecological states conceptual model to examine the impacts of secondary salinisation on wetlands. The theory of alternate stable states is discussed in the text box below.

Alternate stable states

The concept of alternative or multiple stable states has been used to explain ecosystem change in a number of systems including coral reefs and a diverse range of terrestrial systems. The alternate stable states model is based on the concept that within an ecological system there may be two or more stable states that can exist at any one time depending on the influence of a determining factor or factors. A stable state is one where the ecosystem tends to remain the same (i.e. comprises the same species in the same relative abundances) over a certain period of time (eg. a season or a year). Often a positive feedback system is present with a particular state creating conditions that will favour its persistence.

Between the stable states is an unstable equilibrium. The change in the ecosystem between the alternate states often occurs very rapidly and with little warning. Hysteresis is also likely to occur, that is, the condition that caused a shift from one state to another does not necessarily result in a shift back to the first state when the condition is simply reversed.

For shallow European lakes undergoing nutrient enrichment the concept of two states: clear water dominated by aquatic macrophytes (aquatic plants) and turbid (cloudy) water dominated by phytoplankton, has been described. This model appears to fit Australian lakes and has been extended to describe the change in state that occurs with increasing salinisation.

In Wheatbelt lakes, four alternate stable states have been identified. These are:

- clear, aquatic plant-dominated systems
- clear, benthic microbial or benthic mat-dominated systems (these have a thin layer of algal cells and bacteria on the bed of the lake)
- turbid (cloudy) phytoplankton-dominated systems
- turbid, sediment-dominated systems.

The change from freshwater to saline conditions results in the replacement of freshwater plants by a small number of salt-tolerant species. In Wheatbelt systems the main salt tolerant species that are found in the clear macrophyte dominated 'state' are *Ruppia*, *Lepilaena* and *Lamprothamnium*. Further increases in salinity (> 90 g/L) results in a shift to a benthic microbial community-dominated system, or benthic mats, composed mostly of cyanobacteria and halophilic (salt-loving) bacteria. Benthic microbial communities or benthic mats are often visible as pink or purple mats on the beds of shallow, clear salt lakes. Turbid, phytoplankton-dominated systems can occur in both freshwater and saline systems where nutrients are in plentiful supply. Both benthic mats or algal blooms dominate where salinities and nutrients are too high to enable aquatic plants to germinate and persist.

The fourth stable state refers primarily to claypans, which are relatively rare in the Wheatbelt and are more common further east. In these systems the high sediment content of the water means that light penetration into the water column is poor and therefore prevents the proliferation of algae and aquatic plants. Most farm dams essentially replicate this state.

The potential changes in state arising from increasing nutrients and salinity are summarised in the models given in the diagram to the right (Figure 5).

The curve in each plot indicates that there is a range of conditions (of nutrients or salinity) in which either state could potentially be present. However, at the lower or upper end of each range only one state is likely to occur. At lower salinities aquatic plants will dominate and under hypersaline conditions benthic mats will dominate. The presence of permanent water appears to favour the dominance of benthic mats at lower salinities than under a seasonal wetting and drying regime.

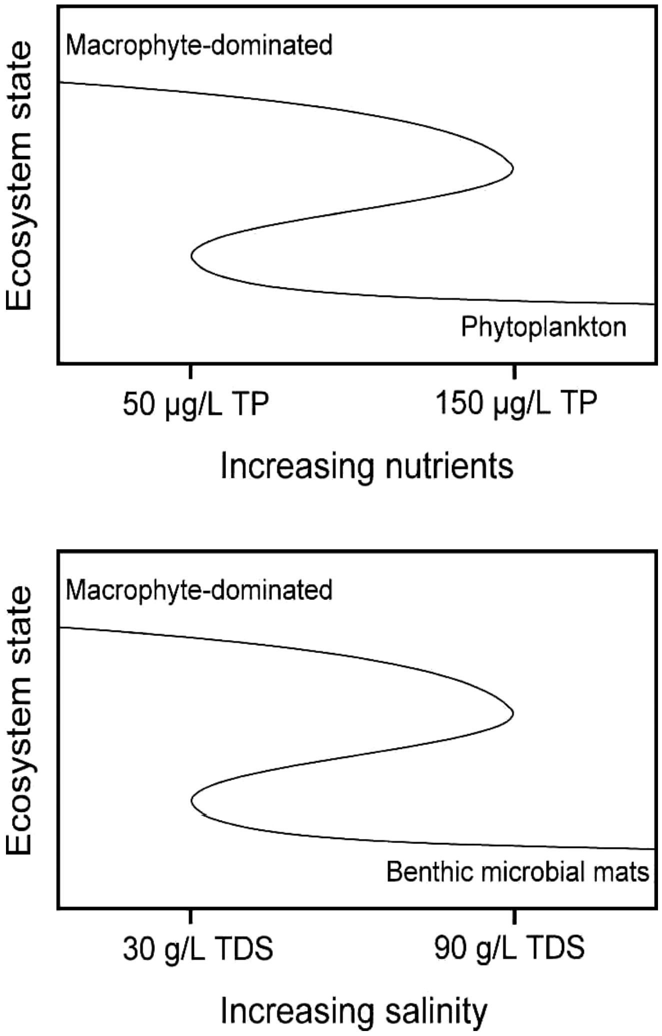

Figure 5. Alternative stable states model for nutrients and salinity.

Clear, macrophyte-dominated systems support the richest and most abundant invertebrate and waterbird faunas. Many waterbirds feed directly on submerged aquatic plants. The presence of black swans at Wheatbelt wetlands is directly related to the presence of aquatic plants which form their main food source. Many species of ducks feed on the rich and abundant invertebrate communities, which occur within stands of aquatic plants. Species such as the long-necked tortoise (*Chelodina oblonga*) can also survive in saline systems containing aquatic plants.

Figure 6. Submerged macrophytes (Ruppia and Lamprothamnium) at Meeking Lake, near Darkan (photo L Sim).

Figure 7. Juvenile long necked tortoise (Chelodina oblonga) in submerged plants at Meeking Lake (photo C Mykytiuk).

Figure 8. A phytoplankton-dominated or 'pink' lake near The Channels in the Yenyening Lakes system (photo J Davis).

Figure 9. A thick benthic microbial mat present at the edge of a hypersaline lake in the Wagin Lakes chain (photo J Davis).

The impact of altered salinities and hydrology on Wheatbelt waterbodies

Because secondary salinisation occurs mostly in association with rising water tables, the immediate ecological impact is often an increase in water depth and loss of seasonal wetting and drying cycles. Permanent inundation over a prolonged time period (i.e. greater than five years) has resulted in the death of once extensive thickets of wetland trees such as swamp sheoak, paperbarks and flooded gums. Higher salinities may act to prevent recruitment of these species even if water regimes become more favourable. Samphires are often the only plants that can survive on salty, waterlogged soils.

The death of trees and woody shrubs from waterlogging and salt has had a negative effect on the mammals, birds and invertebrates, which previously used the live canopies for food and shelter. It has also indirectly affected water quality through increased light and higher water temperatures which can result in lower oxygen concentrations. The loss of terrestrial plants has also resulted in lower inputs of organic matter, such as leaf material, which were often an important part of the food base in these aquatic ecosystems.

Increasing levels of salt have resulted in a switch from systems dominated by submerged aquatic plants to those dominated by benthic microbial mats. Although both occur naturally, the advent of salinisation has meant benthic mat-dominated systems are becoming more common and previously plant-dominated systems are being lost. This in turn has meant a loss of secondary consumers (invertebrates, amphibians, reptiles and waterbirds) that rely on plant-dominated food chains.

However, despite the widespread loss of species from salt-affected systems not all natural values have been lost.

Although it seems unlikely that we will ever be able to restore these systems to their formerly freshwater state, it is important that we protect and enhance the ecological communities and processes that remain. The concept of ‘reversibility’ is an important one for the management of Wheatbelt waterbodies. Systems that appear very dry and salty during drought conditions can support flourishing food chains when wetter, and fresher, conditions return. It is important that systems do not move so far along the gradients of salinity and water regimes (i.e. become deep, permanently wet, hypersaline waterbodies), that the flora and fauna adapted to seasonal water regimes cannot return when wetter conditions prevail.

Further reading

Davis, JA 2004, ‘Valleys of salt, channels of water, pools of life—environmental aspects of salinity engineering’ in S Dogramaci & A Waterhouse (eds) *Proceedings of the 1st National Salinity Engineering Conference*, Institution of Engineers, Australia. pp. 367–372.

Davis, JA, McGuire, M, Halse, SA, Hamilton, D, Horwitz, P, McComb, AJ, Froend, R, Lyons, M & Sim, L 2003, ‘What happens when you add salt: predicting impacts of secondary salinisation on shallow aquatic ecosystems using an alternative states model’, *Australian Journal of Botany*, vol. 51, pp. 715–724.

Department of Environment 2005, *The Wheatbelt’s ancient rivers*, Water note No. 34, DoE, Perth.

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