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Murrumbidgee Vegetation and Wetland Assets Benchmark Report

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Final Report

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1. Introduction

Watering regime (frequency, duration and depth) plays a critical role in structuring aquatic vegetation communities (Wassens *et al.* 2017). Prolonged drought and altered flow regimes can reduce the diversity and cover of aquatic species, lead to declines in seed banks and reduced recovery times (Brock *et al.* 2003; Tuckett *et al.* 2010). Environmental water has an important role in maintaining both vegetation species diversity within wetlands and vegetation community diversity overall across the Murrumbidgee catchment. By reinstating more natural flow regimes, environmental water can also play a role in the recovery of aquatic vegetation communities (Wassens *et al.* 2017).

Commonwealth environmental water, in conjunction with NSW environmental water, are influencing wetland water regime across multiple regions of the Murrumbidgee, including the Yanco-Billabong Creek system, Murrumbidgee Irrigation Area, Coleambally Irrigation area, North Redbank (Lowbidgee) and Junction Wetlands. To date, there has been no formal evaluation of the ecological character and condition of target wetlands or the outcomes of environmental watering actions. This program aims to collect baseline data on the character and condition of priority wetland sites that are currently or likely to receive environmental water but are not monitored under the Murrumbidgee MER program. The baseline data will serve as a quantitative reference point against which future evaluation of Commonwealth and NSW watering actions can be evaluated, support water planning including assessing suitability of wetland sites for environmental water, assist watering objectives and recovery targets as well as identifying habitat suitability for other water depend fauna.

This fixed term project was agreed on 18 January 2020 to create benchmark vegetation transects in Murrumbidgee wetlands using Commonwealth and NSW environmental water not currently monitored under the Murrumbidgee Monitoring Evaluation and Research (MER) Program. The aim was to set up vegetation transects, complete vegetation surveys using accepted local methods and do tree health assessments. These transects could then be surveyed numerous times in the future to enable comparison of aquatic vegetation communities over time, as a response to continued watering.

Evaluation questions:

- What did Commonwealth environmental water contribute to vegetation species diversity?
- What did Commonwealth environmental water contribute to vegetation community diversity?
- What did Commonwealth environmental water contribute to tree condition?
- What is the potential for Commonwealth environmental water to improve vegetation condition against the measured baseline ecological condition?
- What is the potential capacity of Commonwealth Environmental water to increase or maintain habitat suitability for water dependent taxa?

2. Methods

Site selection

The contingency monitoring program focussed on high priority wetlands that were expected to be representative of the broader ecological communities in the area, were scheduled to receive Commonwealth or NSW Environmental water in 2019-20 and not regularly monitored under the current MER program (Figure 1, Table 1). Each wetland location was classified against the Australian National Aquatic Ecosystem (ANAE) based on currently available data and field validation. Coordinates were recorded for each of the surveyed wetlands.

Figure 1 Distribution of Benchmarking survey sites through the Murrumbidgee Valley

Table 1 Survey sites

Full site name	Latitude	Longitude	Estimated area (ha)	Region	Waterbody type	Geomorphic structure	ANAE Vegetation type
Burrabaroon swamp	-34.9507	144.8917	98	Coleambally	Lake	depositional basin	Black box woodland
Campbell Swamp	-34.2292	146.0324	25	MIA	Terminal lake	deflation basin	Black box woodland
Coonacoocabil Lagoon	-34.6090	146.3041	66	mid-Murrumbidgee	Anabranch	lentic channel forms	Red gum woodland
Darlington Point Lagoon	-34.5702	146.0224	26	mid-Murrumbidgee	Oxbow	lentic channel forms	Red gum woodland
Mainie Swamp	-34.6747	143.2742	2357	Junction wetlands	Wetland	lentic channel forms	River Cooba woodland
Murrindi Swamp	-34.5299	143.6528	73	Lowbidgee North Redbank	Wetland	lentic channel forms	Red gum woodland
Narwie East Swamp	-34.4741	143.7060	1393	Lowbidgee North Redbank	Wetland	lentic channel forms	Red gum woodland
Steam Engine Swamp	-34.4826	143.6751	1587	Lowbidgee North Redbank	Wetland	lentic channel forms	Red gum woodland
Toogimbie House Paddock lagoon	-34.5493	144.4902	29	Lowbidgee Gayini	Wetland	lentic channel forms	Lignum
Turkey Flats Wetland	-34.6086	146.3803	7	Murrumbidgee	Lake	deflation basin	Red gum woodland
Wargam Lakes East	-34.9139	145.0282	77	Coleambally	Lake	depositional basin	Black box woodland
Waldaira lagoons	-34.7139	143.3512	55	Junction wetlands	Wetland	lentic channel forms	River Cooba woodland
Wanganella swamp north	-35.2324	144.8124	77	Yanco Ck	Wetland	lentic channel forms	Shrubland
Wargam Lakes West	-34.9116	145.0030	1477	Coleambally	Lake	depositional basin	Black box woodland
Wanganella swamp south	-35.2430	144.8162	71	Yanco Ck	Wetland	lentic channel forms	Shrubland
Yanco Ag (McCaugheys)	-34.6273	146.3942	14	Murrumbidgee	anabranch	lentic channel forms	Red gum woodland

Transects were chosen to start above high water mark, in a direction perpendicular to the shoreline to include the range of water depths (see Figure 2). All but 2 wetlands were set to 30 x 5 m (150 metres) transects, shorter transects were used at Coonancoocabil and Darlington Point Lagoons (30 x 3 m (90 m) transects). Transects were set up where possible, nailed (roofing nails) to existing trees, using a series of large cattle ear tags (ATAG or Zee). Yellow tags were labelled with site number and transect number and point at each end of transects, which were placed perpendicular to the edge of the wetland. Blue tags were placed on the backwards direction (Figure 3) to identify reverse direction. Where trees weren't available, fence posts or protected star pickets were used instead. GPS coordinates were taken at each end of the transects and a series of photopoints at four 90-degree points were collected using a Nikon Coolpix camera or a Samsung 5 smartphone (Figure 3).

Transect data were collected using a Garmin Oregon 300 GPS unit, UTM position format, using WGS 84 map Datum and Spheroid (identical to GDA). These data were imported as spreadsheet format into Google Earth Pro (7.3.2.5776) to produce KML files. Transect polylines imported into ESRI ArcGIS Pro (esriaustralia.com) from KML files, were intersected with a number of Lidar DEMs (1m, 2m and 5m) to create 3D profile graphs. Lidar DEMs were sourced from Geoscience Australia 'ELVIS' website (elevation.fsdf.org.au). These data were used to produce transect images underlain with profiles for each transect. Images of wetlands showing transect locations were also produced (Figure 2). Vegetation transects were set up using a multiple lines of evidence approach.

Surveys

The survey methods followed those described by (Wassens et al. 2014). Surveys were undertaken between 4 and 8 weeks post inundation between January and March in 2020 and 2021 for 16 wetlands. Transects were measured using a 100 metre surveyors tape, with 1 square metre vegetation quadrats taken each 5 (or 3) metres. At each quadrat soil moisture, tree canopy cover and water depth were measured. The percentage cover of bare ground, leaf litter and open water were estimated along with the percentage cover of identified species.

Tree condition was measured for 15 trees at each wetland in February 2021. Trees were selected as the nearest 5 trees from the start of each of the three survey transects. Tree condition assessment followed standard methods outlined by (Souter et al. 2010). Condition assessment included estimates of tree canopy extent and density, dieback, epicormic growth, bark cracking, reproduction and mistletoe. Tree recruitment was estimated for seedlings and sapling under 5 metres within a 5 x 5 metres break out at quadrats 10, 20 and 30.

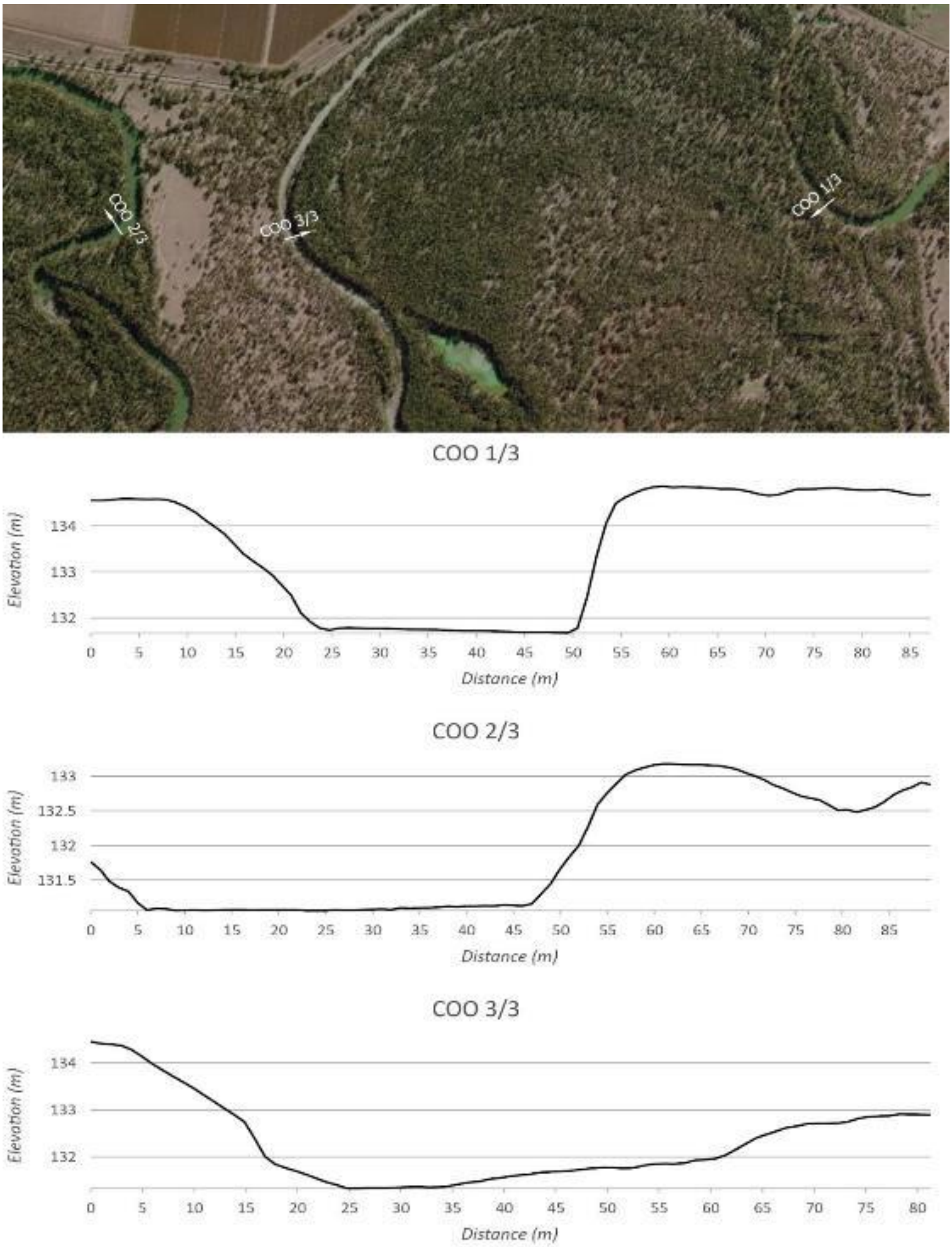

Figure 2 Example of an elevation profile along benchmarking transects for Coonancoocabil Lagoon (Geoscience Australia 'ELVIS' website (elevation.fsdf.org.au)).

Waldaira T2 Q30 Jan20 (Junction)

Wagram East T2 Q30 Jan 2020 CIA

Murrundi T2 Q1 Feb 2021(N Redbank Lowbidgee)

Wanganella East T1 Q1 Jan 2021 (Yanco-Billabong)

Yanco Ag T1 Q1 Jan2020 (mid-Murrumbidgee)

Campbells T3 Q30 (MIA)

Plate 1 Representative from the six main regions Junction wetlands, Coleambally Irrigation Area, Yanco - Billabong, Murrumbidgee Irrigation Area, mid-Murrumbidgee and North Redbank. T – Transect, Q – Quadrat.

3. Results

What did CEWO contribute to species richness

Species Diversity

There were 118 vegetation taxa (37 amphibious and 82 terrestrial species) (see appendix 1) found across the 16 wetlands. The most commonly reported amphibious species aquatic fern Nardoo (*Marsilea drummondi*) and old man weed (*Centipeda cunninghamii)* which were both identified at 14 sites, Common spike rush (*Eleocharis acuta*) 12 sites and Azolla (*Azolla rubra*) 11 sites. The most commonly reported native terrestrial species was Lesser joyweed (*Alternanthera denticulata*) which was reported at all 16 wetlands. The Junction wetlands, Mainie and Waldaira swamps had greatest taxa richness overall, with 20 amphibious species reported at Mainie and 18 at Waldaira. Murrundi in the north Redbank supported 17 amphibious species followed by Wanganella North and South with 16 and 15 species respectively. This pattern is reflected in the higher average species richness (number of species standardised by cover) of amphibious species at these wetlands (Figure 3). Those with lower richness of amphibious species included Burrabaroon (1), Coonancoocabil (3), Toogimbie (5) and Wagram West (6). The overall patterns in the number of species is also reflected in species richness (Figure 3).

Functional diversity

Functional group diversity is another way of describing the complexity of vegetation communities and can be an indicator of habitat availability for wetland dependant fauna. While there are a range of different ways of expressing plant functional groupings we used the classification by (Casanova 2011)(Table 2). As expected wetlands with higher species diversity also had higher functional group diversity with the Junction wetlands, Narwie West, Darlington Lagoon, Campbells Swamp and Wanganella north all containing at least one species from each functional group (see Table 2). Mean percent cover of wetland vegetation functional groups were calculated to identify the relative dominance of each functional group (Figure 4). The percentage cover of Amphibious fluctuation tolerator – emergent including spike rushes and sedges had the highest cover followed by Amphibious fluctuation tolerator - low growing species such as old man weed. As the wetlands were surveyed while they contained water the percentage cover of species within the terrestrial functional groups were low across all sites.

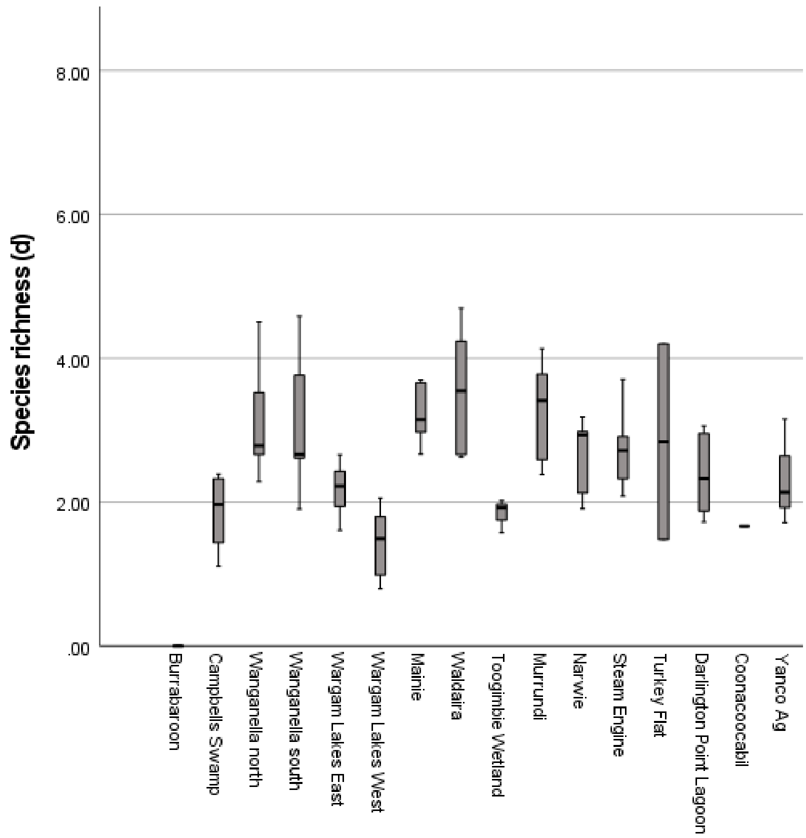

Figure 3 Box plots of the species richness of amphibious species between January 2020 and February 2021 at the BEN monitoring sites. Box shows third and first quartiles, horizontal bar is Median. Error bars show minimum and maximum values.

Plate 2 Mainie Swamp in in the Junction wetland systems has a high functional diversity

Table 2 Number of species in each functional group (Brock and Casanova, 1997; Casanova 2011) for each of the surveyed BEN wetlands.

Functional Group Code	Arf	ARp	ATe	ATl	Sr	Tda	Tdr
Functional Group	Amphibious Fluctuation responder - floating	Aquatic fluctuation responder - plastic	Amphibious fluctuation tolerator - emergent	Amphibious fluctuation tolerator - low growing	Submerged r-selected	Terrestrial damp	Terrestrial dry
Representative species	Azolla, Swamp lily, Common Nardoo	pondweeds, Red water milfoil, some Nardoos	Spike rushes, Knotweeds, Cumbungi, Lignum	Oldman weed	Stonewort, Chara	Common rush, Sedges	Ruby saltbush, Small crumb weed
Coleambally Irrigation Area							
Burrabaroon			**1**				**5**
Wargam Lakes East		**1**	**5**	**3**	**1**	**6**	**14**
Wargam Lakes West		**1**	**2**	**3**		**4**	**17**
Junction wetlands							
Mainie	**1**	**6**	**8**	**3**	**2**	**9**	**15**
Waldaira	**1**	**5**	**6**	**4**	**2**	**8**	**9**
Lowbidgee							
Murrundi	**1**	**4**	**9**	**3**		**6**	**11**
Narwie	**2**	**2**	**5**	**3**	**1**	**4**	**10**
Steam Engine	**2**	**4**	**5**	**3**		**5**	**13**
Telephone Creek*	**2**	**4**	**6**	**2**		**11**	**29**
Toogimbie Wetland			**4**	**1**		**5**	**6**
mid-Murrumbidgee							
Coonacoocabil		**1**	**1**	**1**		**3**	**12**
Darlington Point Lagoon	**2**	**4**	**4**	**1**	**1**	**8**	**14**
Turkey Flat	**1**	**3**	**7**	**2**		**3**	**15**
Yanco Ag	**2**	**1**	**5**	**2**		**2**	**3**
Murrumbidgee Irrigation Area							
Campbells Swamp	**2**	**1**	**5**	**1**	**1**	**5**	**10**
Yanco Creek							
Wanganella north	**2**	**4**	**7**	**2**	**1**	**4**	**10**
Wanganella south	**2**	**3**	**8**	**2**		**7**	**13**

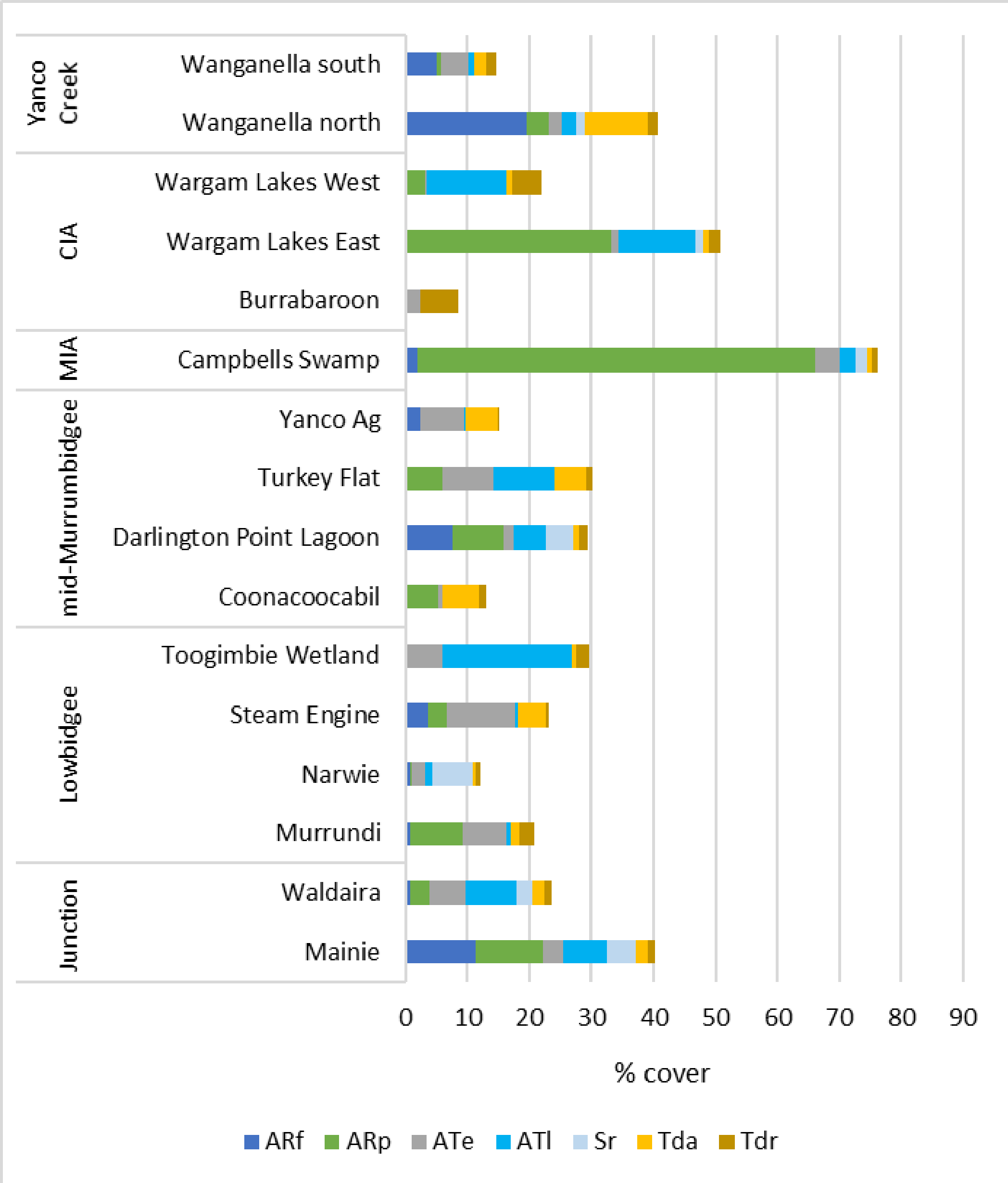

Figure 4 Mean percent cover of wetland vegetational functional groups in transect (averaged for 2020 and 2021 surveys). Arf Amphibious Fluctuation responder- floating, ARp Aquatic fluctuation responder – plastic, ATe Amphibious fluctuation tolerator – emergent, ATl Amphibious fluctuation tolerator - low growing, Sr Submerged r-selected, Tda Terrestrial damp, Tdr Terrestrial dry (Brock and Casanova, 1997; Casanova 2011)

What did Commonwealth environmental water contribute to vegetation community diversity?

Vegetation community structure was tested using multivariate techniques (nMDS) to identify patterns in the overall composition of communities across the benchmarking (BEN) and Murrumbidgee MER (MER) wetlands in 2019-20 and 2020-21. SIMPER analysis in PRIMER 7 was used to identify the species contributing the most to the differences between the benchmarking sites(Table 3), this information can be useful when determining suitable environmental water regimes. As expected species composition varied significantly between wetlands (ANOSIM Global R 0.45, p<0.001), but there was also a high degree of similarity between communities within each region (ANOSIM Global (R): 0.369, p <0.001), meaning that wetland communities within a particular region where more like one another then they were to wetlands outside that region (Figure 5). In terms of species composition the wetlands in the Coleambally Irrigation District tended to be characterised by nardoos (*Marsilea drummondii* and *Marsilea costulifera*) (Table 3). While lignum was a common community determinant through the Lowbidgee Gayini-Nimmie-Caira and Junction wetlands, with milfoils *Myriophyllum verrucosum* and *Myriophyllum papillosum*, and nardoos frequently occurring. Wetlands in the Lowbidgee -Redbank system and mid-Murrumbidgee are characterised by species adapted to deeper, more persistent water including spike rushes (Eleocharis sphacelata, Eleocharis acuta), mud grass (*Pseudoraphis spinescens*), and water primrose (*Ludwigia peploides*). Oldman weed (*Centipeda cunninghamii*) featured in many of the communities across multiple regions.

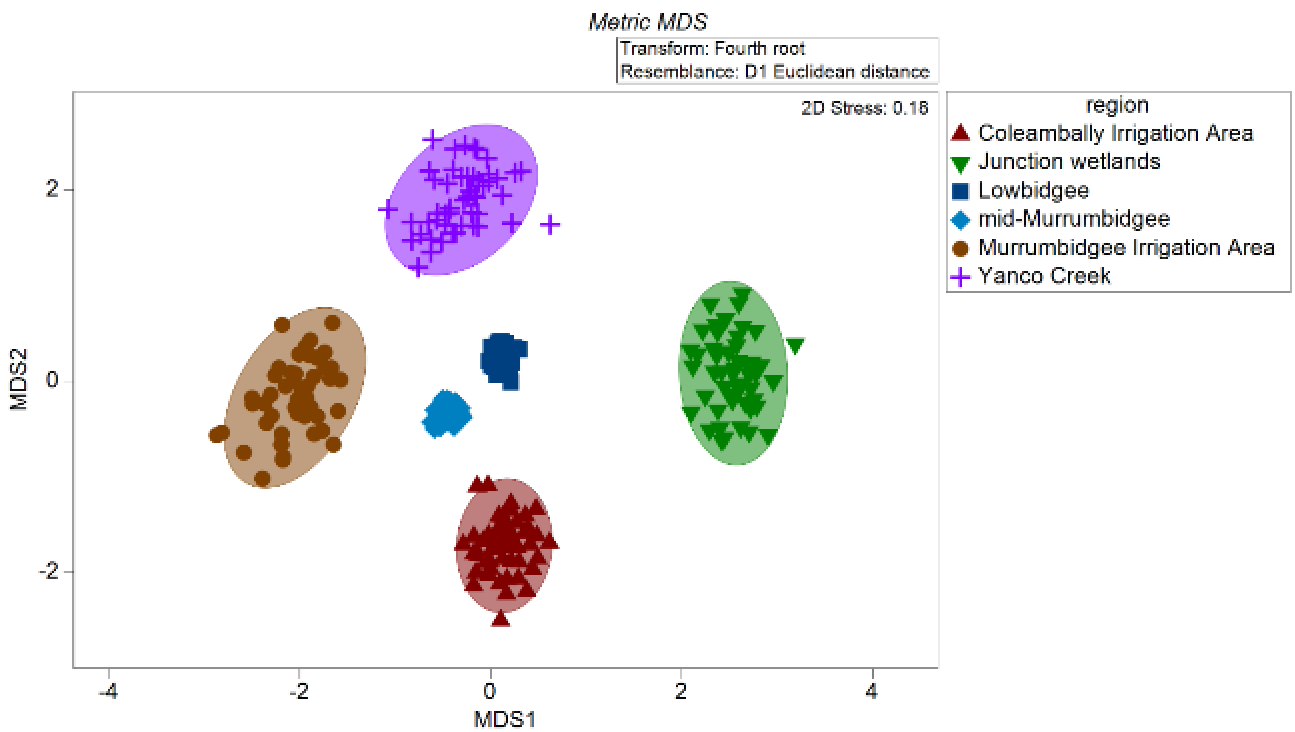

Figure 5 Bootstrapped averages (Primer 7– Clarke and Warwick 2011) of amphibious wetland vegetation 4th root transformed, Euclidean distances across the six survey regions. Includes BEN and MER wetlands between November 2020 and March 2021.

Table 3 SIMPER Amphibious species contributing more than 70% of the differences between wetlands

Region	**Site**	**Species**
CIA	Burrabaroon	*None*
	Wargam Lakes East	*Marsilea drummondii, Marsilea costulifera, Centipeda cunninghamii*
	Wargam Lakes West	*Marsilea costulifera, Myriophyllum verrucosum*
Junction wetland	Mainie	*Duma florulenta, Azolla rubra, Myriophyllum papillosum, Marsilea drummondii*
	Waldaira	*Duma florulenta, Marsilea drummondii, Myriophyllum papillosum, Marsilea costulifera, Centipeda cunninghamii*
Lowbidgee -Gayini Nimmie-Caria	Toogimbie Wetland	*Marsilea drummondii, Duma florulenta, Juncus sp.*
	Eulimbah Swamp*	*Duma florulenta, Myriophyllum verrucosum, Azolla rubra, Myriophyllum papillosum, Eleocharis acuta*
	Avalon Swamp*	*Marsilea drummondii, Duma florulenta*
	Nap Nap Swamp*	*Duma florulenta, Eleocharis acuta, Marsilea drummondii, ,*
	Telephone Creek*	*Duma florulenta, Centipeda cunninghamii*
	Waugorah Lagoon*	*Duma florulenta*
Lowbidgee Redbank	Mercedes Swamp*	*Centipeda cunninghamii, Marsilea drummondii, Ranunculus undosus, Ludwigia peploides Eleocharis sphacelata*
	Piggery Lake*	*Eleocharis acuta, Centipeda cunninghamii, Persicaria decipiens, Myriophyllum papillosum,*
	Two Bridges Swamp*	*Ludwigia peploides Eleocharis sphacelata, Myriophyllum papillosum, Eleocharis acuta, Centipeda cunninghamii*
	Murrundi	*Eleocharis sphacelata, Eleocharis acuta, Ludwigia peploides, Myriophyllum papillosum*
	Narwie	*Eleocharis acuta, Pseudoraphis spinescens, Algae, Ludwigia peploides*
	Steam Engine	*Eleocharis sphacelata, Eleocharis acuta, Pseudoraphis spinescens*
mid-Murrumbidgee	Coonacoocabil	*Ludwigia peploides*
	Darlington Point Lagoon	*Centipeda cunninghamii, Ludwigia peploides, Myriophyllum verrucosum, Eleocharis acuta*
	Turkey Flat	*Marsilea drummondii, Cyperus difformis, Ludwigia peploides*
	Yanco Ag	*Eleocharis sphacelata, Eleocharis acuta*
	Gooragool	*Persicaria decipiens, Centipeda cunninghamii*
	Sunshower Lagoon	*Eleocharis acuta*
	Yarradda Lagoon	*Centipeda cunninghamii, Persicaria decipiens,*
MIA	Campbells Swamp	*Duma florulenta, Azolla rubra*
Yanco Creek	Wanganella north	*Ludwigia peploides, Eleocharis acuta, Marsilea drummondii, Pseudoraphis spinescens, Myriophyllum papillosum*
	Wanganella south	*Persicaria lapathifolia, Ludwigia peploides, Juncus sp., Paspalum distichum*

To help clarify patterns in communities the MDS data has been replotted for each site by region (Figure 6). As expected species composition varied significantly between wetlands (ANOSIM Global R 0.45, $p<0.001$). There are generally strong groupings for wetland sites within the mid-Murrumbidgee and Lowbidgee meaning that wetland vegetation communities in these regions have greater overlap in term of species composition. Wanganella swamp in the Yanco system also has a very high level of variability between sites (Wanganella east and west) and transects. There was also a greater level of dispersion within the CIA, MIA, Yanco and Junction which partly reflects the smaller number of sites within these regions.

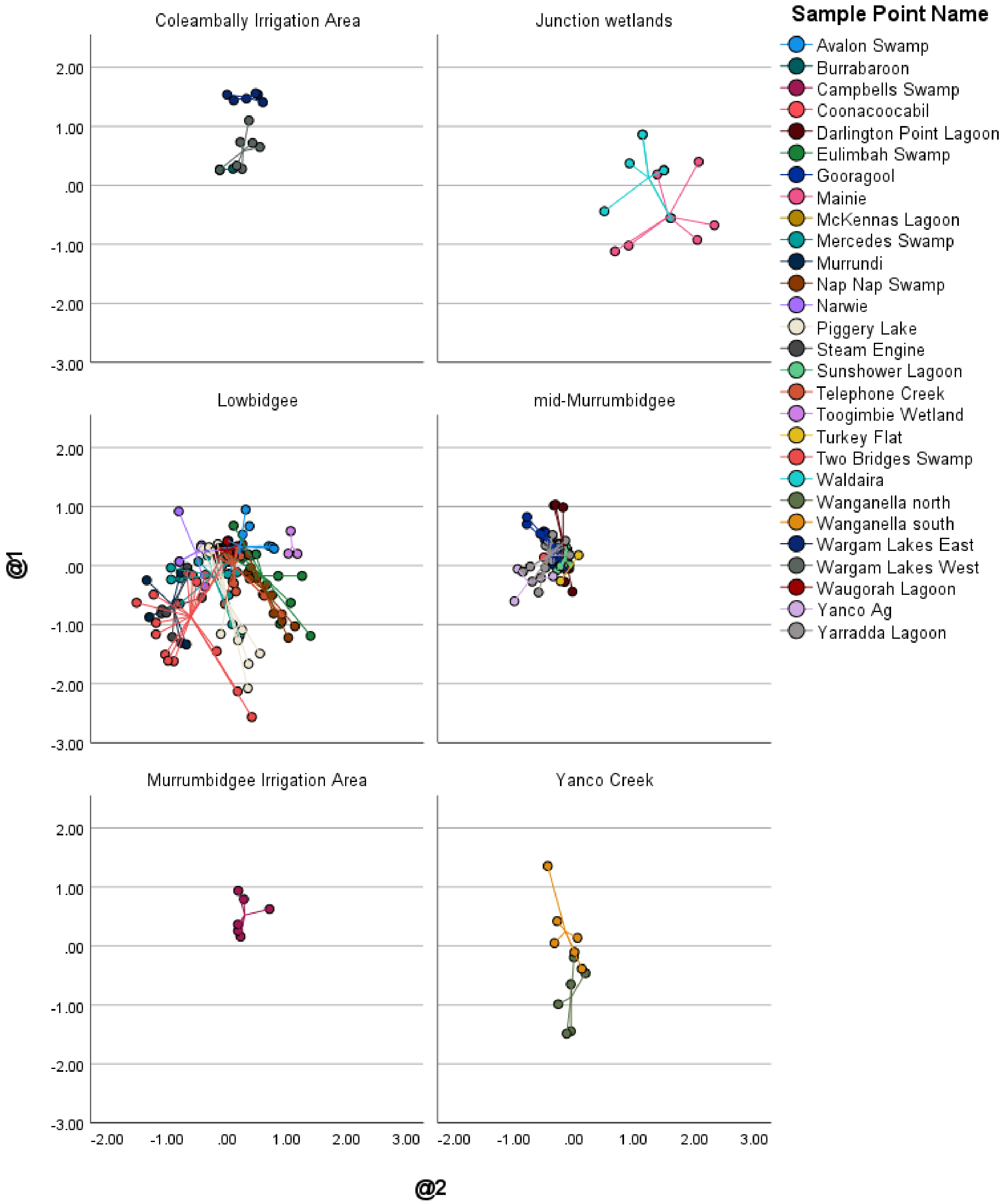

Figure 6 metric MDS (Primer 7– Clarke and Warwick 2011) of amphibious wetland vegetation 4th root transformed, Bray Curtis similarity at the BEN and MER wetlands between January 2020 and March 2021

What did Commonwealth environmental water contribute to tree condition?

Tree condition reflects both longer term stress and recent responses to inundation. For example evidence of dieback and epicormic growth is common in trees that have been subject to extended water stress in the past followed by improving levels of water availability (Souter et al. 2010, Souter 2019). This situation is very common through the Murrumbidgee with trees suffering significant declines in condition during the millennium drought (Wen et al. 2009) followed by partial recovery as managed wetland inundation increased.

Tree condition varied considerably between and within wetlands (Figure 7). Overall levels of dieback and negative indicators of tree condition such as bark cracking, epicormic growth were highest at Campbells in the MIA and Wagram West in the CIA. In the Junction wetlands, River Cooba condition was generally poor in areas that received limited environmental water, for example River Cooba on transect 1, Quadrat 1 at Waldaira but improved in areas which received more environmental water.

Waldaira Transect 1 Quadrat 1

Waldaira transect 1 Quadrat 20

Plate 3 River Cooba condition at Waldaira transect 1 (top) water stressed River Cooba and (bottom) recovering River Cooba

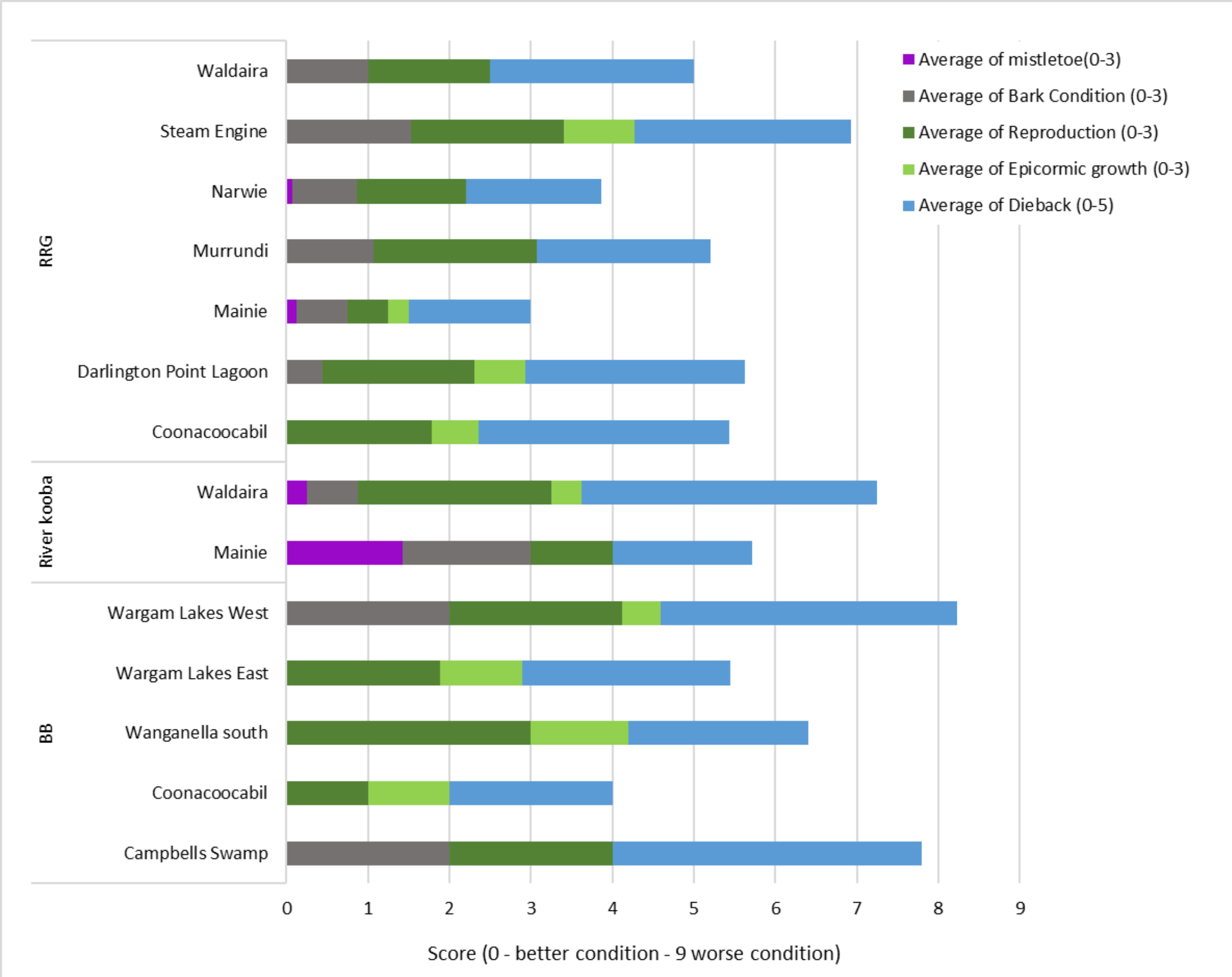

Figure 7 Aggregated tree condition scores. Lower scales are generally indicative of trees in better condition. Note that wetlands dominated by shrubs (such as Lignum, rushes) and without a dominant over story are not included.

4. Discussion and Recommendations

The benchmarking program considered wetlands across five regions over a two year period. Each region supported distinct aquatic vegetation communities across a range of wetland types. We compared vegetation communities within the benchmarking sites to those of the longer-term monitoring sites and found similarities with respect to the Oxbow lagoon system in the Murrumbidgee (Darlington Point, Coonancoocabil and Yanco Ag) as with the north and south Redbank systems in Lowbidgee with Narwie West, Murrundi and Steam Engine supporting very similar communities to those in the south Two Bridges, Mercedes and Piggery. SIMPROF analysis indicated that the Junction wetlands: Maine and Waldaira supported similar communities to those in the Gayini-Nimmie Caria, while Toogimbie was similar to other Lignum systems through Gayini. Similarities between wetland vegetation communities within the mid-Murrumbidgee, Lowbidgee and Junction means that outcomes and management recommendations can be broadly generalised for these regions. Table 4 presents a summary of the likely water requirements for each of the benchmarked sites with respect to maintaining conditions to support growth and survival, and reproduction. However, the complexity of aquatic plant communities requires a much more nuanced watering response. There is strong evidence (Rogers *et al*, 2012) that using 'representative species' flow requirements to guide management may be effective at a macroscale, but small scale differences in watering maximises overall landscape biodiversity.

North Redbank wetlands may not be receiving water for sufficient duration to support reproduction in summer, with evidence of amphibious plant species becoming dry prior to flowering and setting seed. Extending duration of inundation of these wetlands to accommodate summer flowering may be required.

The Junction wetlands support a unique complex and high value aquatic community, this reflects the underlying bathymetry that generates a high level of hydrological diversity (range of water depths and inundation durations) (Plate 4). Maintenance of hydrological diversity is essential for maintaining a diverse amphibious plant community. We do not have past baseline vegetation data against which we can reference the recovery of vegetation communities. It is likely that sections of the wetland targeted for regular inundation are in good condition, while areas close to the levee bank may be experiencing higher water depth and longer durations that might occur naturally. However, the overall impact of these levees on wetland condition is likely to be minimal and localised. In complex wetlands, frequent inundation and long duration of inundation may contribute to declines in species richness as can prolonged drying (Campbell et al. 2021). In wetland systems, frequent partial watering of deeper areas in the absence of larger freshes that inundate the wetlands edges, can lead to declining diversity over time (Wassens et al. 2017).

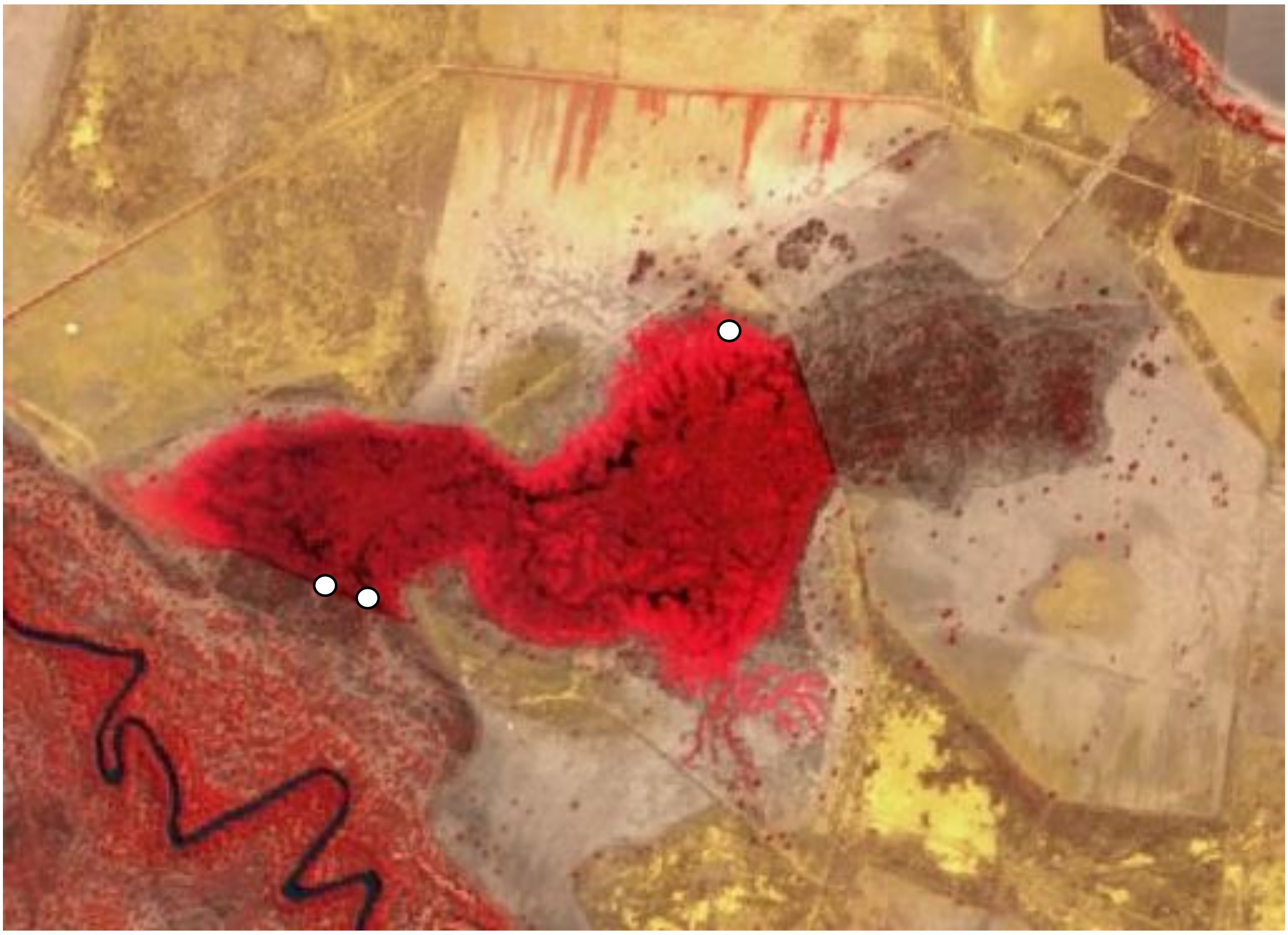

Plate 4 Colour infrared (vegetation) bands 19/02/2021 8,4,3 of Mainie Swamp Junction red areas show actively growing vegetation dark areas of open water. Approximate location of survey transects indicated by white circles. The complex underlying bathymetry is observable.

CEW plays a particularly important role in maintaining aquatic communities that require a higher frequency of inundation. Very few of these high value aquatic communities would persist in the absence of CEW because the required inundation frequency cannot be met through unregulated flows alone.

Table 4 Recommended watering targets based on growth and survival (Roberts and Marston 2011) and reproduction (Roberts and Marston 2011; Higginson et al. 2018)

			Inundation requirements for growth and survival			Inundation requirements for reproduction	
Full site name	**Dominant overstory**	**Key understory species (SIMPER)**	**Frequency (years)**	**Duration (months)**	**Timing**	**Timing**	**Duration**
Yanco Ag (McCaugheys) Lagoon	River red gum	*Eleocharis sphacelata, Eleocharis acuta*	1-3	7-8	winter to summer	spring-summer	4-6 weeks
Murrindi Swamp	River red gum	*E. sphacelata, E. acuta, Ludwigia peploides, Myriophyllum papillosum*	1-3	7-8	winter to summer	spring-summer	4-6 weeks
Narwie East Swamp	River red gum	*Eleocharis acuta, Pseudoraphis spinescens, L. peploides*	1-3	7-8	winter to summer	spring-summer	4-6 weeks
Steam Engine Swamp	River red gum	*E. sphacelata, E. acuta, P. spinescens,*	1-3	7-8	winter to summer	spring-summer	4-6 weeks
Turkey Flats Wetland	River red gum	*Marsilea drummondii, Cyperus difformis, L. peploides*	1-3	7-8	winter to summer	spring-summer	4-6 weeks
Coonacoocabil Lagoon	River red gum	*L. peploides*	1-3	5-7	spring-summer	spring-summer	4-6 weeks
Darlington Point Lagoon	River red gum	*Centipeda cunninghamii, L. peploides Myriophyllum verrucosum, E. acuta*	1-3	5-7	spring-summer	spring-summer	4-6 weeks
Wanganella swamp south	Nil	*Persicaria lapathifolia, L. peploides, Juncus sp., Paspalum distichum,*	1-3	4-6	spring-autumn	Spring to autumn	<4 weeks
Wanganella swamp north	Nil	*L. peploides, E. acuta, Marsilea drummondii, P. spinescens, M. papillosum*	1-3	4-6	spring-summer	spring-summer	4-6 weeks
Burrabaroon swamp	Black box	*None*	3-5	3-6	not critical	spring	2-20 days
Wargam Lakes East	Black box	*M. drummondii, Marsilea costulifera, Centipeda cunninghamii*	3-5	3-6	not critical (Black Box)	spring-summer	20 days
Wargam Lakes West	Black box	*M. costulifera, M. verrucosum*	3-5	3-6	not critical (Black Box)	spring-summer	20 days
Campbell Swamp	Lignum	*D. florulenta, A. rubra, Phragmites*	3-5	3-6	not critical	spring-summer	20 days
Toogimbie lagoon	Black box/Lignum	*M. drummondii, D. florulenta, Juncus sp.*	3-5	3-6	not critical	spring-summer	20 days
Mainie Swamp	River Cooba/Lignum	*D. florulenta, A. rubra, M. papillosum, M. drummondii*	3-7	2-3	not critical	spring-summer	20 days
Waldaira lagoons	River Cooba/Lignum	*D. florulenta, M. drummondii, M. papillosum, M. costulifera, C. cunninghamii*	3-7	2-3	not critical	spring-summer	20 days

4.1 Recommendations

Within wetlands, depth and inundation frequency shape vegetation community composition and diversity. Species including *Centipeda* (old man weed), *Alternanthera* (Joyweeds) and *Marsilea* (nardoos), are typically associated with shallow edges that have short periods of inundation, while water milfoils and water ribbons (Vallisneria sp.) occur in deeper, persistent sections of the wetland (Plate 6). Delivering water water to bankful stage (See Plate 5) with water extending into the tree line and then allowing natural draw down is the best way to maintain the range of plant lifeforms occurring within the wetland.

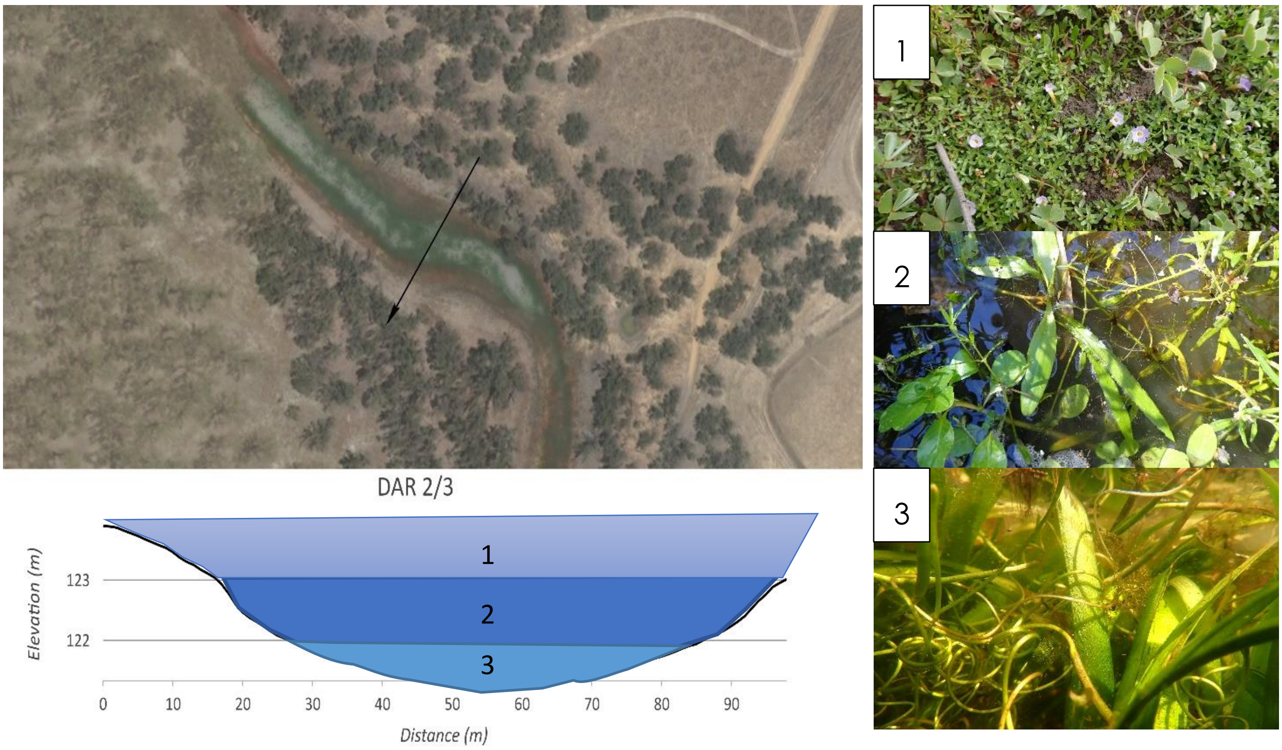

Plate 5 Conceptual representation on the types of water dependent vegetation communities. 1 shallow edge species occurring when the wetland is filly inundated, 2 water responding species that grow in shallower, but more persistent water, and 3 deep water specialists that require longer durations of inundation.

North Redbank wetlands may not be receiving water for sufficient duration to support reproduction in summer (Plate 6). Delivering water earlier in spring and maintaining longer periods of inundation to accommodate summer flowering may be required.

Plate 6 Murrundi North Redbank Feb 2021 Transect 1 showing drying spike rush

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Appendix 1 Wetland vegetation. Status N=Native, I = introduced

group	Common name	Scientific name	status	Burrabaroon	Wargam Lakes East	Wargam Lakes West	Mainie	Waldaira	Murrundi	Narwie	Steam Engine	Toogimbie Wetland	Coonacoocabil	Darlington Point Lagoon	Markeys	Turkey Flat	Yanco Ag	Campbells Swamp	Wanganella north	Wanganella south
Amphibious	Algae	Algae	N					2		4				1				2	6	
	Australian mudwort	Limosella australis	N				1				2			2	1					
	Azolla	Azolla rubra	N				6	2		1	2			3	3	2	1	9	3	3
	Chara spp.	Characeae, Charophyta	N				3								3					
	Common rush	Juncus usitatus	N		1															
	Common sneezeweed	Centipeda cunninghamii	N		4	7	2	8	3	3	7		1	8	1	1	1		2	6
	Common spike rush	Eleocharis acuta	N		2		2	2	9	7	9	6		5	1	2	3		7	
	Common watermilfoil	Myriophyllum papillosum	N				5	8	6	1	1				3				7	3
	Dirty dora	Cyperus difformis	N		1		2	7	6					3	1	3	1		6	5
	Duckweed	Lemna disperma	N							4	5			1			3	2	3	3
	Dwarf sedge	Cyperus pygmaeus	N				1													
	Floating pondweed	Potamogeton tricarinatus auct.	N				4		2					2	2					
	Hornwort	Ceratophyllum demersum	N		1															
	Lignum	Duma florulenta	N	2		8	6	8				6			3			9		3
	Mudgrass	Pseudoraphis spinescens	N				3	5	3	4	7				1				7	2
	Mudmat	Glossostigma elatinoides	N																4	
	Nardoo	Marsilea drummondii	N		4	8	5	8	3	2	8	6			3	3	1	1	8	5
	Narrow nardoo	Marsilea costulifera	N		6	3	3	6	4	2	2				3					
	Narrow pondweed	Potamogeton octandrus	N					1												
	Pale knotweed	Persicaria lapathifolia	N		4	4							1	6		2	1	1	4	7
	Phragmites	Phragmites australis	N							2										
	Princes plume	Persicaria orientalis	N											1						
	Red watermilfoil	Myriophyllum verrucosum	N		6	2	1							6		1		4		
	Rush	Juncus sp.	N		4							6								6
	Slender Knotweed	Persicaria decipiens	N				1		2							1		6		4
	Small nardoo	Marsilea hirsuta	N					2												
	Small spike rush	Eleocharis pusilla	N				2	3	2	2	2	4			1				2	
	Starfruit	Damasonium minus	N					5	6		2					1			1	3
	Stonewort	Nitella sp.	N				2	4							2					
	Swamp lily	Ottelia ovalifolia	N				2								2					
	Tall spike rush	Eleocharis sphacelata	N						9	1	9						3			
	Typha	Typha sp.	N				2		4							2	1	3	1	3
	Umbrella Sedge	Cyperus eragrostis	I					2	1							2				
	Water couch	Paspalum distichum	N						4	4	2					2		3	2	6
	Water primrose	Ludwigia peploides ssp. montevidensis	N					5	5	5	6		2	7		3			9	7
	Water ribbon	Cycnogeton procerum	N														1			

	Waterwort	Elatine gratioloides	N				3	2							3					
	Wavy Marshwort	Nymphoides crenata	N						2											
Terrestrial	Australian hollyhock	Malva preissiana	N									2								
	Barnyard grass	Echinochloa sp.	I													1			6	
	Barrel Medic	Medicago truncatula	I							1										
	Bathurst burr	Xanthium spinosum	I				1	2	3	2	3				1					1
	Berry saltbush	Rhagodia spinescens	N	4		2							1	8						3
	Black berry nightshade	Solanum nigrum	I		1	2			1		1		1							
	Black roly poly	Sclerolaena divaricata	N		2	3	1	6		1			1		1				2	
	Blue rod	Stemodia florulenta	N				1					2		2	1					
	Bulbine lily	Bulbine bulbosa	N		1															
	Burr medic	Medicago polymorpha	I			2														
	Cane grass	Eragrostis australasica	N				1								1					
	Caustic weed	Euphorbia drummondii	N					2	1	3	8		2	4		1	1	1	2	
	Climbing saltbush	Einadia nutans	N													1				
	Common Joyweed	Alternanthera nodiflora	N		1	6												1		4
	Common sowthistle	Sonchus oleraceus	I								1									
	Common verbena	Verbena officinalis	I											1		2				
	Cotton fireweed	Senecio quadridentatus	N											4						
	Cottonbush	Maireana aphylla	N																2	
	couch	Cynodon dactylon	N					2										6		
	Creeping knotweed	Persicaria prostrata	N			6	1				6		1		1					3
	Creeping saltbush	Atriplex semibaccata	N	2										5		1				2
	Curled dock	Rumex crispus	I		1			2				2		2		1		7		5
	Daisy sp	Asteraceae	N													1				
	Desert cucumber	Zehneria micrantha	N				1								1					
	Fleabane	Erigeron bonariensis	I						1				2	3						1
	Forb	unknown	I				1													
	Grass	Grass	I				1					2			1					
	Green copperburr	Sclerolaena decurrens	N											2						
	Grey raspwort	Haloragis glauca	N				1													
	Grey sunray	Rhodanthe corymbiflora	N										2							
	Hairy carpet weed	Glinus lotoides	N							1										
	Hairy Joyweed	Alternanthera nana	N				1								1					
	Hairy panic	Panicum effusum	N						2		1					1		3		
	Hairy pod cress	Harmsiodoxa blennodioides	N													1				
	Heliotrope	Heliotropium europaeum	I		2	6	2	4			2	2			1			2		
	Heliotropium unknown? WAE 2_3	Heliotropium sp	I		1	4														
	Hop clover	Trifolium campestre	I			1														
	Horehound	Marrubium vulgare	I		1	1										1				1

	Hyssop loosestrife	Lythrum hyssopifolia	N		1		2							1	1			1		5
	Jerry jerry	Ammannia multiflora var. multiflora	N				1													
	Jersey cudweed	Pseudognaphalium luteoalbum	N						1	1										
	Lagoon spurge	Phyllanthus lacunarius	N				2								1					
	Lesser joyweed	Alternanthera denticulata	N		3	3	3	8	9	1	7	2	1	8	2	3	3	4	6	5
	Lippia	Phyla canescens	I					5	7	1		4		3						2
	Maireana sp.	Maireana sp.	N										1							
	Monkey flower	Mimulus gracilis	N				1	2												
	Nitre goosefoot	Chenopodium nitrariaceum	N	6	2	9		4				4							9	
	Noogoora burr	Xanthium occidentale	I		1								1	2		2	2		2	4
	Paddy melon	Citrullus amarus	I		1	2	1												2	
	Pale poverty bush	Sclerolaena diacantha	N	4																
	Pattersons curse	Echium plantagineum	I		1													2		
	Pig weed	Portulaca oleracea	N		3	2		2												
	Poison pratia	Lobelia concolor	N								1									
	Prickly lettuce	Lactuca serriola	I			2			1									4		8
	Quena	Solanum esuriale	N		1		1				2				1			4		
	Red flowered mallow	Modiola caroliniana	I			2														
	River bluebell	Wahlenbergia fluminalis	N						1		1		1	1						
	River Cooba	Acacia stenophylla	N				2	2							2					
	River cress	Rorippa eustylis	N						1		1									
	River red gum seedling	Eucalyptus camaldulensis	N						2	7	4		2	7		1				
	Ruby saltbush	Enchylaena tomentosa	N	2						1										3
	Salsola	Salsola australis	N		1											2				6
	Skeleton weed	Chondrilla juncea	I										1							
	Slender dock	Rumex brownii	N		1	6		6	6			2		2			1	5	4	
	Small crumbweed	Dysphania pumilio	N		2	8	2	1	8	5	8		1	7	1	1	1	2	2	3
	Small knotweed	Polygonium plebeium	N		1															
	Spear thistle	Cirsium vulgare	I							1	4			2				1	4	7
	Speedwell	Veronica peregrina	I					4												
	Spreading goodenia	Goodenia heteromera	N				2								1					
	Tall fleabane	Erigeron sumatrensis	I													1				
	Tall groundsel	Senecio runcinifolius	N			2														
	Trailing verbena	Verbena supina	I				1													
	Tufted burr daisy	Calotis scapigera	N										1	6						
	Twining toad flax	Kickxia elatine	N													2			4	
	Unknown shrub Bitou bush?	Chrysanthemoides monilifera	I			6														
	Wallaby grass	Rytidosperma	N								1									
	Warrego summer grass	Paspalidium jubiflorum	N					4	2	1				2					3	1
	White clover	Trifolium repens	I				1								1					
	White top	Rytidosperma caespitosum	N									4								
	Wild mustard	Sisymbrium sp.	I																	1
	Wireweed	Polygonum aviculare	I			6	1		4			2		2	1	2		5	6	3

	Yellow twin heads	*Eclipta platyglossa*	N					3	5	2	9	2		2						
	Yellow wood sorrel	*Oxalis corniculata*	I								1									