

# Gunbower Forest Sentinel Wetland and Understorey Survey autumn 2014

Fire Flood & Flora

Prepared for the North Central Catchment Management Authority







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Gunbower Forest Sentinel Wetland and Understorey Survey autumn 2014

Report prepared by Fire, Flood and Flora for Kathryn Stanislawski and Amy Russell, North Central Catchment Management Authority

NOTE: This report is accompanied by two Technical Addenda: a *Technical Addendum* which provides further details of data, methods and analyses performed as part of the monitoring program; and a *Photographic Addendum* comprising monitoring site photographs for the period from 2005 – 2014.

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# EXECUTIVE SUMMARY

- Fire, Flood and Flora was engaged by the North Central Catchment Authority to repeat sentinel wetland and understorey vegetation monitoring in Gunbower Forest in autumn 2014. The current survey represents the eighth autumnal monitoring event between 2005 and 2014.
- The purpose of the program is to monitor temporal change in vegetation variables in relation to natural and environmental flooding and drying cycles, and to investigate progress toward vegetation-based ecological objectives for the forest. It employs a range of measures to assess floristic composition, canopy health and interpret ecological processes and constitutes part of the Gunbower Koondrook-Perricoota Forest Icon Site Condition Monitoring.
- Floristic data were collected from 125 permanent vegetation monitoring sites that represent the six Water Regime Classes (WRCs) mapped in forest, including permanent and semi-permanent wetlands, River Red Gum forest and woodlands, and Black Box and Grey Box woodlands.
- Wetland sites monitored between 2005 and 2014 transitioned between dry, recently inundated and receding phases of the wetland cycle. The monitoring results suggest the wetlands supported distinct compositions of flora in each phase. Shallowly inundated wetlands were distinguished by a higher richness and cover of characteristic species. Furthermore, 93% of the rare and threatened species recorded in the wetlands were sampled in 2010 after a combination of above average rainfall and environmental water delivery in November 2009.
- In 2014 the wetlands were in dry, drying and receding phases, many having been inundated by the small inflow in spring 2013. Like previous years they were dominated by characteristic flora, had low weed cover but also few rare and threatened species. The data also suggests the average richness and cover of characteristic species had increased from 2013, which in combination with the ordination results, indicate they were transitioning back toward the more mesic states recorded in 2005, 2006 and 2010, and hence in better condition than when assessed last year. Despite this no wetlands met the Points of Reference for the characteristic Plant Functional Group (PFG) species richness Index, suggesting they did not a support a 'healthy' species richness.
- In the Red Gum WRCs, the average richness and cover of characteristic species and presence of rare and threatened species recorded over the monitoring program peaked in 2011 after above average rainfall and natural flooding of 67% of the understorey sites. Vegetation within the WRCs was however heterogeneous both within and between sampled years. The average cover and richness of characteristic flora increased marginally in the two Red Gum WRCs between 2013 and 2014, indicating an improvement in vegetation diversity. Non-characteristic terrestrial species however dominated the Red Gum FTU quadrats.
- The results in the Box woodlands were mixed. As recorded in the Red Gum WRCs the ground flora richness and cover peaked in 2011. Between 2013 and 2014, the average richness and cover of characteristic species increased marginally. However, non-characteristic terrestrial species dominated the Black Box quadrats in all years, indicating they were drier than preferred. The Box results are however influenced by the categorisation of PFGs as 'characteristic' or 'non-characteristic', as the current groupings do not reflect the gradient of vegetation from terrestrial or near terrestrial to flooded in these WRCs.

- When assessed against the Points of Reference for characteristic PFG species Index (i.e.
- Very few understorey sites achieved the characteristic PFG species Index Points of Reference (i.e. 4/50 Red Gum FDU, 1/27 Red Gum FTU, 1/19 Black Box, and 2/14 Grey Box sites). This indicates that the majority of sites did not support a 'healthy' richness of characteristic flora during 2014. The 2014 results were however marginally higher in the Grey Box and Red Gum FDU WRCs than in 2013. The 2014 results are comparable to during the drought (2005 2010).
- The number of Red Gum sites that complied with the Tree Canopy Health Index Points of Reference declined dramatically between 2005 and 2006 (i.e. Red Gum FDU, 18/42 to 2/42 sites; Red Gum FTU, 10/23 to 2/23 sites). There was however a slight increase in the number of sites that achieved the Point of Reference in the Red Gums FDU WRC (6/50) after high rainfall and flooding in 2010 2011. The number of Box woodland sites that complied with the index Points of Reference also declined from 5/15 Black Box and 4/11 Grey Box sites in 2005 to zero by 2014. These results suggest the eucalypts have not yet recovered from the 14 year drought and potentially other disturbances such as 140 years of harvesting and river regulation.
- In conclusion, the wetlands assessed in Gunbower Forest appeared to have improved slightly in condition over the last twelve months, especially in areas that dried out. The high levels of turbidity and paucity of aquatic flora in inundated wetlands suggests that other factors such as Carp are influencing the health of these systems. The Red Gum and Box monitoring results also suggest a modest improvement in health, most likely due to higher rainfall in the preceding 12 months than when sampled in 2013. Despite the above, no wetland sites and only a small number of Red Gum and Box WRC sites assessed were considered satisfactorily species rich, and tree health was found to be generally low and/or declining.

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# 1.0 INTRODUCTION

# 1.1 Project Context

Fire, Flood and Flora was engaged by the North Central Catchment Management Authority (CMA) to conduct sentinel wetland and understorey vegetation monitoring in 2014 in Gunbower Forest, the Victorian half of the Gunbower-Koondrook-Perricoota (GKP) Forest Icon Site. The purpose of the monitoring is to '*determine the change in the environmental condition of individual Icon Sites resulting from water application and implementation of works programs under The Living Murray*' (DSE *et. al.* 2011). The Living Murray (TLM) is Australia's largest river restoration initiative, and is overseen by the Murray Darling Basin Authority (MDBA) (MDBA, 2008).

The Gunbower Forest sentinel wetland and understorey monitoring program was developed by Francis Crome (2004b) as part of a scientific framework that investigates aspects of floodplain ecology including birds, fish, frogs and hydrology. Specific to vegetation and the current investigation, the monitoring method details the collection and analysis of floristic composition and structural data, and guides the interpretation of ecological processes.

Floristic data were collected in autumn 2014 from 125 permanent vegetation monitoring sites that represent the diversity of floodplain communities within the forest, including permanent and semi-permanent wetlands, waterways, River Red Gum Forest, and Black Box and Grey Box Woodlands.

# 1.2 Gunbower Forest

Gunbower Forest is a large (19,450 ha), narrow forest located on the River Murray floodplain between Koondrook and Torrumbarry, approximately 240 kilometres north west of Melbourne (Figure 1). The forest's characteristically flat landscape is punctured by small sandy rises and dissected by a diversity of wetlands and waterways. Soils alternate between clay loams in areas of lower elevation and sandy loams on the higher rises. The region's climate is typically hot and dry in summer and cold and wet in winter (BoM, 2014).

The forest's ecology is reliant on overbank flow from the River Murray washing across the landscape, replenishing groundwater, diluting salinity and revealing a complex system of wetlands and waterways (MDBC, 2005). Vegetation across the floodplain reflects subtle topographic and inundation patterns, with aquatic flora and River Red Gum (*Eucalyptus camaldulensis*) dominating the more frequently flooded areas, and semi-aquatic flora, Black Box (*E. largiflorens*) and Grey Box (*E. microcarpa*) more common higher in the landscape and abutting terrestrial ecosystems. Floristic expression within each of these ecosystems also varies temporally in response to the wetting-drying cycles experienced. Depending on the timing, and depth and duration of inundation, flooded ecosystems can support a rich array of aquatic, amphibious, mudflat and floodplain flora (refer to Technical Addendum for a diagrammatic depiction of an indicative wetting-drying cycle for a Riverine wetland).



Figure 1 Gunbower-Koondrook-Perricoota Icon Site.

Gunbower Forest is recognised as a site of high ecological significance, as well as for timber production, recreation and flood mitigation. It is the one of the largest area of remnant Red Gum vegetation remaining in Victoria, and is recognised at state, national and international scales. At state level the forest supports a range of rare and threatened flora and fauna, and intact endangered Plains Woodland. Nationally, the forest is recognised as an Icon Site by the Murray Darling Basin Authority and is listed in the Directory of Important Wetlands in Australia. Internationally the floodplain is listed as a wetland of International Importance under the Ramsar Convention and is acknowledged for supporting migratory avifauna (i.e. JAMBA and CAMBA bilateral agreements). Gunbower Forest comprises areas of National Park and State Forest, and is jointly managed by Parks Victoria, the Department of Environment and Primary Industries (DEPI) and the North Central CMA. The site falls within the Murray Fans subregion of the Victorian Riverina bioregion.

# 1.3 Rainfall and Flooding

During the last decade Gunbower Forest has experienced both drought and flood. Specifically, the period between 2005 and 2014 included one of the longest and driest periods on record (the Millennium Drought, 1997-2009), unusually low autumn rainfall, and one of the strongest La Nina episodes (2010-2011), which resulted in widespread above average rainfall (Figure 2) and flooding across the Murray Darling Basin (CSIRO, 2011).

A number of localised climatic events (Technical Addendum, Section 2.2) are likely to have influenced the floristic data collected. These include the exceptionally high monthly rainfall between November (2004) and February (2005), preceding the 2005 survey, and in November (2009) prior to the 2010 survey, and the below

average rainfall and above average temperatures recorded between November (2012) and April (2013) prior to the 2013 survey. Similar conditions were reported in the 12 months preceding the 2014 survey as those in the months preceding the 2013, although not as extreme.

Water enters the lower forest landscape at river flows of 15,000 ML/day (Ecological Associates 2003). Consequently many of the wetlands surveyed were inundated to some degree in 2003, 2004, 2005, 2010, 2011, 2012 and 2013 (Figure 2). The forest however requires river flows over 30,000 ML/day for 'worthwhile' flooding and flows of 55,000 ML/day for at least a month of major flooding (O'Bryan, 1977).

Flooding in Gunbower Forest caused by flows over 30,000 ML/day occurred between 2010 and 2012, as indicated by river flow data for Torrumbarry Weir (Figure 3). The largest two inundation peaks occurred in late 2010 (prior to the 2011 survey), followed by three smaller peaks over the subsequent 18 months (one during the 2012 survey). Wetlands in the lower landscape were consequently inundated for over two years prior to the current survey, and considerable areas of River Red Gum and some areas of Black Box vegetation were flooded more than once. A small natural inflow also occurred in spring 2013 prior to the current survey.

Environmental water has been delivered to the wetlands in the lower landscape via three independent regulators on the Gunbower Creek in eight separate events between 2003 and 2014 (Technical Addendum, Section 2.1). Water delivery has targeted particular wetlands or complexes of wetlands and hence has created a mosaic of wet and dry conditions at the wetland sites monitored (refer to Table 8 in Section 3).



Figure 2 Monthly rainfall (recorded and 130 year mean at Kerang) and vegetation condition monitoring events, Victoria between July 2003 to March 2014 (Source: BoM 2014)



Figure 3 Murray River flow at Torrumbarry Weir and vegetation condition monitoring events between July 2003 to March 2014 (Source: MDBA 2014) and combined environmental water delivered to the wetlands (Source: G-MW 2013)

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# 1.4 Icon Site Condition Monitoring Program

Condition monitoring at the Murray River Icon Sites aims to assess change in the health of iconic vegetation and fauna communities over time and with reference to hydrological events. Gunbower Forest sentinel wetland and understorey monitoring is part of this larger program. The site-specific vegetation monitoring program was originally developed in 2004 to "*Determine if implementation of water management options is improving the ecological health/biodiversity of the floodplain system*" (Crome, 2004a) by collating data for 27 ecological objectives, including 12 vegetation objectives.

Over the last decade the ecological objectives for the forest have been revised and targets set (Table 1). The methods for analysing monitoring data and reporting on the objectives have also undergone revision (see Robinson, 2013). Vegetation condition indicators were developed to report on the Gunbower Forest ecological objectives based on the decade of existing data (see Box 1). Quantified definitions of vegetation health (see Points of Reference (PoR) Table 1) were drafted in 2013 and formed the basis of the vegetation condition indicators.

The efficacy of two of these vegetation indicators (PFG species richness and tree canopy health) was analysed by Dr Lien Sim, to determine the ability to detect a difference in index score between years (and what size of 'effect' could be detected) in relation to the number of samples used (power analyses) and whether the proposed indicators show a response to change in index score (sensitivity analyses) (Sim & Bennetts, 2014). These indicators draw on the two key vegetation datasets – ground flora (wetland and understorey sites) and canopy trees (understorey sites) from which all seven indicators proposed for the forest are derived – and hence will reflect likely power results for other indicators. The methods implemented by Dr Sim for analysing the two revised vegetation condition indicators have been applied in the current project.



Table 1 Gunbower Forest site-specific ecological objectives and targets for vegetation and measurement approach

Source: North Central CMA Request for Quote Specification - Gunbower Forest Sentinel Wetland and Understorey Surveys, Contract No: 2014065 autumn 2014.

Note these are subtly different to the Gunbower Forest ecological objectives reported by MDBA (2012).

Overarching objective	Detailed Objectives	Target	Proposed Indicators of condition and associated Points of Reference (Bennetts & Jolly 2013)
Increase area of healthy Permanent and Semi- permanent Wetlands Ensure maintenance of healthy River Red Gum communities Maintain Black Box and Grey Box communities	Maintain and where possible increase the presence of threatened species. Maintain appropriate cover and richness of species in plant functional groups within each water regime class (WRC). Allow for recruitment of species and structural diversity appropriate to wetting and drying cycles. Decrease the abundance of high threat weed species and terrestrial species in flood-reliant vegetation	At least 80% of wetland Water Regime Classes in healthy condition by 2025 At least 30% of River Red Gum Water Regime Classes in healthy condition by 2025 Maintain extent and health of Black and Grey Box Water Regime Classes.	<ul> <li>(1) PFG species cover <ul> <li>PoR: &gt;50% of total cover of PFG species characteristic of the WRC.</li> </ul> </li> <li>(2) PFG species richness* <ul> <li>PoR: 2/3 of all species possible in PFGs characteristic of the WRC.</li> <li>PFGs characteristic of the WRC:</li> <li>PFGs 1 - 5 in Permanent Wetlands</li> <li>PFGs 2 - 5 in Semi-permanent Wetlands</li> <li>PFGs 3 - 5 in RRG Flood Dependant Understorey</li> <li>PFGs 4 - 6 in RRG Flood Tolerant Understorey</li> <li>PFGs 5 - 7 in Grey Box Woodlands</li> <li>(3) Threatened species</li> <li>PoR: &gt;50% of threatened species previously recorded in state databases and the monitoring program in the associated WRC.</li> </ul> </li> <li>(4) Exotic species <ul> <li>PoR: Limited cover of high threat exotic plants (&lt;10%).</li> </ul> </li> <li>(5) Tree canopy health* <ul> <li>PoR: tree crown health score &gt;3</li> </ul> </li> <li>(6) Tree recruitment <ul> <li>PoR: adequate tree growth over the long-term</li> </ul> </li> </ul>

\*PoR updated to the 90<sup>th</sup> percentile of data points, in line with other Icon Sites (Sim & Bennetts, 2014)

As part of the process of revising and testing the indicators, the Points of Reference (PoR) were updated from those originally stated in Table 1, in line with the approach applied at other Icon Sites and as recommended by Wayne Robinson (Robinson 2014). To calculate the PoRs, the long-term database was interrogated to determine what number of species and what proportion of trees with 'healthy canopies' (per site) represented the top 10% of sites for each indicator for each Water Regime Class (WRC) between 2005 and 2014 ('raw percentile' approach). Data within the Red Gum and Box WRCs were given equal weights, since they were all sampled using 10 x 10 m quadrats. Data within the Permanent and Semi-permanent wetland WRCs were converted, using an area-weighted approach, to account for differences in sampling area between sites and years (Sim & Bennetts 2014).

Note: For the purposes of the review, the 'raw percentile' approach was used to set the PoRs based on all 10 years of monitoring data but, depending on what is most important to the project manager in the future, it could be revised to be based on a reference year (i.e. the 'best' year or the first year of monitoring).

# 2.0 METHODOLOGY

# 2.1 Field Survey

A field survey of Gunbower Forest was undertaken between the 1<sup>st</sup> March and 10<sup>th</sup> April 2014, when 110 understorey quadrats and 15 wetland transects were surveyed in accordance with the *Revised Manual of Field Procedures for Monitoring in Gunbower Forest* (Crome, 2004a; revised by Australian Ecosystems, 2008). The sites surveyed represent the full cohort of the 125 permanent monitoring sites established within Gunbower Forest (Table 2, Figure 4).

Year	Strata	Wetland	Understorey	Total sites
2005	autumn	14	90	105
2006	autumn	15	90	105
2006	spring	4	-	4
2007	spring	4	30	34
2008	autumn	15	110	125
2008	spring	15	110	125
2009	summer	15	-	15
2010	autumn	15	110	125
2011	autumn	14	110	125
2012	autumn	13	108	121*
2012	summer	4	-	4
2013	autumn	15	110	125
2014	autumn	15	110	125

Table 2 Number of wetland transects and understorey quadrats surveyed as part of the Gunbower Forest vegetation monitoring program 2005 – 2014

\* Two understorey and two wetland sites were inaccessible in 2012 on account of flooding.



Figure 4 Permanent monitoring sites (understorey quadrats and wetland transects) at Gunbower Forest

# 2.1.1 Sentinel Wetland Transects and Understorey Quadrats

All ground flora species occurring within each 10 x 10 metre understorey quadrat, or within each two metre wide vegetation zone along a wetland transect, were identified to specific level, and projected foliage cover (percentage) was estimated. Tree attributes were recorded for all eucalypts present (Table 3).

Eucalypt category	Sample Size	Measurements
Canony trees*	20 eucalypt trees >3m in height and >10cm DBH,	Species
Callopy liees	located in and around quadrat	Crown condition health score
	All eucalypt trees >3m in beight and >10cm DBH in	Species
Trees	All eucarypt trees >5m in neight and >10cm DDF in	DBH
	quadraviransect	Crown condition health score
	All question traces $2m$ in beight and $<10cm$ DBH (at site	Species
Other trees*	establishment) in quadrat	DBH
		Crown condition health score
	All questions and a 25.3 m in baight in	Species
Saplings	quadrat/transect	Height
		Crown condition health score
Seedlings	All eucalynt seedlings <0.25m in guadrat/transect	Species
Cecumgs		Count

Table 3 Eucalypt tree canopy measurements (Source: Crome, 2004a)

\*not included in wetland assessment.

Tree condition was scored in reference to tree crown health categories (Table 4) and the images contained within the monitoring manual (Crome, 2004a; revised by Australian Ecosystems 2008).

Tree Crown Health Categories		Health Description
		Dead tree with no original canopy
0	Dead Tree	All main branches dead
		No epicormic growth
		Tree with no original/intact canopy
1	Unhealthy Tree	Most main branches dead
		All epicormic growth
		Tree with <25% of the original/intact canopy present
2	Unhealthy Tree	Some main branches dead (<50% canopy)
		Predominantly epicormic growth (>50% of remaining canopy)
		Tree with 25-50% of the original/intact canopy present
3	Tree	Some small dead branches
		Some epicormic growth (<50% of remaining canopy)
		Tree with 50-75% of the original/intact canopy present
4	Healthy Tree	Some dead branchlets (<50% of canopy)
		<10% epicormic growth
		Tree with >75% of the original/intact canopy present
5	Healthy Tree	May include some dead branchlets and leaves
		<5% epicormic growth

Table 4 Tree crown healt	n categories and	descriptions	(Source:	Crome,	2004a)
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Other variables recorded at each site during the field survey included - evidence of disturbance (e.g. inundation, timber harvesting, grazing, fire and tree fall), general vegetation condition (based on categories developed by Doug Frood (2008)) and any incidental observations.

# 2.1.2 Plant Taxonomy

Plant taxonomy in this report follows the Victorian Plant Name Index (DSE, 2011), with consideration to the Census of Victoria Vascular Plants (Walsh and Stajsic, 2007). The conservation status of species is as per the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), the Flora and Fauna Guarantee Act 1988 (FFG Act), and the Victorian rare or threatened species advisory list (DSE, 2005), refer to Box 2. Consideration is also given to the IUCN Red List (IUCN, 2010).

#### Box 2: Key to Conservation Status of Flora Taxa

Status under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

- EN Endangered in Australia: A taxon is endangered when it is not critically endangered but is facing a very high risk of extinction in the wild in the near future.
- VU Vulnerable in Australia: not presently endangered but at risk of disappearing from the wild over a longer period (20 to 50 years) through continued depletion

Status under the Flora and Fauna Guarantee Act 1988 (FFG Act)

L Listed as threatened

Conservation Status in Victoria (DEPI Advisory List of Rare and Threatened Flora)

- e Endangered in Victoria: at risk of disappearing from the wild state if present land use and other casual factors continue to operate
- Vulnerable in Victoria; rare, not presently Endangered but likely to become so soon due to continued depletion of;
   taxa where populations are so low that recovery from a local natural disturbance is doubtful
- r Rare in Victoria but not considered otherwise threatened there are relatively few known populations or the taxon is restricted to a relatively small area
- k Poorly known and suspected, but not definitely known to belong to the one of the categories Presumed extinct, Endangered, Vulnerable or Rare in Victoria

# 2.1.3 Hydrological Data

Local rainfall and flood data were collated to explore the influence of hydrology on floristic results (Figures 2 and 3). Annual and monthly rainfall data were obtained for Kerang weather station (Station Number: 80023) from the Bureau of Meteorology (BoM) Climate Data Online service (BoM, 2014). Flood frequency and extent was inferred from flow data collected at Torrumbarry Weir (MDBA, 2014), using the North Central CMA's ecological flow thresholds (A. Chatfield, 2012, North Central CMA *pers. comm.*), and the known volumes of environmental water allocated (G-MW, 2013).

Without the benefit of precise flood extent data, the probability of flooding at each site was determined based on anecdotal evidence observed during the field surveys. Evidence of flooding included ponded water (on or nearby the site), recent water marks on tree trunks, fresh silt coating over ground flora and litter, and/or vigorous growth of known water dependent species such as *Carex tereticaulis*, *Nymphoides crenulata*, *Myriophyllum* spp. and *Juncus* spp. (excluding *J. subsecundus*) not previously recorded in the previous survey.

# 2.2 Data Analysis

Field data were aggregated (Table 5) to allow the description and analysis of quadrat and transect floristics, canopy health, and vegetation condition indicators. The key aims of these analyses were to:

- Identify potential patterns in the floristic data
- Compare 2014 data to that collected in autumn of previous years
- Identify potential effects of environmental water and/or natural flooding on the floristic data
- Calculate the condition of the survey sites based on vegetation indicators referenced to the top 10<sup>th</sup> of data points from the ten years monitoring data.

Data Grouping	Purpose
Vegetation types	Collate data and results in line with Icon Site ecological objectives     Wetlands
	- River Red Gum Forest & Woodlands
	- Black and Grey Box Woodlands
Water regime classes	• To delineate broad vegetation types and how they are influenced by their landscape position
(WRCs)	(Landscape Logic).
	- Permanent Wetlands
	- Semi-permanent Wetlands
	- River Red Gum with Flood Dependent Understorey
	(Red Gum FDU)
	- River Red Gum with Flood Tolerant Understorey
	(Red Gum FTU)
	- Black Box Woodlands (Black Box)
	- Grey Box Woodlands (Grey Box)
Ecological Vegetation	• To describe vegetation types based on common environmental conditions and a distinct suites
Classes (EVCs)	of flora species
	To assist the interpretation of ecological patterns in vegetation
Plant Functional Groups	• To group plants based on common ecological, morphological and functional responses to
(PFGs)	inundation.
	To reduce scale of data analysis.

#### Table 5 Framework for data analysis

Flora species were classified into Plant Functional Groups (PFGs) based on a system adapted from Brock and Casanova (1997) (Table 6).

PFG Code	Plant Functional Group Name	Description
		S - Submerged (includes strictly aquatic floaters)
1	Floating Aquatic Flora	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.
		ARf - Amphibious Fluctuation - Responders Floating
2	Floating Amphibious	Amphibious species that produce floating foliage when inundation. Aerial parts of plants
2	Flora	survive exposure of the wetland substrate (drying) for sustained periods of time. Plants
		survive drying by dying back to rootstocks.
		ARp - Amphibious Fluctuation - Responders Plastic
2	Adaptive Amphibious	Amphibious species that altered their growth pattern or morphology in response to water
3	Flora	conditions. Can actively grow when substrate exposed but still moist, but may die back to
		rootstocks or seed during sustained dry periods.
		ATI - Amphibious Fluctuation - Tolerators Low Growing
1-	Perennial Mudflat Flora	Perennial amphibious species that tolerate changes in water conditions and maintain same
4a		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	ATI - Amphibious Fluctuation - Tolerators Low Growing
		Annual (or functionally so) amphibious species that may tolerate very brief periods of
4b		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.
		ATe - Amphibious Fluctuation - Tolerators Emergent
	Emergent Amphibious Flora	Amphibious flora that tolerate changes in water conditions, typically with emergent habit.
5		Rootstocks tolerant of shallow inundation but plant intolerant of sustained total immersion.
		Recruitment and/or long-term maintenance of populations are generally dependant on at
		least occasional inundation events.
	Terrestrial Damp	Tda - Terrestrial Damp
6		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
		Tdr - Terrestrial Dry
7	Terrestrial Dry	Dry-land plants (i.e. flood intolerant and going through life cycles independently of flooding
		regime)
0	Not-vegetated	Bare ground, litter, logs, water etc.
NA	Not Assigned	Species for which there is insufficient information to assign them to a PFG

Table 6 Plant Functional Groups applied in Gunbower Forest condition monitoring (adapted from Brock and Casanova 1997)

# 2.2.1 Summary Statistics

Summary statistics were tabulated for vegetation attributes including species richness and cover, rare and threatened taxa, exotic taxa, and canopy condition. Statistics were tabulated for each transect and understorey quadrat, and for each WRC aggregate (i.e. wetlands, Red Gums and Box), and temporal trends identified.

The approach applied to determine flora cover in the wetlands differed from the understorey sites (where percent cover x  $100m^2$  quadrat area was used), as the sampled wetland transect area varied between years due to the presence/absence of water. The process applied was as follows. The area (m<sup>2</sup>) of each species was

calculated by multiplying the estimated species cover (%) by the area in the transect zone. The proportion of the transect covered by each species was determined by dividing the summed species cover ( $m^2$ ) from all transect zones by the total transect area ( $m^2$ ). Further to the above, analysis was performed by wetland (*n*=10) not transect (*n*=15), and hence data from wetlands with multiple transects was averaged prior to analyses.

# 2.2.2 PFG Species Richness Index

The vegetation condition Indicator for PFG species richness was developed to facilitate progress towards measurement of one or more of the Gunbower Forest ecological objectives (see Section 1.4). The indicator comprises a sampling framework, a Point of Reference (PoR), and a series of calculations. The following section details the PoR and the approach applied by Sim and Bennetts (2014) for calculating the PFG Species Richness Index based on the ground flora dataset from both the wetlands and understorey sites.

# **Points of Reference**

For each WRC, the richness of native characteristic PFG species at a site is considered 'healthy' if it is on or above the 90<sup>th</sup> percentile of all records between 2005 and 2014 (the PoR).

The PoR each WRC these values are:

- Permanent Wetlands 1.42 species from PFG 1-5 (weighted data)
- Semi-permanent Wetlands 1.33 species from PFG 2-5 (weighted data)
- Red Gum with FDU 9 species from PFG 3-5
- Red Gum with FTU 11 species from PFG 4-6
- Black Box Woodlands 5.9 species from PFG 4-6
- Grey Box Woodlands 14 species from PFG 5-7

# **Index Calculation**

The PFG Species Richness Index was calculated by applying the following steps.

For wetland WRCs:

- An area-weighted approach was used to summarise the data across the WRC (wetlands as replicates).
- Summarise the richness of characteristic PFG species by site.
- Plot 'area of characteristic PFG species recorded' (as a surrogate measure of abundance) against 'number of characteristic PFG species recorded' and fit non-linear regression line to the data for each WRC (species turnover using abundance).
- Weight PFG richness data by sampled area by dividing PFG richness (number of PFG species recorded) by the number of PFG species predicted by the regression equations.
- Summarise weighted data by site.
- From these data, determine the 90th percentile value (PoR).
- Convert weighted species richness data to a site index using the formula: Index = Sqrt(PFG richness) ÷ Sqrt(Point of Reference)
- Correct so that any values >1 are recorded as 1.
- Site index lies between 0 and 1

- Site PFG richness that is greater than or equal to the PoR results in an index of 1 (it is compliant), and PFG richness less than the POR results in an index of <1 (it is not compliant).
- Calculate the WRC score as the proportion of compliant sites in each WRC.

For Red Gum and Box woodland WRCs:

- Summarise the richness of characteristic PFG species across the WRC (quadrats as replicates).
- From these data, determine the 90th percentile value.
- Convert species richness data to an index using the formula: Index = Sqrt(PFG richness) ÷ Sqrt(PoR)
- Correct so that any values >1 are recorded as 1.
- Index lies between 0 and 1.
- Site PFG richness that is greater than or equal to the PoR results in an index of 1 (it is compliant), and PFG richness less than the POR results in an index of <1 (it is not compliant).
- Calculate the WRC score as the proportion of compliant sites in each WRC

The PFG Species Richness Index represents the number of characteristic PFG flora species recorded per survey site (understorey quadrat or wetland transect), relative to the PoR (the number recorded in the top 10% of records over the period 2005 - 2014 for each WRC).

# 2.2.3 Tree Canopy Health Index

The vegetation condition indicator for tree canopy health has been developed, alongside the PFG species richness indicator, to facilitate progress towards one or more of the Gunbower Forest ecological objectives (see Section 1.4). The following section details the tree canopy PoR and approach recommended by Sim and Bennetts (2014) based on the tree canopy dataset collected from the understorey sites (Red Gum (FDU and FTU), Black Box and Grey Box WRCs). The health of trees is expected to increase with environmental water delivery.

Data points (sites) within the Red Gum and Box WRCs were given equal weights, since the sampled population (20 trees) at the understorey sites did not change in from year to year.

# Points of Reference

For each treed WRC, the proportion of trees with a crown health category of >3 at a site is considered 'healthy' if it is on or above the 90<sup>th</sup> percentile of all index values between 2005 and 2014 (PoR).

The PoR for the treed WRCs are:

- Red Gum FDU 0.80
- Red Gum FTU 0.815
- Black Box Woodland 0.90
- Grey Box Woodlands 0.95

# **Index Calculation**

The Tree Canopy Health Index was calculated by applying the following steps.

- For each tree, determine if it is scored as 'healthy' (Tree crown health category > 3).
- Calculate the proportion of healthy trees in each quadrat.
- From these data, determine the 90th percentile value (PoR).
- The site index score is expressed as a proportion ranging from 0 to a maximum of 1.
- Site index scores greater than or equal to the PoR value for each WRC indicate compliant sites.
- Calculate the WRC score as the proportion of compliant sites in each WRC.

The Tree Canopy Health Index scores the proportion of trees with healthy canopies (based on the crown health categories in Table 4) at a site level. The site index score is compared to the top 10% of records over the period 2005 - 2014 in each WRC (the PoR) to determine compliance.

# 2.2.4 Univariate Analyses

Univariate analyses are statistical analyses carried out on a single dependent variable (e.g. mean PFG species richness). This is in contrast to multivariate analyses, which examine multiple variables at the one time (e.g. cover of each of a suite of species).

Univariate analyses were used to explore the effect of flooding on mean PFG species richness (as the dependent variable) in Red Gum understorey quadrats. They were performed based on the original 65 Red Gum FDU and FTU quadrats established in 2005. Treatments were however unbalanced, with data lacking for some quadrats in some years, and inconsistencies in the flooding regimes. A Generalized Linear Model (GLM, Genstat 14th Edition) approach was therefore used, as it does not make the same assumptions about data normality or variance. Data were only analysed when at least 10% of the available data cells in the spreadsheet were populated, hence PFG 1 and PFG 2 were omitted from the GLM.

Prior to the commencement of the experiment, most sites were last flooded in 1996. We do not know the precise extent to which the research plots were inundated then, but time-since-flooding in 2005 was nonetheless assumed to be 10 years. A sub-section of 65 sites was then flooded (1 site flooded in 2006; 52 sites flooded in 2011; and 33 sites flooded in 2012, see Section 2.1.3).

Because the effects of previous flooding were likely to be more important than the effects of time *per se*, we used Time\*Flood-value as the fitted model, where Time was the number of years since the surveys commenced, and Flood-value was a categorical value related to time-since-flooding (where 1 = flooding within the last year, 2 = flooding within the last 2 or 3 years, and 3 = flooding within 4+ years). Assuming that most of the effects of flooding would be observed within a few years of flooding, such a categorical value was deemed to be more useful than a simple time-since-flooding value, given that the data prior to 2011 were heavily weighted towards values  $\geq$ 10 years.

# 2.2.5 Multivariate Analyses

Multivariate analyses (ordinations) were used to explore similarities between sampling units (wetlands or quadrats in each sampling year). Analyses were performed on the complete set of ground flora sites (wetland transect and understorey quadrat) surveyed (Table 2).

The analyses were undertaken in the PRIMER software package (version 6; PRIMER-E, Plymouth, UK). Percentage cover of all quadrat/transect records (flora species, bare ground, leaf litter and water) were used to generate Bray-Curtis similarity matrices for each vegetation type. Ordination by non-metric multi-dimensional scaling (NMDS) was then performed on these data to examine groupings of records based on percent cover (after square-root transformation to reduce the influence of highly abundant species). Ordinations allow the representation of a multidimensional space in a low number of dimensions (in this case two).

# 2.3 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 when interpreting the results 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:

- Suitable environmental conditions did not exist for all species in all years.
- The monitoring program is principally undertaken in autumn and therefore does not represent the full annual diversity of flora.
- The first six years of the monitoring program were undertaken during the last half of a 14 year drought.
- 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).
- Wetland transects change in length each year, depending on degree of inundation. We would expect more species to be recorded at a larger transect. To correct for this, weighting by area has been performed using a species vs abundance curve (see details under 'Index calculation').
- Wetland data are highly variable due to intrinsic differences in size, condition and flooding regime between wetlands, plus the inability to sample at the same stage of inundation each year, which dramatically affects which species are recorded. Summarising wetland data into a single index value for each WRC is likely to incorporate significant error.
- Wetland transects were re-established using a 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. It is therefore likely there is some data mismatch, namely in the sapling sample in Black Swamp. This limitation is, however, thought unlikely to substantially affect the other results.
- 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 created by the subtle environmental gradient across the floodplain. Consequently naturally
  occurring 'non-characteristic species' can contribute to a poor health score.

Additionally, as the monitoring program is not measuring response under controlled conditions (i.e. there are not control and impact sites), causality is not demonstrated, rather inferences and anecdotal observations can be made as to driving factors that affect floristic composition and ecological condition.

# 3.0 WETLAND STRATUM RESULTS



#### 3.1 Overview

Gunbower Forest is mapped with two wetland WRCs - permanent and semi-permanent wetlands. Permanent wetlands are areas thought to require almost annual inundation, and retain water in deep pools in most years (Crome, 2004b). Semi-permanent wetlands occur in openings in the lower and mid sections of Gunbower Forest and are believed to flood less frequently and potentially at shallower depths than permanent wetlands (URS, 2001). The wetlands surveyed include a deeply incised creek bed (i.e. Little Gunbower Creek), paleoriver lagoons (e.g. Black Swamp and Iron Punt Lagoon) and low points in the forest (e.g. Corduroy Swamp and Little Reedy Lagoon).

The analyses and results for the Permanent and Semi-permanent wetland WRCs have been combined where practical in Section 3, as there is floristic evidence to suggest that wetland phase (refer to Technical Addendum, Section 3 and Table 8) is likely to be more informative than survey year or WRC (refer to the Wetland Case Study on pages 31 and 32).

Water Regime Classes	Permanent and Semi-permanent wetlands									
Extent in Gunbower Forest	381ha (2%) permanent wetlands (MDBA, 2010)									
	992ha (5%) semi-permanent wetlands (MDBA, 2010)									
Wetlands (10)	Black Swamp x2									
Transects (15)	Corduroy Swamp									
	Greens Swamp									
	Little Gunbower Creek Complex x2									
	Reedy Lagoon x3									
	Charcoal Swamp									
	Football Grounds									
	Iron Punt Lagoon									
	Long Lagoon									
	Little Reedy Lagoon x2									
Ecological Vegetation	Un-vegetated Open Water (EVC 990)									
Classes (6)	Floodway Pond Herbland (EVC 810)									
	Tall Marsh (EVC 821)									
	Rushy Riverine Swamp (EVC 804)									
	Fringing the wetlands:									
	Riverine Swamp Forest (EVC 814)									
	Grassy Riverine Forest (EVC 106)									
Indigenous flora	Permanent 73% of species (40/55) (monitoring total for WRC = 89)									
	Semi-permanent 77% of species (41/53) (monitoring total for WRC = 86)									
Exotic flora	Permanent 27% of species (15/55) (monitoring total for WRC = 35)									
	Semi-permanent 23% of species (12/53) (monitoring total for WRC = 34)									
	High threat environmental weeds $48\%$ (10/21) (monitoring total for WRC = 20)									
	Exotic species covered less than 2% of the wetland transects on average when surveyed in 2014.									
Rare or threatened species	Permanent 3 species listed on the Victorian rare or threatened advisory list (monitoring program total for WRC = 8)									
	Semi-permanent 3 species listed on the Victorian rare or threatened advisory list (monitoring program total for WRC = 6)									
Wetland Phases	7 sites were dry									
1 site was drying										
	1 site was receding (shallowly inundated)									
	1 site was receding (deeply inundated)									
Vegetation condition	Characteristic PFG species									
indicators	No wetlands achieved in 2014 the Points of Reference:									
	Permanent Wetlands - 1.42 PFG 1-5 species (weighted data)									
	Semi-permanent Wetlands - 1.33 PFG 2-5 species (weighted data)									
L										

# Table 7 Summary of wetland survey results for Gunbower Forest autumn 2014

Water Regime Classes	Permanent and Semi-permanent wetlands							
	Permanent	2/10 shallowly inundated, receding and 2/10 deeply inundated, receding wetlands met the Point of Reference 2005 - 2014. No recently inundated (0/5), dry (0/11) or drying (0/3) wetlands met the Point of Reference.						
	Semi-permanent	3/9 shallowly inundated, receding and 1/2 recently inundated wetlands met the Point of Reference 2005 - 2014. No deeply inundated (receding, 0/3), dry (0/20) or drying (0/3) wetlands met the Point of Reference.						
Progress towards the WRC	Increase area of healthy Permanent and Semi-permanent Wetlands							
ecological objective	The results suggest that the highest average richness and cover of characteristic PFG flora were recorded when the wetlands were shallowly inundated (receding). Wetlands in other phases were also dominated by characteristic PFG flora suggesting they remained within context as they transitioned between the different stages of the wetland cycle, and did not for example shift into a terrestrial dominated system. The covers of exotic and terrestrial species were also relatively low. These results indicate the wetlands assessed remained relatively 'healthy' (according to the criteria in Table 1).							
	Environmental water delivered between 2004 and 2010 ensured the wetlands experienced wet phases during the drought. The subsequent receding (shallowly and deeply inundated) and drying wetlands included the highest average richness and cover of characteristic species, greatest presence of rare and threatened species and lowest weed cover records.							
	There was however considerable variability between the wetlands. Not all wetlands supported a high diversity of flora in all years. Furthermore, only eight of the 77 wetlands assessed (wetlands x sample year) met the characteristic PFG species richness Index Point of Reference. This implies that the majority of the sites did not support a 'healthy' richness of flora species.							
	In 2014 the wetlands were dominated by characteristic PFG flora, had low weed cover, but also had few rare and threatened species. Ordination of the ground flora cover data indicated the wetlands were transitioning back toward the more mesic states recorded in 2005, 2006 and 2010, and hence had improved on the dry state recorded in 2013. Despite this no wetlands met the Point of Reference for the characteristic PFG species richness Index in 2014, again highlighting the wetlands did not support a 'healthy' species richness. The condition of the wetlands in 2014 possibly still reflects the prolonged inundation event caused by natural inflows between 2010 and 2012, which created turbid and anoxic conditions and introduced carp back into systems.							
	No measurement of wetland area is undertaken in the current study, as it was not included in the original sampling program contracted. The above results therefore report on change in condition rather than 'area of healthy' wetland. It is recommended the ecological objectives be revised to address this inconsistency.							

Year			Permanent Wetla	inds		Semi-permanent Wetlands							
	Black Swamp	Corduroy Swamp	Greens Swamp	Little Gunbower Complex	Reedy Lagoon	Charcoal Swamp	Iron Punt Lagoon	Football Grounds	Long Lagoon	Little Reedy Lagoon			
2005	Drying	-	Receding (shallow)	Receding (deep)	Receding (shallow)	Dry	Drying	Dry	Dry	Receding (shallow)			
2006	Receding (shallow)	Receding (shallow)	Receding (deep)	eceding (deep) Receding (deep) Recedi (shallo		Dry	Receding (deep)	Receding (shallow)	Receding (shallow)	Receding (shallow)			
2008	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry			
2010	Receding (shallow)	Dry	Dry	Receding (deep)	Receding (shallow)	Dry	Dry	Dry	Receding (shallow)	Dry			
2011	Receding (deep)	Receding (shallow)	Receding (deep)	Receding (deep)	Receding (deep)	Receding (shallow)	Receding (deep)	Receding (shallow)	Receding (deep)	Receding (shallow)			
2012	Recently inundated	Recently inundated	Recently inundated	Recently inundated	Recently inundated	Recently inundated	Recently Recently Recently inundated Recently		Recently inundated	Recently inundated			
2013	Drying	Dry	Receding (shallow)	Receding (deep)	Drying	Dry	Receding (shallow)	Dry	Dry	Drying			
2014	Dry	Dry	Receding (shallow)	Receding (deep)	Dry	Dry	Dry	Dry	Dry	Drying			

Table 8 Phase of the wetland cycle observed at wetland monitoring sites in autumn Gunbower Forest 2005 - 2014. Note 2007 and 2009 were not surveyed.

#### Water depth Wetland phase

- > 0 cm Recently inundated (i.e. within last month) (*n* = 10, note only 8 wetlands were accessible in 2012 to survey)
- > 100 cm Receding, deeply inundated (*n*=13)
- 10 100 cm Receding, shallowly inundated (*n*=20)
  - < 10 cm Drying (*n*=6)
    - 0 cm Dry (*n*=31)

# 3.2 Ground Flora

The following section presents the ground flora results based on data collected from the Permanent and Semipermanent Wetland transects between 2005 and 2014. It includes a summary of total, rare, threatened and exotic species, followed by an analysis of characteristic PFG species.

# 3.2.1 Species Summary

## **Species Richness**

A total of 69 flora species were recorded at wetland monitoring sites in autumn 2014, 70% (47) of these were indigenous. This total represents just under half (44%) of the 158 flora species recorded in the 10 wetlands over this period.

The greatest number of species has been recorded to date in wetlands which were shallowly inundated but receding (Figure 5). This is largely due to a higher richness in floating aquatic and amphibious flora (PFGs 1 – 2) and adaptive amphibious flora (PFG 3). The greatest richness of perennial and annual mudflat (PFG 4) species were recorded in the receding wetlands (both shallow and deeply inundated), whereas the dry wetlands supported the highest number of terrestrial species (PFGs 6 – 7). It should however be noted that the sample sizes are not balanced, with nearly twice the number of wetlands in the dry phase than the receding phases, and more than four times the number dry wetlands than drying and recently inundated wetlands (Figure 5).



Figure 5 Total species richness in Permanent and Semi-permanent Wetlands in Dry (n=31), Drying (n=6), Receding, deeply inundated (n=13), Receding, shallowly inundated (n=19), and Recently inundated (n=7) wetland phases relative to average recorded water depth (cm), autumn Gunbower Forest 2005 – 2014. Note years 2007 and 2009 were not surveyed.

# **Rare and Threatened Species**

Three species listed on the Victorian rare and threatened advisory list were recorded in the Permanent and Semi-permanent wetlands in 2014 (Table 9). Between one and four species have been recorded in each year and all in wetlands phases sampled. The highest number of species (8) was recorded in 2010, when wetlands were either dry or receding (shallowly and deeply inundated). 26 of the 28 threatened species records were in wetlands that received an environmental flow in the preceding year. Growth/germination species may have also been promoted by the above average rainfall in November 2009 (Technical Addendum, Section 2.2). The nationally vulnerable River Swamp Wallaby-grass (*Amphibromus fluitans*) and state rare Riverina Bitter-cress (*Cardamine moirensis*) herb were the most commonly sampled species over the monitoring period.

Table 9 Rare and threatened flora taxa recorded in autumn at Permanent and Semi-permanent Wetland transects (*n*=14, 2005, 2011; *n*=15 2006 – 2010, 2013, 2014; *n*=13, 2012), Gunbower Forest. Note years 2007 and 2009 were not sampled.

EPBC	FFG	Vic Adv	IUCN (Vic)	Species	Common Name	PFG Name	2005	2006	2008	2010	2011	2012	2013	2014	Number of Years Recorded
		k		Ceratophyllum demersum	Hornwort	Floating Aquatic Flora (PFG 1)				х	x				2
		r		Najas tenuifolia	Water Nymph	Floating Aquatic Flora (PFG 1)		x		х					2
	L	v	EN	Nymphoides crenata	Wavy Marshwort	Floating Amphibious Flora (PFG 2)	x	х		х					3
V	х		EN	Amphibromus fluitans	River Swamp Wallaby- grass	Adaptive Amphibious Flora (PFG 3)	x	х	х	х		x		x	6
	х	r	CR	Callitriche umbonata	Winged Water- starwort	Adaptive Amphibious Flora (PFG 3)					x				1
		k		Cynodon dactylon var. pulchellus	Native Couch	Perennial Mudflat Flora (PFG 4a)				х					1
		r		Rorippa eustylis	Dwarf Bitter-cress	Annual Mudflat Flora (PFG 4b)				х	x		х	х	4
		r		Cardamine moirensis	Riverina Bitter-cress	Emergent Amphibious Flora (PFG 5)	x	х		х	x	x	х	x	7
		r		Senecio campylocarpus	Floodplain Fireweed	Terrestrial Damp Flora (PFG 6)				x					1
Total species recorded						3	4	1	8	4	2	2	3	9	

## **Exotic Species**

The mean percentage cover of exotic and native species in the wetlands, both over time (2005 - 2014) and in 2014 is presented in relation to wetland phase (Figure 6). It would appear when assessed across the ten years of monitoring, that on average exotic species collectively covered less than 2.75% of the transect areas sampled (Figure 6a), despite contributing 50 of the 158 species recorded in the wetlands. For both 2005 – 2014 and 2014 alone, the cover of exotic species increased as the wetlands dried, with drying wetlands recorded with the highest average cover of weeds (Figure 6a and 6b).



Figure 6 Mean ( $\pm$ SD) cover (%) of native and exotic species across Permanent and Semi-permanent wetlands (a) 2005 – 2014 (Dry (n=31), Drying (n=6), Receding, deeply inundated (n=13), Receding, shallowly inundated (n=19), and Recently inundated (n=7) wetland phases. Note years 2007 and 2009 were not surveyed); (b) in 2014 (Dry (n=7), Drying (n=1), Receding, deeply inundated (n=1), Receding, shallowly inundated (n=1) wetland phases), autumn Gunbower Forest.

The average cover of native species was also higher in the eight wetlands in the drier phases in 2014 than in the two wetlands in receding phases (Figure 6b). Receding wetlands, however, supported the highest average cover of native species when the ten year dataset was averaged by phase (Figure 6b). Natives covered in all instances considerably greater percentages of the sampled transect than exotic species.

## 3.2.2 Characteristic Plant Functional Groups

It has been hypothesised that healthy wetland vegetation should be largely comprised of 'characteristic' PFG species. Gunbower Forests' Permanent Wetlands are characterised by flora grouped functionally as floating aquatic and amphibious species (PFGs 1 - 2), adaptive and emergent amphibious species (PFGs 3 and 5) and mudflat (annual and perennial) species (PFG 4). Semi-permanent Wetlands also characteristically support amphibious and mudflat flora (PFGs 2 – 5), but not floating aquatic flora (PFGs 1), although such species (e.g. *Azolla* spp.) do occur when the WRC is inundated. The temporal change in the species richness and cover in these characteristic PFGs is presented in the following section.

# **Richness of Characteristic PFGs Species**

The richness in native characteristic PFG flora in Permanent and Semi-permanent Wetlands is presented in Figures 7 and 8. The average richness of characteristic species was highest in the receding, shallowly inundated (water depths 10 – 100cm) wetlands in both WRCs when assessed over 2005 – 2014 (Figure 7a). Shallowly inundated wetlands typically include both aquatic and fringing habitat, and are not light-limited and therefore provide suitable conditions for a broader range of species than deeply inundated or dry/drying wetlands.

When the two WRCs are compared, it would appear that there is greater species richness in the Permanent Wetlands than the Semi-permanent Wetlands, but the former includes floating aquatic species (PFG 1) as characteristic and is based on nine transects compared to six. Where the two WRCs do differ, however, is in the recently inundated wetlands. Semi-permanent Wetlands supported a relatively high average richness of characteristic flora when recently inundated (Figure 7b). However, this result was influenced by one wetland – Football Grounds – which was the last to flood in the 2012 event and hence supported a small portion of dry land with 20 flora species when surveyed.

The average richness of non-characteristic flora in Permanent Wetlands followed a similar pattern to characteristic flora, with the highest values in shallowly inundated, receding wetlands. The pattern in the non-characteristic flora of the Semi-permanent Wetlands differed depending on PFG's classification. Non-characteristic aquatic flora (i.e. floating aquatic flora) were only present when water depth was greater than 10 cm (i.e. recently inundated and receding wetlands) and peaked in shallowly inundated wetlands. Non-characteristic terrestrial flora increased as the water level decreased, in a similar pattern to weed cover (see Figure 6).

Notwithstanding the above, there was considerable variability in species richness (indicated by the large standard deviation bars) highlighting the differences between the wetlands and between years. This is not surprising given the range of wetland topologies represented in the sample.



Figure 7 Average richness ( $\pm$ SD) of (a) characteristic (PFGs 1 - 5) and non-characteristic (PFGs 6 - 7) flora sampled in Permanent Wetlands (Recently inundated (*n*=5), Receding deep (*n*=10), Receding shallow (*n*=10), Drying (*n*=3) and Dry (*n*=11)) and (b) Semi-permanent Wetlands (Dry (*n*=20), Drying (*n*=3), Receding, shallow (*n*=9), Receding, deep (*n*=3) and Recently inundated (*n*=2)), Gunbower Forest autumn 2005 - 2014.

In 2014 seven of the ten wetlands were dry, and hence supported a relatively high average richness of noncharacteristic terrestrial species (Figure 8). This is not considered a significant management issue as many of these opportunistic species will be drowned out in the next flood. Of the Permanent Wetlands, the shallowly inundated Greens Swamp (Figure 9) supported the highest number of characteristic PFG flora. In the Semipermanent Wetlands the drying Iron Punt Lagoon (Figure 10) had the highest richness of characteristic PFG flora.



Figure 8 Average richness ( $\pm$ SD) of (a) characteristic (PFGs 1 - 5) and non-characteristic (PFGs 6 - 7) flora sampled in Permanent Wetlands (Receding deep (*n*=1), Receding shallow (*n*=1) and Dry (*n*=3)); and (b) characteristic (PFGs 2 - 5) and non-characteristic (PFGs 1, 6 - 7) flora sampled in Semi-permanent Wetlands (Drying (*n*=1) and Dry (*n*=4)), Gunbower Forest autumn 2014.
# Gunbower Forest Sentinel Wetland and Understorey Survey autumn 2014







Figure 9 Green Swamp Permanent Wetland transect, autumn Gunbower Forest 2010, 2013 and 2014.

# Gunbower Forest Sentinel Wetland and Understorey Survey autumn 2014



2011 Receding, deeply inundated



2013 Receding, shallowly inundated



Figure 10 Iron Punt Lagoon Semi-permanent Wetland transect, autumn Gunbower Forest 2011, 2013 and 2014.

# Index of Characteristic PFGs Species Richness

The proportion of Permanent and Semi-permanent Wetland sites that met the Points of Reference for the characteristic PFG species richness Index between 2005 and 2014 are presented in Figure 11. The Points of Reference for each WRC are the weighted number of characteristic indigenous PFG species recorded per site when compared to the number of characteristic indigenous PFG species recorded in the top 10% of sites over the 2005 – 2014 period.

Five of the eight sites that met the Index Points of Reference were shallowly inundated (receding), two were deeply inundated (receding), and one was recently inundated (Football Grounds 2012) at the time of assessment (Figure 11). Six of these wetlands received environmental water in the 12 months preceding sampling, either to top up natural inflows or as drought relief. One of these wetlands was inundated by the small flood in autumn 2012 and another by the subsequent spring 2012 flood (Figure 3). No dry or drying wetlands complied with the characteristic PFG species richness Index. It should however be noted that the Points of Reference were calculated from the ten year data set for each WRC rather than for each wetland phase.

No wetlands surveyed in 2014 complied with the characteristic PFG species richness Index in 2014. It is possible the high levels of turbidity and presence of carp influenced the 2014 results.



Figure 11 Number of sites that complied with the Species Richness Index PoR in Permanent and Semi-permanent Wetland sites, Gunbower Forest autumn 2005 - 2014. Note years 2007 and 2009 were not sampled

### **Cover of Characteristic PFGs Species**

The cover of characteristic PFG flora species across the wetlands was assessed to determine the relative contribution of characteristic and non-characteristic species to the extant vegetation (Figures 12 - 13). Based on the data collected between 2005 and 2014, the pattern in average cover of characteristic PFG flora follows that reported for richness (Figures 7 and 8), with the highest values of species recorded in shallowly inundated, receding wetlands.

Again the separation of floating aquatic species from the characteristic PFG flora in the Semi-permanent wetlands gives an impression of difference in the two wetland WRCs. However, the Semi-permanent wetlands

did have higher average cover of characteristic PFG species in the dry systems than the Permanent wetlands. This is likely to be driven by the mudflat species common to all wetlands assessed, especially after draw down.

Figure 12 also indicates that the non-characteristic terrestrial flora reported in Figure 7 cover on average less than 5% of the transect area sampled. This supports the hypothesis that they are largely opportunistic species that do not persist once inundated.



Figure 12 Average percentage cover ( $\pm$ SD) of (a) characteristic (PFGs 1 - 5) and non-characteristic (PFGs 6 - 7) flora sampled in Permanent Wetlands (Recently inundated (n=5), Receding deep (n=10), Receding shallow (n=10), Drying (n=3) and Dry (n=11)) and (b) characteristic (PFGs 2 - 5) and non-characteristic (PFGs 1, 6 - 7) flora in sampled Semi-permanent Wetlands (Dry (*n*=20), Drying (*n*=3), Receding shallow (*n*=9), Receding deep (*n*=3) and Recently inundated (*n*=2)), Gunbower Forest autumn 2005 - 2014.



Figure 13 Average percentage cover ( $\pm$ SD) of (a) characteristic (PFGs 1 - 5) and non-characteristic (PFGs 6 - 7) flora sampled in Permanent Wetlands (Receding deep (*n*=1), Receding shallow (*n*=1) and Dry (*n*=3)), and (b) characteristic (PFGs 2 - 5) and non-characteristic (PFGs 1, 6 - 7) flora sampled in Semi-permanent Wetlands (Drying (*n*=1) and Dry (*n*=4)), Gunbower Forest autumn 2014.

When the 2014 data is analysed separately to the ten year dataset, it appears that the dry wetlands supported a higher cover of characteristic PFG flora (Figure 13) than the receding and drying wetlands. This result is influenced by the very low number of wetland in each category. It is however a positive sign that dry wetlands were dominated by characteristic PFG flora, indicating they remained within a desirable framework and did not transition to a terrestrial dominated ecosystem.

### Wetland Case Study

Multivariate analyses (ordinations) based on ground flora cover data have been undertaken to further explore similarities in the wetland transects within and between sampling years (Figure 14). The process groups the data points (wetlands in a given year) with similar flora and non-living (i.e. litter and open water) compositions, such that nearby data points are more similar than distant data points. Factors including WRC, survey year and EVC were overlain on the ordination plots to allow a visual interpretation of the similarities.

The scatter of wetland data points across the ordination space shows different patterns depending on how the wetlands were classified (Figure 14). In the first ordination there is considerable overlap between the Permanent and Semi-permanent wetlands over the monitoring period (Figure 14a). This suggests that while the WRCs can be delineated geographically based on elevation and hydrology, there is little overall difference in the composition between the two WRCs. It is likely that wetlands in the two WRC follow similar wetting and drying cycles but that these potentially occur at slightly different times.

In contrast, the second ordination shows clear groupings of the same data points based on their phase in the wetland cycle (Figure 14b). Groupings include the recently inundated wetlands (that supported very little vegetation) positioned to the left, dry wetlands grouped to the right, and a mix of shallowly and deeply inundated, receding and drying wetlands in the middle of the figure. This pattern indicates that the wetlands support similar composition in the wetland phases, irrespective of their position in the landscape.

The wetland groupings are less distinct but still discernible in the third ordination that is classified by year (Figure 14c). While site differences were a key influence on composition, annual conditions clearly affected the wetlands' flora and cover of non-living components. From this ordination it would appear there were compositional similarities between the wetlands in years 2005, 2006 and 2010 (grouped to the top left), which were all receding to some degree (i.e. predominantly shallowly inundated but also deeply inundated and drying). Wetlands in years 2011 and 2012, which had been recently inundated by the natural flood and supported very little vegetation, were also separated from the other years. Wetlands surveyed in years 2008 and 2013, the conditions preceding both these surveys were notably dry (Technical Addendum, Section 2.2). The 2014 wetlands were also grouped to the left, between the larger 2005 – 2006 - 2010 cluster and the 2008 - 2013 cluster. This indicates the flora composition surveyed in 2014 had shifted away from the drought affected 2008 - 2013 results towards the more mesic results in 2005 - 2006 - 2010.



(c)

Figure 14 NMDS ordination plots showing all Gunbower Wetland vegetation monitoring data points (each wetland on each sampling date) arranged by Bray-Curtis similarity. Sampling units are colour-coded by (a) water regime class (b) wetland phase and (c) survey year.



#### 4.0 UNDERSTOREY STRATUM RESULTS - Red Gum Forest & Woodlands

Gunbower Forest is mapped as supporting two River Red Gum WRCs - Red Gum with Flood Dependent Understorey (Red Gum FDU) and Red Gum with Flood Tolerant Understorey (Red Gum FTU). Red Gum FDU vegetation is the most widespread WRC in Gunbower Forest and is typified by dense forest that occurs in low lying, frequently flooded areas that often adjoin wetlands. The WRC is distinguished by ground flora that require flooding to complete their lifecycle (i.e. Water Ribbons (*Triglochin* spp.), Poong'ort (*Carex tereticaulis*), Common Spike-sedge (*Eleocharis acuta*), and Warrego Summer-grass (*Paspalidium jubiflorum*)) (URS, 2001). Red Gum FTU vegetation includes the drier, more elevated spectrum of the trees' floodplain continuum. The WRC is thought to flood less often, for shorter periods and at shallower depths than Red Gum FDU and is hence typified by open woodlands with understorey flora that is more independent of flooding (URS, 2001).

Section 4 summarises the 2014 Red Gum WRCs monitoring results, with consideration of previous years' data (2005 – 2013).

# 4.1 Overview

Table 10 Summary of Red Gum FDU survey results for Gunbower Forest autumn 2014

Water Regime Classes	River Red Gum with Flood Dependent Understorey (Red Gum FDU) River Red Gum with Flood Tolerant Understorey (Red Gum FTU)							
Extent in Gunbower Forest	8,423ha (44%) R 4,509ha (23%) R	ted Gum FDU (MDBA, 2010) ted Gum FTU (MDBA, 2010)						
Sites	50 quadrats Red 27 quadrats Red	Gum FDU Gum FTU						
Ecological Vegetation Classes	Floodplain Ripari Grassy Riverine Riverine Grassy Riverine Swamp Riverine Swamp Sedgy Riverine F	ian Woodland (EVC 56) Forest (EVC 106) Woodland (EVC 295) Forest (EVC 814) y Woodland (EVC 815) Forest (EVC 816)						
Indigenous flora	Red Gum FDU Red Gum FTU	71% of species (58/82) (monitoring program total for WRC = 138) 73% of species (61/84) (monitoring program total for WRC = 117)						
Exotic flora	Red Gum FDU Red Gum FTU High threat envir	<ul> <li>29% of species (24/82) (monitoring program total for WRC = 68)</li> <li>2.5% average cover in quadrats</li> <li>27% of species (23/84) (monitoring program total for WRC = 62)</li> <li>4.1% average cover in quadrats</li> <li>onmental weeds 42% (16/38) (monitoring program total for WRC = 34)</li> </ul>						
Rare or threatened species	Red Gum FDU and/or in Australi Red Gum FTU in Australian legi	No species listed as rare or threatened on Victorian advisory list ian legislation (monitoring program total for WRC = 10) 3 species listed as rare or threatened on Victorian advisory list and/or slation (monitoring program total for WRC = 8)						
Inundation	1 site was floode Red Gum FDU Red Gum FTU	ed at the time of survey in autumn 2014 (114) from farm run off. 1/42 site flooded 2005 - 2006 45/50 sites flooded 2010 - 2011 30/50 sites flooded 2011 – 2012 4/50 sites flooded 2013 – 2014 18/27 sites flooded 2010 - 2011 8/27 sites flooded 2011 – 2012 2/27 sites flooded 2013 – 2014						
Vegetation condition indicators	Characteristic PH Red Gum FDU Red Gum FTU The greatest num	FG species Index 8% (4/50) sites achieved the PoR (9 species from PFG 3-5) 4%(1/27) site achieved the PoR (11 species from PFG 4-6) nber of Red Gum sites met the PoR in 2011 and 2012.						
	<i>Tree Canopy He</i> Red Gum FDU	alth Index 6 sites achieved the PoR (0.8 proportion of trees with a crown health category of >3)						

Water Regime Classes	River Red Gum with Flood Dependent Understorey (Red Gum FDU) River Red Gum with Flood Tolerant Understorey (Red Gum FTU)					
	Red Gum FTU 2 sites achieved the PoR (0.815 proportion of trees with a crown health category of >3)					
Progress towards the WRC ecological objective	Ensure maintenance of healthy River Red Gum communities The monitoring results suggest that the ground flora increased in characteristic species richness and cover following above average rainfall and flooding in 2010 - 2011 but that it has since returned to levels comparable to those recorded at the outset of the monitoring program (during the 14 year drought). The tree canopy results however suggest the River Red Gum population has declined in health over the monitoring period, with only minor improvement after 2010.					
	If the reference condition for assessing 'maintenance' is set as the condition recorded a the commencement of the monitoring program (2005) then it could be said that th condition of the Red Gum vegetation has been maintained, as the 2014 ground flor result are comparable with those from 2005. However, if the reference condition for th vegetation was set based on the best recorded condition (i.e. 2011, following a natura flood) then the condition of the Red Gum vegetation would be considered poorer, as th 2014 results for species richness and cover, rare and threatened species, and canop health, are lower than recorded in 2011.					
	It should however be noted, the reported results do not reflect changes in the forests' vegetation in response to environmental water delivered but rather climatic conditions and natural flooding, as environmental water had not been delivered to the forest (outside the wetlands) prior to the 2014 survey event.					

### 4.2 Ground Flora

The following section presents the ground flora results based on data collected from the Red Gum FDU and Red Gum FTU understorey quadrats between 2005 and 2014. It includes a summary of total, rare, threatened and, exotic species, followed by an analysis of characteristic PFG species.

#### 4.2.1 Species Summary

#### **Species Richness**

A total of 82 flora species (exotic and indigenous) were recorded in the Red Gum FDU quadrats and 83 in the Red Gum FTU sites in 2014 (Figure 15). This represents a 10-14 species increase from 2013, most likely in response to the rise in rainfall and possibly the small flood in spring 2013 (Figure 3). The number of species recorded in 2014 is, however, considerably lower than totals recorded in 2011 (i.e. Red Gum FDU 140 species and Red Gum FTU 129 species) after the above average rainfall and flood in 2010-2011. Terrestrial dry and damp species (PFGs 6 and 7) made the largest contribution to these WRCs' species richness in all years surveyed (refer to Section 4.2.2 for more details).



Figure 15 Temporal change in the total number of species per PFG in (a) Red Gum FDU quadrats (n=42, 2005 - 2006; n=50, 2008 - 2011 and 2013 - 2014, and n=48 2012) and (b) Red Gum FTU quadrats (n=23, 2005 - 2006; n=27, 2008 - 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled.

# **Red Gum Case Study**

The mean cover of PFGs in the original 65 Red Gum quadrats established in 2005 was analysed in more detail as a side project (Figure 16). From this analysis it is clear that terrestrial dry species (PFG 7) responded strongly to high rainfall occurring prior to the 2010 survey, yet there was almost no increase in the mean cover of these species following flooding in 2011 – 2012. Furthermore, the cover of the terrestrial dry species declined below pre-flood levels (i.e. 2005 - 2008) in 2013. These results suggest the trend in the terrestrial dry species was at least partly driven by rainfall and that the species were potentially inhibited by flooding.

In contrast, floating aquatic and amphibious species (PFGs 1 – 2) only increased in mean cover after flooding in 2010 - 2011. Their cover then began to decrease again by 2012, suggesting that the subsequent floods had a lesser effect on their abundance. This may be partly due to the lower number of sites flooded in years 2011 - 2013. The remaining amphibious PFGs (3 - 5) followed a similar pattern but, unlikely the aquatic and amphibious species, were present both prior and post flooding. The effect of flooding on the aquatic and amphibious species was highly significant (P<0.001, Technical Addendum, Section 6.5), except for emergent amphibious species (PFG 5). While emergent amphibious species did increase substantially after the 2010 - 2011 flood, they also had a relatively high mean cover in 2005 despite sites having had no flooding for at least 10 years.





Figure 16: Temporal trends in the mean cover of Plant Functional Groups in River Red Gum WRCs (n=65), autumn Gunbower Forest 2005 – 2014. Note years 2007 and 2009 were not sampled, and for clarity standard error bars are shown for PFG 7 and PFG 5 only.

# **Rare and Threatened Species**

Three terrestrial species listed on the Victorian rare and threatened advisory list were recorded in elevated Red Gum FTU quadrats, while none were recorded in the Red Gum FDU quadrats in 2014 (Tables 11 and 12). The perennial lifecycle of the recorded species means they are likely persist from year to year and hence be observed outside spring and over time.

These results represent a decline in rare and threatened species from the peak in richness observed in 2011 (Red Gum FDU, 7 species and Red Gum FTU, 6 species) and 2012 (Red Gum FTU, 6 species and Red Gum FDU 3 species), after above average rainfall in 2010 - 2011 and repeated flooding between 2010 and 2012. While the 2014 results could be interpreted as a decline in such species, it would be unrealistic to expect the aquatic and amphibious flora recorded in 2011 and 2012 to occur during dry conditions such as those recorded in 2013 and 2014 (Technical Addendum, Section 2.2).

Table 11 Rare and threatened flora taxa recorded in autumn at Red Gum FDU quadrats (*n*=42, 2005 - 2006; *n*=50, 2008 – 2011 and 2013 - 2014, and *n*=48 2012). Note years 2007 and 2009 were not sampled.

EPBC	FFG	Vic Adv	Scientific Name	Common Name	PFG Name	2005	2008	2010	2011	2012	2013	2014
		k	Ceratophyllum demersum	Hornwort	Floating Aquatic Flora				х			
	L	v	Nymphoides crenata	Wavy Marshwort	Rhizomatous Aquatic Flora					х		
V			Amphibromus fluitans	River Swamp Wallaby-grass	Adaptive Amphibious Flora	х			х			
		r	Callitriche umbonata	Winged Water-starwort	Adaptive Amphibious Flora				х			
		r	Cardamine moirensis	Riverina Bitter-cress	Annual Mudflat Flora				х	х		
		k	Cynodon dactylon var. pulchellus	Native Couch	Perennial Mudflat Flora				х			
		k	Eleocharis pallens	Pale Spike-sedge	Perennial Mudflat Flora			х				
		k	Alternanthera sp. 1 (Plains)	Plains Joyweed	Terrestrial Damp Flora			х	х	х		
		r	Senecio campylocarpus	Floodplain Fireweed	Terrestrial Damp Flora		х	х				
		r	Calotis cuneifolia	Blue Burr-daisy	Terrestrial Dry Flora				x			
	Total species recorded						1	3	7	3	0	0

Table 12 Rare and threatened flora taxa recorded in autumn at Red Gum FTU quadrats (n=23, 2005 - 2006; n=27, 2008 - 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled.

EPBC	FFG	Vic Adv	Scientific Name	Common Name	PFG Name	2005	2008	2010	2011	2012	2013	2014
	L	v	Nymphoides crenata	Wavy Marshwort	Rhizomatous Aquatic Flora					х		
V	Х		Amphibromus fluitans	River Swamp Wallaby-grass	Adaptive Amphibious Flora	х						
		r	Cardamine moirensis	Riverina Bitter-cress	Annual Mudflat Flora			х	х	х		
		r	Gratiola pumilo	Dwarf Brooklime	Annual Mudflat Flora				х			
		k	Cynodon dactylon var. pulchellus	Native Couch	Perennial Mudflat Flora			х	х	х	х	
		k	Alternanthera sp. 1 (Plains)	Plains Joyweed	Terrestrial Damp Flora			х	х	х	х	х
		v	Dianella spp. aff. longifolia (Riverina)	Pale Flax-lily	Terrestrial Damp Flora		х	х	х	х	х	х
		r	Calotis cuneifolia	Blue Burr-daisy	Terrestrial Dry Flora			х	х	х	х	x
	Total species recorded						1	5	6	6	4	3

#### **Exotic Species**

Exotic species accounted for around a third of the total species richness recorded in Red Gum quadrats in 2014 (i.e. 29% of Red Gum FDU species and 27% of Red Gum FTU species). However, the average cover of these species was low (i.e. 2.0 - 4.2% in 2014), (Figure 17). Interestingly the cover of exotic species did not increase to the same magnitude as the native species with the above average rainfall and flooding in 2010 – 2011, but remained relatively constant. There was however an increase in weed covers in 2012 at the Red Gum FTU sites. Notwithstanding the above, there was considerable variation between sites, with weeds covering up to 30% of the quadrats assessed in the more disturbed areas (e.g. near camping areas along the Gunbower Creek and the Murray River).

Based on average percentage weed cover Red Gum FTU quadrats appear more weed infested than Red Gum FDU and the Box Woodland quadrats (Figures 17 and 26). Red Gum FTU vegetation occurs higher in the landscape than Red Gum FDU and therefore is more accessible to herbivores and humans during flooding, which may have led to greater disturbance and invasion by weeds.



Figure 17 Temporal change in the mean ( $\pm$ SD) cover (%) of exotic and native species in (a) Red Gum FDU quadrats (*n*=42, 2005 - 2006; *n*=50, 2008 - 2011 and 2013 - 2014, and *n*=48 2012) and (b) Red Gum FTU quadrats (*n*=23, 2005 - 2006; *n*=27, 2008 - 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled.

Of the 89 exotic species recorded in the Red Gum WRCs (2005 – 2014), 16 are ranked as medium to very high risk weeds (Adair *et al.* 2008a and 2008b). Paterson's Curse (*\*Echium plantagineum*), Horehound (*\*Marrubium vulgare*), Sticky Ground-cherry (*\*Physalis hederifolia*) and exotic grasses (e.g. *\*Bromus* spp., *\*Ehrharta longiflora*, *\* Vulpia bromoides* etc.) were the most widespread. While not reflected in the randomly located monitoring sites, Bridal Creeper (*\*Asparagus asparagoides*) was also common along the Murray River near

Koondrook and, the floodplain invaders, Lippia (\**Phyla canescens*), Noogoora Burr (\**Xanthium occidentale*) and Californian Burr (\**X. orientale*) were scattered within the Red Gum WRCs.

#### 4.2.2 Characteristic PFG Species Richness

Emergent and adaptive amphibious flora and mudflat flora (PFGs 3 - 5) characterise Red Gum FDU vegetation. Flora considered characteristic of Red Gum FTU vegetation also include mudflat and emergent amphibious flora (PFGs 4 and 5), along with terrestrial damp species (PFG 6) but not adaptive amphibious flora (PFG 3). Other amphibious and aquatic species do occur in the Red Gum WRCs, in flood runners and depressions, but they are not the focus of the following section. The richness of characteristic PFG species (flora species from PFGs characteristic of each WRC) has been proposed as one indicator of vegetation condition (see Section 2.2.3).

#### **Richness of Characteristic PFGs Species**

The average richness of native characteristic and non-characteristic PFG species in the Red Gum WRCs quadrats over time is presented in Figures 18 and 19. There is a distinct similarity in the temporal pattern in characteristic flora (and non-characteristic aquatic/amphibious flora) and annual rainfall between 2005 and 2014. In particular, the average richness in characteristic flora declined between 2005 and 2006, peaked in 2011, declined again between 2012 and 2013, before increasing marginally between 2013 and 2014.



Figure 18 Temporal change in the mean richness of characteristic (PFGs 3 - 5, ±SD) and non-characteristic (PFGs 1, 6 and 7) flora for Red Gum FDU quadrats (*n*=42, 2005 - 2006; *n*=50, 2008 – 2011 and 2013 - 2014, and *n*=48 2012) in Gunbower Forest autumn 2005 – 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.



Figure 19 Temporal change in the mean ( $\pm$ SD) richness of characteristic (PFGs 4 - 6) and non-characteristic (PFGs 1-3 and 7) flora for Red Gum FTU quadrats (*n*=23, 2005 - 2006; *n*=27, 2008 - 2014) in Gunbower Forest autumn 2005 – 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.

The average richness of non-characteristic terrestrial flora followed a slightly different pattern to the above, increasing between 2005 and 2006 (while rainfall declined), notably between 2008 and 2010 (after high November 2009 rainfall), and again between 2013 and 2014. During the drought (2005 – 2010) there were on average more terrestrial species in the Red Gum WRC quadrats than characteristic species. This was also true for Red Gum FTU sites in 2013 and 2014. Red Gum FTU vegetation, positioned higher on the floodplain than Red Gum FDU vegetation, naturally supports some percentage of terrestrial flora (i.e. terrestrial damp PFG 6 species), but is also susceptible to invasion by dryland species (i.e. terrestrial dry PFG 7 species) when not adequately flooded. The increase in terrestrial species in the Red Gum sites during the drought is likely to be due to the latter process.

#### Index of Characteristic PFGs Species Richness

The PFG Species Richness Index represents the number of characteristic indigenous flora species recorded per site, relative to the Point of Reference (the number of characteristic indigenous flora species recorded in the top 10% of sites over the period 2005 – 2014) for each WRC. The proportion of sites that met the PFG species richness Points of Reference for the Red Gum WRCs in each sampling year is depicted in Figure 20.



Figure 20 Proportion of sites that complied with the Species Richness Index PoR in Red Gum FDU quadrats (n=42, 2005 - 2006; n=50, 2008 – 2011 and 2013 - 2014, and n=48 2012) and Red Gum FTU quadrats (n=23, 2005 - 2006; n=27, 2008 - 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled.

Only three of the 42 Red Gum FDU sites (2005) and one Red Gum FTU site (2010) met the characteristic PFG species richness Point of Reference during the drought (2005 – 2010). This indicates that the majority of sites did not support a 'healthy' richness of characteristic flora during this dry period. The number of sites that achieved this benchmark however increased to around half of the sample (e.g. 27/50 Red Gum FDU sites and 12/27 Red Gum FTU sites) in 2011 after above average rainfall and flooding in 2010 – 2011. While the proportion of compliant sites declined after 2011 and was much lower in 2013 and 2014, there was a small increase in the Red Gum FDU sites between the latter years. This implies there was marginal improvement in PFG species richness in the Red Gum FDU WRC during between 2013 and 2014; possibly due to higher rainfall preceding the 2014 survey than prior to the 2012 survey (Technical Addendum, Section 2.2).

Notwithstanding the above, it should be noted that the PFG Species Richness Index scores varied temporally and spatially within the two Red Gum WRCs (not represented in Figure 20). For example Red Gum FDU sites spanned index scores of 0 (lowest possible minimum score) to 1 (highest possible maximum score) in 2011, as did Red Gum FTU in 2013, indicating vegetation condition was not homogenous within the WRCs. There were also a number of outlier sites that scored an index of zero (e.g. years 2008, 2010, 2011, 2013 and 2014 in Red

Gum FDU sites and years 2008, 2010 and 2013 in Red Gum FTU sites), which indicates that these sites did not support any PFG species characteristic of the WRCs in these years.

#### **Cover of Characteristic PFGs Species**

The average cover of native characteristic PFG species in Red Gum quadrats followed a similar temporal trend to the richness of characteristic PFG species (Figures 18 and 19), peaking after above average rainfall and flooding in 2010 – 2011 and increasing slightly between 2013 and 2014 (Figures 21 and 22). The increase in average cover of non-characteristic terrestrial PFG species between 2010 and 2011 was also subdued, as was the richness of these species (see discussion about terrestrial species in the Red Gum Case Study on page 36). Non-characteristic aquatic species cover also peaked in 2011 in both WRCS driven largely by the floating aquatic - Azolla (*Azolla* spp.).



Figure 21 Temporal change in the mean cover of characteristic (PFGs 3 - 5,  $\pm$ SD) and non-characteristic (PFGs 1, 6 and 7) flora for Red Gum FDU quadrats (n=42, 2005 - 2006; n=50, 2008 – 2011 and 2013 - 2014, and n=48 2012) in Gunbower Forest autumn 2005 – 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.



Figure 22 Temporal change in the mean ( $\pm$ SD) richness of characteristic (PFGs 4 - 6) and non-characteristic (PFGs 1-3 and 7) flora for Red Gum FTU quadrats (*n*=23, 2005 - 2006; *n*=27, 2008 - 2014) in Gunbower Forest autumn 2005 – 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.

Further to the above, the average cover of characteristic PFG species increased to values higher than recorded for non-characteristic terrestrial species in Red Gum FDU quadrats after the above average rainfall and flooding in 2010 – 2011. Non-characteristic terrestrial species however dominated the Red Gum FTU quadrats in all years except 2011 and surprisingly 2013.

Quadrat photographs in Figure 23 visually demonstrate these changes in vegetation cover.



2005 during 14 year drought



2005 during 14 year drought





2012 after flooding 2010 - 2011



2013 after below average rainfall



2013 after flooding in 2012 but also below 2014 after low rainfall average rainfall





2011 after flooding 2010 - 2011



2012 inundated with farm run-off

2013 inundated with farm run-off



2014 inundated with farm run-off

Figure 23 Red Gum understorey quadrats from top to bottom – Quadrat 3 (Red Gum FTU), Quadrat 11 (Red Gum FDU) and Quadrat 114 (Red Gum FDU)

fire, flood and flora

# 4.3 Tree Canopy

# **Tree Crown Health**

The proportion of River Red Gum trees in each crown health category (see Table 4) sampled between 2005 and 2014 is presented in Figure 24. There was a clear decline in the percentage of healthy trees (i.e. >50% intact canopy) towards the end of the 14 year drought (2005 - 2010), before a slight recovery after the above average rainfall and flooding in 2010 – 2011 (2011) in both WRCs. While a similar percentage of trees died in each WRC (e.g. 12.4% of Red Gum FDU and 13.9% of Red Gum FTU trees), the Red Gum FDU sites had slightly higher percentages of healthy trees than the Red Gum FTU sites (e.g. 43.2% vs 39.4%).



Figure 24 Proportion of tree population in each crown condition class in (a) Red Gum FDU quadrats (n=42, 2005 - 2006; n=50, 2008 – 2011 and 2013 - 2014, and n=48 2012) and (b) Red Gum FTU quadrats (n=23, 2005 - 2006; n=27, 2008 - 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled.

# **Tree Canopy Health Index**

The proportion of trees with healthy canopies has been suggested as an indicator of vegetation condition (see Section 2.2.3). The Tree Canopy Health Index scores the proportion of trees with at least 50% of their canopy intact at each site. The site index score is then compared to the Index Point of Reference (the proportion of trees with healthy canopies in the top 10% of records over the period 2005 - 2014 in each WRC) to determine compliance. Temporal variation in the proportion of compliant sites is depicted in Figure 25.



Figure 25 Proportion of sites that comply with the Tree Canopy Health Index PoR in Red Gum FDU quadrats (n=42, 2005 - 2006; n=50, 2008 – 2011 and 2013 - 2014, and n=48 2012) and Red Gum FTU quadrats (n=23, 2005 - 2006; n=27, 2008 - 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled.

Compliance with the Tree Canopy Health Index in the Red Gum WRC sites was 43% when first surveyed in 2005 but declined to less than 8% in the subsequent years. There was a small improvement in the number of Red Gum FDU sites that complied with the WRC Point of Reference after above average rainfall and flooding in 2010 – 2011 to between 12 - 14% of sites. Compliance in the Red Gum FTU sites however remained low (i.e. 4 - 7%). There are no obvious climatic or environmental clues as to why the proportion of compliant sites declined dramatically between 2005 and 2006, although there was a change in observers.

In 2014 six of the 50 Red Gum FDU sites met the WRC Point of Reference (80% of trees sampled per site with >50% intact canopy), while only two of the 27 Red Gum FTU sites achieved the WRC Point of Reference (81.5% of trees sampled per site with >50% intact canopy). Further to the above, the above average rainfall in 2010 - 2011 and repeated flooding (2010 - 2013) appears to have had limited effect on the collective tree health at the Red Gum sites.

# 5.0 UNDERSTOREY STRATUM RESULTS - Box Woodlands



Gunbower Forest is mapped as supporting two box woodland WRCs – Black Box and Grey Box. The box woodlands are common to the upper forest (south – east) and are positioned above Red Gum FDU vegetation.

Black Box woodland is defined by the presence of *Eucalyptus largiflorens*, a species that requires some level of flooding but is relatively drought tolerant. The woodland is therefore commonly found in the ecotone between flooded and terrestrial vegetation and supports an understorey ranging from wetland to dryland flora. Given the woodland's landscape position they are thought to require up to three months flooding once every 10 - 25 years at the drier end of its spectrum (e.g. Riverine Chenopod Woodland, EVC 103, Figure 33) and up to two months flooding almost annually (i.e. 2 - 3 years in 3) at the wetter end of its spectrum (e.g. Riverine Swampy Woodland, EVC 815, Figure 33) (Fitzsimons *et al.* 2011).

Grey Box constitutes the third canopy species in Gunbower Forest, occupying more elevated areas in the south-east. While this eucalypt typifies terrestrial Plains Woodland vegetation (EVC 803, Figure 33) in combination with an array of dryland grasses and shrubs, it also occurs in periodically inundated Riverine Swampy Woodland (EVC 815), with flood-stimulated species such as Nardoo (*Marsilea* spp.), often in association with River Red Gums and/or Black Box trees.

The following section presents the 2014 monitoring results from the 33 understorey quadrats established in these woodlands.

# 5.1 Overview

Water Regime Classes	Black Box and Grey Box Woodland						
Extent in Gunbower	3,126 ha (16%) Black Box Woodlands (MDBA, 2010)						
Forest	1,768 ha (9%) Grey Box Woodlands (MDBA, 2010)						
Sites	19 quadrats Black Box Woodland						
	14 quadrats Grey Box Woodland						
Ecological Vegetation	Riverine Chenopod Woodland (EVC 103)						
Classes	Riverine Swampy Woodland (EVC 815)						
	Plains Woodland (EVC 803)						
Indigenous flora	Black Box 87% of species (41/47) (monitoring program total for WRC = 111)						
	Grey Box 90% of species (45/50) (monitoring program total for WRC = 100)						
Exotic flora	Black Box 13% of species (6/47) (monitoring program total for WRC = 38)						
	2.8% average cover in quadrats						
	Grey Box 10% of species (5/50) (monitoring program total for WRC = 35)						
	2.3% average cover in quadrats						
	High threat environmental weeds $38\%$ (3/8) (monitoring program total for WRC = 19)						
Rare or threatened species	Black Box 3 species listed on the Victorian rare or threatened advisory list (monitoring program total for WRC = 10)						
	Grey Box 2 species listed on the Victorian rare or threatened advisory list (monitoring program total for WRC = $6$ )						
Inundation	All sites were dry at the time of survey in autumn 2014						
	Black Box 32% (6/19) sites flooded 2010 - 2011						
	Grey Box 36% (5/14) sites flooded 2010 - 2011						
	7% (1/14) sites flooded 2011 - 2012						
Vegetation condition	Characteristic PFG species Index						
indicators	Black Box 5% (1/19) site achieved the PoR (5.9 species from PFG 4-6)						
	Grey Box 14% (2/14) sites achieved the PoR (14 species from PFG 5-7)						
	The greatest number of Black Box or Grey Box sites met the PoR in 2011 and 2012.						
	Tree Canopy Health Index						
	No Black Box or Grey Box sites in 2014 met the PoR:						
	Black Box - 0.9 proportion of trees with a crown health category of $>3$						
	Grey Box - 0.95 proportion of trees with a crown health category of >3						
	Declining numbers of Black Box or Grey Box sites met the PoR over 2005 – 2014.						
Progress towards the	Maintain Black Box and Grey Box communities						
WRC ecological objective	As stated for the Red Gum WRCs:						
	As for the Red Gum WRCs, the Box woodland results suggest that the ground flora increased in characteristic species richness and cover following above average rainfall and flooding in 2010 -2011, but that it has since returned to levels comparable to those recorded at the outset of the monitoring program (during the 14 year drought). However, the flora results are influenced by the selection of characteristic PFGs for each of the						

Table 13 Summary of Box Woodland survey results for Gunbower Forest autumn 2014

Water Regime Classes	Black Box and Grey Box Woodland
	WRCs. Ordination of the flora and non-living cover data suggests both WRCs support a gradient of vegetation from terrestrial or near terrestrial to flood. The tree canopy results also suggest the Black and Grey Box populations have declined in health over the monitoring period.
	If the reference condition for assessing 'maintenance' is set as the condition recorded at the commencement of the monitoring program (2005) then it could be said that the condition of the Box woodland vegetation has been maintained, as the 2014 ground flora result are comparable with those from 2005. However, if the reference condition for the vegetation was set based on the best recorded condition (i.e. 2011, following a natural flood) then the condition of the Red Gum vegetation would be considered poorer, as the 2014 results for species richness and cover, rare and threatened species and canopy health are lower than recorded in 2011.
	It should however be noted, the reported results do not reflect changes in the forests' vegetation in response to environmental water delivered but rather climatic conditions and natural flooding, as environmental water had not been delivered to the forest (outside the wetlands) prior to the 2014 survey event.

# 5.2 Ground Flora

The following section presents the ground flora results based on data collected from the Black and Grey box woodland understorey quadrats between 2005 and 2014. It includes a summary of total, rare, threatened and exotic species, followed by an analysis of characteristic PFGs.

### 5.2.1 Species Summary

#### **Species Richness**

Forty seven flora species were recorded in the Black Box quadrats and 49 in the Grey Box quadrats surveyed in autumn 2014 (Figure 26). This represents a small increase (of 3-6 species) from the totals recorded in 2013 but a considerable decrease (of 52-58 species) from the peak in richness recorded in 2011 after above average rainfall and flooding in 2010 - 2011. The highest richness of amphibious and mudflat species (PFGs 2 – 5) occurred in 2011 and terrestrial dry species (PFG 7) accounted for more than half of the ground flora species in both WRCs in all years surveyed.



Figure 26 Temporal change in the total number of species per PFG in (a) Black Box quadrats (n=14, 2005 - 2006; n=19, 2008 - 2014) and (b) Grey Box quadrats (n=11, 2005 - 2006; n=14, 2008 - 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled.

The temporal pattern in species richness was relatively similar in the two WRCs, although Black Box sites supported more species than Grey Box sites between 2005 and 2012, most notably in 2010 (27 additional species) after high rainfall in November 2009. Grey Box sites however supported more species in 2013 and

2014 than the Black Box, despite the smaller sample size, possibly because a higher percentage of the former sites were flooded in 2010 - 2011 (5/14) than the latter (6/19).

# **Rare and Threatened Species**

Three species listed on the Victorian rare and threatened advisory list were recorded in the Black Box quadrats and two list species were recorded in the Grey Box quadrats in 2014 (Tables 14 and 15). The perennial Blue Burr-daisy (*Calotis cuneifolia*) and annual Native Peppercress (*Lepidium pseudohyssopifolium*) can be found in less frequently inundated areas. Whereas the amphibious Smooth Minuria (*Minuria integerrima*) and Smooth Blue-rod (*Stemodia glabella s.s.*) are likely to have emerged in response to localised ponding.

The greatest richness of rare and threatened species was recorded after above average rainfall and flooding in 2010 – 2011. The 2014 result represents a decline in the number of such species from 2011, but is not considered a significant concern given the drier conditions recorded over the last two years. No legislatively listed species have been recorded in the box WRCs.

Table 14 Rare and threatened flora taxa recorded in autumn in Black Box Woodland quadrats (n = 14, 2005 - 2006; n = 19, 2008 - 2014), Gunbower Forest autumn 2005 – 2014). Note years 2007 and 2009 were not sampled.

EPBC	FFG	Vic Adv	Scientific Name	Common Name	PFG Name	2005	2006	2008	2010	2011	2012	2013	2014
		r	Cardamine moirensis	Riverina Bitter-cress	Emergent Amphibious Flora					х			
		r	Minuria integerrima	Smooth Minuria	Emergent Amphibious Flora				х	х	х		х
		k	Stemodia glabella s.s.	Smooth Blue-rod	Emergent Amphibious Flora						х		x
		r	Gratiola pumilo	Dwarf Brooklime	Annual Mudflat Flora					х			
		k	Cynodon dactylon var. pulchellus	Native Couch	Perennial Mudflat Flora						х		
		k	Alternanthera sp. 1 (Plains)	Plains Joyweed	Terrestrial Damp Flora				х	х	х		
		r	Lepidium pseudohyssopifolium	Native Peppercress	Terrestrial Damp Flora								x
		r	Atriplex pseudocampanulata	Mealy Saltbush	Terrestrial Dry Flora				х	х			
		r	Calotis cuneifolia	Blue Burr-daisy	Terrestrial Dry Flora				х				
		v	Chenopodium desertorum subsp. rectum	Frosted Goosefoot	Terrestrial Dry Flora					x			
					Total species recorded	0	0	0	4	6	4	0	3

Table 15 Rare and threatened flora taxa recorded in autumn in Grey Box Woodland quadrats (n = 11, 2005 - 2006; n = 14, 2008 - 2014) in Gunbower Forest autumn 2005 - 2014. Note years 2007 and 2009 were not sampled.

EPBC	FFG	Vic Adv	Scientific Name	Common Name	PFG Name	2005	2006	2008	2010	2011	2012	2013	2014
		r	Rorippa eustylis	Dwarf Bitter-cress	Annual Mudflat Flora			х					
		r	Cardamine moirensis	Riverina Bitter-cress	Emergent Amphibious Flora					х	х		
		k	Alternanthera nodiflora	Common Joyweed	Perennial Mudflat Flora						х		
		k	Alternanthera sp. 1 (Plains)	Plains Joyweed	Terrestrial Damp Flora				х	х			
		k	Lepidium pseudohyssopifolium	Native Peppercress	Terrestrial Damp Flora			х		х			х
		r	Calotis cuneifolia	Blue Burr-daisy	Terrestrial Dry Flora			х	х	x	х	х	x
	Total species recorded					0	0	3	2	4	3	1	2

### **Exotic Species**

A total of 8 exotic species covering less than 3% on average of the area surveyed were recorded in the Box woodland quadrats in 2014 (Figure 27). This represents a small increase (0.5% - 1.2%) in weed extent between 2013 and 2014, most likely in response to the higher annual rainfall over the last 12 months.

While these results suggest weeds were relatively limited in the Box woodlands, the 2011 results indicate exotic species have the capacity to double in cover providing adequate rainfall and/or flooding. The cumulative cover of weeds also varied considerably between sites from, for example, 0 - 22% in Black Box quadrats and 0 – 13% in Grey Box quadrats in 2014. Further to this, 16 of the 50 exotic species observed in the box WRCs are ranked as medium to very high risk weeds (Adair *et al.* 2008a and 2008b). Of these species Bridal Creeper (\**Asparagus asparagoides*) and African Box-thorn (\**Lycium ferocissimum*) were the most widespread in the box woodlands.



Figure 27 Temporal change in the mean ( $\pm$ SD) cover (%) of exotic and native species in (a) Black Box quadrats (n = 14, 2005 - 2006; n = 19, 2008-2014) and (b) Grey Box quadrats (n=11, 2005 - 2006; n=14, 2008 – 2014), Gunbower Forest. Note years 2007 and 2009 were not sampled. Standard deviation represented by error bars.

### 5.2.2 Characteristic Plant Functional Groups

Box woodlands are typified by emergent amphibious (PFG 5) and mudflat (PFG 4) flora in areas that are more regularly inundated (e.g. Riverine Swampy Woodland), and by terrestrial damp (PFG 6) and terrestrial dry (PFG 7) species in areas that are rarely if ever flooded (e.g. Riverine Chenopod Woodland and Plains Woodland). While these PFGs span both Black and Grey Box WRCs, for the purpose of the condition monitoring program, Black Box are analysed as characterised by PFGs 4 – 6, and Grey Box characterised by PFGs 6 – 7. Other amphibious and aquatic species do occasionally occur in the Box WRCs, but are not typical

of these more elevated WRCs. The richness of characteristic PFG species has been suggested as one indicator of vegetation condition (see Section 2.2.3).

#### **Richness of Characteristic PFGs Species**

The results from the monitoring program to date indicate the average richness of PFGs characteristic of the box woodland WRCs peaked in 2011 after above average rainfall and flooding in 2010 – 2011, but in 2013 and 2014 returned to levels similar to that recorded before the hydrological event (2005 - 2008) (Figures 28 and 29). Characteristic species also increased marginally in the Grey Box WRC from 7.6 average species in 2013 to 8.6 species in 2014.



Figure 28 Temporal change in the mean richness of characteristic (PFGs 4, 5 and 6,  $\pm$ SD) and non-characteristic (PFGs 1-3 and 7) flora for Black Box Woodland quadrats (n = 14, 2005 - 2006; n = 19, 2008 - 2014) in Gunbower Forest autumn 2005 – 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.



Figure 29 Temporal change in the mean richness of characteristic (PFGs 5, 6 and 7,  $\pm$ SD) and non-characteristic (PFGs 1-4) flora for Grey Box Woodland quadrats (n = 11, 2005 - 2006; n = 14, 2008 - 2014) in Gunbower Forest autumn 2005 - 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.

Non-characteristic terrestrial dry species (PFG 7) dominated the Black Box sites, with three (2011) to 18 (2008) times the average species richness than characteristic species over the monitoring period. In addition, terrestrial species increased dramatically between 2008 and 2010, most likely in response to the high November 2009 rainfall. The average richness of terrestrial species also increased marginally between 2013 and 2014 (e.g. 6.8 species in 2013 to 8.4 in 2014). The above average rainfall and flooding in 2010 – 2011, however, appears to have had limited effect on the terrestrial species richness.

Non-characteristic aquatic and amphibious PFG species richness in Grey Box quadrats followed a similar pattern to characteristic species, peaking in 2011. Interestingly, more so in the Grey Box sites than the Black Box sites. While these species are not typical of Plains Woodland vegetation they highlight the response of the more mesic Riverine Swampy Woodland vegetation in the WRC to the hydrological conditions in 2010 – 2011.

The richness of species varied between sites as indicated by the large standard deviation for the annual means. This suggests the WRCs' understorey flora composition is heterogeneous and possibly not well captured by the current suite of characteristic PFGs.

# Index of Characteristic PFGs Species Richness

Compliance with characteristic PFG species richness targets for the Box WRCs (Figure 30) varies temporally in a similar pattern to that depicted in Figures 28 and 29 above – with compliance peaking after above average rainfall and flooding in 2010 - 2011. For each WRC the Index references the number of characteristic indigenous PFG species recorded per site relative to the number of characteristic indigenous PFG species recorded per site relative to the number of Reference). At best, only 37% (7/19) of Black Box and 36% (5/14) of Grey Box quadrats met this Point of Reference (in 2011). In 2014 only one Black Box and two Grey Box quadrats achieved this target. This indicates the majority of box woodland quadrats fell short of the nominated health target in all years.



Figure 30 Proportion of sites that complied with the Species Richness Index PoR in Black Box Woodland sites (n = 14, 2005 - 2006; n = 19, 2008 - 2014) and Grey Box Woodland sites (n = 11, 2005 - 2006; n = 14, 2008 - 2014), Gunbower Forest autumn 2005 - 2014. Note years 2007 and 2009 were not sampled.

### **Cover of Characteristic PFGs Species**

The average cover of characteristic PFG species in Black Box and Grey Box quadrats followed a similar temporal trend to the richness of characteristic PFG species, peaking after above average rainfall and flooding in 2010 – 2011 (Figures 31 and 32). The cover of non-characteristic species was also considerably higher than characteristic species in the Black Box quadrats. However, unlike the richness trend, the average cover of characteristic PFG species in the Grey Box quadrats decreased slightly between 2013 and 2014, most likely due to a decline in terrestrial dry species (PFG 7).



Figure 31 Temporal change in mean ( $\pm$ SD) quadrat cover of characteristic (PFGs 4, 5 and 6) and non-characteristic (PFGs 1-3, and 7) flora at Black Box Woodland quadrats (n = 14, 2005 - 2006; n = 19, 2008 - 2014), Gunbower Forest autumn 2005 – 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.



Figure 32 Temporal change in mean ( $\pm$ SD) quadrat cover of characteristic (PFGs 5, 6 and 7) and non-characteristic (PFGs 1-4) flora at Grey Box Woodland quadrats (n = 11, 2005 - 2006; n = 14, 2008 - 2014) in Gunbower Forest autumn 2005 – 2014. Note years 2007 and 2009 were not sampled and for clarity standard deviation is included for characteristic PFG only.

Quadrat photographs in Figure 33 visually represent the results discussed above.





Figure 33 Box Woodland understorey Quadrat 31 (Riverine Chenopod Woodland) and Grey Box Quadrat 90 (Plains Woodland) and Quadrat 93 (Riverine Swampy Woodland)

# Black Box Case Study

Multivariate analyses (ordinations) based on ground flora and non-living cover data have been undertaken to explore similarities in the box woodland quadrats within and between sampling years (Figures 34).

The ordination of the Black and Grey Box understorey data suggest the 33 quadrats supported relatively similar ground flora composition at the end of the 14 year drought 2005 - 2010 and again in 2013 - 2014 (i.e. tightly clustered data points in the middle of the figure) (Figure 34a). The spread in data points in 2011 and 2012, after above average rainfall and flooding in 2010 - 2011, indicates the composition changed (reflected by an increase in diversity) and quadrats were less similar to other years. This pattern reflects the 2011 and 2012 peak in flora richness and cover reported in Section 5. While above average rainfall is likely to have influenced this diversification, flooding was found to significantly (P<0.001) increase the cover of mudflat flora in the Box quadrats established in 2005 (Technical Addendum, Section 6.5).

One of the complicating factors when trying to determine trends and patterns in the two Box woodlands is the gradient of vegetation from terrestrial to that which responds vegetatively to flooding within each WRC. While the Black and Grey Box WRCs appear to occupy distinct areas in the ordination (i.e. support distinct ground flora composition) there is considerable overlap (Figure 34b). There however appears to be less overlap in the Box data points when they are classified by EVC (Figure 34c), with the rarely flooded Riverine Chenopod Woodland (Black Box canopy, Figure 33) positioned to the right, the terrestrial Plains Woodland (Grey Box canopy, Figure 33) to the left and the flood responsive Riverine Swampy Woodland (Black Box, Grey Box and/or River Red Gum canopy, Figure 33) spreading towards the top of the graph. The spread of Riverine Swampy Woodland data points marries up with the data points that diversified after the flood (Figures 34a and c).

A similar gradient of terrestrial to flooded vegetation also occurs in the Red Gum FTU WRC. This result highlights that vegetation within these elevated WRCs is heterogeneous and hence likely to require a range of water regimes to sustain healthy vegetation.



Figure 34. NMDS ordination plots showing all Gunbower Forest Box Woodland monitoring data-points (each quadrat on each sampling year) arranged by Bray-Curtis similarity. Sampling units are colour-coded by (a) Water Regime Class, (b) year and (c) EVC.

# 5.3 Tree Canopy

The following section presents the canopy health results based on data collected at the Black and Grey Box understorey sites between 2005 and 2014.

# **Tree Crown Health**

The percentage of Black and Grey Box trees in each crown health category (see Table 4) surveyed between 2005 and 2014 is presented in Figure 35. As recorded in the Red Gum WRCs, there was a clear decline in the percentage of healthy (>50% intact canopy) Black Box trees from 81% in 2005 down to 46% in 2014. There was also a decline in the percentage of healthy Grey Box trees, although not to the same magnitude (i.e. 16% decline compared to 35%).



Figure 35 Proportion of tree population in each crown condition class in (a) Black Box (n=280, 2005 - 2006; n=380, 2008 - 2014) and (b) Grey Box (n=220, 2005 - 2006; n=280, 2008 - 2014) sites, Gunbower Forest. Note years 2007 and 2009 were not sampled.

# Tree Canopy Health Index

The proportion of trees with healthy canopies has been suggested as an indicator of vegetation condition (see Section 2.2.3). The Tree Canopy Health Index scores the proportion of trees with at least 50% of their canopy intact at each site. The site index score is then compared to Point of Reference (the proportion of trees with healthy canopies in the top 10% of records over the 2005 - 2014 period in each WRC) to determine compliance. Temporal variation in the proportion of compliant sites is depicted in Figure 36.



Figure 36 Proportion of sites that comply with the Tree Canopy Health Index PoR in Black Box (n=280, 2005 - 2006; n=380, 2008 - 2014) and Grey Box (n=220, 2005 - 2006; n=280, 2008 - 2014) sites, Gunbower Forest. Note years 2007 and 2009 were not sampled.

The number of Box woodland sites which achieved the canopy health Points of Reference declined over the monitoring period, from 5/14 Black Box and 4/11 Grey Box compliant sites in 2005 to zero compliant sites in both WRCs in 2014. This indicates that the sites assessed in did not support sufficient numbers of healthy trees in 2014 to meet the health target set. Furthermore, that canopy health has deteriorated in the box woodlands, despite above average rainfall and flooding recorded between 2010 and 2012.

# 7.0 DISCUSSION & CONCLUSION

Over the last decade Gunbower Forest has experienced wet and dry climatic conditions, along with natural and engineered floods. Seven of the ten years were recorded with below average annual rainfall (2006 - 2009 and 2012 - 2014) and one year with extremely high annual rainfall (i.e. 2011, more than twice the annual average), (Technical Addendum, Section 2.2). In 2010 - 2011 the forest benefited from widespread natural flooding, followed by four small natural floods between 2011 and 2013 (Figure 3). Environmental water was also delivered to a combination of the wetlands on eight occasions over the ten years (G-MW, 2013).

As a result of these hydrological events, the wetlands were inundated between seven to nine years out of ten and areas of the forest have been inundated multiple times. Despite these events significant areas of the forest remained dry throughout the monitoring period and are unlikely to have been flooded since the 1970s.

The wetland and understorey flora composition and cover and canopy tree health varied in response to these hydrological and climatic conditions. The impact of environmental water delivered to the wetlands is included in this response. However the environmental flow engineered to water larger areas of the forest via the Hipwell regulator, did not commence until after the 2014 survey, and is therefore not reflected in the data. Vegetation monitoring in 2015 will prove invaluable for determining the benefit of this large scale flood to the forest.

#### Wetlands

Wetland sites monitored between 2005 and 2014 transitioned between dry, recently inundated and receding phases of the wetland cycle (Table 8). The monitoring results suggest the wetlands supported distinct compositions of flora in each phase. In particular, shallowly inundated wetlands were distinguished by a higher richness and cover of characteristic species. Whereas recently inundated (i.e. 2012) and dry wetlands had a lower richness and cover of such species. This result is not surprising, given that shallowly inundated wetlands typically include a gradient of habitats from wet to dry and therefore offer suitable conditions for a broader range of species than other phases. Furthermore, and in contrast to recently inundated wetlands which can support a similar habitat gradient, flooding in the shallowly inundated wetlands sampled was of sufficient duration to facilitate germination and growth in aquatic and semi-aquatic species. The cover of weeds while generally low also varied with wetland phase, with higher average covers recorded at lower water depths.

Rare and threatened species were recorded in all wetland phases, there were however more than twice the number of species recorded in 2010 (when wetlands were both dry and receding) than any other year surveyed. The majority (93%) of the species were recorded in wetlands that received an environmental flow in November 2009. This suggests the species responded positively to the water, yet it was possibly the combination of above average rainfall and environmental water delivery that created this response, as water delivered in other years did not have the same effect on rare and threatened species.

In 2014 the wetlands were in dry, drying and receding phases, many having been inundated by the small inflow in spring 2013. Like previous years they were dominated by characteristic flora, had low weed cover but albeit few rare and threatened species. The data also indicates the average richness and cover of characteristic species had increased from 2013, which in combination with the ordination results, suggests they were possibly shifting back toward the more mesic states recorded in 2005, 2006 and 2010, and hence in better condition than when assessed last year. Despite this no wetlands met the Point of Reference for the
characteristic PFG species richness Index in 2014, highlighting they were below the richness target (top 10% of data points). Annual variability observed in wetlands that naturally dry out is likely to influence this result. However, the condition of the wetlands in 2014 possibly still reflects the prolonged inundation event caused by natural inflows between 2010 and 2012, which created turbid and anoxic conditions and introduced carp back into system. While attempts were made to dry the wetlands in the subsequent period, flooding between 2012 and 2013 hamper this effort.

### **Red Gum and Box vegetation**

The pattern in the forest differed to that recorded in the wetlands. The average richness and cover of characteristic species and presence of rare and threatened species peaked in 2011 after above average rainfall and flooding of 67% of the understorey sites. The cover of weeds also peaked in this year, but along with other species declined again in 2013, despite 35% of sites flooding again in 2012. Vegetation within the WRCs was however heterogeneous and there was considerable variability in cover and richness values between sites in all years sampled.

Unlike the wetlands, the understorey sites were not dominated by characteristic flora in all years assessed. For example, during the drought (2005 - 2010) non-characteristic terrestrial species had, more often than not, higher average richness and cover in Red Gum WRCs than characteristic species. Terrestrial species also exceeded characteristic species again in 2014 in the Red Gum FTU quadrats. This suggests that the conditions during the drought and in 2014 were not adequate to support flora considered typical of these floodplain WRCs. Unlike amphibious flora, terrestrial flora do not depend on flooding to persist but rather respond to peaks in rainfall, as recorded in 2010 after the above average rainfall in November 2009. There were, however, also modest increases in the average cover and richness of characteristic flora in the two Red Gum WRCs between 2013 and 2014, indicating an improvement in vegetation diversity.

The results in the Box woodlands were mixed. As recorded in the Red Gum WRCs the richness and cover of ground flora peaked in 2011. Between 2013 and 2014, the average richness and cover of characteristic species increased marginally. However, non-characteristic terrestrial species dominated the Black Box quadrats in all years, indicating they were drier than preferred. Non-characteristic aquatic species also made a substantial contribution to the Grey Box quadrats flora in 2011 after flooding. These results appear influenced by the selection of characteristic PFGs for the WRCs, which suggest that Grey Box woodlands do not support significant numbers of flood stimulated species and that Black Box do not support terrestrial species. Further analysis of the flora data highlight the Box WRCs include a gradient of vegetation from terrestrial (Plains Woodland in the Grey Box) or near terrestrial (Riverine Chenopod Woodland in the Black Box) to flooded vegetation (Riverine Swampy Woodland in both WRCs). Any condition assessment that does not consider this gradient in the Box woodlands is likely to misrepresent the vegetation.

The results of the characteristic species PFG Index assessment mirrored the key trend above, with the number of compliant sites peaking in 2011. Yet in 2014 very few understorey sites achieved the Points of Reference for these WRCs (i.e. 4/50 Red Gum FDU, 1/27 Red Gum FTU, 1/19 Black Box, and 2/14 Grey Box sites). This indicates that the majority of sites did not support a 'healthy' richness of characteristic flora during 2014. The 2014 results were however marginally higher in the Grey Box and Red Gum FDU WRCs than 2013, suggesting a slight improvement in condition, most likely due to higher rainfall in the preceding 12 months. There was however no change in the Red Gum FTU and Black Box sites during this period.

The results of the Tree Canopy Health Index assessment indicated the Red Gum and Box trees followed slightly different trends. The number of sites that complied with the Points of Reference declined dramatically between 2005 and 2006 in all WRCs and, in the Black and Grey Box WRCs, continued to decline to zero by 2014. This indicates the proportion of trees with at least 50% of their canopy intact deteriorated in the Box woodlands over the ten years. The proportion of sites that complied with the Point of Reference nonetheless increased in the Red Gum WRCs around 2011 – 2012, indicating there was some improvement in the species' canopy with above average rainfall and flooding. However, the number of sites that achieved the Point of Reference in the Red Gums was low in 2014 (6/50 Red Gum FDU and 2/27 Red Gum FTU). These results suggest the eucalypts have not yet recovered from the 14 year drought and potentially other disturbances such as 140 years of harvesting and river regulation.

# **Condition Indicators and Ecological Objectives**

As discussed above of the refined vegetation condition indicators (characteristic PFG species richness and tree canopy health) were trialled in the current project. These were developed in the recent vegetation condition indicator refinement project. Work required to progress the indicators includes revisiting the vegetation objectives and monitoring targets for the Gunbower Forest Icon Site. It is critical that the objectives are specific and measurable. Questions to consider, in view of such are:

- Is the aim of the condition monitoring to determine a trend (or trends) over time or current condition in reference to a benchmark condition?
- What are the specific and measurable objectives? For example, maximising diversity (species richness and evenness); maintaining conservation values (threatened species), maintaining vegetation community intactness (cover of exotic flora); maximising the long term persistence of tree populations (recruitment); and/or maintaining habitat quality (large old trees with hollows).

In addition, for the purposes of this report, Index results were summarised from site to WRC level by calculating the proportion of compliant sites, yet it may prove that an average is a more appropriate way to summarise Index scores from site level to WRC level (and to Icon Site level). The decision in part depends on the monitoring 'Targets' and what the CMA ultimately wants to measure. For example, if the ultimate measure of vegetation 'health' is a particular proportion of compliant sites per WRC, (e.g. '*At least 30% of sites in each Red Gum WRC in 'healthy'* condition (compliant with Point of Index Reference) by 2025'), then proportion of compliant sites could be used to generate a WRC level score for both indices. Alternatively, an area-weighted WRC level score could then be averaged to get an Icon Site level score. However, if the ultimate measure of vegetation 'health' is an average Index score per WRC, then the target would be worded along the line of 'At least 30% of sites in each Red Gum WRC in 'healthy' condition (average index score at or above PoR) by 2025'. These examples go some way to explain the difficulty in reporting progress on the current ecological objectives (Table 1).

Notwithstanding the above, overall statements of health have been drafted for the three Icon Site overarching ecological objectives, based on the 2005 - 2014 monitoring program results:

## Increase area of healthy Permanent and Semi-permanent Wetlands

In 2014 the wetlands were dominated by characteristic flora, had low weed cover, but also had few rare and threatened species. Ordination of the ground flora cover data indicated the composition of wetlands had shifted

away from that recorded in 2013 when dry, towards the more mesic states recorded in in 2005, 2006 and 2010. These results suggest the wetlands were in slightly better condition in 2014 than 2013. Despite such no wetlands met the Points of Reference for the characteristic PFG species richness Index in 2014, which implies that the wetlands were not satisfactorily species rich. The condition of the wetlands in 2014 possibly still reflects the prolonged inundation event caused by natural inflows between 2010 and 2012, which created turbid and anoxic conditions and introduced carp back into systems.

Environmental water delivered between 2004 and 2010 ensured the wetlands experienced wet phases during the drought. The subsequent receding (shallowly and deeply inundated) and drying wetlands included the highest average richness and cover of characteristic species, greatest presence of rare and threatened species and lowest weed cover records.

No measurement of wetland area is undertaken in the current monitoring program.

# Ensure maintenance of healthy River Red Gum communities

The monitoring results suggest that the ground flora increased in characteristic species richness and cover following above average rainfall and flooding in 2010 -2011 but that it has since returned to levels comparable to those recorded at the outset of the monitoring program (during the 14 year drought). The tree canopy results however suggest the River Red Gum population has declined in health over the monitoring period, with only minor improvement after 2010.

If the reference condition for assessing 'maintenance' is set as the condition recorded at the commencement of the monitoring program (2005) then it could be said that the condition of the Red Gum vegetation has been maintained, as the 2014 ground flora result are comparable with those from 2005. However, if the reference condition for the vegetation was set based on the best recorded condition (i.e. 2011, following a natural flood) then the condition of the Red Gum vegetation would be considered poorer, as the 2014 results for species richness and cover, rare and threatened species, and canopy health, are lower than recorded in 2011.

## Maintain Black Box and Grey Box communities

As for the Red Gum WRCs, the Box woodland results suggest that the ground flora increased in characteristic species richness and cover following above average rainfall and flooding in 2010 -2011, but that it has since returned to levels comparable to those recorded at the outset of the monitoring program (during the 14 year drought). The tree canopy results however suggest the Black and Grey population has declined in health over the monitoring period. However, unlike the Red Gum WRCs, the flora results are influenced by the selection of characteristic PFGs for each of the WRCs. As ordination of the flora data suggests both WRCs support a gradient of vegetation from terrestrial or near terrestrial to flood.

If the reference condition for assessing 'maintenance' is set as the condition recorded at the commencement of the monitoring program (2005) then it could be said that the condition of the Box woodland vegetation has been maintained, as the 2014 ground flora result are comparable with those from 2005. However, if the reference condition for the vegetation was set based on the best recorded condition (i.e. 2011, following a natural flood) then the condition of the Red Gum vegetation would be considered poorer, as the 2014 results for species richness and cover, rare and threatened species and canopy health are lower than recorded in 2011.

#### Conclusion

In conclusion, the wetlands assessed in Gunbower Forest appeared to have improved slightly in condition over the last twelve months, especially in areas that dried out. The high levels of turbidity and paucity of aquatic flora in inundated wetlands suggests that factors such as Carp are influencing the health of these systems. The Red Gum and Box vegetation in the forest also had higher species richness and cover of characteristic flora in 2014 than 2013, but the canopy health results were mixed. Despite the above, no wetland sites and only a small number of Red Gum and Box WRC sites assessed were considered to support healthy species richness, and tree health was found to be generally low and/or declining.

#### Recommendations

- Revise the Icon Site ecological objectives to be measurable
- Revise characteristic PFGs in the Black and Grey Box woodland WRCs to reflect the gradient from terrestrial to flooded vegetation included in the WRCs
- Continue the refinement of vegetation condition indicators
- Revise PoRs for wetland indicators to reflect wetland phases rather than WRCs
- Investigate the cause of turbidity in the wetlands and its effect on aquatic vegetation
- Investigate the direct (i.e. physical removal) and indirect (i.e. increased turbidity due to bio-turbation) impact of Carp on aquatic vegetation in the wetlands
- Investigate the effect of the 2014 environmental flow delivered via the Hipwell Road regulator using a scientific approach of comparing treated (flooded with environmental water) sites and control (dry) sites.

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