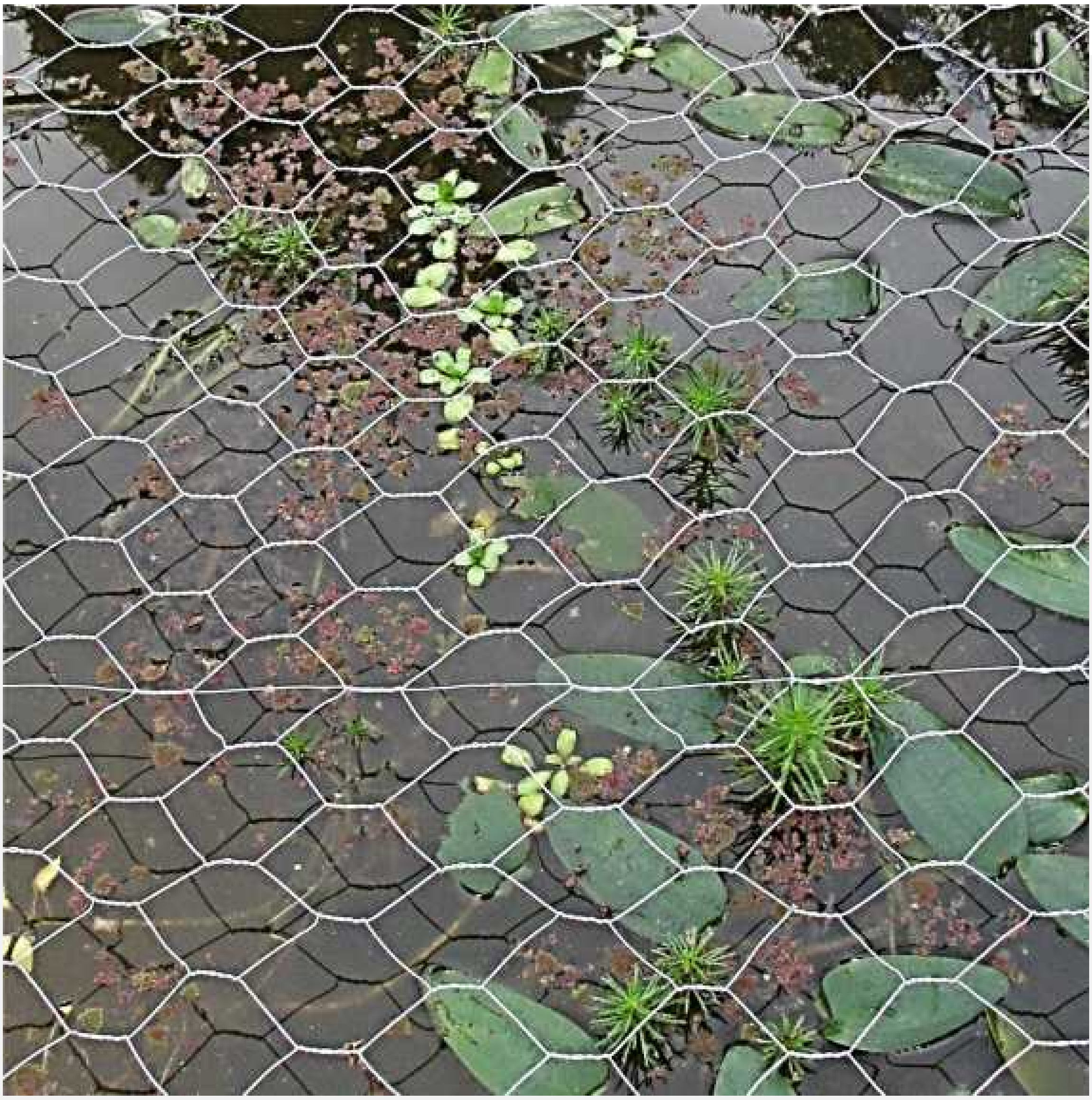

Gunbower Forest Wetland Exclusion Study

Spring - Summer Report

May 2016

Fire Flood & Flora

Prepared for the North Central Catchment Management Authority

This project was funded by The Living Murray initiative of the Murray-Darling Basin Authority. The Living Murray is a joint initiative funded by the New South Wales, Victorian, South Australian, Australian Capital Territory and Commonwealth governments, coordinated by the Murray–Darling Basin Authority.

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Cover photograph: Exclusion plots (control and partially, vertically and horizontally fenced), Little Reedy Gunbower Forest, 2016

EXECUTIVE SUMMARY

- Fire, Flood and Flora was engaged by the North Central Catchment Management Authority to undertake and report on spring and summer surveys of wetland exclusion study plots in Gunbower Forest.

- The aim of the study was to investigate the effect of carp and/or waterbirds on aquatic flora species (i.e. submerged, free floating and amphibious species that adapt with changes in water level).

- The study included 32 plots - half in each Reedy and Little Reedy Lagoons - and four treatments:
  - 8x side fenced plots (designed to exclude large-body carp),
  - 8x partially fenced plots (to test the effect of the fence),
  - 8x floating fence plots (designed to exclude grazing waterbirds), and
  - 8x unfenced control plots.

- The results confirmed that there is not a simple relationship between aquatic plant cover and the four treatments at Reedy and Little Reedy Lagoons.

- The mean richness and cover of aquatic plants were higher, and significantly so in many instances, in the three fenced treatments than in the unfenced control. From this, we infer that the exclusion of animals causing physical disturbance (e.g. carp and/or waterbirds) and/or the altered physical conditions (e.g. slowing of water movement) positively affected the aquatic plants.

- The floating fence treatment, which was designed to exclude waterbirds, had a strong positive impact on aquatic plant cover and richness, and the effect was actually stronger than that of the side fence treatment (designed to exclude carp). It is possible that the floating fences provided protection to young plants, which once established, were more resilient to carp impacts.

- There was some evidence of a negative relationship between sediment-based turbidity and aquatic plant species cover at Little Reedy Lagoon, but this was not replicated at Reedy Lagoon, where turbidity appeared to be algal-derived rather than sediment based.

- Caution should, however, be applied when interpreting the results, as more data is required before we can be certain that the effect detected in each treatment relate exclusively to carp and waterbirds.

KEY POINTS

Four types of experimental plots (fences) were designed to see if keeping carp and waterbirds out of aquatic plant beds would change the number of plant species (richness) and amount (cover) recorded.

The presence of fencing improved aquatic plant richness and cover: lowest in unfenced plots, usually followed by partially fenced, then sides fenced, and then highest under floating fences.

Partially fenced plots appeared to have lower disturbance by carp than unfenced, even though they were open on one side.

Side fenced plots excluded carp, but may also have restricted waterbird access.

Floating fenced plots had high plant cover and richness, despite being open to carp, perhaps because the young plants need protection from bird grazing, and once they are big enough they are better able to withstand carp. Floating fenced plots were designed to exclude waterbirds but since waterbird numbers weren't recorded, we can't know this for sure – they may have had other positive effects on plant growth.

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Definitions of terms and acronyms referenced in the current report

Term/Acronym	**Definition in this report**
CMA	Catchment Management Authority
eFlow	Environmental water delivered to ecological assets.
Extent	Short for 'spatial extent', the distribution of the organism in the environment. Where it occurs. Similar to occupancy, but different because it geo-references or maps the distribution (e.g. species X occurs in this (mapped) portion of the Icon Site).
Floating fence (FF)	Plot treatment with a horizontal floating fence
Generalized linear mixed-effects modelling (GLMEM)	A type of univariate data analysis (analysis with one 'response' variable)
MDBA	Murray Darling Basin Authority
Partially fenced (PF)	Plot treatment with three sides fenced
Plant Functional Groups (PFGs)	Groups pf plants based on common ecological, morphological and functional responses to inundation based on a system adapted from Brock and Casanova (1997) (See Appendix 1.)
Receding (R)	Receding wetland phase class
Recently Inundated (RI)	Recently inundated wetland phase class
Sides fenced (SF)	Plot treatment with all four sides fenced
Unfenced (UF)	Control plot treatment
Wetland Phase Classes	Classes of wetland (i.e. receding, dry, recently inundated) based on the stage of the hydrological cycle at which they were sampled.

1 INTRODUCTION

Fire Flood & Flora, in partnership with Dr Lien Sim, was contracted by the North Central Catchment Management Authority (CMA) to undertake a wetland exclusion study in Gunbower Forest (Figure 1), in spring 2015 and summer 2016. The primary aim of this intervention monitoring was to detect possible effects of excluding large-bodied carp (*Cyprinus carpio*) and waterbirds from aquatic vegetation in Reedy and Little Reedy Lagoons. The secondary aim was to determine if the patterns of high vegetation cover inside exclosures, observed in the 2014-2015 carp exclusion pilot study (see Bennetts & Sim 2015), were repeated.

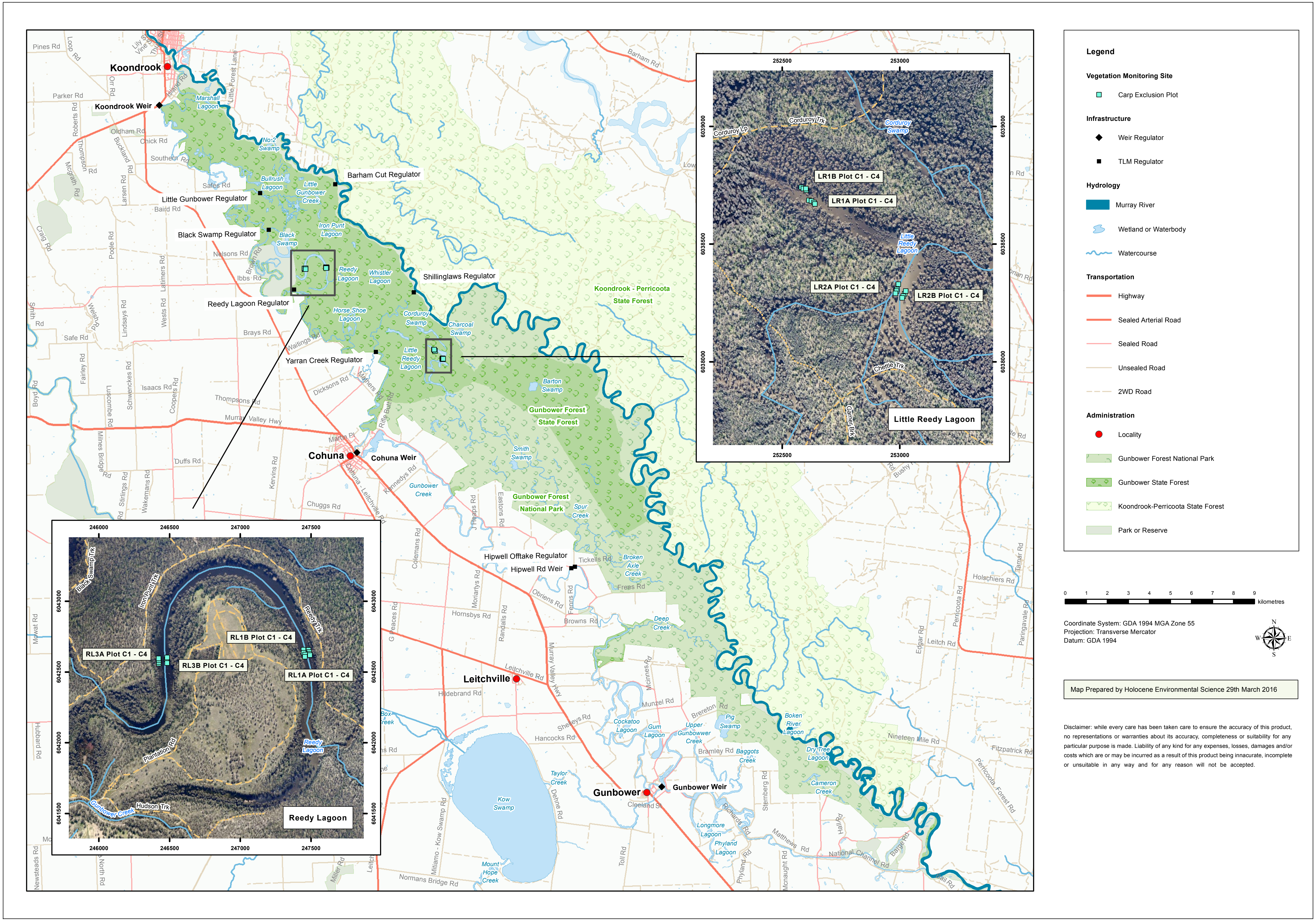
The current report briefly documents the background to the experiment, study sites and methods, before detailing and discussing the results. Recommendations have also been provided to progress our understanding of the impact of both carp and waterbirds on aquatic vegetation.

1.1 Study area

Reedy and Little Reedy Lagoons are located within Gunbower Forest, a Murray River Icon Site in Victoria (Figure 1). The wetlands are situated in the lower end of the floodplain and are, therefore, inundated relatively regularly. The depth and duration of flooding is, however, likely to have declined since river regulation commenced the early 1900s.

Reedy Lagoon is a horse-shoe shaped wetland that was once a bend in the nearby Gunbower Creek. While normally isolated, the lagoon connects to the creek when the natural levee between them is breached or water is delivered. It also connects to the forest via flood runners when deeply inundated. The size of the River Red Gum trees lining Reedy Lagoon suggests that the wetland has maintained its shape and extent for hundreds, if not thousands of years.

Little Reedy Lagoon is a large boomerang-shaped opening in River Red Gum forest. Water flows into the wetland through flood runners connected to Yarran and Spur Creeks. The density of relatively young River Red Gums inside the larger, older trees surrounding the wetland indicates that the area of open wetland has contracted over the last century.


Legend
Vegetation Monitoring Site
Carp Exclusion Plot
Infrastructure
Weir Regulator
TLM Regulator
Hydrology
Murray River
Wetland or Waterbody
Watercourse
Transportation
Highway
Sealed Arterial Road
Sealed Road
Unsealed Road
2WD Road
Administration
Locality
Gunbower Forest National Park
Gunbower State Forest
Koondrook-Perricoota State Forest
Park or Reserve
0 1 2 3 4 5 6 7 8 9 kilometres
Coordinate System: GDA 1994 MGA Zone 55
Projection: Transverse Mercator
Datum: GDA 1994
Map Prepared by Holocene Environmental Science 29th March 2016
Disclaimer: while every care has been taken care to ensure the accuracy of this product, no representations or warranties about its accuracy, completeness or suitability for any particular purpose is made. Liability of any kind for any expenses, losses, damages and/or costs which are or may be incurred as a result of this product being innacurate, incomplete or unsuitable in any way and for any reason will not be accepted.
Koondrook
Koondrook Weir
Barham Cut Regulator
Little Gunbower Regulator
Black Swamp Regulator
Shillinglaws Regulator
Reedy Lagoon Regulator
Yarran Creek Regulator
Cohuna
Cohuna Weir
Hipwell Offtake Regulator
Hipwell Rd Weir
Leitchville
Gunbower
Gunbower Weir
Koondrook - Perricoota State Forest
Gunbower Forest State Forest
Gunbower Forest National Park
Little Reedy Lagoon
LR1B Plot C1 - C4
LR1A Plot C1 - C4
LR2A Plot C1 - C4
LR2B Plot C1 - C4
Reedy Lagoon
RL3A Plot C1 - C4
RL3B Plot C1 - C4
RL1B Plot C1 - C4
RL1A Plot C1 - C4

1.2 Flooding History

In 2014, water was delivered through the forest to the wetlands during winter and spring via the Hipwell regulator (Figure 2). In 2015, Little Reedy Lagoon was inundated in mid-spring via the Hipwell regulator and Reedy Lagoon was inundated in late-spring via the Reedy regulator on Gunbower Creek. In general, Reedy Lagoon holds water at greater depths than Little Reedy Lagoon (e.g. 23 November 2015, Reedy Lagoon was measured as 2.1m deep and Little Reedy Lagoon was 1.4 m deep) and therefore takes longer to dry out.

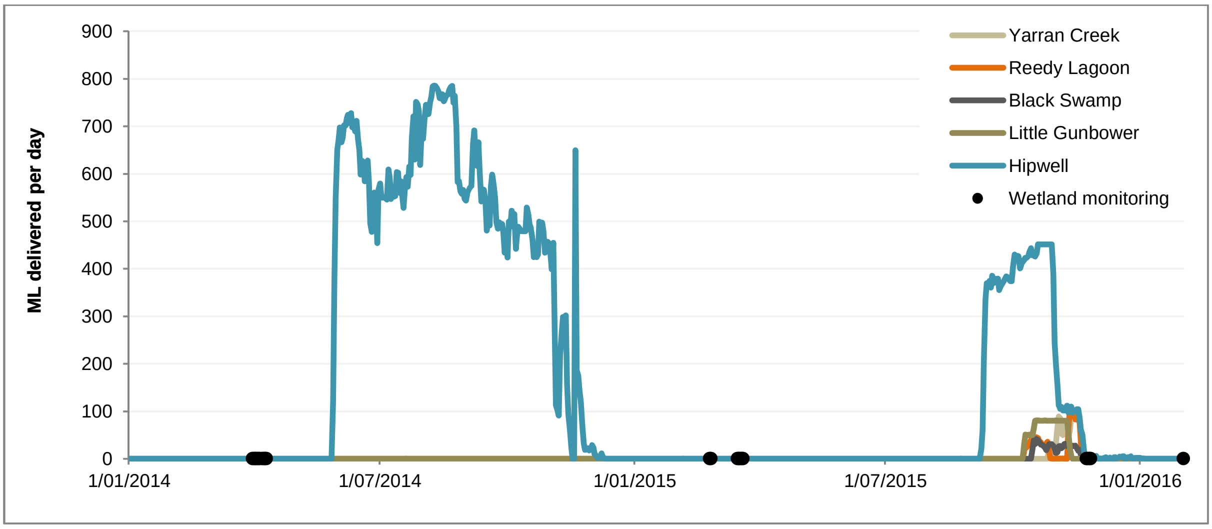


Figure 2 Combined environmental water delivered (source: North Central CMA 2016) and timing of wetland vegetation monitoring events, Gunbower Forest, 2014-2016.

1.3 Project Background

The 2014-2015 pilot study included a wetland-scale and plot-scale experiment, designed to examine the effect of excluding carp from aquatic vegetation (i.e. submerged, free floating and amphibious species that adapt with changes in water level). The wetland-scale experiment involved fencing off flood runners connecting Reedy Lagoon to the forest, in order to restrict access to large-bodied carp, while allowing unrestricted carp access Little Reedy Lagoon. Flora data was collected prior to (May 2014) and after (February and April 2015) inundation with environmental water.

While there was some evidence in the pilot study to suggest that the carp were limited (e.g. low carp numbers, low turbidity and high floristic diversity) by the wetland-scale exclusion at Reedy Lagoon, a considerable number of large-bodied carp have since been recorded in the wetland. (See Section 1.4). The presence of carp in Reedy Lagoon suggests that the exclusion fence was, at best, temporarily effective and limits the efficacy of the wetland-scale experiment. This component of the experiment is therefore not reported on in the current document.

The current project extends the plot-scale experiment with the addition of eight waterbird exclusion (floating fence) treatment plots, in order to determine if the high covers of aquatic flora recorded in the side fence plots in the pilot study were exclusively due to restricting carp access. It is possible the fenced plots also deterred waterbirds given their small scale (3m x 3m) and, in the side fenced plots, tall sides (2m). The bird exclusion plots had floating covers that allow fish to access the aquatic habitat in the plot but restricted bird access (see Figure 6 on page 16). These bird exclusion plots were designed using local knowledge on waterbird grazing behaviour. The aim of the new plots is to differentiate the effect of carp from the effect of waterbirds on aquatic vegetation.

1.4 Summary of 2015 Carp Data

The following summarises the carp data collected by Clayton Sharpe in Reedy and Little Reedy Lagoon in spring and summer 2015. While the timing of sampling was different to that of the exclusion plot study, it provides some insight into the carp population in the wetlands studied.

- Fish sampling took place in both wetlands in September 2015 (pre-watering) and in Reedy Lagoon in December 2015 (post-watering).
- These wetlands were sampled with equivalent/consistent effort on each date (same number and type of nets set overnight on each occasion).
- September 2015:
    - Little Reedy Lagoon 6 individuals were caught ranging from 105-620 mm in length.
    - Reedy Lagoon 1 individual 99 mm in length was caught.
- December 2015:
    - Little Reedy Lagoon not sampled.
    - Reedy Lagoon 1474 individuals ranging from 30-427 mm, with a median of 56.5 mm were caught. This increase in carp numbers occurred despite the presence of a carp screen on the wetland.
- The increase in carp numbers seen at Reedy Lagoon from September to December 2015 was apparently mirrored at other Gunbower wetlands, and was due to carp spawning on the floodplain. This is likely to have occurred at Little Reedy Lagoon as well (C. Sharpe February 2016 pers. comm.).

2 METHODS

2.1 Hypotheses

We have made a number of assumptions, predictions (Table 1) and hypotheses for Reedy and Little Reedy Lagoons, based on the pilot study data and a literature review on the known effects of carp and waterbirds on aquatic vegetation (Bennetts & Sim 2015). Figures 3 and 4 illustrate a model of the predicted relationship between carp, turbidity, water depth and aquatic flora in Little Reedy Lagoon.

Assumptions 1: Carp negatively impact on aquatic plant cover and richness by generating turbidity (from 2015 literature review, see Table 1 and Figures 3-4).

Assumptions 2: The same turbidity level would have a greater impact on aquatic plant communities in deeper waters than it would in shallower waters.

Assumption 3: There is a feedback loop with low density aquatic vegetation being more susceptible to carp, resulting in more turbidity, and in turn seeing the reduction of the density of aquatic vegetation (from 2015 literature review).

Table 1 Predictions of aquatic plant cover under different water depths, turbidity levels, and carp and/or water bird access based on the 2014-2015 pilot study.

Carp & Waterbirds	Turbidity	Water Depth	Aquatic plant cover
Carp absent or low numbers & Waterbird access (i.e. side fence plots) →	Low →	Deep	Low – Moderate[2]
		Shallow	High[2]
	Moderate →	Deep	Low
		Shallow	High
Carp high numbers & Waterbird access (i.e. control plots) →	Moderate →	Deep	Low
		Shallow	Low-Moderate
	High →	Deep	Low
		Shallow	Low
Carp present & Waterbirds restricted (i.e. floating fence plots) →	Moderate →	Deep	Low
		Shallow	Moderate
	High →	Deep	Low
		Shallow	Low - Moderate

Note: predictions in this table still need to be validated. Data from pilot study did not provide enough information to fully populate this table, particularly on the interaction between depth and turbidity.

[1]Carp presence is not recorded in individual exclusion plots, however the effect of carp presence in a wetland may not be even across the entire wetland, given differences in bathymetry and plant cover.

[2]Due to the level of light penetration.

Hypothesis 1: Turbidity that is generated by carp increases at higher numbers/densities of carp (see Table 1, Figure 4).

Hypothesis 2: Waterbird exclusion will have a positive impact on aquatic plant cover and richness, but this effect will be less than that of carp exclusion.

Hypothesis 3: The combined effect of carp and waterbirds on aquatic plant communities will be more strongly negative than the effect of either carp or waterbirds alone (see Table 1, Figures 3-4).

The current project aims to evaluate the validity of the predictions in Table 1 and test the above hypotheses with data collected in 2015-2016.

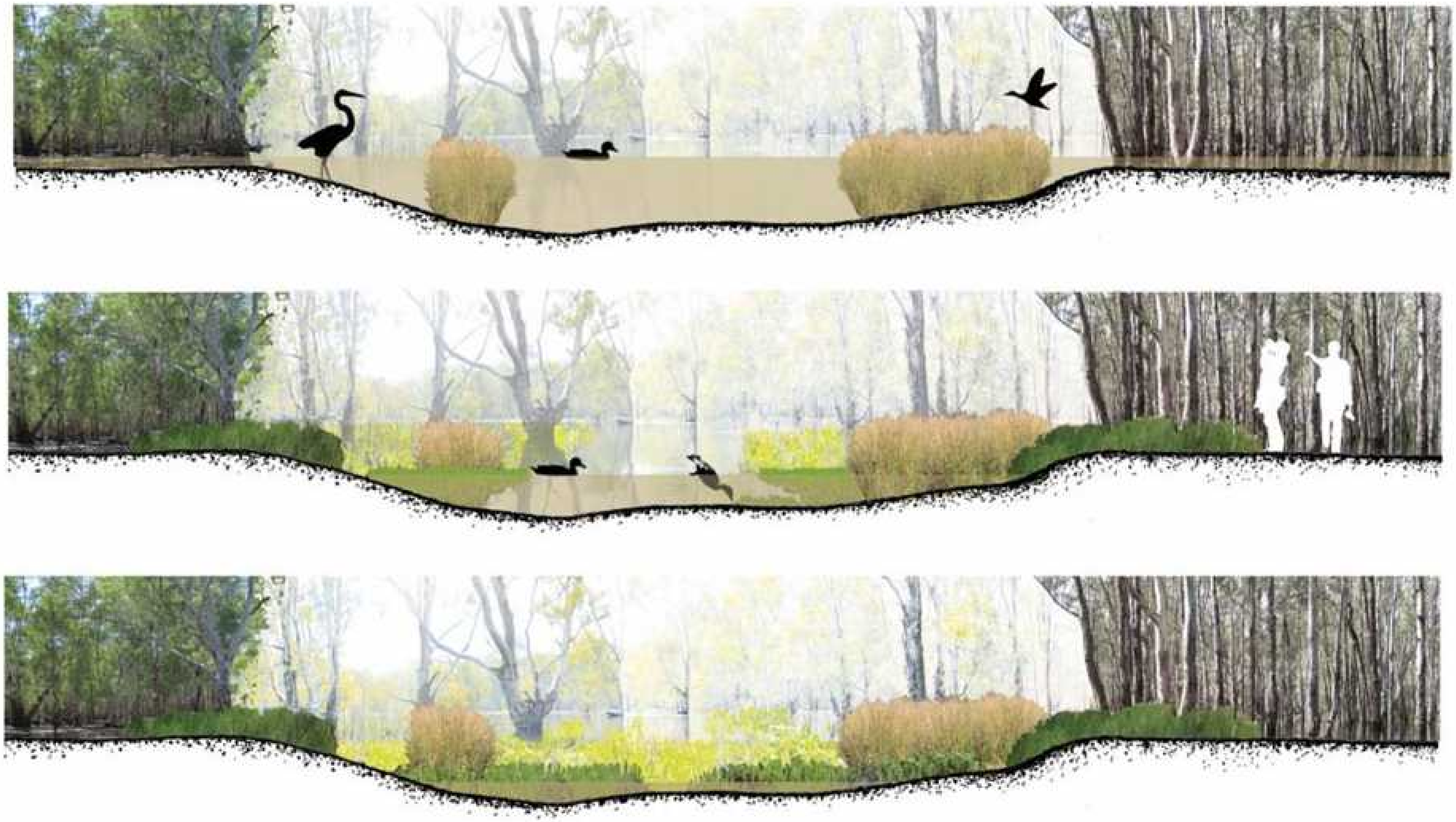


Figure 3 Conceptual model of Little Reedy Lagoon under natural (no carp) conditions when (a) recently inundated, (b) receding, deeply inundated and (c) receding, shallowly inundated

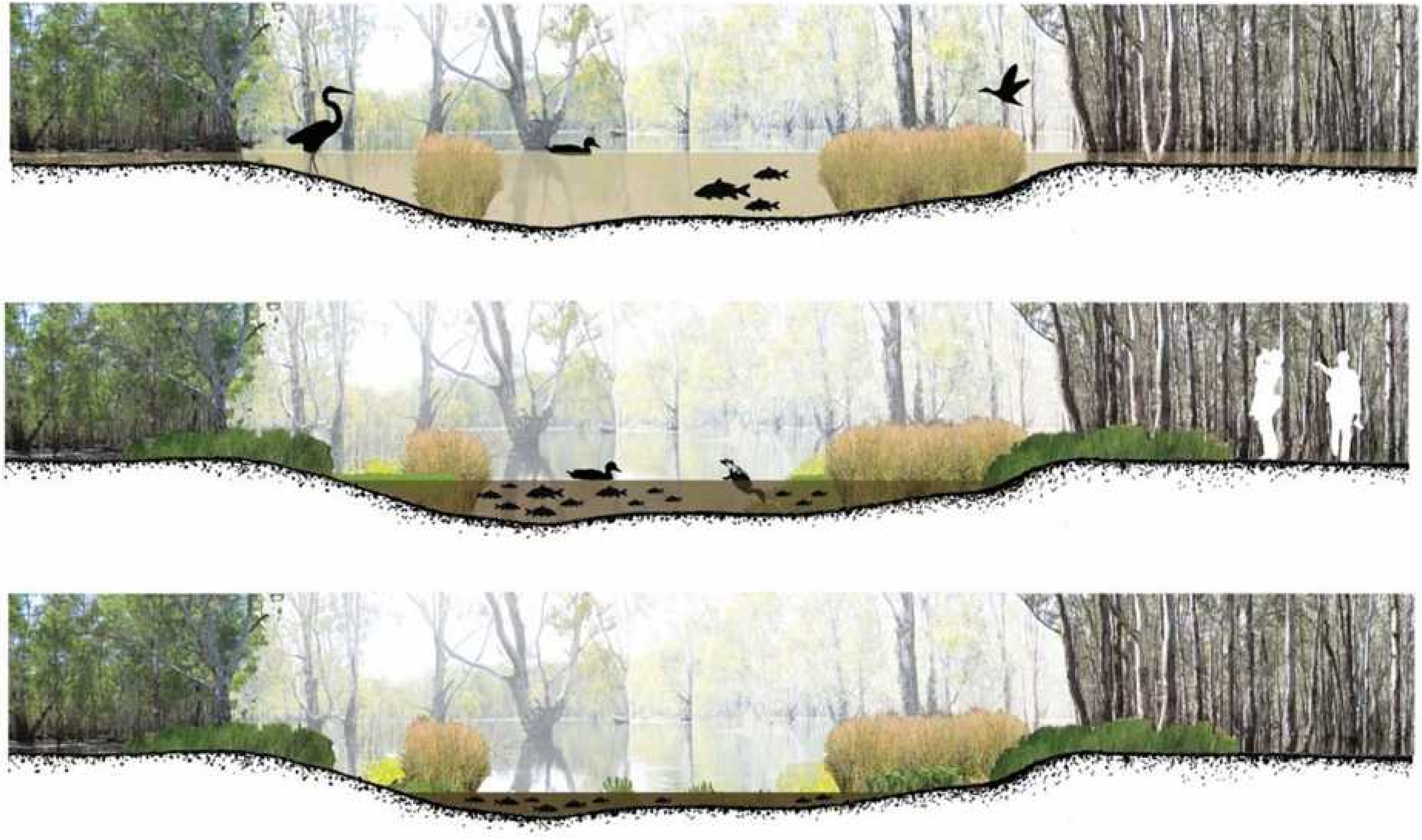


Figure 4 Conceptualised model of Little Reedy Lagoon under current (carp present) conditions when (a) recently inundated, (b) receding, deeply inundated and (c) receding, shallowly inundated

2.2 Experimental Design

In 2014, 24 3x3 m pilot study plots were established in deep and shallow sections of Reedy and Little Reedy Lagoons (Figure 1). Within each wetland, plot treatments were side fenced (SF), partially fenced (PF, allowing access to the plot) and controls (UF, unfenced) (Figure 4). There was a total of eight of each plot treatments (four at each wetland). Each plot was marked with a coded star picket in the north-west corner of the quadrat. The side fence plots were fenced to a height of 2 m, with a 0.2 m lip of wire pinned to the ground on the outside of the plot to prevent access by burrowing under. The partially fenced plots were enclosed on three sides to a height of 1 m, with the opening facing the middle of the wetland. Fences were constructed out of wire netting with 40 mm gaps.

In 2015, eight bird exclusion plots were added to the above design, four in each wetland. Each of these 3x3 m plots were established by securing the wire netting (as above) to a floating plastic and metal frame, held in place by star pickets (Figure 6). The plot treatment is referred here forth as floating fence (FF).

Figure 5 Carp exclusion plots, sides fenced (left), partially fenced (middle), and unfenced (right), Gunbower Forest, February 2015.

Figure 6 Floating fence, bird exclusion plot, Gunbower Forest, November 2016.

Table 2 Gunbower Forest wetland exclusion plots, sample season and recorded water depth category (refer to Table 3).

Wetland	Site & side	Plot	Treatment	2014 May	2015 Feb	2015 April	2015 Nov	2016 Feb
Little Reedy Lagoon	LR1A	C1	Partially fenced	D	SI	SI	DI	SI
		C2	Not fenced	D	SI	SI	DI	SI
		C3	Sides fenced	D	SI	SI	DI	SI
		C4	Floating fence	-	-	-	DI	*
	LR1B	C1	Partially fenced	D	SI	SI	DI	SI
		C2	Sides fenced	D	SI	Dn	DI	SI
		C3	Not fenced	D	SI	Dn	DI	SI
		C4	Floating fence	-	-	-	DI	SI
	LR2A	C1	Not fenced	D	SI	D	DI	SI
		C2	Partially fenced	D	SI	D	DI	SI
		C3	Sides fenced	D	SI	D	DI	SI
		C4	Floating fence	-	-	-	DI	SI
	LR2B	C1	Partially fenced	D	Dn	D	MI	SI
		C2	Sides fenced	D	SI	D	MI	SI
		C3	Not fenced	D	Di	D	MI	SI
		C4	Floating fence	-	-	-	DI	SI
Reedy Lagoon	RL1A	C1	Not fenced	D	MI	MI	DI	MI
		C2	Sides fenced	D	MI	MI	DI	MI
		C3	Partially fenced	D	MI	MI	DI	DI
		C4	Floating fence	-	-	-	DI	DI
	RL1B	C1	Partially fenced	D	MI	MI	DI	DI
		C2	Not fenced	D	MI	MI	DI	DI
		C3	Sides fenced	D	MI	MI	DI	DI
		C4	Floating fence	-	-	-	DI	*
	RL3A	C1	Partially fenced	D	SI	D	DI	SI
		C2	Not fenced	D	SI	D	DI	SI
		C3	Sides fenced	D	SI	D	MI	SI
		C4	Floating fence	-	-	-	MI	SI
	RL3B	C1	Partially fenced	D	SI	D	DI	SI
		C2	Sides fenced	D	SI	D	DI	SI
		C3	Not fenced	D	SI	D	DI	SI
		C4	Floating fence	-	-	-	DI	MI

*plots removed from sample due to design issues (they sank)

Table 3 Water depth categories for Gunbower Forest wetland exclusion study.

Water depth	Category code	Water depth category
0 cm	D	Dry
0 - <10cm	Dn	Drying
10 - <50cm	SI	Shallowly inundated
50- 100cm	MI	Moderately inundated
>100cm	DI	Deeply inundated

2.3 Data Collection

The projected foliage cover of flora species (vascular species and charophytes) was estimated within each of the 32 plot following inundation in spring (23 and 25 November 2015) and on draw down in summer (28 January and 1-2 February 2016), (Appendix 1). Photographs of the vegetation were taken and water depth and turbidity were measured in the north-west corner of each plot.

2.4 Data Analysis

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

Turbidity data were converted to categories (<10 NTU, 10-20 NTU, 21-30 NTU, 31-50 NTU and >50 NTU). During analysis, fewer categories were used due to insufficient replicates in some categories. Where data were combined, two categories "Low" (0-20 NTU) and "High" (>20 NTU) were used.

Species richness and cover of aquatic plants was compared between wetlands, sampling dates, water depths, turbidity categories and plot treatments (Table 2). Exploratory data analysis is presented in the forms of boxplots and bar graphs to provide a visual assessment of differences in the data.

2.4.1 Univariate analyses

Generalized Linear Mixed Effects Modelling

Generalized linear mixed effects model (GLMEM) was undertaken to test the percentage cover of characteristic PFG species in experimental plots in relation to sampling depth, turbidity and experimental plot type, with experimental plot 'Site' as a random variable. Analyses were run in the open-source statistical package R (version 3.2.2, R Core Team 2015), using the interface RStudio (version 0.99.484, RStudio 2015).

For each wetland in February 2016, GLMEMs with a negative binomial distribution were run on 'diversity,' using the `glmer.nb` function in the `lme4` package. The GLMM incorporates a non-linear 'link function' to link the 'predictor' variable/s (e.g. sampling depth) with the 'response' variable (e.g. percent cover of characteristic PFG species).

In most cases, a beta distribution would be used for the analysis of percentage cover data. However, in this case, the total percent cover of PFGs 1-3 could exceed 100% (due to overlapping cover of several species), and therefore did not have an upper limit. Instead, we treated it as abundance data and used a negative binomial distribution.

A GLMEM is a form of Linear Model, which can explain how much effect 'a' and/or 'b' (factors or predictor variables) have on 'y' (response variable), while allowing for both the non-independence of data from different treatments that is grouped by site, and for non-normal error structures. A simple GLMEM can also be expressed by the following linear equation:

y = a + b + a x b + c(random)

where *'a x b'* refers to the interaction between factor *a* and factor *b*. This means that the measure of one factor (e.g. reference site) depends on the level of the other factor (e.g. sampling year). *a* and *b* are 'fixed' factors and *c* is a 'random' factor.

In our case, this equation would be:
Percent cover of characteristic PFG species = Depth + Turbidity level + Experimental treatment + Treatment site (random)

Where:

- Depth = average depth of wetland at time of sampling
- Turbidity level = turbidity category ((<10 NTU, 10-20 NTU, 21-30 NTU, 31-50 NTU and >50 NTU)
- Experimental treatment = type of plot:

  FF – floating fence (bird exclusion only)

  NF – no fence

  PF – partially fenced (three sides)

  SF – sides fenced (carp but not bird exclusion)
- Treatment site = 'block' of experimental treatments in the same spatial area.

As part of the analysis, data exploration and diagnostic assessments were run on the dataset in order to ensure that it conformed to the assumptions for GLMEM (Crawley 2007, Zuur et al. 2009).

Where relevant, a post-hoc Tukeys test was run on the model output in order to determine where significant differences lay between levels of a factor.

2.4.2 Limitations

The wetland exclusion study was designed to trial measures for excluding the large-bodied carp and waterbird species from areas of aquatic habitat, at both wetland and local scales. However, the following limitations apply to this dataset:

- The wire netting selected to exclude carp may have limited the activity of other species (e.g. large bodied native fish and/or water birds) in the monitoring plots and thereby influenced the results.

- The floating fence design was unstable, which caused seven of the eight floating fences to sink on more than one occasion. Deep water and design flaws hindered the resurrection two of these plots, which have been excluded from the analysis.
- Differences in the height of side fences in the 'sides fenced' and 'partially fenced' plots (2m and 1m respectively) may have had different influences on waterbird access, carp access and water movement.
- The cryptic nature and seasonal growth cycles of certain species may have hindered the detection of these taxa at the monitoring sites. In particular, submerged species were at times concealed, and possibly inhibited by a thick cover of floating species. Therefore, when interpreting the results, it should be noted that the data are skewed towards reporting a lower than actual level of richness.
- Turbidity data was expressed in categories due to the limitations of the sampling equipment used.
- Data for spring 2015 were not analysed using statistical models, since there was only one data point in one of the three turbidity categories (insufficient replication) for Little Reedy Lagoon. In addition, turbidity values were low across all plots at both wetlands, suggesting there was unlikely to be a turbidity effect on the submerged vegetation.
- The number and species of waterbirds were not recorded, and hence it is difficult to explicitly link the flora results to bird presence/absence.
- The fish surveys were generally performed in the wetland area, but not in the exclosures, and the timing of the fish surveys was different to that of the flora surveys. This means that it is not possible to explicitly link flora results to carp results for the purposes of statistical analysis.
- The presence of carp in Reedy Lagoon in 2015 after exclusion fences were erected at the wetland inlet/outlet, limits the usefulness of analysing the effect of wetland scale exclusion.

3 RESULTS

The following section presents the results for the exclusion study in Reedy and Little Reedy Lagoons. It focuses on the response of aquatic PFGs, given that they are likely to be the most susceptible to carp and waterbird impacts.

The aquatic PFGs are:

- Submerged & Free-floating Flora (PFG 1) - Adult plants do not survive prolonged exposure of the wetland substrate (drying) and lack perpetuating rootstocks. Seed or spores may persist in soil during dry times.
- Floating Amphibious Flora (PFG 2) - Amphibious species that produce floating foliage when inundated. Aerial parts of plants survive exposure of the wetland substrate (drying) for sustained periods of time. Plants survive drying by dying back to rootstocks.
- Adaptive Amphibious Flora (PFG 3) - Amphibious species that alter their growth pattern or morphology in response to water conditions. These species can actively grow when substrate is exposed but still moist, but may die back to rootstocks or seed during sustained dry periods.

For the purposes of this study, all turbidity records over >50 NTU are considered very high in relation to light availability for plant growth.

3.1 General Condition

All plots in the wetland exclusion study were inundated in spring 2015 (Table 2).There was, however, an 18 day delay in the time that water commenced flowing into Reedy Lagoon (9 October 2016) compared with Little Reedy Lagoon (estimated at 22 September 2016, K. Woods North Central CMA April. 2016 pers. comm.).

Water depth and turbidity differed between the wetlands and seasonally (Figures 7-8). Reedy Lagoon was on average deeper and less turbid than Little Reedy Lagoon. Turbidity was recorded at low levels (<20 NTU) in all plots in spring (November 2015) and was higher in summer (February 2016). This was particularly true in Little Reedy Lagoon, where turbidity was consistently >20 NTU in summer and, in a control plot, 200 NTU. Turbidity reached a maximum of 60 NTU in Reedy Lagoon in summer, however, this was largely due to dense algae growth rather than suspended sediment particles.

Figure 7 Control plots November 2015 (left) and February 2016 (right), Reedy Lagoon (top) and Little Reedy Lagoon (bottom).

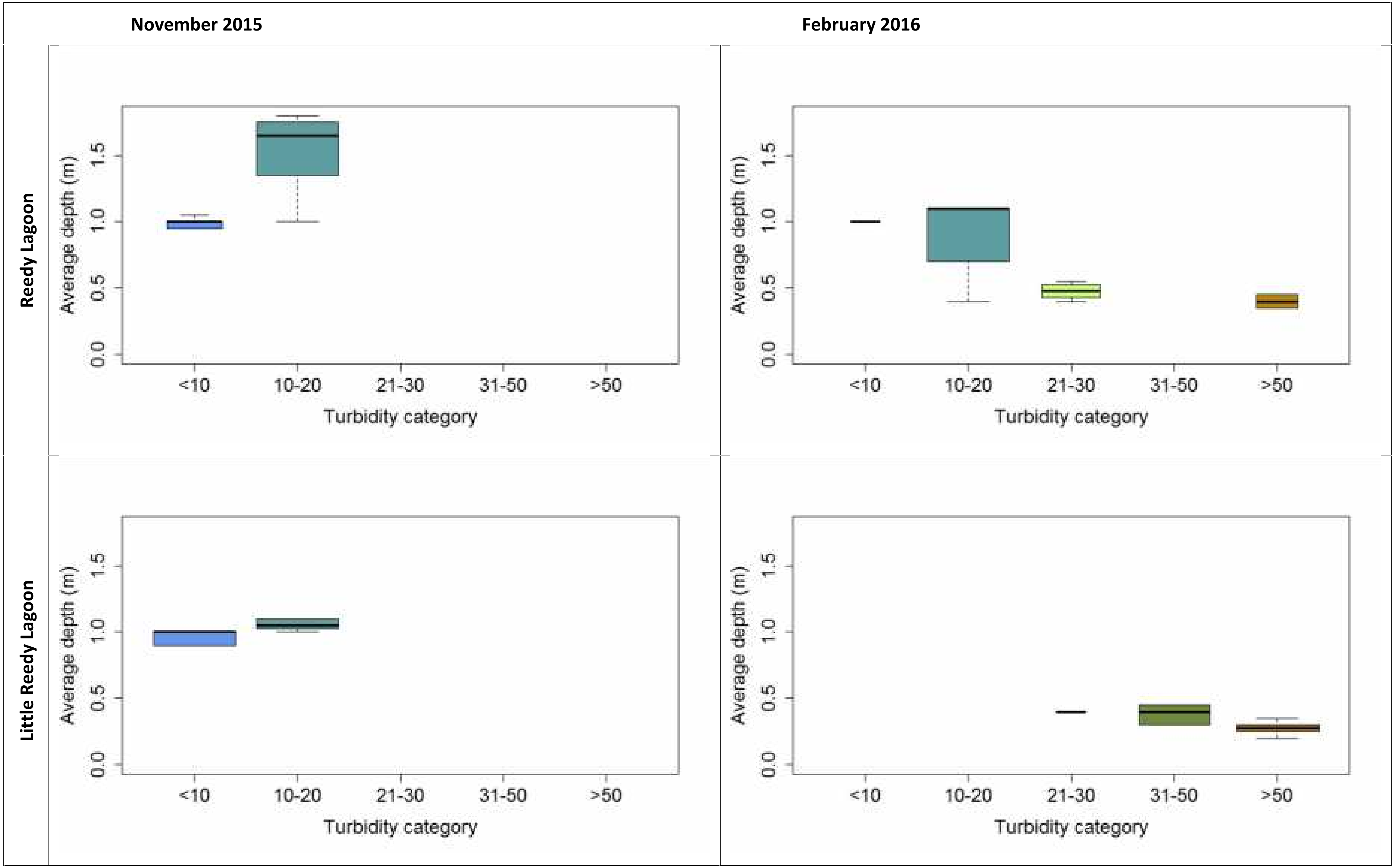


Figure 8 Boxplots of water depth by turbidity category (NTU) Reedy Lagoon (top) and Little Reedy Lagoon (bottom) in November 2015 and February 2016.

Figure 9 Floating and submerged flora (PFG 1) and dense algal growth in control plot, February 2016, Reedy Lagoon (shallow end).

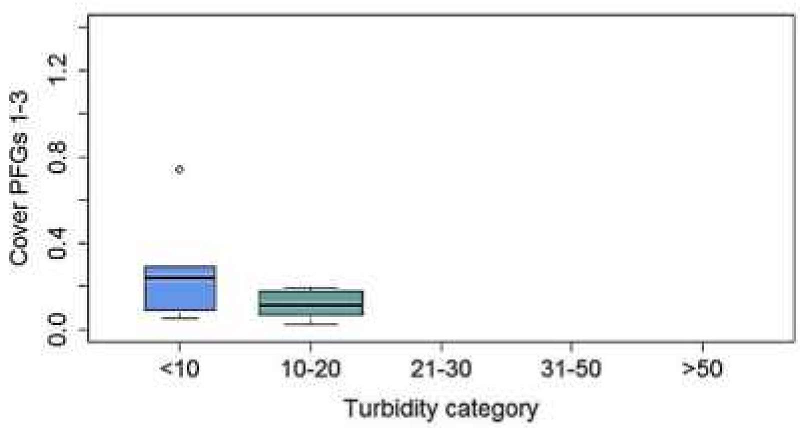
A total of 25 aquatic plant species (all native) were recorded in the plots (Appendix 1), 17 of these in Reedy Lagoon and 21 in Little Reedy Lagoon. Three species of conservation significance were observed. The nationally vulnerable River Swamp Wallaby-grass (*Amphibromus fluitans*) was the most common, being recorded in both wetlands and all treatment types. The state listed Wavy Marshwort (*Nymphoides crenata*) was recorded in Reedy Lagoon and the rare Winged Water-starwort (*Callitriche umbonata*) was recorded in Little Reedy Lagoon, both in spring.

Figure 10 Nationally endangered Riverine Swamp Wallaby-grass (*Amphibromus fluitans*), amidst Azolla spp. in side fence plot February 2016, Reedy Lagoon.

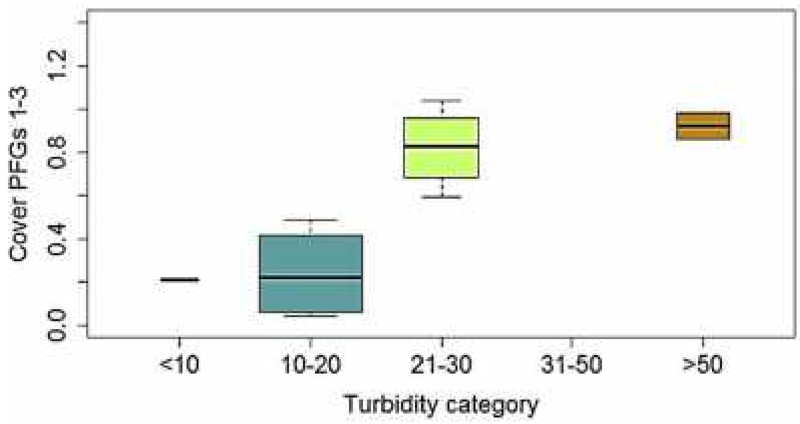
3.2 REEDY LAGOON

3.2.1 Flora Cover and Richness

The percentage cover of aquatic plant species (PFGs 1-3) in Reedy Lagoon was relatively low in spring and high in summer, despite higher summer turbidity levels (Figures 11-13). It should however be noted that there was limited time (i.e. 3 days) for the plants to respond to inundation (9 October – 20 November 2015) before the flora survey (23 November 2015).



Spring



Summer

Figure 11 Boxplots of percent cover of aquatic species (PFGs 1-3) by turbidity category (NTU) in November 2015 (top) and February 2016 (bottom), Reedy Lagoon.

The patterns in the cover and richness of aquatic species were consistent within each season, but differed between seasons (Figures 12-14). Both mean cover and richness were highest in the side fence plots in spring, followed by partial fence, floating fence and then control plots (Figure 13). In summer, the floating fence treatment had the highest mean cover and richness, followed by side and partial fence treatments and then the control (Figure 14). The differences in water depths between treatments did not appear to be related to mean cover or richness values.

Figure 12 Side fence plot, November 2015 (top) and February 2016 (bottom), Reedy Lagoon (shallow end).

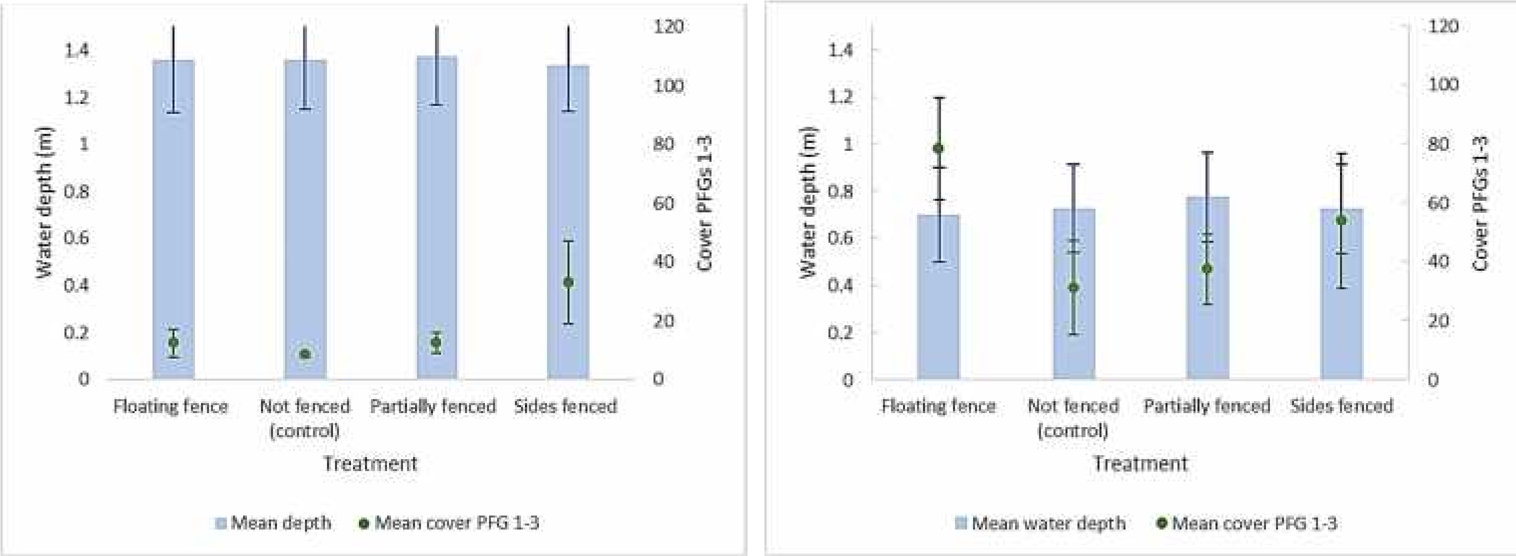


Figure 13 Mean water depth and mean (±SE) cover of aquatic plant species (PFGs 1-3) in November 2015 (left) and February 2016 (right), Reedy Lagoon. Right (summer) plot illustrates cover data tested in the GLMEM below (Table 4)

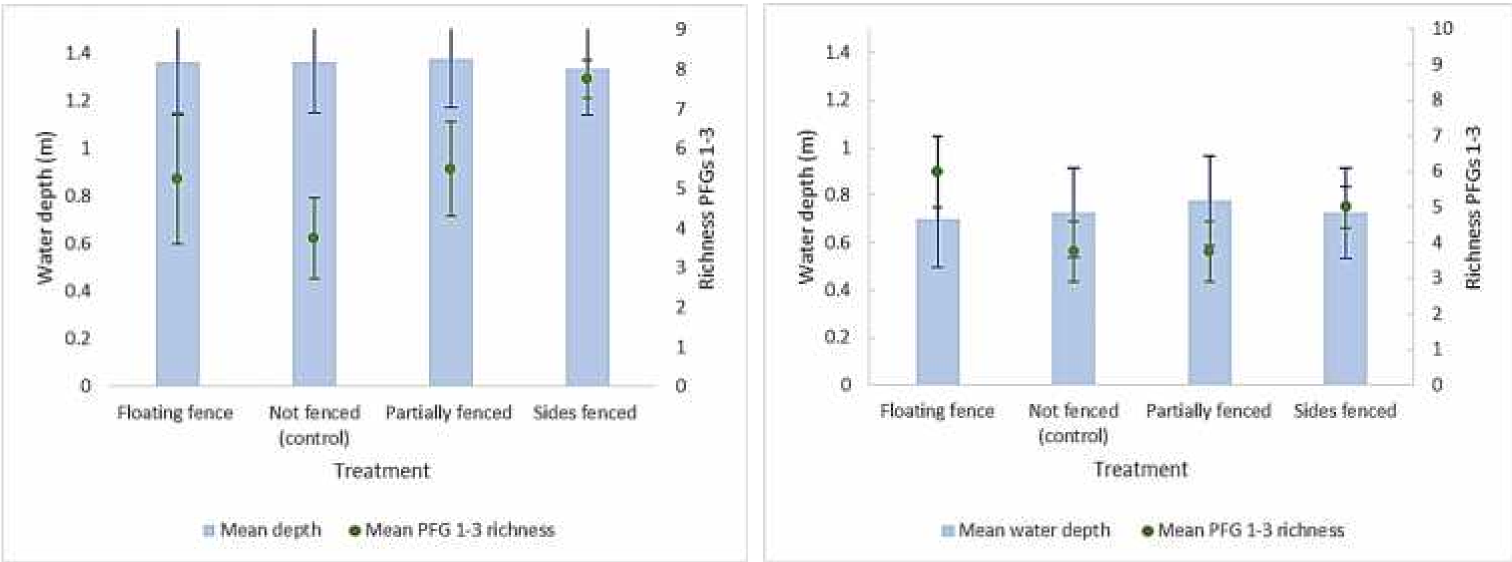


Figure 14 Mean water depth and mean (±SE) richness of aquatic plant species (PFGs 1-3) in November 2015 (left) and February 2016 (right), Reedy Lagoon.

Of the three PFGs analysed, the submerged and free-floating species (PFGs 1) exhibited the greatest richness and cover across both seasons. PFG 1 species do not survive drying, but can persist as seed or spores. Floating PFG 1 species observed include *Azolla* spp., Thin Duckweed (*Landoltia punctata*), Common Duckweed (*Lemna disperma*) and Fringed Heartwort (*Ricciocarpos natans*). Submerged PFG 1 species observed included Swamp Lily (*Ottelia ovalifolia subsp. ovalifolia*), Yellow Bladderwort (*Utricularia australis*) and Eel-grass (*Vallisneria americana var. americana*).

3.2.2 Relationship of plant cover with depth, turbidity and treatment

A GLMEM was used to test the relationship between percentage cover of aquatic species (PFGs 1-3) at Reedy Lagoon in summer, the variables of water depth, turbidity level and experimental treatment, and the interaction between depth and turbidity (Table 4). There was a significant relationship between the cover of aquatic plants (PFGs 1-3) and average wetland depth, treatment, turbidity level and the interaction between depth and turbidity level (Table 4). In other words, there was a significantly higher cover of aquatic plants in the shallowly inundated, more turbid (>20 NTU) plots than the deeper, less turbid plots (<20 NTU) in summer in Reedy Lagoon. This result may appear counterintuitive, but turbidities were not excessively high at Reedy Lagoon in summer (only two plots >30 NTU, and these did not exceed 60 NTU), and the turbidity in these plots appeared to be due to the presence of algae (phytoplankton), rather than suspended sediment particles (Figure 9).

Table 4 Output from a GLMEM (negative binomial distribution) on exclusion experiment data with equation *Percent cover = depth + turbidity level + treatment + depth * turbidity level + site(random),* February 2016, Reedy Lagoon (significant results in bold)

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
Floating fence treatment (Intercept)	5.4357	0.8180	6.645	**3.03e-11 *** **
Control treatment	-1.2254	0.2267	-5.406	**6.43e-08 *** **
Partial fence treatment	-0.6430	0.1505	-4.273	**1.93e-05 *** **
Side fence treatment	-0.7301	0.1756	-4.157	**3.22e-05 *** **
Depth	-1.8358	0.9063	-2.026	**0.042809 * **
Turbidity	2.4073	0.6359	3.785	**0.000153 *** **
Depth x Turbidity	-5.0978	1.6089	-3.168	**0.001533 ** **

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

A post hoc Tukeys test revealed significant differences in the percentage cover of aquatic species at Reedy Lagoon in summer between all treatments except the partial fence and side fence treatments (Figure 15 and Table 5). Therefore, the mean cover of aquatic plants in summer was significantly higher in *all* fenced plots compared to the control, and higher in the floating fence plot compared with the side and partial fenced plots. (Note that Figure 15 shows the spread of the raw data, rather than mean values).

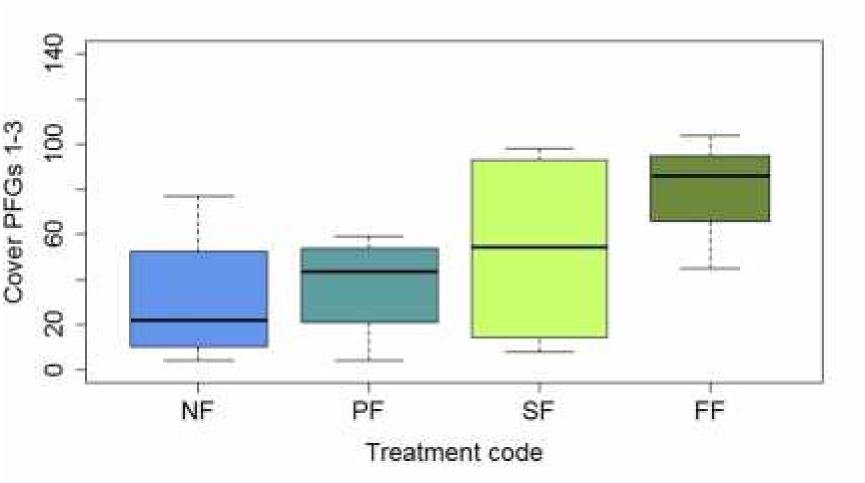


Figure 15 Boxplot of percentage cover of aquatic species (PFGs 1-3) by treatment (NF – no fence control, PF – partial fence, SF – sides fenced, FF – floating fence) February 2016, Reedy Lagoon.

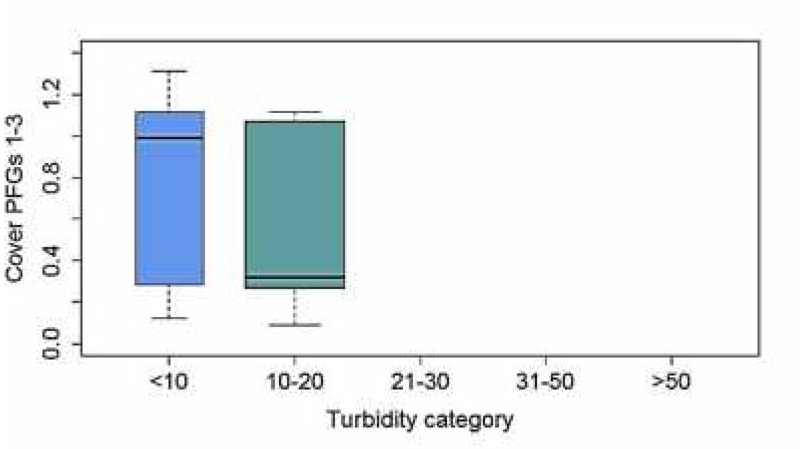
Table 5 Post hoc Tukeys test of 'Treatment' for Reedy Lagoon. Confidence level used: 0.95 (significant results in bold)

Contrast	Estimate	SE	df	z.ratio	P value
Floating fence - Control	1.225447	0.226667	NA	5.406368	**<.0001**
Floating fence - Partial fence	0.64295	0.150475	NA	4.272816	**0.0001**
Floating fence - Side fence	0.730059	0.175601	NA	4.15748	**0.0002**
Control - Partial fence	-0.5825	0.159803	NA	-3.64509	**0.0015**
Control - Side fence	-0.49539	0.131914	NA	-3.75538	**0.001**
Partial fence - Side fence	0.087108	0.135935	NA	0.640808	0.9188

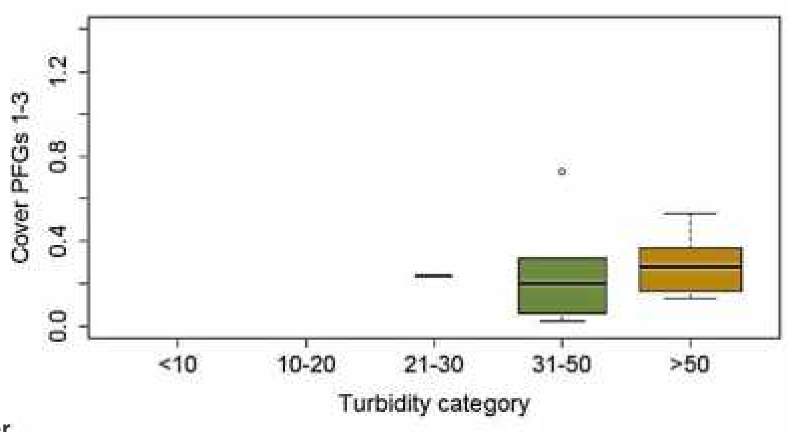
3.3 LITTLE REEDY LAGOON

3.3.1 Flora Cover and Richness

In Little Reedy Lagoon, the percentage cover of aquatic species (PFGs 1-3) was higher in spring than summer, when turbidity were lower (Figures 16-17). The highest cover of aquatic species was recorded in plots with turbidity <10 NTU and at the shallow end of the wetland (Figure 17, in three different treatments LR2A, data not shown).



Spring



Summer

Figure 16 Boxplots of percentage cover of aquatic species (PFGs 1-3) by turbidity category (NTU) in November 2015 (top) and February 2016 (bottom), Little Reedy Lagoon.

When mean (± SE) percentage cover and species richness are plotted with water depth (Figures 18-19), it can be seen that both cover and richness were higher in spring (at high water levels and low turbidity, Figure 8) than summer across all treatments. The cover of aquatic flora in the unfenced treatment (control) was very low in both seasons (Figure 17).

While floating species (PFG 1) were often recorded with high cover scores in the Little Reedy Lagoon plots (in both seasons), adaptive amphibious flora (PFG 3) were the more species rich, especially in spring. PFG 3 species alter their growth pattern or morphology in response to water conditions and can actively grow when substrates are exposed but still moist, but may die back to rootstocks or seed during sustained dry periods.

Examples include the Water-starwort (*Callitriche* spp), Waterwort (*Elatine gratioloides*), Water-milfoils (*Myriophyllum* spp.), and Pondweeds (*Potamogeton* spp.). (See Figure 22.)

Figure 17 Control plot November 2015 (top) and February 2016 (bottom), Little Reedy Lagoon.

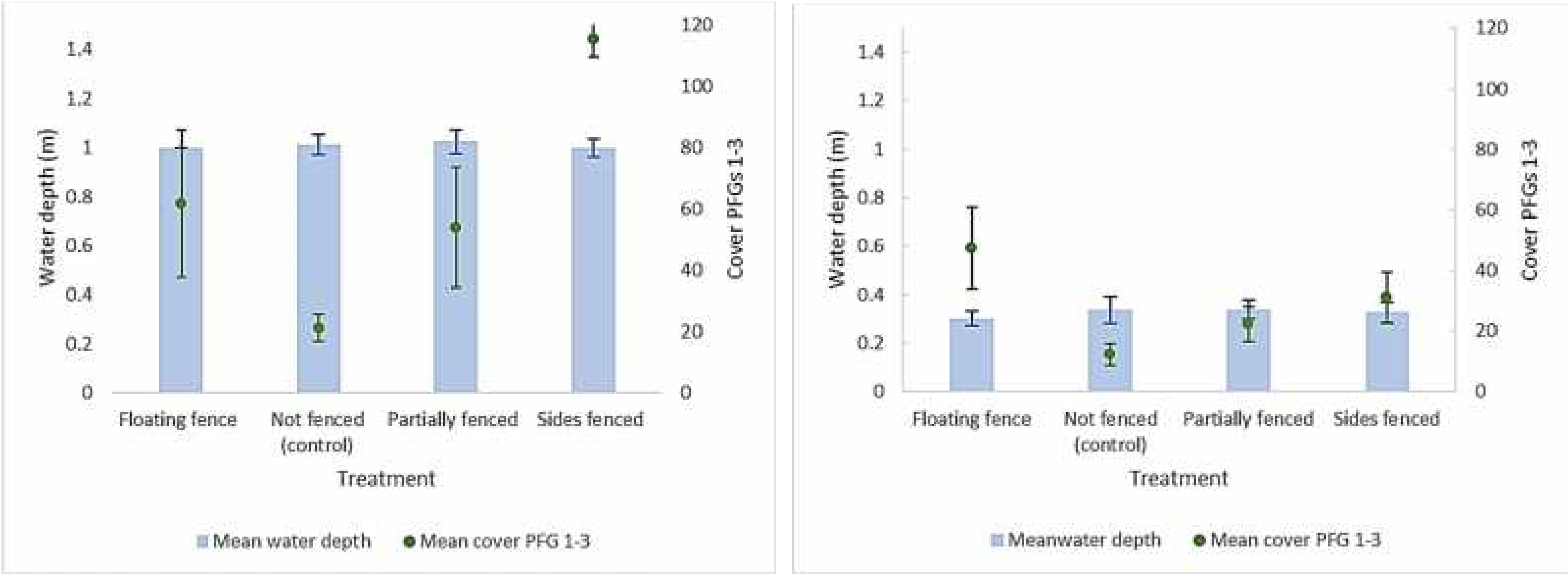


Figure 18 Mean water depth and mean (±SE) cover of aquatic plant species (PFGs 1-3) in November 2015 (left) and February 2016 (right), Little Reedy Lagoon. Right (summer) plot illustrates cover data tested in the GLMEM below (Table 6**)**

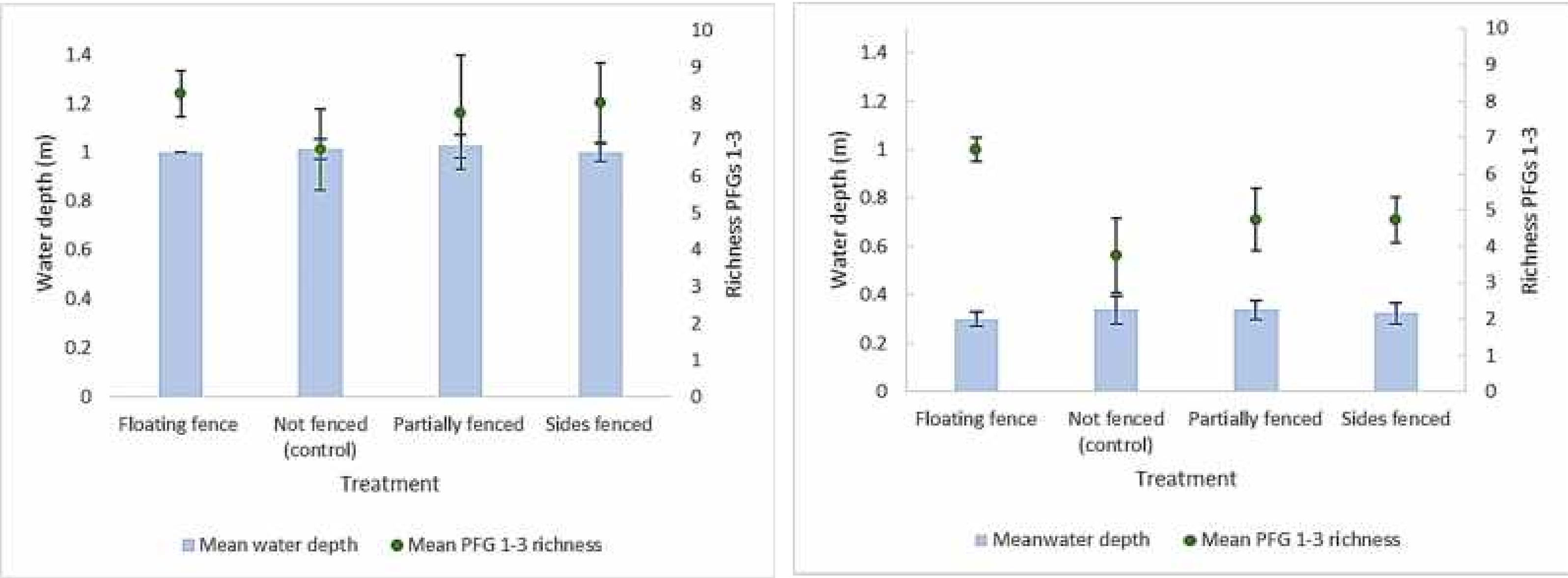


Figure 19 Mean water depth and mean (±SE) richness of aquatic plant species (PFGs 1-3) in November 2015 (left) and February 2016 (right), Little Reedy Lagoon.

The pattern in cover and richness of aquatic plants (PFGs 1-3) across the treatments was remarkably consistent in the two seasons. They were highest in floating fence plots followed by the side fenced, then partially fenced and lowest in the control (Figures 18-20). The exception was a very high mean cover in the side fence plots in spring, which was driven by high cover of Azolla. There was no obvious relationship between mean cover or richness values and water depths.

Figure 20 Control (top left), partial fence (top right), floating fence (bottom left) and side fence (bottom right) plots, February 2016, Little Reedy Lagoon.

3.3.2 Relationship of plant cover with depth, turbidity and treatment

A GLMEM was used to test the relationship between the percentage cover of aquatic species (PFGs 1-3) at Little Reedy Lagoon in summer with the variables of water depth, turbidity level and experimental treatment, and site as a random variable (Table 6). The results of the full model indicated that the variables of depth and turbidity did not help to explain the differences in aquatic plant cover between the Little Reedy Lagoon plots in summer.

However, the results of a nested model (i.e. the model excluding depth and turbidity Table 6), indicate that there was a significant effect of treatment on percentage cover of aquatic flora (PFGs 1-3) (Table 6). Furthermore, a post hoc Tukeys test on the nested model identified a significant higher mean cover of aquatic flora in the floating fence treatment compared to the control treatment (Table 7, Figure 22). The treatments appeared to be increasing in effectiveness from the control, to partial fence, to side fence and to floating fence (Figure 21). Notwithstanding this, many of these differences were too small to be statistically significant.

Table 6 Output from a GLMEM (negative binomial distribution) on exclusion experiment data from Little Reedy Lagoon in February 2016 with equation *Percent cover ~ treatment + site(random).* (significant results in bold)

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
Floating fence treatment (Intercept)	3.8572	0.2806	13.748	**< 2e-16 *****
Control treatment	-1.3517	0.3910	-3.457	**0.000546 *****
Partially fenced treatment	-0.7549	0.3791	-1.991	**0.046443 ***
Sides fence treatment	-0.4232	0.3749	-1.129	0.258903

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 7 Post hoc Tukeys test of 'Treatment' for Little Reedy Lagoon. Confidence level used: 0.95

Contrast	Estimate	SE	df	z.ratio	P value
Control - Partial fence	-0.59682	0.373026	NA	-1.59994	0.3786
Control - Side fence	-0.92847	0.368751	NA	-2.51787	0.0572
Control - Floating fence	-1.35169	0.390988	NA	-3.45711	**0.0031**
Partial fence - Side fence	-0.33165	0.356098	NA	-0.93134	0.788
Partial fence - Floating fence	-0.75487	0.379078	NA	-1.99133	0.1912
Floating fence - Side fence	-0.42322	0.374872	NA	-1.12898	0.6716

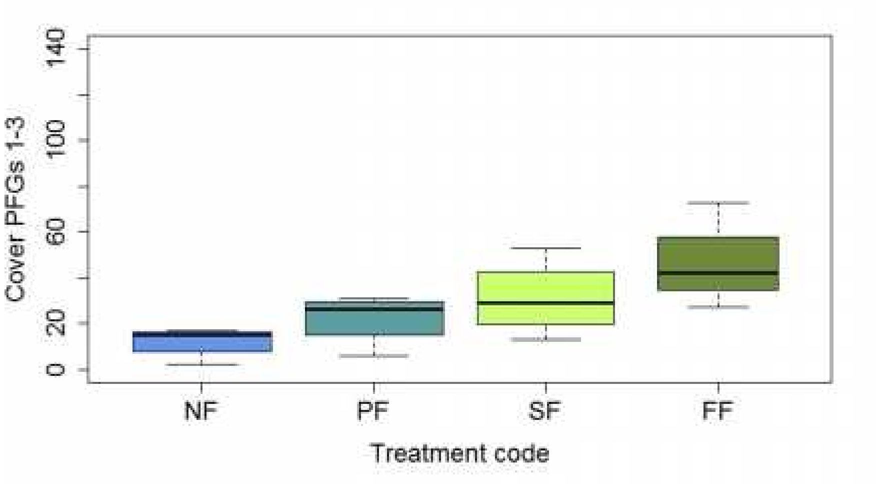


Figure 21 Boxplot of percentage cover of characteristic PFG species by treatment (NF – no fence control, PF – partial fence, SF – sides fenced, FF – floating fence) in February 2016, Little Reedy Lagoon.

Figure 22 Aquatic flora outside (left) and inside the floating fence (right), February 2016, Little Reedy Lagoon.

4 DISCUSSION

Aquatic flora cover and richness recorded at Reedy Lagoon and Little Reedy Lagoon in the 2015-2016 Gunbower Forest wetland exclusion study differed according to season and wetland, and water depth and turbidity, although rarely in a consistent manner. The results confirmed that there is no simple relationship between aquatic plant cover and the measured variables at the two Reedy Lagoons. However, the effect of fence treatment was much clearer than in the 2014-2015 pilot study.

Aquatic plants proliferated inside the horizontally and vertically fenced plots, indicating that the fences protected the plant community from grazing or other damage. The treatments at both wetlands generally showed a repeated pattern of low cover and richness values in the unfenced control treatment, followed by partial fence, side fence and highest values in floating fence. The exception to this pattern was Reedy Lagoon in spring (November) 2015, where the plant community may not have fully re-established after recent inundation and Azolla was common in fenced plots.

Which hypotheses were most clearly supported by evidence?

- **Hypothesis 1:** Turbidity generated by carp increases with higher numbers of carp.

  It was not possible to test this hypothesis without linked fish and turbidity data.

- **Hypothesis 2:** Waterbird exclusion will have a positive impact on submerged plant cover and richness, but this effect will be less than that of carp exclusion.

  Not validated: The floating fence treatment (designed to exclude waterbirds) had a stronger positive impact on aquatic plant cover and richness than that of the side fence treatment (designed to exclude carp). It is important to note that we don't actually have data on waterbird numbers or timing of visitations, so we cannot be sure that the success of the floating treatment is just due to the exclusion of waterbird grazing. Furthermore, this does not necessarily mean that waterbird grazing is a problem for aquatic plant communities in and of itself. The observed effects may be a result of the floating fences giving protection to young plants, allowing them to develop resilience to carp disturbance.

- **Hypothesis 3:** The combined effect of carp and waterbirds on submerged plant communities will be more severe than either carp or waterbirds alone.

  Probably validated: This appears to be true, since the lowest cover and richness was consistently recorded in the control treatment, which is open to carp and waterbird disturbance. Again, without detailed evidence of carp and waterbird activity in the plots, it is not possible to be definitive.

In addition to the above, there does appear to be some evidence for a negative relationship between sediment-based turbidity and aquatic plant cover at Little Reedy Lagoon. The mean cover of aquatic plants was lower at higher turbidity levels. Turbidity was also higher at lower water depths, which was possibly due to an increase in carp density as the wetland contracted. This relationship was not replicated at Reedy Lagoon in 2015-2016. Reedy Lagoon, however, filled much later, meaning that plants were not at the same stage of growth (as at Little Reedy Lagoon) at the time of the surveys. Moreover, dense algal growth (which did not appear to hinder aquatic plant growth) caused the elevated turbidity, rather than suspended soil particles.

Based on the current results, we are not able to confirm the predictions in Table 1, especially since high turbidity levels were not always linked to low cover of aquatic plants, and the floating fence treatment had a greater impact on flora cover and richness than predicted. Not having comparable carp data for both sites in both seasons has also impeded our understanding of the relationships between carp, turbidity and aquatic plant cover.

It is unclear what impact the wetland-scale carp exclusion has had on the above results. For example, despite the presence of carp in Reedy Lagoon in September and December 2015, it is possible that the exclusion fences reduced the numbers of mature benthic feeding (and therefore turbidity generating) fish below a critical density threshold.

Differences in inundation timing, duration and source point between the two wetlands may have also influenced the results. Reedy Lagoon was anecdotally more diverse in summer 2015, following a longer winter-spring flood, than in summer 2016, after a short, late-spring flood (D. Cook, wetland ecologist, pers. comm. 2016).

4.1 Further Research

Areas of shallowly inundated wetlands in the floodplain forest (Figure 23) appeared in very good condition in spring 2015 and summer 2016, with higher covers of characteristic PFG species and lower turbidity, than the monitored, adjacent sentinel wetlands. It would be useful to understand the conditions and processes that lead to this positive response in the forest. The following hypotheses have been proposed to assist us to better understand the dynamics of these systems and inform watering and other management strategies for the forest.

Figure 23 Aquatic herbland in a flood runner connected to Little Reedy Lagoon, November 2015 (photographer: D. Osler).

Possible Hypotheses

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

Suggested sampling for suggested hypotheses

It is recommended to survey sites prior to delivery of eFlow to record if dry, damp, wet, isolated and if live macrophytes present. Follow this with flora and water quality data sampling in winter/spring when the wetlands are expected to first fill. Repeat flora surveys at least 3 times (preferably more to capture seasonal differences) in the recently inundated, mid cycle, drying stages.

Table 8 Variables to measure

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

4.2 Recommendations

- Install motion sensor cameras to detect faunal activity in the exclusion plots and determine the number and species impacting on the flora (see Table 8).
- Undertake future wetland exclusion surveys (including turbidity readings) within the same week as the fish survey in order to allow a more accurate assessment of the relationship between carp and wetland flora condition.
- Establish the density of carp in the wetlands in order to allow a more accurate evaluation of their impact on the flora and the density threshold.
- Increase the sample size by expanding the study to wetlands where carp data is consistently collected (i.e. Black Swamp, Greens Swamp) in order to reduce the impact of site idiosyncrasies on the data. (refer to section 4.1). This will also allow more powerful statistical analyses.
- Monitor adjacent wetland areas (i.e. surrounding Little Reedy Lagoon) with healthy aquatic plant communities in order to better understand how these communities can succeed despite being open to carp and waterbird grazing. This may provide directions for future management strategies in the event that carp cannot be eradicated completely.

Implementing the above recommendations will make it easier for us to be definitive about the reasons the treatments (especially the floating fence treatment) have been so effective. The success of this experiment supports the argument that carp are having a detrimental effect on aquatic plant communities in the Gunbower Forest, and also that the combined effect of multiple stressors can have a greater impact than each stressor individually. We want to emphasise that whatever waterbird grazing that is occurring in these wetlands is a natural occurrence and would only have a lasting negative impact on plant communities in the presence of other stressors such as carp.

5 REFERENCES

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6 APPENDIX 1

Flora species recorded in Gunbower Forest exclusion plots, 2014-2016.

Taxonomy and status of plants recorded follows the Victorian Plant Name Index (DELWP 2015), with consideration to the Census of Victoria Vascular Plants (Walsh & Stajsic 2015).

Scientific Name	Common Name	PFG	Origin	Threatened Status			Little Reedy Lagoon					Reedy Lagoon				
				EPBC	FFG	Vic Adv	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016
Alternanthera denticulata	Lesser Joyweed	4a	native				x	x	x		x	x	x	x	x	
Amphibromus fluitans	River Swamp Wallaby-grass	3	native	Vulnerable	De-listed				x	x	x	x	x	x	x	x
Aster subulatus	Aster-weed	5	exotic									x				
Atriplex semibaccata	Berry Saltbush	7	native									x				
Azolla filiculoides	Pacific Azolla	1	native					x	x	x					x	
Azolla pinnata	Ferny Azolla	1	native					x	x	x	x		x	x	x	x
Bromus spp.	Brome	7	exotic									x				
Callitriche sonderi	Matted Water-starwort	3	native				x		x	x						
Callitriche spp.	Water-starwort	3	native				x		x					x		
Callitriche umbonata	Winged Water-starwort	3	native		De-listed	Rare				x						
Cardamine moirensis	Riverina Bitter-cress	5	native			Rare			x							
Centipeda cunninghamii	Common Sneezeweed	4b	native				x		x			x		x		
Centipeda minima subsp. minima s.s.	Spreading Sneezeweed	4b	native				x		x							
Chara spp.	Stonewort	1	native					x								
Cirsium vulgare	Spear Thistle	7	exotic				x		x			x				
Conyza spp.	Fleebane	6	exotic				x					x				
Cyperus eragrostis	Drain Flat-sedge	5	exotic						x			x				
Dysphania pumilio	Clammy Goosefoot	4b	native				x		x			x				
Elatine gratioloides	Waterwort	3	native						x	x						
Eleocharis acuta	Common Spike-sedge	4a	native						x							
Enchylaena	Ruby Saltbush	7	native									x				

Scientific Name	Common Name	PFG	Origin	Threatened Status			Little Reedy Lagoon					Reedy Lagoon				
				EPBC	FFG	Vic Adv	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016
tomentosa var. tomentosa																
Eucalyptus camaldulensis	River Red Gum	5	native		De-listed		x		x			x				
Glinus lotoides	Hairy Carpet-weed	4b	native				x		x			x				
Glinus oppositifolius	Slender Carpet-weed	4b	native				x									
Heliotropium supinum	Creeping Heliotrope	4b	exotic				x		x							
Helminthotheca echioides	Ox-tongue	7	exotic				x					x				
Juncus flavidus	Gold Rush	5	native									x				
Juncus ingens	Giant Rush	5	native									x	x			
Juncus spp.	Rush	6	native				x									
Lachnagrostis filiformis s.s.	Common Blown-grass	4b	native				x					x				
Lactuca saligna	Willow-leaf Lettuce	6	exotic				x									
Lactuca serriola	Prickly Lettuce	6	exotic				x		x			x				
Landoltia punctata	Thin Duckweed	1	native												x	x
Lemna disperma	Common Duckweed	1	native					x	x	x	x		x	x	x	x
Lolium spp.	Rye Grass	6	exotic				x					x				
Ludwigia peploides subsp. montevidensis	Clove-strip	2	native					x	x	x	x		x	x	x	x
Lythrum hyssopifolia	Small Loosestrife	6	native				x		x			x		x		
Marrubium vulgare	Horehound	7	exotic									x				
Marsilea costulifera	Narrow-leaf Nardoo	3	native						x							
Medicago spp.	Medic	7	exotic									x				
Myosurus australis	Mousetail	4b	native				x									
Myriophyllum caput-medusae	Coarse Water-milfoil	2	native								x			x		x
Myriophyllum crispatum	Upright Water-milfoil	3	native				x		x	x	x					x
Myriophyllum papillosum	Robust Water-milfoil	3	native					x	x	x	x		x	x	x	x
Myriophyllum	Amphibious Water-	3	native										x			

Scientific Name	Common Name	PFG	Origin	Threatened Status			Little Reedy Lagoon					Reedy Lagoon				
				EPBC	FFG	Vic Adv	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016
simulans	milfoil															
Myriophyllum verrucosum	Red Water-milfoil	3	native						x	x						
Najas tenuifolia	Water Nymph	1	native			Rare							x	x		
Nitella spp.	Stonewort	1	native					x	x							
Nymphoides crenata	Wavy Marshwort	2	native		Listed	Vulnerable									x	
Ottelia ovalifolia subsp. ovalifolia	Swamp Lily	1	native					x	x	x	x		x	x		
Persicaria decipiens	Slender Knotweed	4a	native						x	x						
Persicaria lapathifolia	Pale Knotweed	4b	native				x		x			x				
Persicaria prostrata	Creeping Knotweed	4a	native				x	x	x			x				
Polygonum aviculare	Prostrate Knotweed	7	exotic									x				
Polygonum plebeium	Small Knotweed	4b	native				x		x			x				
Potamogeton cheesemanii	Red Pondweed	3	native						x	x	x			x	x	x
Potamogeton ochreatus	Blunt Pondweed	3	native							x			x	x		
Potamogeton sulcatus	Furrowed Pondweed	3	native							x						
Pseudoraphis spinescens	Spiny Mud-grass	2	native							x					x	
Ranunculus sceleratus subsp. sceleratus	Celery Buttercup	5	exotic				x						x			
Rhagodia spinescens	Hedge Saltbush	7	native									x				
Riccia spp.	Crystalwort	1	native						x							
Ricciocarpos natans	Fringed Heartwort	1	native											x	x	x
Rorippa eustylis	Dwarf Bitter-cress	4b	native			Rare	x		x			x		x		
Rorippa laciniata	Jagged Bitter-cress	4a	native				x									
Rumex brownii	Slender Dock	6	native				x					x				
Senecio quadridentatus	Cotton Fireweed	6	native				x		x			x				
Sonchus oleraceus	Common Sow-thistle	6	exotic				x		x			x				
Stellaria caespitosa	Matted Starwort	4b	native						x	x		x	x	x	x	x

Scientific Name	Common Name	PFG	Origin	Threatened Status			Little Reedy Lagoon					Reedy Lagoon				
				EPBC	FFG	Vic Adv	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016	May 2014 (dry)	Feb 2015	April 2015	Nov 2015	Feb 2016
Trifolium spp.	Clover	6	exotic				x									
Utricularia australis	Yellow Bladderwort	1	native												x	
Vallisneria americana var. americana	Eel Grass	1	native					x	x	x	x		x	x	x	x
Vittadinia cuneata var. cuneata	Fuzzy New Holland Daisy	7	native				x									

Plant Functional Groups applied in Gunbower Forest flora data analysis.

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