Spring & Summer Wetland Vegetation Intervention Monitoring Gunbower Forest

June 2016

Fire Flood & Flora

Australian Government
MURRAY–DARLING BASIN AUTHORITY
NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

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Cover photograph: Reedy Lagoon, Gunbower Forest, November 2015 (D. Osler)

EXECUTIVE SUMMARY

- Fire, Flood and Flora was engaged by the North Central Catchment Management Authority to undertake spring and summer sentinel wetland vegetation intervention monitoring in Gunbower Forest.
- The primary aim of monitoring was to capture the seasonal response of wetland vegetation to the second flow of environmental water delivered (eFlow) to the forest through the Hipwell Regulator during the 2015 spring period.
- The secondary aim was to assess the condition of the wetland vegetation and report on progress toward Icon Site ecological objectives.
- The presence of aquatic and amphibious species in the eleven wetland monitoring sites in spring 2015 and summer 2016 suggests that the 2015 eFlow triggered seed and spore germination, and resprouting in wetland flora.
- The range and maximum species diversity was higher in the wetlands inundated earlier and for longer (i.e. wetlands inundated via Hipwell Regulator).
- There appears to be a weak negative relationship between species diversity and water depth (i.e. higher diversity at lower depths). It is however difficult to separate the effect of depth from season and turbidity, as the wetlands were typically deeper and less turbid in spring than summer.
- It is likely that multiple influences and stressors (see Bennetts & Sim 2016) are interacting with the wetland flora, as well as local environmental and climatic conditions, making the results for wetlands, even within the same Wetland Phase Class, highly variable and difficult to interpret.

Management Recommendations:

Where practical, it is recommended, based on the findings in the current study to:

- Deliver environmental water early in spring rather than later in spring, and
- Prioritise environmental water delivery in years predicted to receive average or above spring and summer rainfall, over years predicted to receive below average rainfall.

Research Recommendations:

- In order to investigate the influence of water regime on wetland flora while eliminating the variability caused by combining results for different wetlands, we recommend focusing in detail on two case study wetlands – Reedy and Little Reedy Lagoons.
- We also recommend researching the ecological drivers of vegetation in wetland areas with high diversity additional to the sentinel wetland monitoring sites.

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Term/Acronym	**Definition in this report**
Black Swamp (BLS)	Wetland monitoring site, includes two transects (BLS1 & BLS2)
Charcoal Swamp (CS)	Wetland monitoring site, comprises one transect
CMA	Catchment Management Authority
Compliant	Index score that meets or exceeded the indicator PoR
Component	An ecological attribute monitored to report on condition (e.g. threatened flora species richness).
Corduroy Swamp (COS)	Wetland monitoring site, comprises one transect
Ecological objective	The stated reason for including this ecological component in the program. Comparable with management objective.
eFlow	Environmental water delivered to ecological assets.
Extent	Short for 'spatial extent', the distribution of the organism in the environment.
Football Grounds (FB)	Wetland monitoring site, comprises one transect
Green Swamp (GS)	Wetland monitoring site, comprises one transect
Healthy	Site - Meeting or exceeding the PoR in all condition indicators (i.e. compliant). Broad vegetation type – Meeting the target percentage of sites that meet or exceed the PoRs.
Icon Site score	Compliance of quadrat/wetland level indices at an Icon Site level.
Index	A reported measure (some type of summary of the Indicator; see below), usually compared against a PoR. For example, weediness may be the ecological indicator of condition, and the measured presence of weeds at a site may be the Index.
Indicator	A component or aspect of the ecosystem that provides information on the condition or state of the ecosystem.
Iron Punt Lagoon (IPL)	Wetland monitoring site, comprises one transect
Little Gunbower Complex (LG2)	Wetland monitoring site, comprises one transect
Little Gunbower Creek (LG1)	Wetland monitoring site, comprises one transect
Little Reedy Lagoon (LR)	Wetland monitoring site, comprises two transects (LR1 & LR2)
Long Lagoon (LL)	Wetland monitoring site, comprises one transect
Maintain	Retain similar PFG species richness, appropriate to the stage of wetting and drying, and canopy condition over time, to that sampled in the first year of the monitoring program (2005).
MDBA	Murray Darling Basin Authority
Plant Functional Groups (PFGs)	Plants grouped based on common ecological, morphological and functional responses to inundation based on a system adapted from Brock and Casanova (1997) (See Appendix 1 in the current report.)
Point of Reference	The 90^{th} percentile value for the indicator component across the autumn 2005-2014 sampling period.

Term/Acronym	Definition in this report
(PoR)	
Promote	Undertake actions that facilitate vegetation processes important for ecosystem function (e.g. nutrient cycling, energy flow, interactions).
Receding (R)	Receding wetland phase class
Recently Inundated (RI)	Recently inundated wetland phase class
Reedy Lagoon (RL)	Wetland monitoring site, comprises three transects (RL1, RL2 & RL3)
Species diversity	The 'effective number of species' or 'true diversity'.
Water regime class (WRC)	WRCs are a classification system that describes broad vegetation communities in Gunbower Forest based on forest stand-class and hydrological mapping (Crome 2004a).
Wetland Phase Classes	Classes of wetlands based on the hydrological regime (i.e. receding, dry, recently inundated).

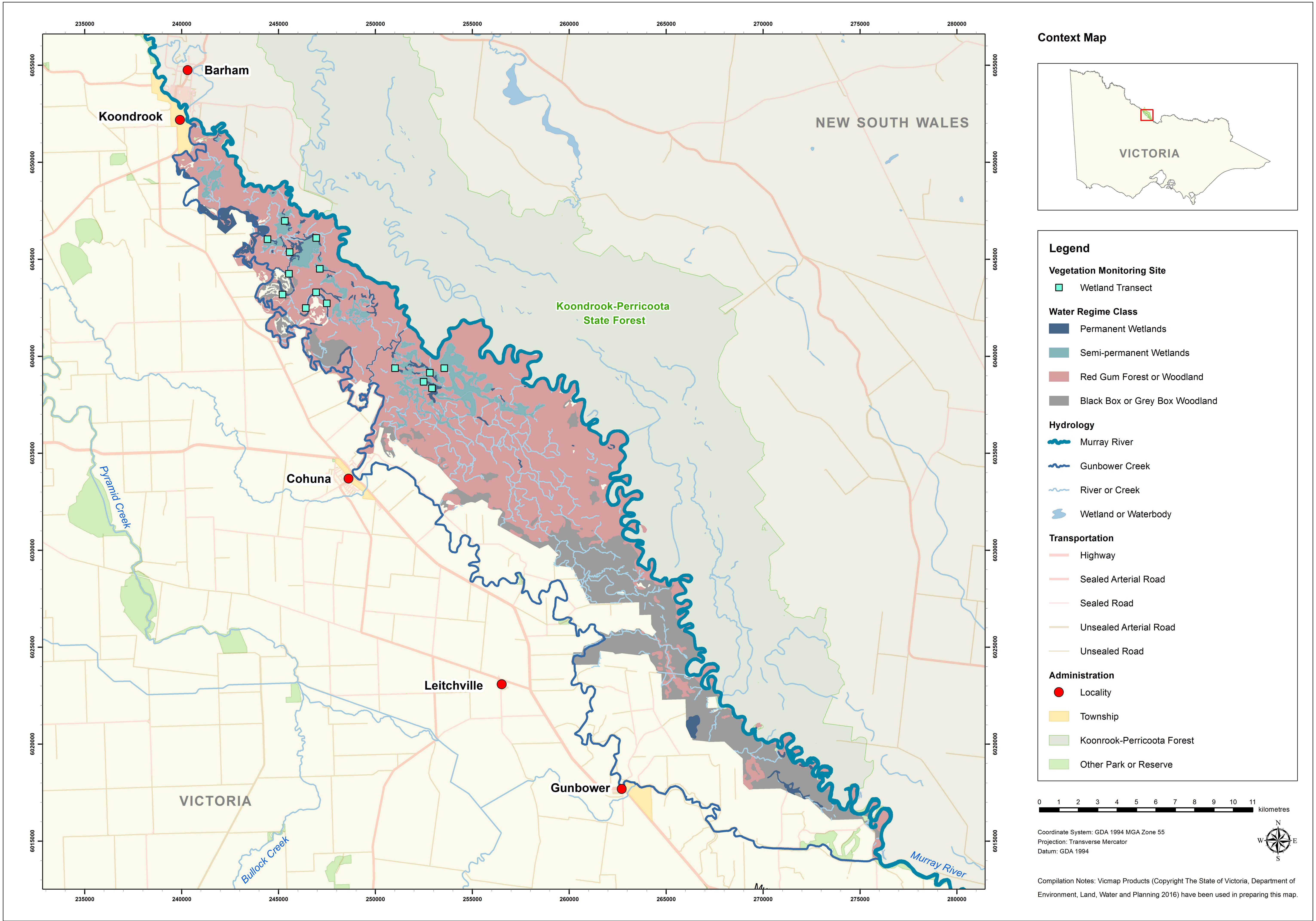
1 INTRODUCTION

Wetland flora were surveyed in Gunbower Forest, a Murray Darling Basin Icon Site, in spring 2015 and summer 2016. The primary aim was to capture the seasonal response of wetland vegetation to environmental water delivered (eFlow) in spring 2015. The secondary aim was to assess progress toward vegetation health targets and ecological objectives for Gunbower Forest. The North Central Catchment Management Authority's (CMA) objective for the 2015 watering event was to improve vegetation health, waterbird populations and the succession of small bodied fish species in forest wetlands (North Central CMA 2015).

The current report presents the outcomes from the intervention monitoring undertaken by Fire Flood & Flora, in partnership with Dr Lien Sim, for the North Central CMA. It includes an account of the data collection, analysis and results, along with a discussion of the findings and recommendations to advance our understanding of the forest's wetland and floodplain ecology.

1.1 Study area

The 11 wetland monitoring sites are located in the north-west of Gunbower Forest (Figure 1). They range in size, shape, depth and bathymetry. Wetland types represented include paleo-channels (e.g. Reedy and Iron Punt Lagoons, Black and Green Swamps, Little Gunbower Creek and Football Grounds) and low lying openings in the swamp forest (i.e. Little Reedy and Long Lagoons, Charcoal and Corduroy Swamps, and Little Gunbower Complex). Consequently each wetland and its governing water regime differ from the other sites monitored.



Barham
Koondrook
Cohuna
Leitchville
Gunbower
NEW SOUTH WALES
VICTORIA
Koondrook-Perricoota State Forest
Pyramid Creek
Bullock Creek
Murray River
Context Map
VICTORIA
Legend
Vegetation Monitoring Site
Wetland Transect
Water Regime Class
Permanent Wetlands
Semi-permanent Wetlands
Red Gum Forest or Woodland
Black Box or Grey Box Woodland
Hydrology
Murray River
Gunbower Creek
River or Creek
Wetland or Waterbody
Transportation
Highway
Sealed Arterial Road
Sealed Road
Unsealed Arterial Road
Unsealed Road
Administration
Locality
Township
Koonrook-Perricoota Forest
Other Park or Reserve
0 1 2 3 4 5 6 7 8 9 10 11 kilometres
Coordinate System: GDA 1994 MGA Zone 55
Projection: Transverse Mercator
Datum: GDA 1994
Compilation Notes: Vicmap Products (Copyright The State of Victoria, Department of Environment, Land, Water and Planning 2016) have been used in preparing this map.

1.2 Flooding History

In 2015 wetlands in the mid-landscape (e.g. Little Reedy Lagoon and Greens, Corduroy and Charcoal Swamps) were 'topped up' in mid-spring via the Hipwell regulator. Environmental water was delivered through the Hipwell regulator for 75 days and was observed in Little Reedy Lagoon, and presumably other wetlands nearby, on the 22 September 2015 (K. Woods April 2016 pers. comm.). Wetlands in the lower-landscape (e.g. Long, Iron Punt and Reedy Lagoons, Little Gunbower Creek and Complex, Black Swamp and Football Grounds) were inundated in late-spring (November) via regulators on Gunbower Creek (Figure 2). The lower landscape wetlands were delivered water for between 35 and 37 days.

It has been estimated that the mid-landscape wetlands were inundated for 62 days prior to sampling in November 2015, whereas the low-landscape wetlands were inundated for less than 45 days at this time. Water delivery ceased around four days prior to flora sampling. Water depth is therefore likely to have been close to maximum.

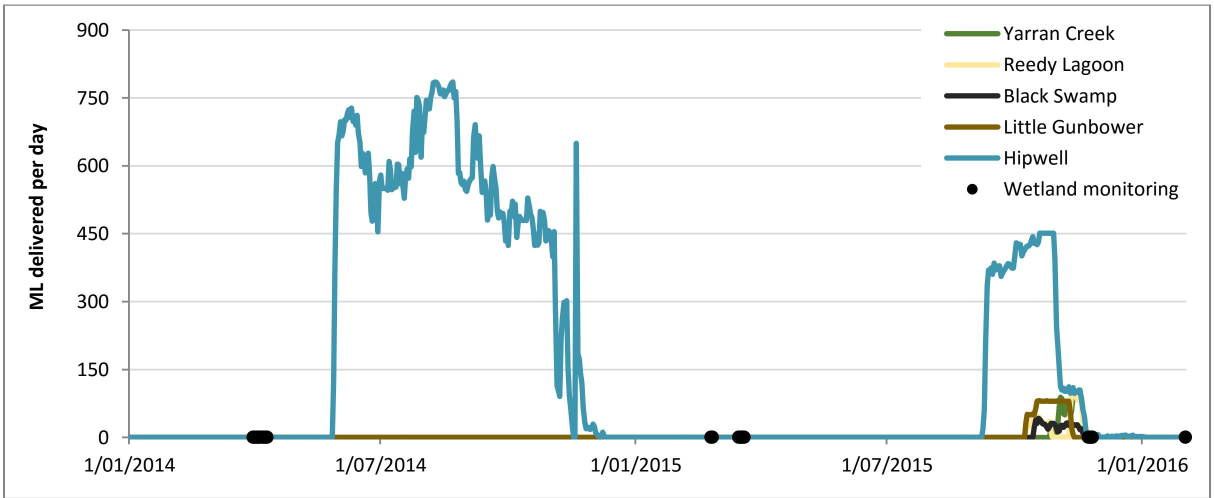


Figure 2 Combined environmental water delivered (source: North Central CMA 2016) and timing of wetland vegetation monitoring events, Gunbower Forest, 2014-2016.

1.3 Icon Site Objectives

Ecological objectives have been developed to guide environmental water delivery in Icon Sites. For example, the ecological objective for Gunbower Forest wetlands is - 80% of permanent and semi-permanent wetlands in healthy condition (MDBA 2012). Monitoring of biotic components of the floodplain is undertaken in order to determine progress towards objectives, typically, as part of the condition monitoring program.

Four vegetation indicators have been developed to quantify wetland condition and report on ecological objectives in Gunbower Forest. (See Sim & Bennetts 2014 and Sim 2015):

- Characteristic PFG species richness
- Characteristic PFG species cover

- Presence of threatened species
- Absence of high threat weed species.

The premise for the vegetation indicators is that wetlands are dynamic ecosystems, the flora composition of which varies spatially and temporally in response to flooding and rainfall. Further, that the richness, cover, rarity and origin of flora species observed provide an indication as to the wetland's condition or 'health'. It is expected the richness and cover of characteristic PFG species and occurrence of threatened species will increase with flooding, while the occurrence of high threat weed species will decrease.

The vegetation indicators are trialled in the current intervention monitoring project for benchmarking spring and summer wetland condition and reporting on ecological objectives. It should be noted, however, that the condition monitoring tool was developed from autumnal (2005 – 2014) flora data.

2 METHODS

2.1 Field Survey

A field survey of the wetland monitoring sites was undertaken between the 23rd and 26th of November 2015 (spring) and the 1st and 4th February 2016 (summer). All 15 transects established within the 11 wetland monitoring sites in Gunbower Forest (Table 1) were sampled in accordance with the Manual of Field Procedures for Monitoring in Gunbower Forest (Crome 2004b).

All ground flora species that occurred within each two metre wide vegetation zone along the wetland transects, were identified to a species level, and projected foliage cover (percentage) was estimated. The plant taxonomy that was employed follows the Victorian Plant Name Index (DELPW 2015), with consideration to the Census of Victoria Vascular Plants (Walsh & Stajsic 2015).

Table 1 Total number of wetland sites sampled spring 2015 and summer 2016, Gunbower Forest.

Wetland Sites	Wetland code	No. of transects	Sampling year & Wetland Phase Class (refer to Table 3)	
			November 2015	February 2016
Black Swamp	BLS	2	Recently inundated	Receding, shallowly inundated
Corduroy Swamp	COS	1	Recently inundated	Receding, shallowly inundated
Green Swamp	GS	1	Recently inundated	Receding, deeply inundated
Little Gunbower Creek	LG1	1	Recently inundated	Receding, deeply inundated
Little Gunbower Complex	LG2	1	Recently inundated	Receding, shallowly inundated
Reedy Lagoon	RL	3	Recently inundated	Receding, shallowly inundated
Permanent wetland total		*9*	*6*	*6*
Charcoal Swamp	CS	1	Recently inundated	Receding, shallowly inundated
Football Grounds	FG	1	Recently inundated	Receding, shallowly inundated
Iron Punt Lagoon	IPL	1	Recently inundated	Receding, deeply inundated
Little Reedy Lagoon	LR	2	Recently inundated	Receding, shallowly inundated
Long Lagoon	LL	1	Recently inundated	Receding, shallowly inundated
Semi-permanent wetland total		*6*	*5*	*5*
Total for all wetlands		***15***	***11***	***11***
Total for Dry wetlands			*0*	*0*
Total for Receding wetlands			*0*	*11*
Total for Recently Inundated wetlands			*11*	*0*

2.2 Data Preparation

Field data were aggregated (Table 2) to allow the description and analysis of transect floristics and vegetation condition indicators.

Table 2 Framework for data analysis

Data Grouping	Purpose
Broad vegetation type (Wetland)	Collate data and results in line with Icon Site ecological objectives
Water Regime Classes (WRCs)	To delineate vegetation types and establish how they are influenced by their landscape position (Landscape Logic). Permanent Wetlands Semi-permanent Wetlands
Wetland Phase Classes	To group wetlands based on the stage of the hydrological cycle at which they were sampled
Plant Functional Groups (PFGs)	To group plants based on common ecological, morphological and functional responses to inundation.

Wetland sites were classified into wetland phase classes based on the stage of the hydrological cycle at which they were sampled, in accordance with categories in Table 3. Wetland phases were found to reflect more similar floristic composition than Water Regime Classes (WRC) and, therefore, produce more meaningful results (see Bennetts 2014).

Table 3 Phase of the wetland cycle observed at monitoring sites in Gunbower Forest.

Water depth	Wetland phase	Wetland phase class analysed
0 cm	Dry	Dry
> 0 cm	Recently inundated (i.e. within last week)	Recently inundated
< 10 cm	Drying	Receding
10 - 100 cm	Receding, shallowly inundated	
> 100 cm	Receding, deeply inundated	

Flora species were classified into Plant Functional Groups (PFGs), employing a system adapted from Brock and Casanova (1997) which groups species in terms of their response to both inundation and drying (Appendix 1).

2.3 Data Analysis

The main aims of the data exploration were to investigate the effect of average wetland depth and inflow (duration of eFlows in the last 12 months) on the diversity, richness and cover of characteristic PFG vegetation species. Numbers of sampling units and wetland phase classes are outlined in Table 1.

Analysis of this and previous years of monitoring data have highlighted the differences between wetland sites within the Gunbower Forest, and the difficulty in summarising floristic data across sites that vary in their size, condition, bathymetry and water regime. This variability means that it is challenging to find consistent patterns across all sites in a Wetland Phase Class (or WRCs) and makes it therefore difficult to assess the effects of eFlow on wetland condition.

Notwithstanding the above, we are able to make broad summaries on vegetation health based on the condition indicators, which were designed to quantify variable wetland components.

2.3.1 Calculating diversity

The 'effective number of species' (henceforth known as 'species diversity') for each sample was calculated as exponential Shannon diversity in Excel. Analyses were run in the open-source statistical package R (version 3.2.2, R Core Team 2015), using the interface RStudio (version 0.99.484, RStudio 2015).

2.3.2 Vegetation Condition Indicator Analysis

Vegetation indicators were used as a tool to gauge wetland condition or 'health' relative to Points of Reference (PoR) that benchmark the top 10% of the 2005 – 2014 autumnal Gunbower flora records. Sites were given a 'compliant' score if they met or exceeded the indicator PoR.

Four vegetation condition indicators were assessed:

- characteristic PFG species richness
- characteristic PFG species cover
- presence of threatened flora
- absence of high threat weeds

Characteristic PFGs include submerged, aquatic, and amphibious plant species (PFGs 1-4, see Appendix 1).

Index scores were calculated for all wetlands classed as receding when sampled in spring or summer between 2005 and 2016. These occurred in summer 2016 (n=11), spring 2006 (n=1), spring 2007 (n=0), spring 2008 (n=9), and summer 2009 (n=6), summer 2013 (n=3), and summer 2015 (n=2). For the purposes of this study, we assumed that richness, cover, threatened flora and high threat weeds would be similar between seasons.

In spring 2015 all eleven wetlands were classified as recently inundated. PoRs have not been developed for this wetland phase class due to lack of data between 2005 and 2014 (Sim & Bennetts 2014). This data was therefore not included in the condition assessment.

PFG Species Richness Index

The wetland PFG Species Richness Index represents the number of characteristic PFG flora species recorded per survey site (wetland), relative to a wetland phase class PoR curve created using the top 10% of residuals (residual = difference between the observed and expected richness for each recorded area of characteristic PFG species) over the period 2005 - 2014. PFG species richness at a site is considered 'appropriate' (e.g. compliant) if it is on or above the PoR curve (based on the 90th percentile of residuals). (See Sim & Bennetts 2014 for details.)

The PoR for the wetland phase classes analysed are:

Dry phase wetlands = 2.506

Receding phase wetlands = 6.870

PFG Species Cover Index

The cover of characteristic PFG species at a site is considered ‘appropriate’ if it is on or above the wetland phase class PoR (the 90th percentile of PFG species cover across the 2005-2014 sampling period). The PoR for PFG species cover values for the wetland phase classes analysed were:

Dry phase wetlands = 56.9

Receding phase wetlands = 69.7

The method for calculating wetland species cover index scores was as follows:

- The cover of characteristic PFG species was summarised for each wetland site and sample date within the receding or dry wetland phase classes.
- From the 2005-2014 autumnal data, determine the 90th percentile value.
- For each wetland site (in each year), species cover data was converted to an index using the formula:

  Index = $\sqrt{(\text{Characteristic PFG cover})} \div \sqrt{(\text{PoR})}$
- Indices equal or greater than 1 were deemed compliant and scores less 1 were considered not compliant.

Threatened Species Index

A site is considered compliant if one or more threatened species are present (i.e. PoR is one). Since the number and cover of threatened species at any site is generally very low, and occurrences are deemed to be significant whether there are one or more threatened species present. This indicator is simply based on presence.

The method for calculating wetland threatened species index scores was as follows:

- The presence of threatened species (listed under state or federal legislation or on the DELWP 2015 Rare and Threatened Species Advisory List) was summarised at each wetland site on each sample date.
- Wetland sites with one or more threatened species recorded were given a score of 1 (compliant); sites with no threatened species were given a score of 0 (not compliant).

Weediness Index

A site is considered compliant if no high threat exotic species are present (i.e. PoR is zero). Since the occurrence and cover of high threat exotic species at a site is generally very low and occurrences are deemed to be significant whether there are one or more species present. This indicator is simply based on absence.

That is, the presence of one or more high threat exotic species results in an index score of 0, and their absence results in a score of 1.

The method for calculating absence of high threat exotic species index scores was as follows:

- The presence of high threat exotic species (listed with a Declared Noxious Weed Status in the North Central region (DEPI 2014) and/or Aquatic or Inland Weed Ranking (DSE 2008 and 2009)) was summarised at each wetland site and sample date within the wetland phase classes.
- Wetland sites with one or more high threat exotic species recorded were given a score of 0 (not compliant); sites with no high threat exotic species were given a score of 1 (compliant).

2.4 Limitations

Sample size, pattern and frequency all influence the utility of a dataset. Due to the cryptic nature and seasonal growth cycles of certain species, ecological surveys are often unable to detect all taxa present at a particular site. It should be recognised, therefore, that the sample data are, at best, indicative of the total species richness supported by the forest, and are skewed towards reporting a lower than actual level of richness.

Overall limitations with the study and analysis include:

- Sentinel wetland monitoring sites were subjectively located at known wetlands. The results may therefore be biased and may not reflect the diversity and/or trends of wetlands as a whole in Gunbower Forest.
- Wetland transects were re-established using a hand-held compass. While care was taken to overlap the sampled transect with previous years, this was not always possible, particularly at the longer (i.e. >100m) and/or densely treed sites. Consequently, it is likely there is some data mismatch. This limitation is, however, unlikely to substantially affect the results.
- Wetland transects change in length each year, depending on degree of inundation. We would expect more species to be recorded at larger transects. To correct for this, weighting by area has been performed using a species vs abundance curve for the wetland PFG species richness indicator. (See Sim & Bennetts 2014).
- Inflow data is not specific to wetlands, but is from the nearest regulator, so doesn’t give an accurate picture of the duration of eFlow inflows at the wetland scale.
- Turbidity data can only be expressed in categories due to the sampling equipment available.
- The spring 2015 and summer 2016 wetland dataset is small, and its size and the variability inherent in the wetlands make it difficult to draw firm conclusions about relationships with explanatory variables.
- Ground flora data is analysed within WRCs based on pre-determined ‘characteristic PFGs’. This approach implies that distinct groups of species occur in discrete WRCs. While this approach offers a practical method for analysing the data, it does not account for the broad ecotones between

communities that are created by the subtle environmental gradient across the floodplain. Consequently, naturally occurring 'non-characteristic species' can contribute to a poor health score.

- For the analysis of wetland data, we have assumed spatial independence of sites (although sites are located close to each other and are likely to be connected when inundated). Assessment of spatial independence using a bubble plot of the residuals did not indicate any patterns. As described earlier, wetlands are highly variable in their physical characteristics and this can have a profound influence on the flora. It is likely that site-specific factors such as size, bathymetry and water regime had a greater influence on PFG species richness than spatial proximity.
- The PoRs for the condition indicators were set using autumn data. Caution therefore needs to be used in applying these indices to data collected in other seasons.
- Wetland data are highly variable due to intrinsic differences in size, condition and flooding regime between wetlands. Summarising wetland data into a single index value for each WRC is likely to incorporate some error.

Additionally, as the monitoring program is not measuring response under controlled conditions (i.e. there are no control or impact sites), causality is not demonstrated. Rather inferences and anecdotal observations have been made in relation to driving factors that affect floristic composition and ecological condition.

3 RESULTS

The following section presents the results from the spring and summer wetland flora surveys. It commences with a brief account of the wetlands as sampled in spring 2015 and summer 2016, and includes exploratory data analysis, vegetation indicator results and qualitative ecological observations.

3.1 Inundation

All wetland monitoring sites were inundated in spring 2015 (Table 1) however there was a delay of 17 days between the time that water commenced flowing into the lower landscape wetlands compared with the mid landscape wetlands (Figure 2). All wetlands recorded shallower water depths when sampled in summer than when the same wetlands were sampled in spring (Figure 3). That is except the Little Gunbower Creek site which was over six metres deep in both seasons.

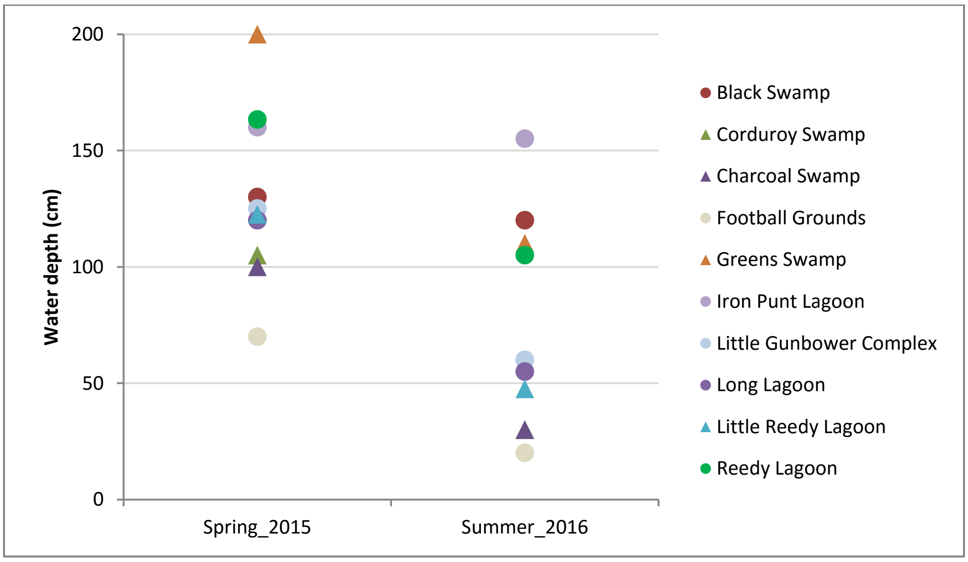


Figure 3 Water depths sampled at wetland sites in spring 2015 and summer 2016, Gunbower Forest.
Note the Little Gunbower Creek site is not included as it was over 6m deep in both spring and summer.

The 11 wetlands were classified as recently inundated in spring, since water delivery ceased within the week preceding the November 2015 survey. The summer wetlands were classified in the receding wetland phase class, with four deeply inundated (i.e. > 1m) and seven shallowly inundated (i.e. < 1m).

3.2 Photo-point Monitoring

Figures 4 to 14 provide a photographic account of the wetlands when sampled in spring and summer.

Figure 4 Black Swamp Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 5 Corduroy Swamp Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 6 Charcoal Swamp Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 7 Football Grounds Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 8 Greens Swamp Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 9 Iron Punt Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 10 Little Gunbower Creek Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 11 Little Gunbower Complex Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 12 Long Lagoon Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 3Little Reedy Lagoon Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

Figure 14 Reedy Lagoon Gunbower Forest, spring 2015 (top) and summer 2016 (bottom).

3.3 Flora Composition

A total of 71 flora species were identified in the wetland sites in spring. The number of species increased to 116 in summer with the addition of 45 new species (refer to Appendix 1).

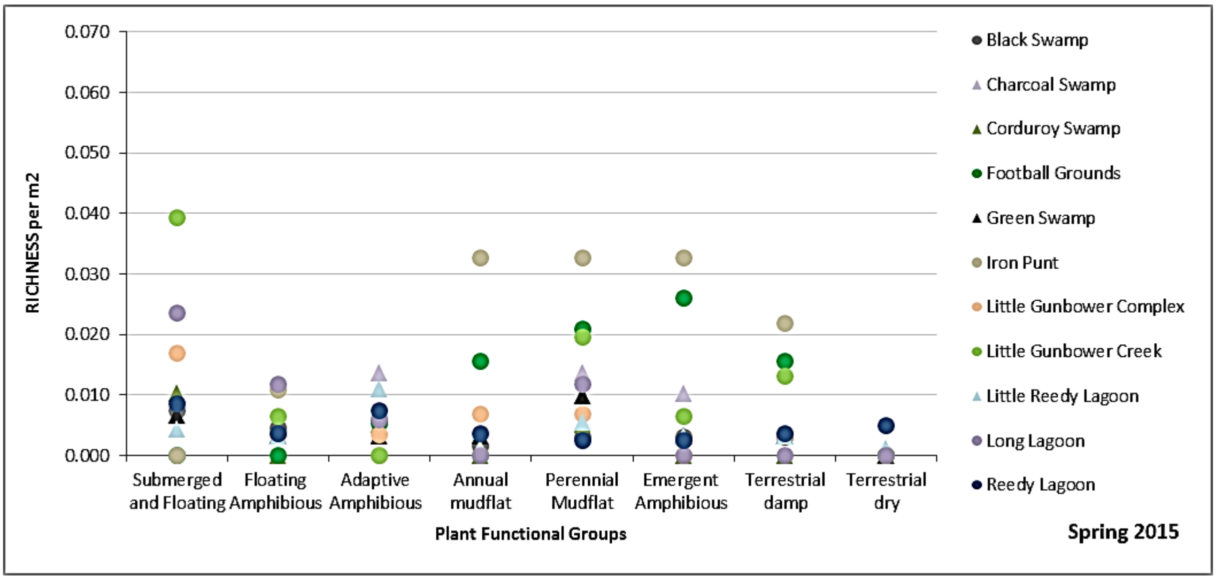
Included in these lists are the:

- Nationally vulnerable River Swamp Wallaby-grass (*Amphibromus fluitans*)
- State listed Wavy Marshwort (*Nymphoides crenata*)
- Rare Dwarf Bitter-cress (*Rorippa eustylis*), Riverina Bitter-cress (*Cardamine moirensis*) and Cotton Sneezeweed (*Centipeda nidiformis*)
- Poorly known Native Couch (*Cynodon dactylon var. pulchellus*) and Pale Spike-sedge (*Eleocharis pallens*).

Of these species River Swamp Wallaby-grass was the most common but did not appear to reach the same extent observed in autumn 2015.

3.3.1 Richness

Richness in PFG species varied considerably between wetlands within the sample seasons (Figure 15). Three relatively small wetlands (Iron Punt Lagoon (Figure 9), Football Grounds (Figure 7) and Little Gunbower Creek (Figure 10)) recorded the highest numbers of species per area in several PFGs, and in both seasons. In spring 2015, Little Gunbower Creek had the highest richness of submerged and floating species per area of all the wetlands (i.e. Hornwort (*Ceratophyllum demersum*), Thin Duckweed (*Landoltia punctata*), Common Duckweed (*Lemna disperma*), Fringed Heartwort (*Ricciocarpos natans*) and Azolla spp). In summer, Iron Punt Lagoon was recorded with the highest richness of perennial mudflat species per area; nearly double that recorded at the site in spring. Perennial mudflat species recorded include the Lesser Joyweed (*Alternanthera denticulata*), Common Spike-sedge (*Eleocharis acuta*), Slender Knotweed (*Persicaria decipiens*) and Creeping Knotweed (*Persicaria prostrata*).



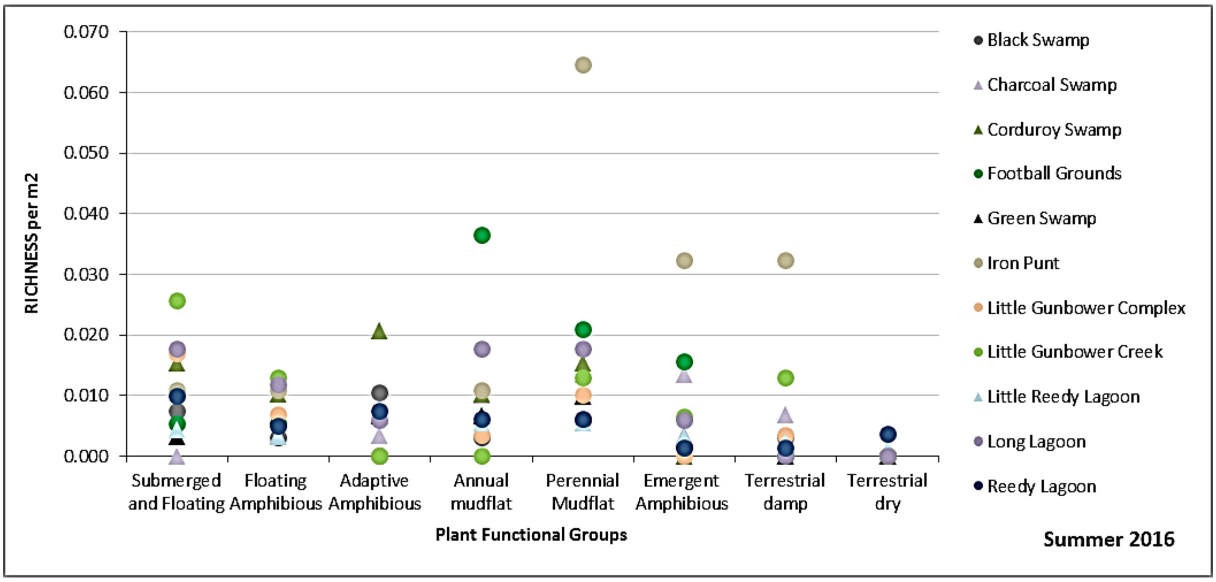


Figure 15 Richness per m^2 of PFGs species in wetland sites, spring 2015 (top) and summer 2016 (bottom), Gunbower Forest.

Note sites with circle symbols were delivered eFlow for 35-37 days and sites with triangle symbols were delivered eFlow for 75 days.

3.3.2 Cover

The covers (per m^2) of PFGs in the wetlands were relatively similar in spring and summer, with some inter-wetland variability (Figure 16). For example, most wetlands had high covers of submerged and floating species, low covers of amphibious and annual mudflat species, and very low covers of terrestrial species. The key divergences from this pattern were Corduroy Swamp and Reedy Lagoon in spring, and the increase in perennial mudflat species between spring and summer in many of the wetlands.

In spring, Corduroy Swamp (Figure 5) and Reedy Lagoon (Figure 14) were recorded with more than twice the cover of submerged and floating plants than the other wetlands. While in Corduroy Swamp this was largely due to Azolla, in Reedy Lagoon a range of species contributed, such as Thin Duckweed, Common Duckweed, Fringed Heartwort, Eel Grass (*Vallisneria australis*) and Swamp Lily (*Ottelia ovalifolia subsp. ovalifolia*).

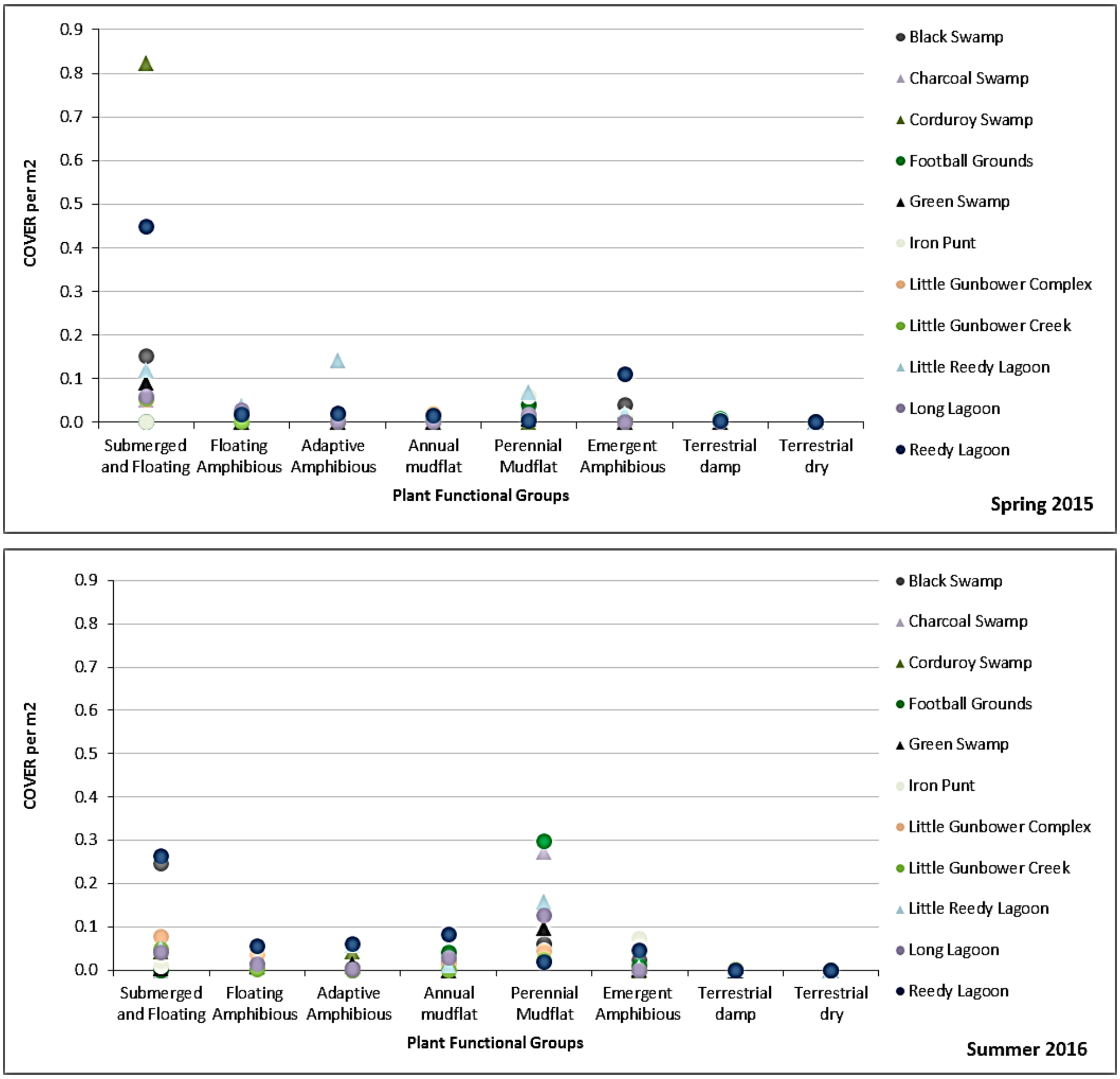


Figure 16 Cover (per m²) of PFG species in wetland sites in spring 2015 (top) and summer 2016 (bottom), Gunbower Forest.

Note sites with circle symbols were delivered eFlow for 35-37 days and sites with triangle symbols were delivered eFlow for 75 days.

3.3.3 Species Diversity

When data were pooled across seasons, the maximum and range in species diversity was higher in wetlands with 75 inflow days (i.e. watered through Hipwell regulator) than the wetlands with only 35-37 inflow days (Figure 17). However, the median and minimum species diversities were similar.

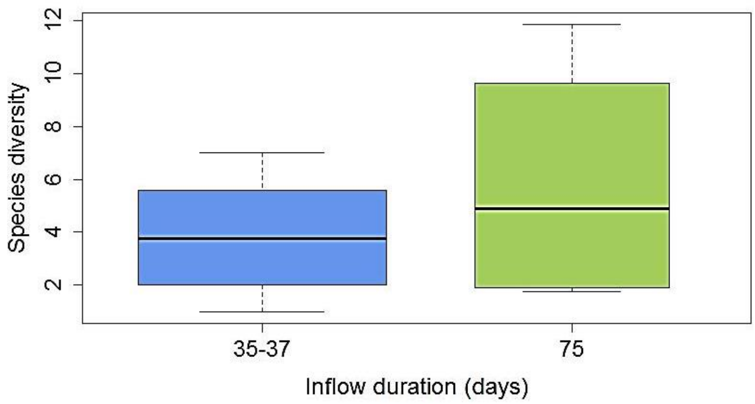


Figure 17 Boxplots of species diversity (Shannon Exponential Mean) for wetlands sampled in November 2015 and February 2016 and grouped by inflow duration. Relative width of boxes indicates relative sample sizes.

When species diversity was categorised by turbidity, the ranges of most of the turbidity categories overlapped, with no clear relationship between turbidity and flora species diversity (Figure 18). The 21-30 NTU and >50 NTU categories had very small sample sizes.

Notwithstanding the above, the median species diversity was lower in the sites with clear water (NTU <10) and highest in those with turbid water (NTU 31-50). While this may appear counter intuitive, the clear water sites were typically also deeper and sampled in spring (recently inundated), and the turbid water sites were shallower and sampled in summer (receding).

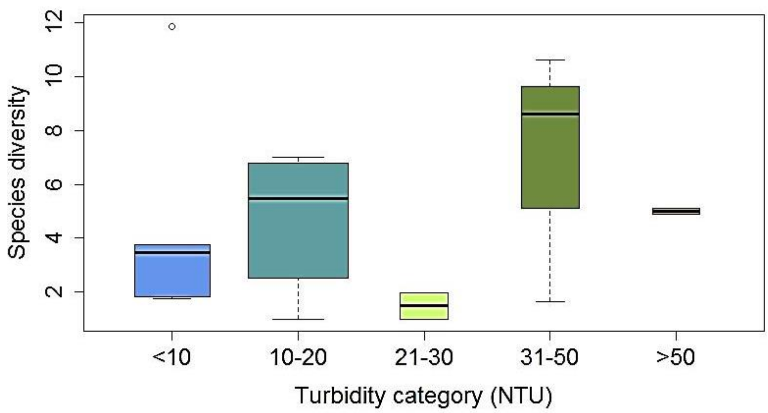


Figure 18 Boxplots of species diversity (Shannon Exponential Mean) for wetland sampled in November 2015 and February 2016 and grouped by turbidity category.

It is also possible there is a weak negative relationship between average water depth and species diversity (Figure 19). Species diversity values were higher at lower water depths.

Further analysis of the effect of depth, season and turbidity on species diversity found these variables were collinear (i.e. are linearly related), (Sim 2016). This means it is not possible, with the data we have, to distinguish which of the collinear variables (e.g. depth, turbidity and season) is having the observed effect on the response variable (diversity).

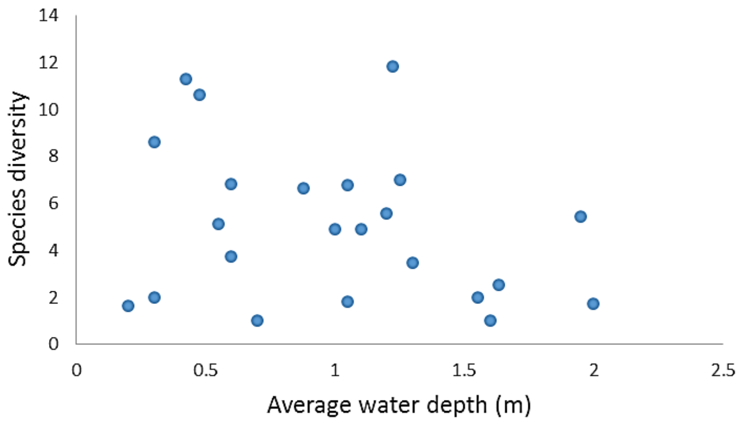


Figure 19 Scatterplot of species diversity for Gunbower wetlands sampled in Spring 2015 and Summer 2016, against average water depth (m).

3.4 Condition Indicators

The following indicators summarise the richness, cover, rarity and origin of species observed and measure compliance to the PoRs at a site level in receding wetlands. A wetland site is considered 'compliant' if its index score equals or exceeds the PoR for the indicator. A wetland site is deemed 'healthy' for the purposes of this assessment if it complies with all four indicators.

3.4.1 PFG Species Richness Indicator

Receding wetlands supported sites with appropriate (i.e. compliant) species richness in two of the seven years in which they were sampled (spring 2008 and summer 2009, Figure 20). The PoR for receding wetland flora richness was not achieved at any sites in summer 2016.

3.4.2 PFG Species Cover Indicator

Four of the 11 wetlands sampled in summer 2016 recorded appropriate (i.e. compliant) covers of characteristic aquatic and amphibious PFG species. Several wetlands also complied with the indicator in spring 2006 and 2008, and summer 2009 and 2015 (Figure 20).

3.4.3 Presence of Threatened Species Indicator

At least one listed rare or threatened flora species was recorded at four of the 11 wetlands sampled in summer 2016 and therefore complied with the indicator. Several sites were also compliant in spring 2008 and summer 2009, 2013 and 2015 (Figure 20).

3.4.4 Absence of High Threat Weed Species Indicator

Six of the 11 wetlands sampled in summer 2016 were free of high threat weed species and therefore complied with the indicator. Wetlands sampled in spring 2006 and summer 2009 and 2013 also complied (Figure 20).

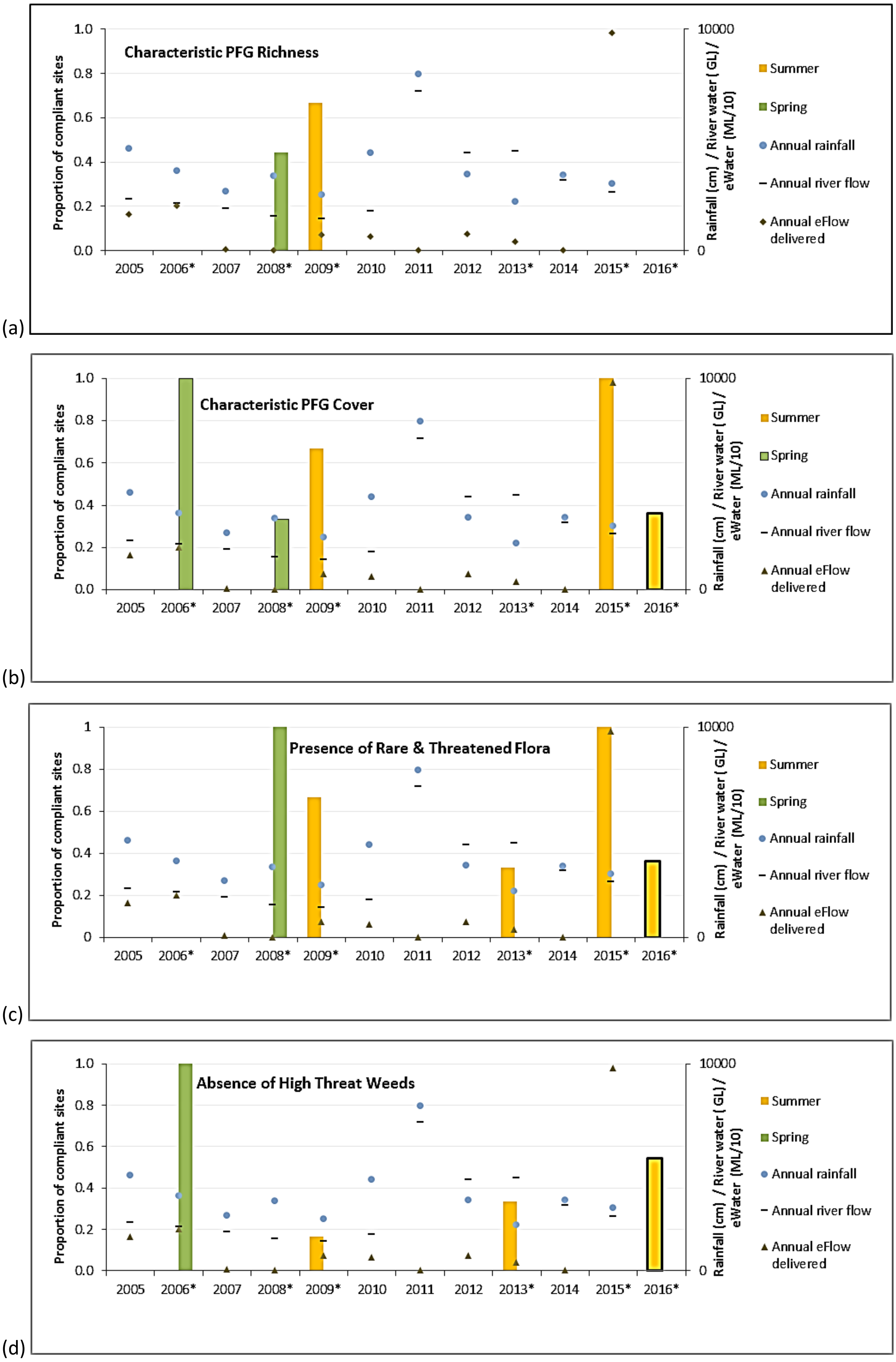


Figure 20 Proportion of receding wetland sites that complied with the PoRs for (a) Characteristic PFG Richness, (b) Characteristic PFG Cover, (c) Presence of Threatened Flora; and (d) Absence of High Threat Weeds; and annual (autumn-autumn) rainfall, river flow at Torrumbarry Weir, and environmental water delivered to the wetlands, Gunbower Forest 2005-2015.

*Receding wetlands were sampled in 2006 (*n*=1), 2007 (*n*=0), 2008 (*n*=9), 2009 (*n*=6), 2013 (*n*=3), 2015 (*n*=2), and 2016 (*n*=11, outlined in black).

3.4.5 Receding Wetland Condition Score

While most of the receding wetlands sampled in spring and summer between 2006 and 2016 complied with at least one of the four vegetation indicators, only one of the 43 samples (Greens Swamp, 2009 Figure 21) complied with all four indicators and was therefore considered 'healthy' for the purposes of this assessment.

No wetlands sampled in summer 2016 were considered healthy when assessed using the vegetation condition indicator process. It should however be noted that the indicators were developed from autumnal data, and may therefore reflect a slightly higher diversity and cover of species than observed in summer, meaning that more wetlands may have been compliant if the indicators had been developed from spring or summer data.

Figure 21 Greens Swamp, lagoon (top) and wetland bench (bottom) summer 2009, Gunbower Forest.

3.5 Ecological Observations

Considerable areas of lush aquatic vegetation were observed in spring 2015 in low lying forest areas near the wetlands inundated via the Hipwell regulator (e.g. Little Reedy, Figure 22). Common species included the Robust Milfoil (*Myriophyllum crispatum*) with Red Pondweed (*Potamogeton cheesemanii*), Wavy Marshwort (*Nymphoides crenata*), Water Ribbon (*Triglochin* spp.) and Swamp Lily (*Ottelia ovalifolia*). These areas appeared to have drawn down quickly and were dry in summer 2016. Most species were presumably able to set seed before they dried, with the exception of Swamp Lily, which was still flowering when the drying occurred.

Figure 22 Riverine Swamp Forest connected to Little Reedy Lagoon when inundated (November 2015, top) and dry (February 2016, bottom). Photographer: D. Osler

Around the wetlands, the upper flood zone supported key structural species (i.e. Common Spike-sedge *Eleocharis acuta*) often at high levels of cover, indicating the species were sufficiently inundated (Figure 23). Vegetation in the draw down zone was sparse, particularly in the lowest zone (Figure 23). It is likely that germination and proliferation of amphibious species was limited by the hot, dry spring and summer weather conditions and macropod grazing.

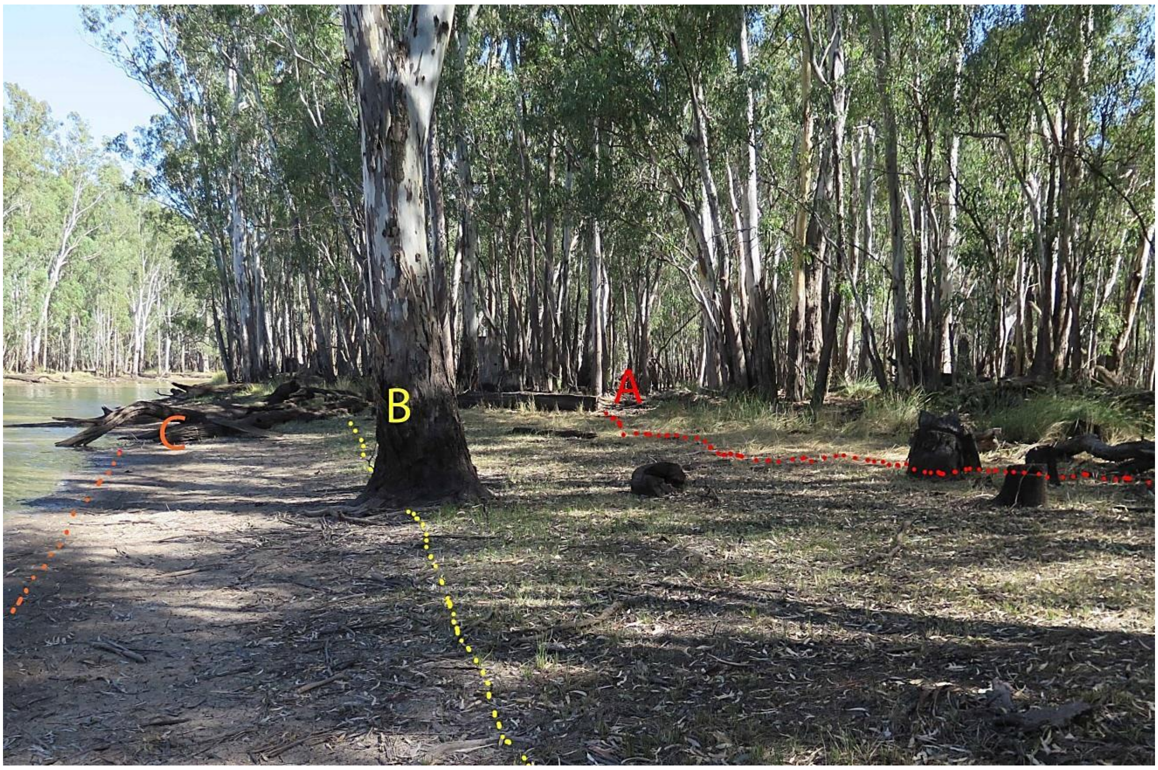


Figure 23 Inundation zones in Little Reedy Lagoon - upper flood zone (zone A), draw down (zone B), lower draw down (zone C) and open water. Photographer: D. Osler

In spring 2015, recently inundated areas were recruiting mudflat species Creeping Knotweed (*Persicaria prostrata*), Common Joyweed (*Alternanthera denticulata*) and, at low abundances, Oldman Weed (*Centipeda cunninghamii*). Amphibious species such as Spiny Mud-grass (*Pseudoraphis spinescens*) and Clove strip (*Ludwigia peploides*), were also observed along the water's edge (see Figure 24), but rarely in deeper areas.

Figure 24 Aquatic Herbland, November 2015 Reedy Lagoon. Photographer: D. Osler

4 DISCUSSION

The presence of aquatic and amphibious species at the wetland monitoring sites in spring 2015 and summer 2016, suggests that the 2015 eFlow triggered seed and spore germination, and resprouting in wetland flora. The most notable responses were from the submerged, floating, adaptive amphibious and perennial mudflat species.

In 2015, water reached the wetlands east of Yarran Creek (Corduroy, Greens and Charcoal Swamps and Little Reedy Lagoon) around 17 days earlier than the seven wetlands to the west (Reedy and Long Lagoons, Football Grounds, Black and Iron Punt Swamp, and Little Gunbower Creek and complex). The range of and maximum species diversity was higher in the former wetlands, suggesting that at some wetlands at least, the flora responded positively to the earlier and longer inundation period.

There also appears to be a weak negative relationship between species diversity and water depth (i.e. higher diversity at lower depths). It is however difficult to separate the effect of depth from season and turbidity, as the wetlands were typically deeper and less turbid in spring than summer. There was no clear pattern in species diversity relative to turbidity category when data were pooled across seasons.

The wetland sites monitored in Gunbower Forest are diverse. They differ in bathymetry, size and therefore hydrology. This site diversity underwrites a level of variation in the structure, richness and composition of the plant communities. For example, River Red Gums have remained on the banks of the well-defined lagoons and but followed the receding water line in the low gradient wetlands.

Other factors such as rainfall and grazing are also likely to affect wetland flora. Flood-triggered flora species that depend on follow-up rainfall (i.e. annual mudflat species) are likely to have been restricted by the exceptionally low rainfall between October and December 2015. Such conditions are likely to have increased the rate of draw down at all wetlands and may have caused the scolding observed.

The relationship between carp, turbidity and aquatic plants in Gunbower wetlands remains murky. Some wetlands are almost always clear (e.g. Iron Punt Lagoon). While others are almost always turbid (e.g. Greens Swamp), possible due to a naturally higher load of fine sediment. Without synchronised carp population and wetland flora data it is difficult to accurately assess the impact of the former on the latter. Further it is likely that the effect of turbidity on aquatic plants changes with water depth (Bennetts & Sim 2016).

Progress Towards Icon Site Ecological Objectives

The overarching objective for permanent and semi-permanent wetlands in Gunbower Forest is to secure an increase in wetland health. The suggested target for this objective is 80% of wetlands in healthy condition (relative to autumn data collected 2005-2014) by 2025.

No receding wetland sites sampled in summer 2016 complied with all four condition indicators and were deemed 'healthy' for the purposes of this assessment. However, while the indicators provide a means to assess spring and summer wetland condition, the lack of compliance may be due to the fact that the indicator PoRs were developed on autumn data.

Conclusions

Wetlands receiving eFlow in 2015 supported a diversity of aquatic and amphibious flora in spring 2015 and summer 2016. These inundated habitats contrasted with the dry floodplain. Analysis of the spring and summer flora data confirmed the high level of natural variation in the wetlands, and potentially that delivering water earlier and for longer to wetlands may increase species diversity. Further data is however required to confirm this hypothesis.

Management Recommendations

Where practical, it is recommended, based on the findings in the current study to:

- Deliver environmental water early in spring rather than later in spring, and
- Prioritise environmental water delivery in years predicted to receive average or above spring and summer rainfall, over years predicted to receive below average rainfall.

5 FURTHER RESEARCH

In order to build on the results of the current study, and to clarify relationships between vegetation variables, the delivery of eFlows and other aspects of wetting and drying, we recommend focusing on two case study wetlands over time. If these data are re-analysed independently, this will allow us to investigate patterns in species diversity, richness and cover with water regime, while reducing site-driven variation in the data. Reedy Lagoon and Little Reedy Lagoon are the recommended study sites, since they have comprehensive datasets and the analyses will allow additional insight into the carp exclusion study involving these wetlands.

We also recommend sampling high diversity areas outside the monitoring wetlands to add to our learning about the drivers of wetland plant ecology in Gunbower Forest. Some areas of shallowly inundated wetland in the floodplain forest (Figure 22) were anecdotally in very good condition in spring 2015 and summer 2016, with higher covers of characteristic PFG species and lower turbidity than the larger, monitored, adjacent sentinel wetlands. It would be useful to understand the conditions and processes that lead to this positive response in these areas of the forest. The following hypotheses have been proposed to assist us to better understand the dynamics of these systems and inform watering and other management strategies for the forest.

Possible Hypotheses

(as reported in Bennetts & Sim 2016):

1. Carp prefer larger, deeper sentinel wetlands than shallow forest wetlands
2. Waterbirds prefer grazing in the larger, open sentinel wetlands
3. The smaller forest wetlands are more protected from the effects of wind on sediment resuspension
4. The smaller forest wetlands have a shorter hydrologic duration, which doesn’t allow carp to complete their life cycle
5. Water temperature in the smaller forest wetlands exceeds the upper tolerance limit of carp (35°C)
6. pH in the smaller areas smaller forest wetlands exceeds the upper tolerance limit of carp (pH 9)

Suggested Sampling Strategy

We recommend surveying these sites prior to delivery of eFlow to record whether they are dry, damp, wet or isolated and if live macrophytes are present. This would be followed with flora and water quality data sampling in winter/spring when the wetlands are expected to first fill. We recommend repeating the flora surveys at least 3 times (preferably more to capture seasonal differences) in the recently inundated, mid cycle, drying stages.

Suggested Variables to Measure

Variables to measure	Frequency	Notes
Tree canopy cover	Once if unlikely to change, but every sampling occasion if likely to change in a few weeks.	To give an idea of degree of shading and possibly litter input. Potentially with hemispherical photos and calculated Plant Area Index
Wind exposure	Once if unlikely to change, but every sampling occasion if likely to change in a few weeks.	To give an idea of degree of effect of wind exposure on wetland turbidity
Waterbird visitation	Multiple intervals at times when birds are likely to be undisturbed (i.e. not during flora sampling) during monitoring program.	Use camera traps. You can process 500-1000 photos/hr Can set to be motion triggered Can set sensitivity Can set to take the min number of photos each time Can set an unresponsive interval after being triggered so you are not just getting same animal. ~$200-800 ea. Small animals, better camera (move faster) Probably need $300-400 models. Ideally one photo for each quadrat, but since this may not be feasible, at least 2 per wetland.
Timing of drying	Records of each time there is no standing water left in the wetland during the monitoring program	Data specific to each wetland.
Timing of inflow	Records of each time there is a significant inflow during the monitoring program	Data specific to each wetland.
Maximum depth	Records of each time there is a significant inflow during the monitoring program	Data specific to each wetland.
Hydrologic connectivity	Each sampling occasion	Are the wetlands connected by surface water flows to other wetlands and/or forest?
Along transects or in quadrats (fixed locations between sampling occasions) Minimum of 3 quadrats per wetland, preferably more.		
Maximum water depth	Every flora sampling occasion	
Water temperature	Every flora sampling occasion	If at all possible at a consistent time of day, and in either case with time of day noted
Ambient temperature	Every flora sampling occasion	If at all possible at a consistent time of day, and in either case with time of day noted
Water pH	Every flora sampling occasion	This may not be feasible, since to measure pH accurately, you need to do it in the field with a hand held pH meter. Lab samples are not accurate enough since pH changes over time.
Visual clarity	Every flora sampling occasion	Ideally with a hand held meter.
Presence of dead carp	Every flora sampling occasion	
Degree of sediment drying	Every flora time sampled if the wetland is dry	For example dry/cracking or damp.
Cover of aquatic and amphibious flora	Every flora sampling occasion	PFGs 1-4
Diversity of aquatic and amphibious flora	Every flora sampling occasion	PFGs 1-4
Composition of aquatic and amphibious flora	Every flora sampling occasion	PFGs 1-4

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7 APPENDIX 1

Plant Functional Groups applied in Gunbower Forest flora data analysis.

PFG Name	PFG Code	Description
Submerged & Free floating Flora	1	S - Submerged (including strictly aquatic floaters) Adult plants do not survive prolonged exposure of the wetland substrate (drying) and lack perpetuating rootstocks. Seed or spores may persist in soil during dry times.
Floating Amphibious Flora	2	ARf - Amphibious Fluctuation - Responders Floating Amphibious species that produce floating foliage when inundation. Aerial parts of plants survive exposure of the wetland substrate (drying) for sustained periods of time. Plants survive drying by dying back to rootstocks.
Adaptive Amphibious Flora	3	ARp - Amphibious Fluctuation - Responders Plastic Amphibious species that alter their growth pattern or morphology in response to water conditions. Can actively grow when substrate exposed but still moist, but may die back to rootstocks or seed during sustained dry periods.
Perennial Mudflat Flora	4a	ATl - Amphibious Fluctuation - Tolerators Low Growing Perennial amphibious species that tolerate changes in water conditions and maintain same general growth form during brief periods of inundation, but may die back to rootstocks if unable to develop emergent growth during sustained inundation.
Annual Mudflat Flora	4b	ATl - Amphibious Fluctuation - Tolerators Low Growing Annual (or functionally so) amphibious species that may tolerate very brief periods of shallow flooding during growth phase, but essentially short-lived plants which germinate following flood water recession and produce inundation-tolerant seed during the drying phase.
Emergent Amphibious Flora	5	ATe - Amphibious Fluctuation - Tolerators Emergent Amphibious flora that tolerates changes in water conditions, typically with emergent habit. Rootstocks tolerant of shallow inundation but plants intolerant of sustained total immersion. Recruitment and/or long-term maintenance of populations are generally dependent on at least occasional inundation events.
Terrestrial Damp	6	Tda - Terrestrial Damp Rootstocks intolerant of more than superficial inundation, but occurring in areas of good soil moisture conditions which may be influenced by proximity to river and water seepage through soil
Terrestrial Dry	7	Tdr - Terrestrial Dry Dry-land plants (i.e. flood intolerant and going through life cycles independently of flooding regime)
Not-vegetated	0	Bare ground, litter, logs, water etc.
Not Assigned	NA	Species for which there is insufficient information to be assigned to a PFG

Plant species recorded in Gunbower Forest wetland monitoring sites during spring and summer 2006 - 2016.

Plant species	Common Name	Origin	VROT	Plant Functional Group	Receding						Recently inundated	Receding
					Spring		Summer				Spring	Summer
					2006	2008	2009	2013	2015	2015	2015	2016
Alisma lanceolatum	Water Plantain	*		Perennial Mudflat							x	x
Alisma plantago-aquatica	Water Plantain			Perennial Mudflat					x			x
Alternanthera denticulata	Lesser Joyweed			Perennial Mudflat		x	x	x	x	x	x	x
Amphibromus fluitans	River Swamp Wallaby-grass		VX	Adaptive Amphibious		x	x		x	x	x	x
Amphibromus nervosus	Common Swamp Wallaby-grass			Emergent Amphibious		x	x	x	x	x		x
Aster subulatus	Aster-weed	*		Emergent Amphibious		x	x	x	x		x	x
Atriplex semibaccata	Berry Saltbush			Terrestrial Dry			x					x
Azolla filiculoides	Pacific Azolla			Submerged & Floating Aquatic		x		x	x	x	x	x
Azolla pinnata	Ferny Azolla			Submerged & Floating Aquatic	x	x	x	x	x	x	x	x
Brachyscome basaltica var. gracilis	Woodland Swamp-daisy			Perennial Mudflat						x		
Bromus diandrus	Great Brome	*		Terrestrial Dry		x					x	x
Bromus madritensis	Madrid Brome	*		Terrestrial Dry		x	x					x
Callitriche brutia subsp. brutia	Thread Water-starwort	*		Adaptive Amphibious		x						
Callitriche sonderi	Matted Water-starwort			Adaptive Amphibious		x	x				x	x
Callitriche spp.	Water-starwort			Adaptive Amphibious		x				x		
Cardamine moirensis	Riverina Bitter-cress		r	Emergent Amphibious		x	x				x	x
Carex inversa	Knob Sedge			Terrestrial Dry		x					x	x
Carex tereticaulis	Poong'ort			Emergent Amphibious		x		x			x	x
Centipeda cunninghamii	Common Sneezeweed			Annual Mudflat	x	x	x	x	x	x	x	x
Centipeda minima subsp. minima s.s.	Spreading Sneezeweed			Annual Mudflat			x	x				x
Centipeda nidiformis	Cotton Sneezeweed		r	Annual Mudflat				x				x
Cerastium glomeratum	Common Mouse-ear Chickweed	*		Terrestrial Dry		x						
Ceratophyllum demersum	Hornwort			Submerged & Floating Aquatic							x	
CHARACEAE spp.	Stonewort			Submerged & Floating Aquatic		x	x		x			x
Cirsium vulgare	Spear Thistle	*		Terrestrial Dry		x	x	x	x	x	x	x
Conyza bonariensis	Flaxleaf Fleabane	*		Terrestrial Damp			x				x	x
Conyza spp.	Fleabane	*		Not Assigned		x						
Cotula australis	Common Cotula			Terrestrial Dry		x						

Plant species	Common Name	Origin	VROT	Plant Functional Group	Receding						Recently inundated	Receding
					Spring		Summer				Spring	Summer
					2006	2008	2009	2013	2015	2015	2015	2016
Cynodon dactylon var. pulchellus	Native Couch		k	Perennial Mudflat							x	
Cyperus eragrostis	Drain Flat-sedge	*		Emergent Amphibious		x	x	x	x		x	x
Cyperus spp.	Flat-sedge			Not Assigned							x	
Damasonium minus	Star Fruit			Perennial Mudflat		x	x		x	x		x
Dittrichia graveolens	Stinkwort	*		Terrestrial Dry			x					x
Dysphania glomulifera subsp. glomulifera	Globular Pigweed			Annual Mudflat			x					x
Dysphania pumilio	Clammy Goosefoot	#		Annual Mudflat		x	x		x			x
Eclipta platyglossa	Yellow Twin-heads	#		Perennial Mudflat							x	x
Einadia hastata	Saloop			Terrestrial Dry		x						
Einadia nutans subsp. nutans	Nodding Saltbush			Terrestrial Dry		x	x		x		x	x
Elatine gratioloides	Waterwort			Adaptive Amphibious		x	x		x	x	x	x
Eleocharis acuta	Common Spike-sedge			Perennial Mudflat	x	x	x	x	x	x	x	x
Eleocharis pallens	Pale Spike-sedge		k	Perennial Mudflat			x					x
Eleocharis sphacelata	Tall Spike-sedge			Adaptive Amphibious			x					x
Enchylaena tomentosa var. tomentosa	Ruby Saltbush			Terrestrial Dry		x	x		x		x	x
Epilobium billardierianum	Variable Willow-herb			Emergent Amphibious	x	x	x					x
Euchiton japonicus	Creeping Cudweed			Terrestrial Dry			x					x
Euphorbia drummondii	Flat Spurge	#		Annual Mudflat			x				x	x
Fumaria bastardii	Bastard's Fumitory	*		Terrestrial Dry		x						
Fumaria spp.	Fumitory	*		Terrestrial Damp					x	x	x	x
Galium aparine	Cleavers	*		Terrestrial Damp		x						
Glinus lotoides	Hairy Carpet-weed			Annual Mudflat		x	x	x	x			x
Glinus oppositifolius	Slender Carpet-weed			Annual Mudflat			x					x
Glossostigma cleistanthum	Small-flower Mud-mat		r	Annual Mudflat		x						
Gnaphalium polycaulon	Indian Cudweed			Annual Mudflat			x				x	x
Helichrysum luteoalbum	Jersey Cudweed			Terrestrial Damp		x	x					x
Heliotropium europaeum	Common Heliotrope	*		Annual Mudflat			x	x				x
Heliotropium supinum	Creeping Heliotrope	*		Annual Mudflat					x			x
Helminthotheca echioides	Ox-tongue	*		Terrestrial Dry		x	x					x
Hordeum spp.	Barley Grass	*		Not Assigned		x						
Hypochaeris glabra	Smooth Cat's-ear	*		Terrestrial Dry		x						

Plant species	Common Name	Origin	VROT	Plant Functional Group	Receding						Recently inundated	Receding
					Spring		Summer				Spring	Summer
					2006	2008	2009	2013	2015	2015	2015	2016
Hypochaeris radicata	Flatweed	*		Terrestrial Dry		x					x	x
Juncus amabilis	Hollow Rush			Emergent Amphibious				x				x
Juncus aridicola	Tussock Rush			Emergent Amphibious		x	x	x	x	x	x	x
Juncus australis	Austral Rsuh			Emergent Amphibious							x	
Juncus bufonius	Toad Rush			Annual Mudflat		x						
Juncus holoschoenus	Joint-leaf Rush			Perennial Mudflat		x						
Juncus ingens	Giant Rush			Emergent Amphibious		x	x	x	x	x	x	x
Juncus semisolidus	Plains Rush			Emergent Amphibious			x					x
Juncus spp.	Rush			Not Assigned		x						
Juncus usitatus	Billabong Rush			Terrestrial Damp					x			x
Lachnagrostis filiformis s.l.	Common Blown-grass			Terrestrial Damp						x	x	x
Lachnagrostis filiformis s.s.	Common Blown-grass			Annual Mudflat		x	x	x	x			x
Lactuca serriola	Prickly Lettuce	*		Terrestrial Damp		x	x		x	x	x	x
Lactuca spp.	Lettuce	*		Terrestrial Damp		x						
Landoltia punctata	Thin Duckweed			Submerged & Floating Aquatic		x	x	x			x	x
Lemna disperma	Common Duckweed			Submerged & Floating Aquatic		x	x	x		x	x	x
Leontodon taraxacoides subsp. taraxacoides	Hairy Hawkbit	*		Terrestrial Damp			x					x
Lobelia pratioides	Poison Lobelia			Perennial Mudflat		x						
Lolium perenne	Perennial Rye-grass	*		Terrestrial Dry		x						
Lolium rigidum	Wimmera Rye-grass	*		Terrestrial Dry		x			x		x	x
Ludwigia peploides subsp. montevidensis	Clove-strip			Floating Amphibious	x	x	x	x	x	x	x	x
Lysimachia arvensis	Pimpernel	*		Terrestrial Dry		x						
Lythrum hyssopifolia	Small Loosestrife			Terrestrial Damp		x	x					x
Marrubium vulgare	Horehound	*		Terrestrial Dry		x					x	x
Marsilea costulifera	Narrow-leaf Nardoo			Adaptive Amphibious		x	x		x			x
Marsilea drummondii	Common Nardoo			Adaptive Amphibious			x					x
Marsilea hirsuta	Short-fruit Nardoo			Adaptive Amphibious	x	x	x			x	x	x
Marsilea spp.	Nardoo			Adaptive Amphibious							x	
Medicago polymorpha	Burr Medic	*		Terrestrial Dry		x						
Myosurus australis	Mousetail			Annual Mudflat		x						
Myriophyllum caput-medusae	Coarse Water-milfoil			Floating Amphibious	x				x			x

Plant species	Common Name	Origin	VROT	Plant Functional Group	Receding						Recently inundated	Receding
					Spring		Summer			Spring		Summer
					2006	2008	2009	2013	2015	2015	2015	2016
Myriophyllum crispatum	Upright Water-milfoil			Adaptive Amphibious		x	x			x		x
Myriophyllum papillosum	Robust Water-milfoil			Adaptive Amphibious		x	x		x	x	x	x
Myriophyllum simulans	Amphibious Water-milfoil			Adaptive Amphibious					x			x
Myriophyllum spp.	Water-milfoil			Not Assigned						x	x	
Myriophyllum verrucosum	Red Water-milfoil			Adaptive Amphibious						x		
Najas tenuifolia	Water Nymph			Submerged & Floating Aquatic					x			x
Nymphoides crenata	Wavy Marshwort		Lv	Floating Amphibious		x	x		x	x	x	x
Ottelia ovalifolia subsp. ovalifolia	Swamp Lily			Submerged & Floating Aquatic		x	x	x	x	x	x	x
Parietaria debilis	Shade Pellitory			Terrestrial Dry		x						
Paspalidium jubiflorum	Warrego Summer-grass	#		Emergent Amphibious	x	x	x	x		x	x	x
Persicaria decipiens	Slender Knotweed			Perennial Mudflat						x	x	x
Persicaria lapathifolia	Pale Knotweed			Annual Mudflat			x		x		x	x
Persicaria prostrata	Creeping Knotweed			Perennial Mudflat	x	x	x	x	x	x	x	x
Petrorhagia dubia	Velvety Pink	*		Terrestrial Dry		x	x					x
Phalaris paradoxa	Paradoxical Canary-grass	*		Terrestrial Dry		x						
Physalis hederifolia	Sticky Ground-cherry	*		Terrestrial Dry			x					x
Pilularia novae-hollandiae	Austral Pillwort			Perennial Mudflat		x						
Polygonum aviculare	Prostrate Knotweed	*		Terrestrial Dry		x	x					x
Polygonum plebeium	Small Knotweed			Annual Mudflat		x	x	x				x
Polypogon monspeliensis	Annual Beard-grass	*		Terrestrial Damp			x					x
Potamogeton cheesemanii	Red Pondweed			Adaptive Amphibious	x	x			x	x	x	x
Potamogeton ochreatus	Blunt Pondweed			Adaptive Amphibious					x	x	x	x
Potamogeton sulcatus	Furrowed Pondweed			Adaptive Amphibious			x		x		x	x
Pseudoraphis spinescens	Spiny Mud-grass			Floating Amphibious	x	x	x	x	x	x	x	x
Ranunculus pumilio	Ferny Small-flower Buttercup			Terrestrial Damp		x						
Ranunculus sceleratus subsp. sceleratus	Celery Buttercup	*		Emergent Amphibious							x	
Rhagodia spinescens	Hedge Saltbush	#		Terrestrial Dry							x	x
Riccia duplex var. duplex	Floating Crystalwort			Submerged & Floating Aquatic		x	x					x
Ricciocarpos natans	Fringed Heartwort			Submerged & Floating Aquatic		x	x			x	x	x
Rorippa eustylis	Dwarf Bitter-cress		r	Annual Mudflat		x	x					x
Rorippa laciniata	Jagged Bitter-cress			Perennial Mudflat		x	x		x			x

Plant species	Common Name	Origin	VROT	Plant Functional Group	Receding						Recently inundated	Receding
					Spring		Summer				Spring	Summer
					2006	2008	2009	2013	2015	2015	2015	2016
Rorippa spp.	Bitter-cress			Not Assigned								x
Rumex bidens	Mud Dock			Emergent Amphibious		x			x			x
Rumex brownii	Slender Dock			Terrestrial Damp		x	x	x	x	x	x	x
Rumex spp.	Dock			Not Assigned		x				x	x	
Rumex tenax	Narrow-leaf Dock			Perennial Mudflat			x					x
Senecio quadridentatus	Cotton Fireweed			Terrestrial Damp	x	x	x			x	x	x
Senecio runcinifolius	Tall Fireweed			Terrestrial Damp	x	x	x				x	x
Solanum nigrum	Black Nightshade	*		Terrestrial Dry		x					x	x
Sonchus asper	Rough Sow-thistle	*		Terrestrial Damp		x						
Sonchus oleraceus	Common Sow-thistle	*		Terrestrial Damp		x	x				x	x
Stellaria caespitosa	Matted Starwort			Annual Mudflat	x	x	x	x	x	x	x	x
Stellaria media	Chickweed	*		Terrestrial Dry		x						
Triglochin procera	Water Ribbons			Adaptive Amphibious		x			x			x
Triglochin spp.	-			Not Assigned						x	x	
Utricularia australis	Yellow Bladderwort			Submerged & Floating Aquatic			x		x			x
Vallisneria australis	Eel Grass			Submerged & Floating Aquatic			x		x			x
Vallisneria australis	Eel Grass			Submerged & Floating Aquatic						x	x	x
Verbena officinalis	Common Verbena	*		Terrestrial Damp		x					x	x
Vicia spp.	Vetch	*		Terrestrial Dry		x						
Vittadinia gracilis	Woolly New Holland Daisy			Terrestrial Dry			x					x
Vulpia bromoides	Squirrel-tail Fescue	*		Terrestrial Dry		x						
Wahlenbergia fluminalis	River Bluebell			Emergent Amphibious		x					x	
Xerochrysum bracteatum	Golden Everlasting			Terrestrial Dry		x	x		x	x		x

Number of Receding wetlands sampled in spring and summer between 2006 and 2016 that complied with the condition indicators.

Sample season	Sample site & year	Number of compliant sites	Site Index compliance			
			Characteristic PFG richness	Characteristic PFG cover	Rare or threatened species	High threat weed species
Spring	BLS_2008	3	yes	yes	yes	
Spring	COS_2008	1			yes	
Spring	CS_2008	1			yes	
Spring	GS_2008	3	yes	yes	yes	
Spring	IPL_2008	1			yes	
Spring	LG1_2008	1			yes	
Spring	LG2_2008	2		yes	yes	
Spring	LL_2006	2		yes		yes
Spring	LL_2008	2	yes		yes	
Spring	LR_2008	2	yes		yes	
Summer	BLS_2009	3	yes	yes	yes	
Summer	BLS_2016	2		yes	yes	
Summer	COS_2016	1				yes
Summer	CS_2016	2		yes		yes
Summer	FB1_2013	0				
Summer	FB1_2016	1			yes	
Summer	GS_2009	4	yes	yes	yes	yes
Summer	GS_2016	1				yes
Summer	IPL_2016	0				
Summer	LG1_2009	0				
Summer	LG1_2016	1				yes
Summer	LG2_2009	2	yes	yes		
Summer	LG2_2016	1				yes
Summer	LL_2009	1			yes	
Summer	LL_2013	1				yes
Summer	LL_2016	1				yes
Summer	LR_2009	3	yes	yes	yes	
Summer	LR_2013	1			yes	
Summer	LR_2015	2		yes	yes	
Summer	LR_2016	2		yes	yes	
Summer	RL_2015	2		yes	yes	
Summer	RL_2016	2		yes	yes	