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Time and Contingency: key factors in the recovery of Murrumbidgil Swamp, a distinctive mound-channel wetland

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Key Points

- Murrumbidgil Swamp, in the lower Lachlan River valley NSW, is listed as a wetland of national importance, but is also notable for its unusual mound-channel morphology.
- The River Red Gum woodland is now in recovery: three recovery pathways are evident, each with its own water requirements and timeframes.
- The recovery of the River Red Gum woodland at Murrumbidgil Swamp will require favourable growing conditions over an extended time, probably decades.
- Maintaining the distinctive mound-channel morphology of Murrumbidgil Swamp, and hence its ecological character, is likely to require deliberate flooding, periodically.
- Time and contingency flooding are identified as key factors in the recovery of this wetland.

Abstract

A common practice when establishing the water needs of individual wetlands is to use the water requirements of the dominant plants. Standard descriptions of these requirements refer either to well-established (ie mature) vegetation or to germination triggers, and may not be adequate for objectives such as woodland recovery, or maintaining distinctive features. For these management objectives, a different approach is proposed, one that focuses on three critical areas: hydro-ecological context, ecological distance, and wetland distinctiveness or ecological character. It is here applied to Murrumbidgil Swamp, a small wetland on Merimajeel Creek, a distributary of the lower Lachlan River, NSW. Its River Red Gum woodland is currently in recovery following several years of extreme dry conditions. Three recovery pathways are present, each with its own time frame and own water requirements: branch tip re-growth, epicormic growth, and regeneration from seed. Hydrological modelling shows that the frequency of wetland filling flows, identified as a key to recovery, has been halved relative to pre-development, and the average interval between filling flows almost doubled. Recovery of the River Red Gum woodland and the maintenance of the distinctive mound-channel topography is likely to depend on supplementing the current flow regime. Using environmental water, it will be possible to provide reliable and sustained favourable growing conditions by minimizing water stress, and to periodically deliver filling flows on an 'as needed' contingency basis. If Murrumbidgil Swamp is to persist as a vigorous River Red Gum wetland with a distinctive mound-channel topography, then environmental watering will be needed frequently and into the foreseeable future.

Keywords

Wetland, environmental water, ecological character, recovery pathway, River Red Gum

Introduction

It is common practice for small wetlands to be treated as comprising a single vegetation type, and for wetland water requirements to be expressed only in terms of that vegetation type. Typically, vegetation water requirements are given for just two purposes, to maintain well-established (ie mature) vegetation or to provide a regeneration opportunity, and are expressed as simple metrics of frequency, duration and timing of flooding. It is common to source this information from reference books such as Rogers and Ralph (2011) or Roberts and Marston (2011). Requirements for other purposes such as post-drought recovery are not included in these reference books even though stress-recovery is currently relevant to many wetlands and floodplains in the Murray-Darling Basin.

This paper presents a simple process for determining the water requirements of a small wetland when the management objectives are other than maintenance and regeneration opportunity. Three critical points are considered: the *hydro-ecological context* of the wetland, which means understanding the ecological consequences and dependencies of the various inflows (river flow, rainfall and local run-off); the *ecological distance*, which refers to the magnitude of the difference

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between current condition and the management objective; and the *distinctiveness* or *ecological character* of the wetland, which means understanding its relationship with its formative water regime.

The value of these three points is demonstrated here using Murrumbidgil Swamp as an example.

Murrumbidgil Swamp

Murrumbidgil Swamp is a small (approx. 100 ha) shallow (1-2 m deep) deflation basin, with a low lunette on the eastern side, that is set in a red soil landscape, of extremely low grades. It is one of several wetlands along Merrimajeel Creek, a distributary of the lower Lachlan River, NSW, and recognized as one of seven major *wetland regions* in this part of the lower Lachlan (Thomas and Cox 2012). Climate here has hot dry summers, with cold winters (http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp). Murrumbidgil Swamp is listed in the Directory of Important Wetlands in Australia (ANCA 1996), because it satisfies criteria 1, 3 and 6 (a good example of a wetland type in a biogeographic region; important as habitat for animal taxa at a vulnerable stage in their life cycles; outstanding historical and cultural significance). In addition, Murrumbidgil Swamp has an unusual internal topography, which is a network of linear mounds, separated by shallow channels.

River Red Gum *Eucalyptus camaldulensis* is a keystone species here. The trees provide the structure, control the micro-climate, and are a principal source of carbon. The condition of the trees, and the woodland they form, therefore dictates the ecological condition of Murrumbidgil Swamp. Swamp condition has not been monitored, and the following time-line is compiled from diverse sources.

Over the last 40 years, the condition of the River Red Gum woodland has swung from one extreme to another. In the 1970s-1980s, Murrumbidgil Swamp was inundated continuously for 5 years, and then for a further 2-3 years (Maher 1984). Photographs from these years show the woodland was vigorous: the trees were in excellent condition, with full canopies and no yellowing or dieback, and with spreading branches hanging low over the water (Figure 1). Canopy cover, as measured from Landsat imagery, was 60% in 1973, and 69% in 1993 (Armstrong et al 2009). In the 2000s, the swamp was dry for several years (Roberts and Robinson 2014) and by March 2007, the trees were in poor to very poor condition (Roberts 2007), and in 2008, canopy cover was only 29% (Armstrong et al 2009). Between November 2010 and early 2013, Murrumbidgil Swamp filled and dried three times. In October 2013, the woodland was showing signs of recovering from drought (Roberts and Robinson 2014), with recovery progressing along three different pathways: branch-tip growth, epicormic growth and regeneration. Many young River Red Gum trees were present, ranging from recent germinants to saplings: the saplings, although patchily distributed, accounted for 16% of live canopy cover (Roberts and Robinson 2014). The wetland was also recovering as a habitat for wetland fauna, with signs of recent or current breeding in birds and reptiles.

Target and Water requirements

For demonstrating this process and three critical points, the management target for Murrumbidgil Swamp is assumed to be a mature River Red Gum woodland in good condition.

The watering (flooding) requirements for maintaining River Red Gums are given by one reference as ideally every 1-3 years, with a duration of 2-4 months, and a maximum interval between floods of 36-48 months (Rogers and Ralph 2011); and by another reference as, assuming the goal is a vigorous woodland, a frequency of every 2-4 years, with a duration of 2-4 months, and reflooding at 5-7 years to avoid ecological damage (Roberts and Marston 2011).

Figure 1. Murrumbidgil Swamp in September 1980 (provided by Dr Peter Fullagar).

Three Critical Points

Hydro-ecological context: Water Sources

Merrimajeel Creek enters Murrumbidgil Swamp on the north-east side and spills to the south-west into Lake Merrimajeel when the wetland is full. Modelling indicates that, prior to development, flows likely to fill Murrumbidgil Swamp would have occurred 182 times in 112 years, mostly in winter (approx. 36% of events) with an average interval of 167 days between fills (Table 1). However, in the Lower Lachlan, flows down distributary creeks such as Merrimajeel Creek have been modified by regulation and are reduced in volume relative to pre-development although retaining the seasonal pattern (Driver et al. 2005). Modelling indicates that, under current or “WSP” conditions, filling flows now occur 88 times in 112 years, mostly in winter (44% of events), with an average interval between fills of 417 days (Table 1).

Table 1. ‘Filling flows’ under Pre-development and WSP (water-sharing plan, equivalent to current) scenarios for GS 412122 on Merrimajeel Creek, approximately 40 km upstream of Murrumbidgil Swamp, showing also % change for 3000 ML cumulative volume and 4500 ML cumulative volume. Spells analysis used IQQM runs N15 and 137, trimmed to 1900-2012, with a spell gap of 6 days.

	Number of spells	Longest spell (days)	Mean duration (days)	Mean period between spells (days)	Longest period between spells (days)
Pre-development	182	290	58	167	1297
Water Sharing Plan	88	259	52	417	3624
% change for 3000 Ml event	-52%	-11%	-11%	+149%	+179%
% change for 4500 Ml event	-58%	-11%	-2%	+190%	+236%

Mean annual rainfall at “Woorandarra”, approximately 5 km from Murrumbidgil Swamp, is relatively low, 332 mm (1954-2006), and is fairly uniformly distributed through the year (monthly average ranges from 23 to 33 mm). The catchment immediately around Murrumbidgil Swamp is small, extending up to 900 m away from the wetland only in the north-west. The small catchment and low annual average mean that rainfall is not enough to fill the Swamp (estimated capacity of approximately 1 GL). Heavy local rainfall is unusual: monthly total have equaled or exceeded 100 mm only 19 times in the 50 year record. Although unlikely to fill Murrumbidgil Swamp, locally heavy rainfall has a particular ecological significance: it results in disconnected pools, causes opportunistic plants to germinate in the channels, and even triggers frogs to call, as happened following 93 mm in September-October 2010 (Roberts and Robinson 2014). Heavy rainfall can also alleviate water stress in trees, at least temporarily, and can even trigger River Red Gum seeds to germinate across the channel bed.

In summary: Murrumbidgil Swamp fills from Merrimajeel Creek and the Lachlan River, rather than from local rains or local run-off, and hence the flow regime of Merrimajeel Creek drives ecological processes related to persistent and deep inundation. Prior to regulation, Murrumbidgil Swamp filled frequently, more than once per year, on average, and refilled, on average, in about six months: these conditions would have been ideal for maintaining the River Red Gum woodland in vigorous condition, and for the wetland to be highly productive. Under current conditions, filling frequency is reduced to less than once per year on average, and the wetland is re-filled on average in about 14 months. Although drier, current conditions do not appear likely to be detrimental to the River Red Gum woodland, although productivity would certainly be less than what was recorded in the mid-1970s (Briggs and Maher 1983a). Local heavy rain can result in moist soils, and shallow flooding, ecological conditions that are very different from Merrimajeel Creek inflows.

Ecological Distance

Ecological distance, which is the difference between current condition and the management target, is largely determined by antecedent conditions, in particular by recent stress history.

Eucalypt trees such as River Red Gum *Eucalyptus camaldulensis* have three ways to recover from stress, depending on the intensity of stress experienced (Figure 2, next page). Trees that have been only slightly stressed (Stress_1) recover by *branch tip re-growth*, from existing twigs and branches. This recovery pathway does not need to invest in developing new twigs or branches. Trees that have been severely stressed (Stress_2) must develop new twigs and branches *by epicormic growth* from specialized buds in remaining viable stems and branches. Trees that have been fatally stressed do not recover (Stress_3), and a woodland can only be re-established by *regeneration from seed*. This pathway requires a major growth investment, and the development of a new population of trees, as well as a reasonable success in transitioning from one growth stage to the next (germinant, seedling, juvenile, sapling, pole and then mature).

These pathways differ in carbon investment needed and in time required to re-establish a woodland. Recovery from Stress_1 by branch tip re-growth takes only 1-3 years (estimated) of favourable (maintenance) conditions. Recovery from Stress_2 by epicormic re-growth requires favourable (maintenance) growing conditions over 6-15 years (approximate estimate) but will take even longer if interrupted by drought. Recovery by re-establishing a woodland from seed (recovery from Stress_3) takes decades, and is also prolonged by drought. The conceptual model (Figure 2) draws on the canopy condition concepts developed by Souter et al (2010) and the importance of antecedent condition in determining ecological responses (Overton et al 2014).

In terms of ecological distance, a woodland with a recent history equivalent to Stress_1 is closer to the target of a mature River Red Gum woodland in good condition than is a woodland recovering from Stress_3. Unexpectedly, the assessment of Murrumbidgil Swamp in October 2013 found that recovery was proceeding along all three pathways simultaneously, thus giving three measures of ecological distance. A subjective appraisal is that all three pathways are needed for the recovery of River Red Gum woodland at Murrumbidgil Swamp, and the integration of these water requirements is that: maintenance conditions and avoidance of stress (drought) are needed, for the first two pathways; frequent flooding (every 1-2 years) is needed to ensure seedlings establish well and progress through to juvenile stages for the third pathway, as well as maintenance conditions *and* avoidance of stress (drought).

In summary: The trees at Murrumbidgil Swamp are in a variable and non-uniform state, and the recovery of the wetland to a mature woodland in good condition will need to proceed along different pathways simultaneously; this will require not just maintenance conditions, but also the avoidance of drought, over a sustained period of several decades, as well as more frequent flooding to ensure seedlings and juveniles establish.

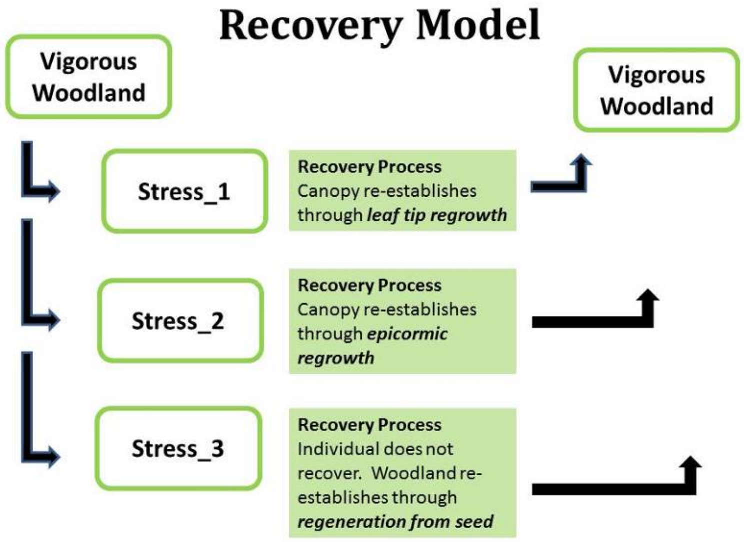

Figure 2. Recovery Model: increasing stress leads to different recovery pathways and longer time to recover

Ecological Character

The genesis of the mound-channel topography in Murrumbidgil Swamp is not yet understood, but, by analogy with flowing systems (eg Tooth and Nanson 2000, Erskine et al 2009), is likely to involve critical feedbacks between plant growth, species submergence-emergence tolerances, sediment deposition and flow regime.

River Red Gums are restricted to the top of the mounds, and form sinuous strings of woodland (Figure 3, left). When Murrumbidgil Swamp is partly filled, the tops of the mounds remain unflooded, like islands. Because each mound is ringed by its own littoral zone, the wetland has an exceptionally high density of littoral zones. The tops of the mounds are shallow flooded (about 25-40 cm) only when Murrumbidgil Swamp is surcharged. In contrast to the tops of the mounds, vegetation in the channels is non-woody (Figure 3, right), and changes with hydrological phase. Aquatic plants such as milfoil *Myriophyllum* sp., ribbon weed *Vallisneria* sp. and *Azolla* sp are abundant when channels are flooded; pasture plants and amphibious species such as medic *Medicago* and tall *Persicaria* establish occur on flood recession; opportunistic terrestrial herbs grow in the channel in response to rain (Briggs and Maher 1983a, Roberts and Robinson 2014). Primary productivity is high (Briggs and Maher 1983 a), and this drives secondary production and detrital pathways that in turn support waterbirds, and build carbon reserves in the soil (Briggs and Maher 1983b). This productivity, attributable in part to its mound-channel topography, gives Murrumbidgil Swamp its distinctive ecological character.

River Red Gum wetlands occur widely throughout the Murray-Darling Basin, but wetlands with this mound-channel topography have not been previously described. All the examples located to date, in a non-systematic search of satellite imagery, were in the lower Lachlan Valley. Assuming this type of River Red Gum wetland is indeed rare at the Basin-scale, then an appropriate management objective for Murrumbidgil Swamp is to maintain and safeguard its distinctive internal topography.

Figure 3. Linear woodlands at Murrumbidgil Swamp, during turbid inflows (left) and showing the contrast in vegetation between mound and channel (right), with Lignum and River Red Gums on the mound, and senescent forbs on the slopes of the mound and in the channel.

In the absence of understanding how the mound-channel topography is maintained, a sensible target is to maintain the contrast in mound-channel vegetation, and restrict woody vegetation notably River Red Gums to the tops of mounds. However, this presents a challenge, as the hydraulic characteristics that determine where seed deposition occurs and where seedlings establish are not known well enough to apply to a particular site such as Murrumbidgil Swamp. One way to do this is to allow River Red Gum regeneration to occur, but to deliberately prevent seedlings from establishing in the channels. This can be done by hydrological intervention, ie by flooding the channels deeply enough and long enough to cause seedling mortality, but must be done while seedlings are still young, preferably within a year of germination, as their capacity to survive flooding increases with age (Roberts and Marston 2011).

In Summary: Maintaining the mound-channel contrast in vegetation at Murrumbidgil Swamp is assumed to depend on preventing seedlings from establishing in the channels. Seedling establishment did not occur under the pre-development flow regime for Merrimajeel Creek probably because the interval between fills was shorter and capped the period for growing to about six months on average. Without intervention, the likelihood of seedlings establishing is much greater under current conditions as the interval between filling flows is about 14 months, on average, giving more than double growing time.

Is there a Role for Environmental Watering ?

Consideration of the three critical points (hydro-ecological context, ecological distance and ecological character) showed that relying on maintenance water requirements alone would not be enough to meet management objectives such as woodland recovery and maintaining ecological character, as these have complex needs that involve other flow components.

The recovery objective requires predictable and sustained favourable growing conditions, and this means avoiding extended dry spells. Under pre-development conditions, extended dry spells were not particularly long and the River Red Gum woodland would not have been much exposed to stress from dry spells. The longest period between filling flows (Table 1) was 3.4 years, equivalent to the maximum interval recommended by Rogers and Ralph (2011) but shorter than the critical interval recognized by Roberts and Marston (2011). Under current conditions, stress from extended dry spells is inevitable. The longest interval between fills is nearly ten years (Table 1) which would probably have catastrophic effects as it far exceeds the upper limit recommended by Rogers and Ralph (2011) and also exceeds the critical threshold suggested by Roberts and Marston (2011). Under current conditions, Murrumbidgil Swamp will experience a much drier regime, resulting in less growth and longer dry spells, as shown in the representation of return intervals for filling flows (Figure 3). Intervals that occurred about once in 120 years under pre-development conditions are likely to recur in 15 years under current conditions; and intervals lasting two years or longer which did not occur at all under pre-development condition will recur about once every 15 years on average (Figure 3). Under these conditions, full recovery is unlikely without environmental watering.

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The ecological character objective requires a filling flow to be delivered at short notice, as a contingency measure analogous to contingency allocations for extending waterbird breeding or flushing algal blooms. It will require some kind of monitoring to give timely and reliable advice as to when this will be needed.

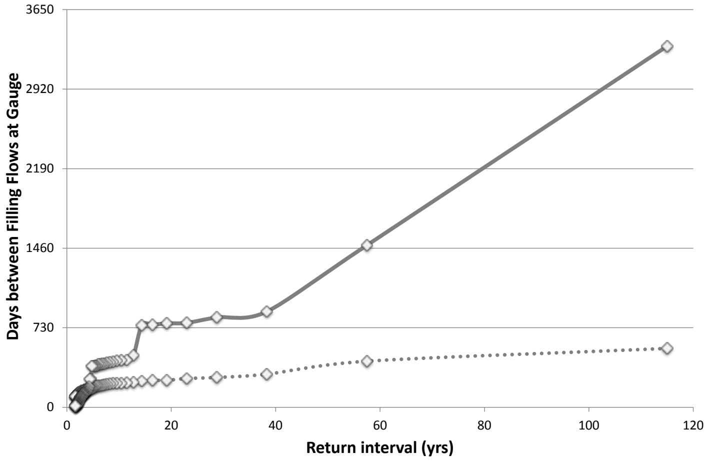

Figure 4. Return interval for filling flows at GS 412122, upstream of Murrumbidgil Swamp, under current (solid line) and pre-development (dashed line) conditions. The y-axis is marked in 2-year intervals.

Conclusions

There is a clear role here for environmental watering, and what it can achieve. Considering the hydro-ecological character, the ecological distance and the ecological character of Murrumbidgil Swamp showed that its long-term needs would not be satisfied by considering only maintenance requirements for River Red Gums. Conserving Murrumbidgil Swamp as a River Red Gum woodland, with a distinct and unusual mound-channel topography, is likely to require repeated watering into the foreseeable future, and may also require filling flows as a contingency measure to prevent seedlings from establishing. Without environmental watering, recovery will be incomplete, tree deaths will occur, understorey changes can be expected, and the distinctive mound-channel topography could be at risk.

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