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Survey of soil seed bank of Murrumbidgee floodplain wetlands

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Published by: Land & Water Australia

Product Code: PN30288

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Survey of soil seed bank of Murrumbidgee floodplain wetlands

Prepared by

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Summary

Wetland resiliency depends on maintaining good wetland health. A healthy and diverse wetland seed bank is vital for maintaining wetland resiliency. Resiliency is promoted through good wetland management, such as controlling stock access to wetlands. However landholders are often reluctant to fence wetlands to control stock, because they perceive the fenced area as a source of weeds that will become uncontrollable and invade other parts of their property.

To establish if weeds in wetlands are a major problem, a survey of 11 wetland soil seed banks was conducted from summer 2003 to spring 2004. The survey was to examine if weeds may be a large management issue for landholders. The wetlands were located between Gundagai and Hay and were chosen on two attributes that influence wetland plant composition, frequency of inundation and permanency of water.

Results from this study show that wetlands may harbour weeds, but whether wetlands are a source or the sink for weed species is hard to determine. Class 4 Noxious weeds did not appear to have a preference for winter or summer, except Horehound which was only found in winter and only in paddock samples.

Results suggest that saturating paddock soils will suppress weeds, but the viability of the seeds is not compromised because they readily germinated in winter when the soils were kept moist.

Some wetland plants may not germinate readily from seed as shown by the lack of any plants germinating of Lignum and *Eleocharis sphacelata* even though large numbers of parent plants were present at the time of sampling.

The lack of a distinctive wetland community compared to the surrounding paddock may be due to a high representation of common floodplain plants being present in both wetland and paddock samples. It may also indicate the decline in the wetland plant community due to the soil disturbance caused by stock. This latter may also be a factor in the lack of a distinctively different plant community in wetlands of different water permanency and flooding frequency.

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Introduction

Floodplain wetlands in the Murrumbidgee catchment experienced major changes in their hydrology from catchment management practices that support human needs. Resiliency of wetlands depends on maintaining good wetland condition, such as a viable and diverse soil seed bank. This resiliency is promoted through good wetland management, such as controlling stock access to wetlands. Many studies have shown that livestock are a major impact on wetland condition (Nicol et al, 2007; Jansen and Healey, 2003; Jansen and Robertson, 2001; Whitten and Bennet, 2000). Grazing of wetlands is not uncommon, Whitten and Bennett (2000) found over 90% of farmers in the Murrumbidgee catchment grazed their wetlands.

An impediment to fencing wetlands to control stock is the reluctance of farmers, because they perceive wetlands as a harbour for weeds without grazing (Whitten and Bennett, 2000). Whitten and Bennett (2000) survey found that 77% of farmers considered weeds as a problem, with 37% of farmers perceiving weeds as a major problem. The practice of controlling weeds with grazing is not without merit as Nicol *et al* (2007) found weed control was necessary when stock grazing was removed from wetland.

To determine if weeds might be a major problem, wetland soil seed banks were examined to determine what weeds were there and at what level. Wetland soil seed banks provide a valuable source of wetland vegetation information (Brock and Britton, 1995; Brock *et al,* 1993). Using the methods of Brock *et al* (1993), the weed potential of wetlands impacted by river regulation was examined. Eleven wetlands were chosen in the mid-Murrumbidgee floodplain wetlands between Gundagai and Hay. These wetlands had different commence-to-fill levels and water permanency. Examination of the impact of different grazing management was considered, but not enough ungrazed wetlands could be found to make a valid comparison with grazed wetlands.

The following questions were explored:

- Do wetlands have a distinctly different plant community to the adjacent paddock?
- Do wetlands with different water permanency, as indicated by profile, have distinctly different plant communities?
- Do wetlands with different frequently of filling have distinctly different plant communities?
- Is the density of weeds at a level to cause concern?
- Were weed species and densities different between adjoining paddocks and wetlands?
- Were paddocks a source of weeds in wetlands? Or visa versa?

Methods

The study area

The study area was the Murrumbidgee River floodplain between Gundagai and Hay in southern New South Wales. The Murrumbidgee River is the 3rd largest river in the Murray-Darling Basin and one of the most reliable sources of water in the Murray Darling Basin. However, it is highly regulated with two major reservoirs in its upper catchment and numerous dams and weirs elsewhere to support extensive irrigation areas and major population centres in the catchment. Regulation has seen changes in the natural flow patterns of the river which have impacted floodplain wetlands.

Floodplain wetlands were chosen between Gundagai and Hay because they have probably been impacted the most by river regulation which impacts their resiliency. In addition, many wetlands are further impacted by agricultural practices such as stock grazing. The potential for weeds is probably high for these wetlands, but the need for controlled stock access important. Assessing the weed potential is therefore an important consideration for their better management.

The wetlands

Eleven target wetlands between Gundagai and Hay were chosen based on their commence-to-fill level (based on river flow volumes) and profile (Figure 1, Table 1). Wetland profile (shallow or deep) was used as a surrogate for water permanency and commence-to-fill was used as a surrogate for flooding frequency. Choosing wetlands based on different grazing management was considered, but this was abandoned because not enough non-grazed wetlands could be found to make a valid comparison.

Table 1 Summary data on 11 selected wetlands.

Profile: deep = >1 to 3 m deep; shallow = less than or equal to 1 m (Paterson *et al,* 2002)

Wetland Name	Wetland grazed	Tree regeneration	Commence-to-fill (ML/day), gauge location and rating - High, Medium, Low	Profile (shallow/deep)
Bulgari Lagoon	Yes	River Red Gum	58,000 Wagga Wagga High	deep
Bulls Run Swamp	Yes	River Red Gum	61,000 Wagga Wagga High	shallow
Coldene Lagoon	Yes	River Red Gum	29,000 Gundagai Low	deep
Currawanna Lagoon	Yes	River Red Gum	30,000 Wagga Wagga Low	deep
Dry Lake	Yes	River Red Gum	23,000 Narrandera Low	shallow
Ganmain Station	Yes	River Red Gum	31,000 Wagga Wagga Low	deep
Kurrajong	Yes	River Red Gum	43,000 Wagga Wagga Medium	deep
McKennas Lagoon	No - since 1996	River Red Gum & Black Box	13,000 Darlington Point Low	shallow
Molleys Lagoon	Yes	River Red Gum & Black Box	23,000 Narrandera Low	deep
Toogambie	Yes	Lignum	30,000 Hay Medium	shallow
Uri East	Yes	River Red Gum & Black Box	21,017 Darlington Point Medium	shallow

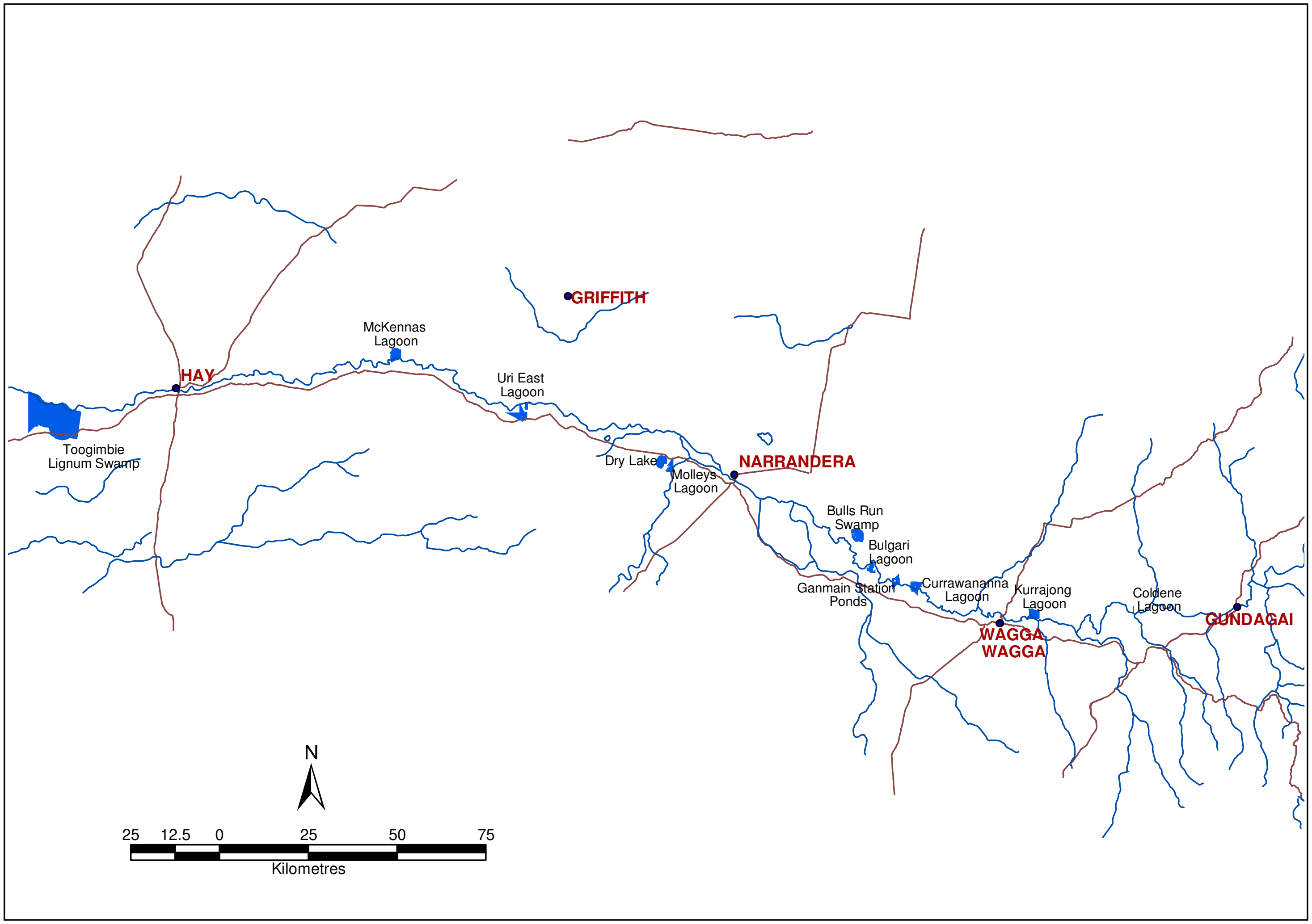


Figure 1 Location of eleven wetland seed bank sites.

The soil samples

At each wetland, soil was collected from four transects that ran from 20 m into the adjoining land and to the lowest point in the wetland. Each transect was at least 50 m apart (Figure 2).

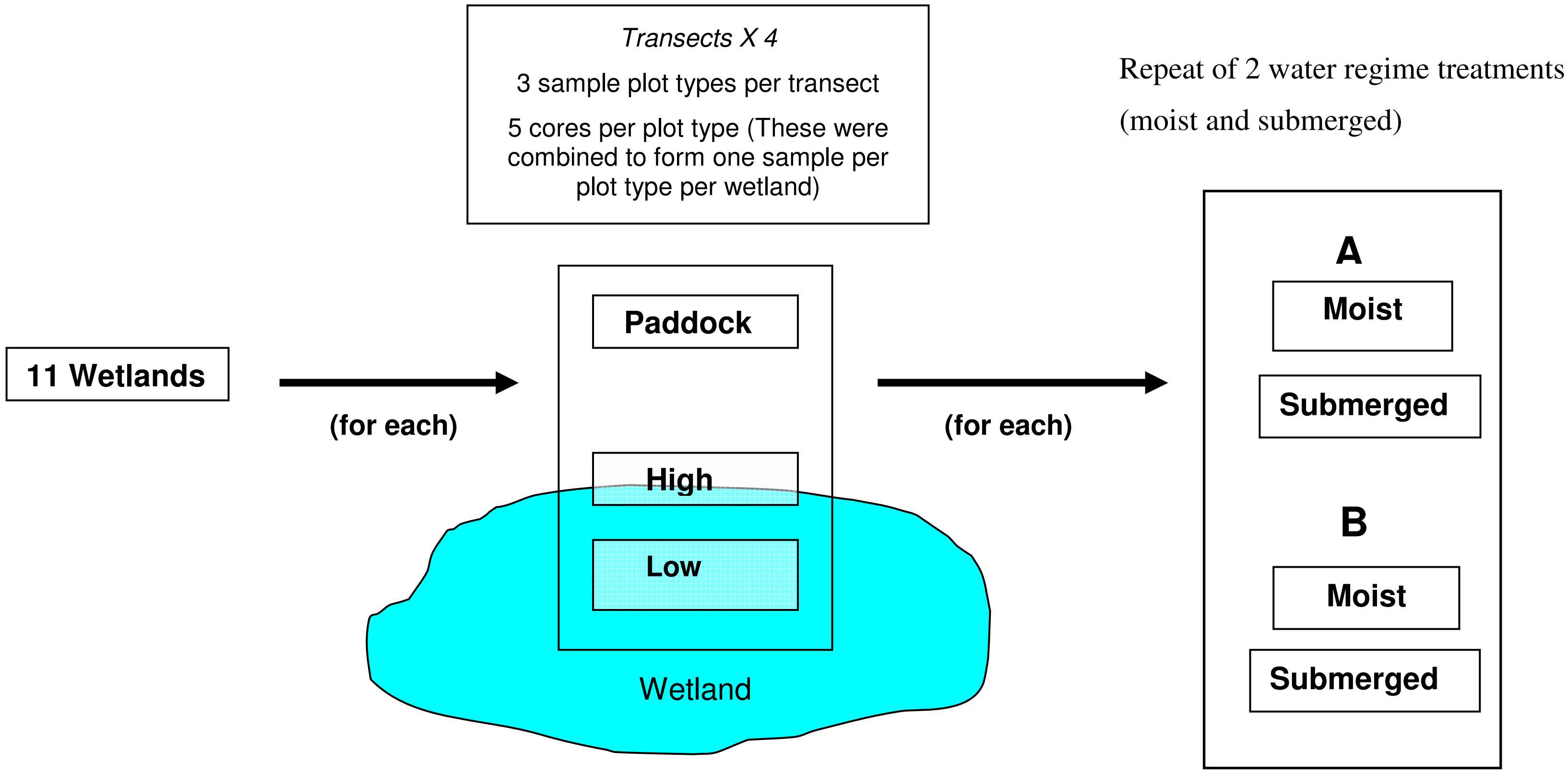
Within the transect three $4m^2$ (2 x 2m) plot were established (Figure 3):

- one in the adjoining land (labelled Paddock) located at least 20 m from the edge of the wetland
- one at the full level (labelled High) or littoral zone of wetlands; and
- one at the lowest (deepest) point of the wetland (labelled Low).

Within each plot type (Paddock, High, Low) five random core samples were taken. Each core sample measured 55 mm in diameter by 30 mm deep. They were taken using a sharpened PVC pipe. The core samples for each plot type (n = 20 core samples) were combined for each wetland, thus each wetland had one sample for plot type Paddock, Wetland High and Wetland Low.

The plot soil samples were allowed to air dry then stored in calico bags for four months. Each plot soil sample was then well mixed before performing routine soil tests for pH, EC and texture. After the soil test, the dry plot soil samples were divided into five equal portions by weight. One sample was kept as a reserve, while the other four samples were used in the experiment.

Figure 2 Collecting a "low" wetland soil sample at Mollys Lagoon – December 2003.



4 samples from each plot type were combined to form one sample for each plot type per wetland

(11 wetlands X 3 plot type samples per wetland X 2 treatments x 2 repeats + 4 controls = 132 pots

Figure 3 – Sampling and Experimental Design.

Soil Tests

Common soil parameters of pH, salinity and field texture were done on each soil sample to examine if these might influence the plant species present. Electrical conductivity (EC) was determined on a 1-5 solution using a Radiometer Mark 1 conductivity meter with a specific ion meter for EC.

Seedbank experiment

The wetland soil seed bank experiment was divided into two parts. The first stage propagation trial was outside and lasted six weeks, from early January-to late February 2004. Two treatments were applied to each soil sample, moist and submerged.

The second stage of the experiment ran for eight months from late February to late October 2004. The treated soil samples from stage one were used, but only one treatment, moist, was continued. The purpose of the second trial was to examine if more species, especially weed species, might germinate over winter.

First stage - Summer Experiment

For each plot type, two water treatments were applied. moist and submerged. Two soil samples were used for the moist treatment and two for the submerged (Figure 4). The submerged soils were kept totally submerged for the duration of the experiment. The moist treatment had soils with the bases of their containers sitting in 1-2cm of water.

The soil samples were placed in 2L ice-cream containers with holes drilled in the bottom. The containers were half-filled with a 50% washed and sterilized sand (<2mm) and 50% vermiculite mixture on which the wetland soil sample was placed. The sand was sterilised by autoclaving at 120°C for 2 hours to destroy any seeds present. Four moist and four submerged controls were filled with sand/vermiculite mixture only.

Each pair of water regimes (A or B) was placed in a Styrofoam cooler. Submerged treatments were placed on the bottom of the cooler, while the moist was raised above the bottom using an inverted ice-cream container. A newspaper wick was used to ensure the moist treatment never became dry. The boxes were filled so the water just covered the base of the moist container, while the submerged was covered by approximately 2cm of water (Figure 4, Figure 5).

The coolers were placed outside randomly on the ground and rotated weekly to minimise the effects of shading on plant germination and growth. Water level in the boxes was checked daily and topped to initial levels when necessary. All the water in the coolers was changed weekly to prevent algal built-up. Daily maximum and minimum water temperatures were recorded.

Figure 4 Styrofoam cooler showing moist and submerged treatment.

Figure 5 Experimental set up of Styrofoam coolers – January 2004.

Second stage - On-going

The ice cream containers were removed from the Styrofoam coolers and placed on a shade house bench. The wetland soils were initially watered daily to maintain a moist profile. As the temperatures cooled in winter the soils were checked daily and water as per needed to maintain a moist but not saturated soil moisture. When plants of some species became very numerous and appeared to be compromising the growth of other species, they were identified, removed and counted.

Counting and harvesting species

For both stages

Plant species were marked as they emerged using coloured matchsticks or coloured pins (Figure 6). Photos were also taken of each type specimen of a “species”. The species were given code names until they could be positively identified. At least two type specimen plants for each "species" were transplanted into pots for later identification when they had matured and flowered (Figure 7).

Figure 6 (Left) Example of marking an emergent seedling of a Common sneezeweed (*Centipeda cunninghamii*).

Figure 7 (Right) “Type specimens” of species and set up for winter experiment. Ice cream containers on bench.

Identifying plant species

Species were identified using a variety of literature, but mainly Flora of New South Wales (1990) and Plants of Western New South Wales (Cunningham *et al.*, 1992). Assistance was also obtained from the Gillis Horner, botanist Department of Infrastructure, Planning and Natural Resources (DIPNR), and Lorraine Hardwick, aquatic ecologist DIPNR. For those species that did not mature enough for positive identification their code name remained as the species name.

Data Analysis

An average species count was calculated for each treatment. Species data were explored for relationships amongst wetlands, treatments and plots. Non-metric Multidimensional scaling (MDS) was used from the PRIMER data analysis package. Bray-Curtis similarity matrix was used after the data were square root transformed as per standard methods. Analysis of similarities was also explored using ANOSIM. Other iterations of data analysis were done to reduce noise, including reducing the number of species by eliminating those species with 10 or fewer individuals were eliminated from the analysis.

The concentration of weeds was calculated using the formula of Brock (1997). The corer used for this experiment had a radius of 2.75 cm. The surface area of the corer was 23.75 cm^2 multiplied by the number of cores per treatment (n = 8, combining the two reps) gives 190 cm^2 per plot sample. To calculate the number of individuals per square metre: 10,000/190 cm^2 x (average number of seedlings per plot), where 10,000 is the number of cm^2 per m^2. Formula becomes 52.63 x (average number of seedlings per plot)

Results

Soils

The EC ranges from 11 to 625 µm/cm, with an average of 152 µm/cm, which is well below saline levels. The pH ranged from 5.25 to 6.69, the average being 6. The texture varied considerably among the wetlands from sandy loam to clay loam (Appendix 1).

Species

A total of 73 species germinated over the 10 months of the experiment, of which 15 (20%) were classified as agricultural weeds for this investigation (Appendix 2, Table 2A.1, 2A.2). Of the 15 agricultural weeds three, Paterson's Curse, Bathurst Burr and Horehound, were Class 4 weeds under the Noxious Weeds Act 1993. The growth and spread of these species must be controlled.

No plants germinated in the controls. Most species were able to be identified at least to the genus level, but many of the grass species failed to mature for positive identification.

Most (69% or 51 species) of the species that germinated were dicots, with one algal species (*Chara* sp) and 22 (30%) monocots species. Most, 68% (n = 15), of the monocots were grasses.

Fifty two species germinated over winter compared to 50 for summer. Twenty-one species were unique to summer compared to 20 for winter. Thirty-five species were common to both winter and summer, 11 of these were classified as agricultural weeds.

First Stage - Summer

Not all plot soil samples had species germinate in them. All moist treatments had species germinate in them, but not all submerged treatment had plants germinating in them (Table 2).

Table 2 Number of wetlands and treatment having species germinated in soil samples

Plot	**High**		**Low**		**Paddock**	
Treatment	**Moist**	**Submerged**	**Moist**	**Submerged**	**Moist**	**Submerged**
Number of wetlands	11	10	11	9	11	3

Data exploration of the whole summer data set using MDS ordination showed no distinctive clustering of sites according to treatment, plot type, commence-to-fill or profile. (Figure 8 to Figure 11). There is a suggestion of a transition of different commence-to-fill in the loose clustering of paddock and wetlands of different commence-to-fill levels from top left to bottom right. With paddocks to the upper left, then low commence-to-fill, followed by medium then high in the lower left (Figure 10).

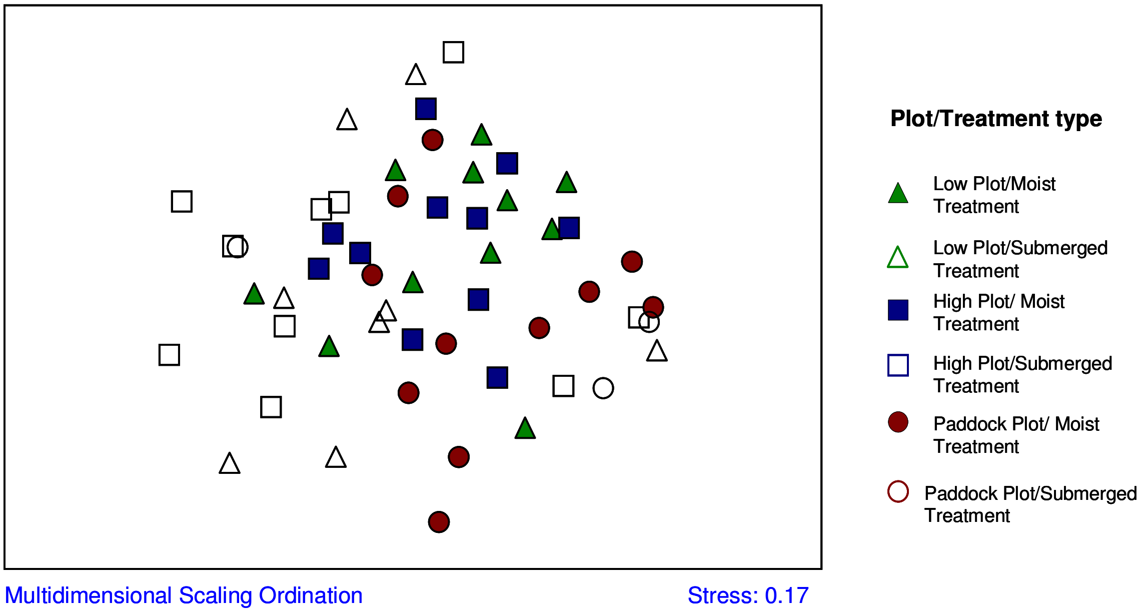


Figure 8: Examination of plot and treatment effect on plant community composition.

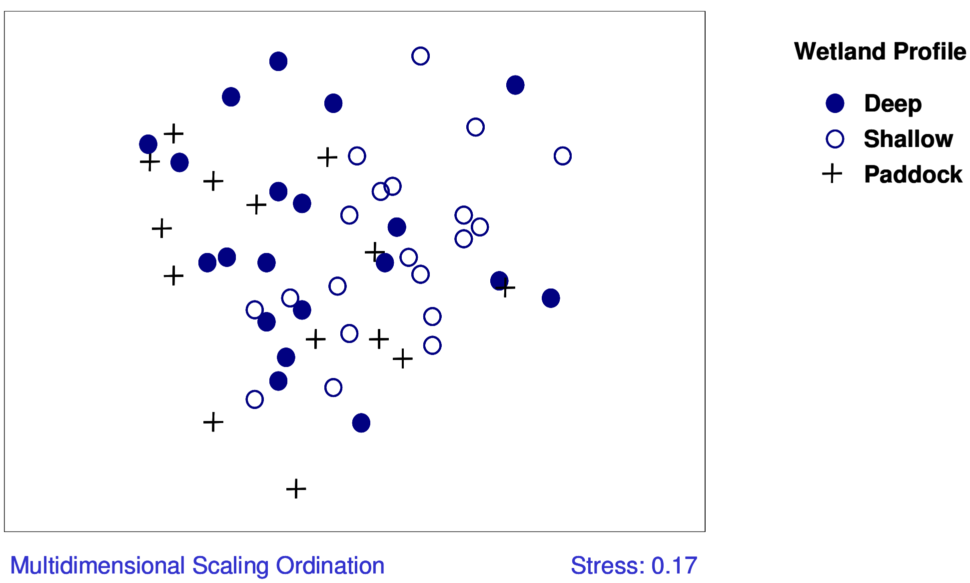


Figure 9: Examination of water permanency (profile as surrogate) on plant community composition.

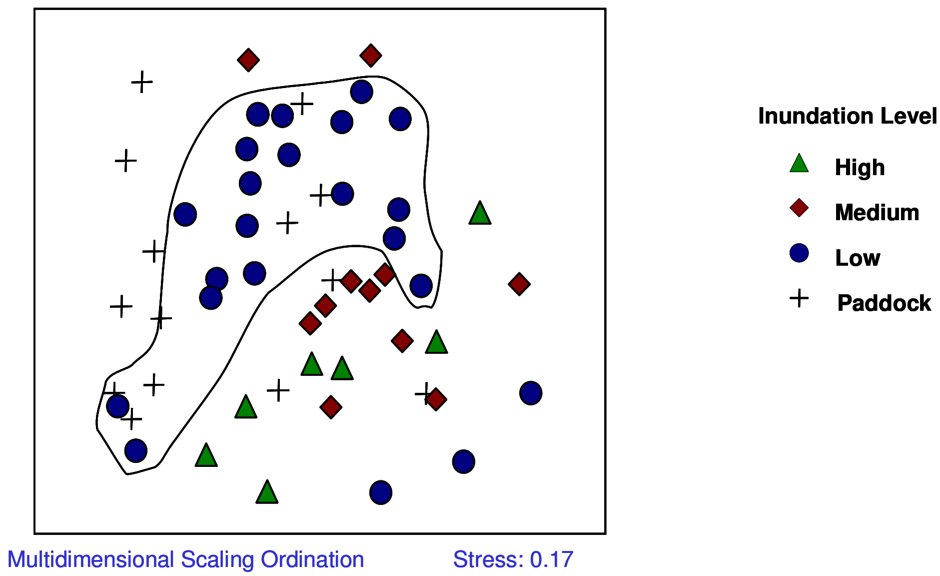


Figure 10: Examination inundation effect on plant community composition.

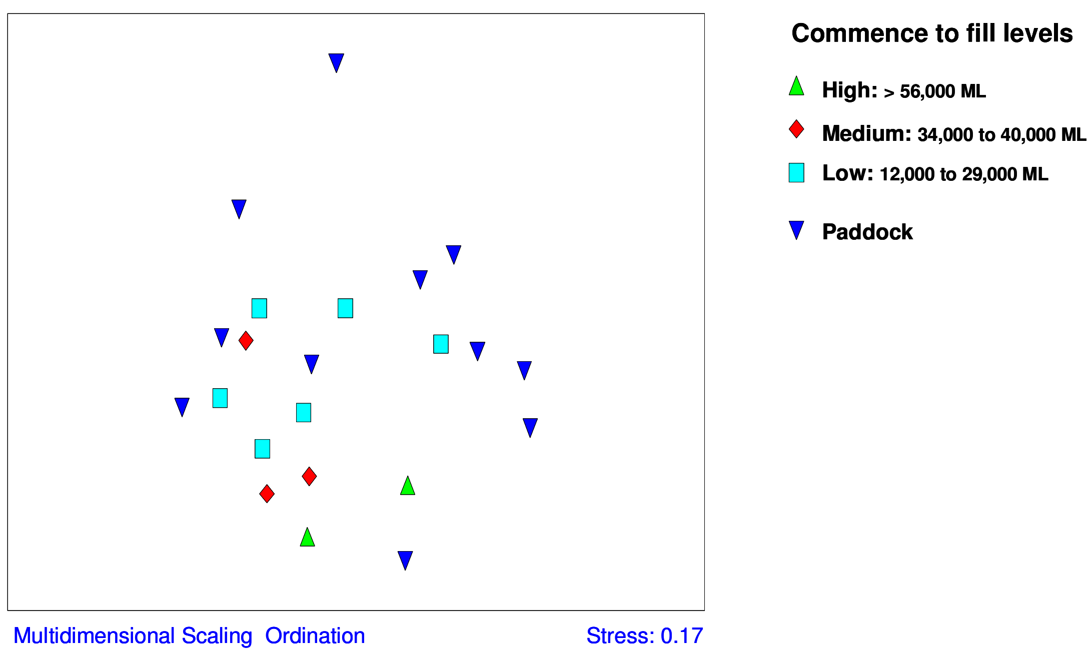


Figure 11: Examination of commence-to-fill effect on plant community composition.

Exploration of aggregated data

Data were aggregated at hierarchical levels to examine of if tighter clustering and lower Ordination stress might occur. Plot types and treatments were combined for each wetland to produce a plant community per wetland and paddock. The combining of the data produced some weak clustering but the stress levels were higher than desired.

A weak clustering for plot type was indicated in Figure 12. Wetland samples are better clustered than paddock samples.

Examination of water permanency effect showed a better clustering of deep more permanent wetlands than shallow less permanent wetland. Paddock sites were more scattered than either of the two wetland types (Figure 13).

Frequency of flooding effect as shown by commence-to-fill, showed a tight clustering of high and a weaker but noticeable clustering of low (Figure 14).

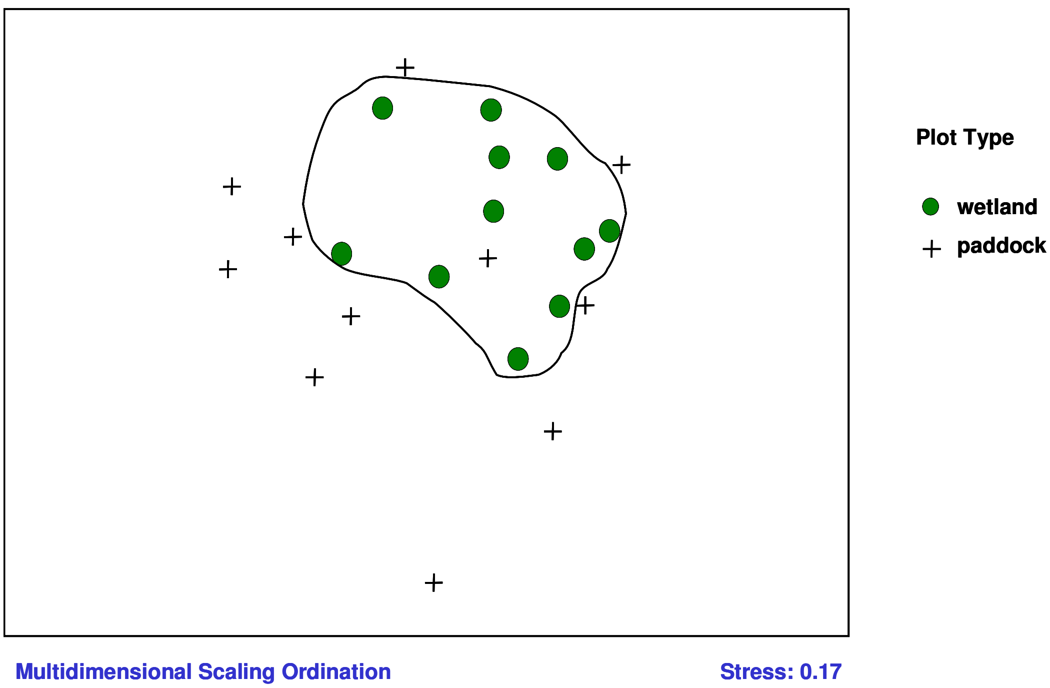


Figure 12: Examination of aggregated data for plot type effect, wetland versus paddock.

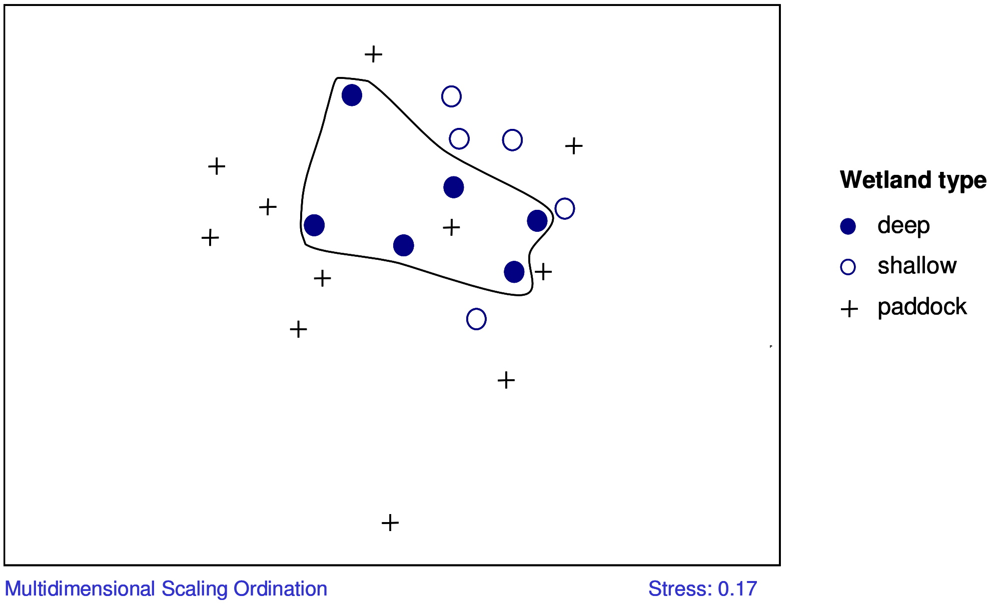


Figure 13 Examination of aggregated data for water permanency effect.

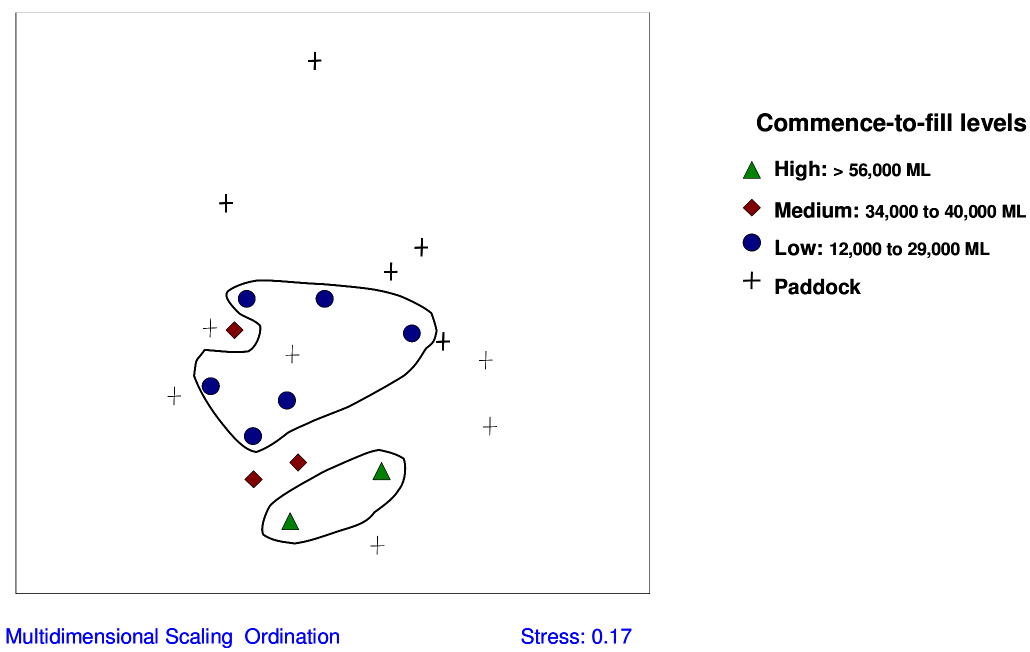


Figure 14 Examination of aggregated data for frequency of flooding effect.

Wetland only data were examined for cluster and again only weak clustering was noted.

Permanency of water effect showed a tighter clustering of more temporary (shallow) wetlands than more permanent (deep) wetlands (Figure 15).

Frequency of flooding effect (commence-to-fill) showed a clustering of frequently filled wetland (low) except for one site that was quite different (Figure 16).

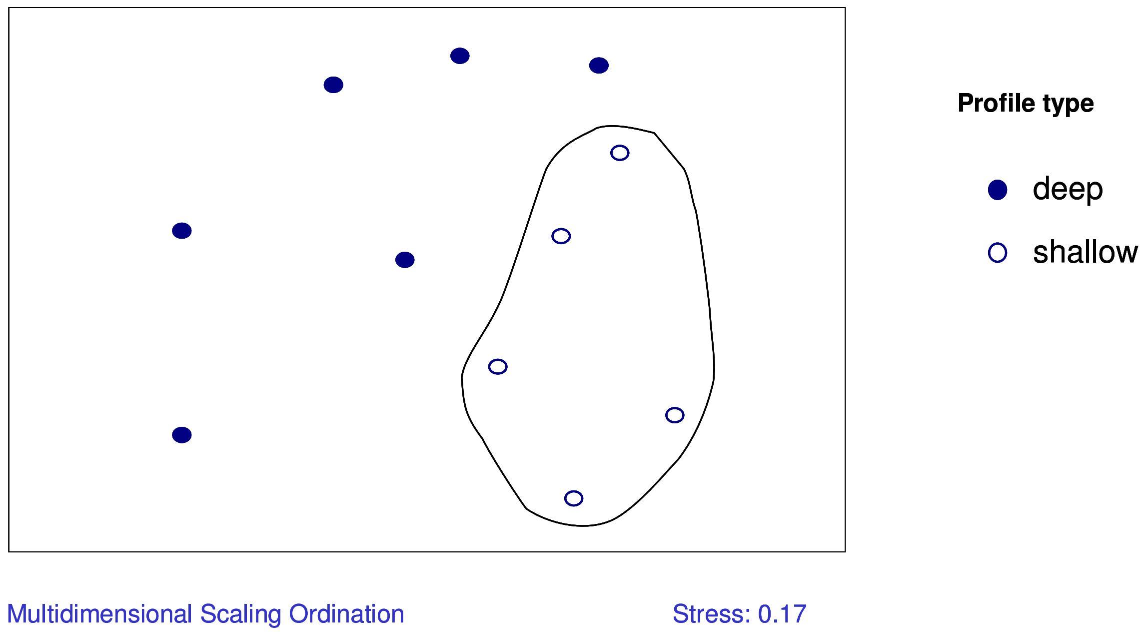


Figure 15 Examination of aggregated wetland only data for water permanency effect.

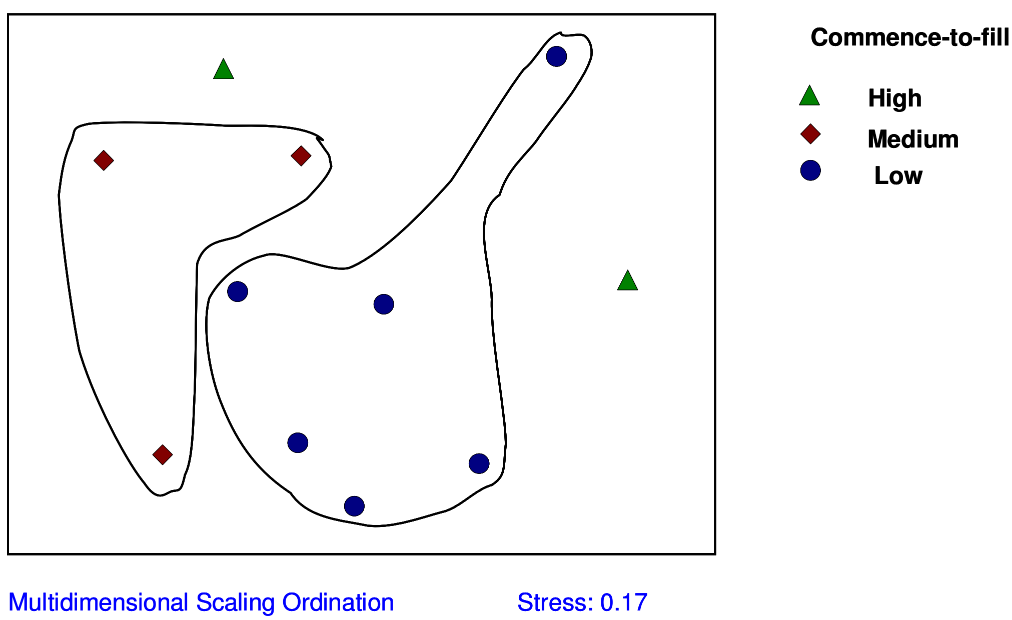


Figure 16 Examination of aggregated wetland only data for frequency of filling (commence-to-fill) effect

Second Stage -Winter

One of the most noticeable differences in the winter experiment was the germination of plants in all the submerged samples that had no germination over summer (Appendix 2, Table 2A.4). The most striking were the paddock submerged samples, which during summer only three samples had any germination.

Winter data were explored as for summer data, with similar but very weak association suggested. Summer and winter moist data were explored to see if stronger patterns might emerge and again there was nothing definite except for season effect which showed a tight clustering of winter samples (Figure 17).

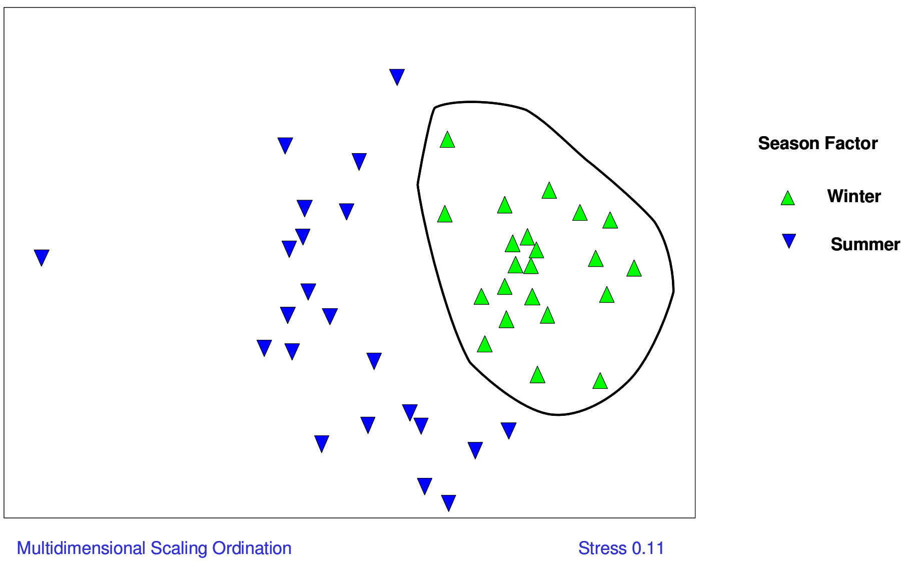


Figure 17 Examination of aggregated winter moist treatment data for seasonal effect

Density of weeds

Weed density was calculated for summer and winter experiment for each treatment and plot type (Table 3). Summer show few species germinating in the submerged samples, but winter results showed germination in all treatment and plot samples.

Diversity and density of weeds were greater in summer than winter. Class 4 weeds were not any more numerous in summer than winter.

Table 3: Density of weed species

(Class 4 weeds are highlighted)

Table 3.1 Summer data

Summer Wetland Low Plots											Summer Wetland High Plots									
Species Code	Submerged Treatment					Moist Treatment					Submerged Treatment					Moist Treatment				
	Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density	
BIRP	0/11					0/11					0/11					0/11				
BMed	0/11					0/11					0/11					2/11	1	2	52.63	105.26
D14	1/11	0	1	0	52.63	1/11	0	9	0	473.67	0/11					0/11				
D37	0/11					1/11	0	1	0	52.63	0/11					1/11	0	1	0	52.63
HCl	0/11					1/11	0	1	0	52.63	0/11					1/11	0	1	0	52.63
JJ	0/11					1/11	0	9	0	473.67	0/11					0/11				
M05	3/11	0	1	0	52.63	4/11	1	3	52.63	157.89	2/11	0	2	0	105	3/11	1	8	52.63	421.04
M06	0/11					3/11	0	1	0	52.63	0/11					0/11				
M10	0/11					1/11	0	9	0	473.67	0/11					1/11	0	21	0	1105.23
M15	0/11					1/11	0	2	0	105.26	0/11					2/11	1	6	52.63	315.78
NTh	0/11					0/11					0/11					1/11	0	4	0	210.52
PC	0/11					1/11	0	1	0	52.63	0/11					1/11	0	1	0	52.63
RMil	1/11	0	5	0	263.15	2/11	0	2	0	105.26	1/11	0	10	0	526	1/11	0	5	0	263.15
XSp	0/11										0/11					2/11	0	1	0	52.63

Summer Paddock Plots										
Species Code	**Submerged Treatment**					**Moist Treatment**				
	Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density	
BIRP	0/11					1/11	0	3	0	157.89
BMed	0/11					0/11				
D14	0/11					1/11	0	1	0	52.63
D37	0/11					0/11				
HCl	0/11					0/11				
JJ	0/11					0/11				
M05	1/11	1	3	52.6	157.89	5/11	1	6	52.63	315.78
M06	0/11					0/11				
M10	1/11	0	9	0	473.67	0/11				
M15	0/11					1/11	0	3	0	157.89
NTh	0/11					2/11	0	1	0	52.63
PC	0/11					1/11	0	1	0	52.63
RMil	0/11					0/11				
XSp	0/11					0/11				

Table 3.2 Winter data – all samples kept moist

Winter Wetland Low Plots											Winter Wetland High Plots									
Species Code	Submerged Treatment					Moist Treatment					Submerged Treatment					Moist Treatment				
	Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density	
BLP	0/11					0/11					0/11					0/11				
BMd	3/11	1	4	52.63	210.5	3/11	2	3	105.26	157.89	2/11	0	1	0	52.63	2/11	0	1	0	52.6
D19	0/11					0/11					0/11					0/11				
HCl	0/11					0/11					0/11					0/11				
JJ	1/11	26		1368.4	0	1/11	0	150	0	7894.5	0/11					0/11				
M05	0/11					1/11	0	1	0	52.63	2/11	1	2	52.63	105.26	2/11	0	1	0	52.6
M06	3/11	1	6	52.63	315.8	6/11	0.5	18	26.315	947.34	7/11	0.5	6	26.315	315.78	7/11	1	9.5	52.6	50
M15	4/11	1	6	52.63	315.8	5/11	0.5	8	26.315	421.04	9/11	0.5	6	26.315	315.78	7/11	2.5	15	132	78
NTh	0/11					0/11					0/11					0/11				
PC	2/11	1	6	52.63	315.8	1/11	0	1	0	52.63	0/11					1/11	0	1		52.6
RMil	1/11	0	2	0	105.26	0/11					0/11					0/11				
XSp	0/11					1/11	0	1	0	52.63	0/11					0/11				

Winter Paddock Plots										
Species Code	Submerged Treatment					Moist Treatlent				
	Plots with plants	Range of number present		Range of density		Plots with plants	Range of number present		Range of density	
BLP	0/11					1/11	0	2	0	105.26
BMd	1/11	0	1	0	52.63	1/11	0	1	0	52.63
D19	1/11	0	1	0	52.63	0/11				
HCl	0/11					0/11				
JJ	0/11					0/11				
M05	2/11	1	2	52.63	105.3	3/11	2	10	105.26	526.3
M06	6/11	0.5	6.5	26.315	342.1	8/11	0.5	5	26.315	263.15
M15	9/11	0.5	6.5	26.315	342.1	9/11	0.5	8	26.315	421.04
NTh	1/11		01	0	52.63	0/11				
PC	1/11		01	0	52.63	0/11				
RMil	0/11					0/11				
XSp	0/11					0/11				

Discussion

No significant difference was found for soil salinity and pH amongst wetlands and sites. They were also within normal range and would not compromise the composition of wetland plant species. Soil texture varied with a trend for more clay present in paddock soils compared to wetland soils.

The purpose of this experiment was to answer a number of questions relating to wetland management. The discussion of the results in context of the various questions follow:

Do wetlands have distinctly different plant community to the adjacent paddock?

Results from this experiment suggest that the wetland plant community is not distinctly different to the adjoining paddock. This might be related to the patchy distribution of wetland plants species and the quick sampling method in this study did not adequately account for this in the design. The high stress level of the ordination suggests that the plants do show a very patchy distribution which results in high noise (stress) in the data, which is not unusual for biological data. This can result from a lot of species with low number of individuals and a few with very large number of individuals, which is the case for this study.

The results may reflect a sampling of the floodplain plant community that copes with periodic flooding. Most other studies have concentrated only on the wetland plant community and not on how it relates to the adjoining landscape. The low germination rate of wetland plants noted in this study is not unusual, as Brock and Britton (1995) found that only a small proportion of seeds germinate in any one flooding event.

How representative are the plants that germinate from seed bank to those that actually germinate from a flood event is unknown. Integrated Moniotoring of Environmental Flow (IMEF) vegetation survey results after a flood in McKenna's wetland showed two distinctive wetland plants species, Water Ribbon (*Triglochin procera*) and Swamp Lily (*Ottelia ovalifolia*) (Pers Comm Lorraine Hardwick) present. Neither of these was represented in the seed bank in the soil collected for this study.

These results may also indicate the impact that stock have already had on the wetlands sampled in this study. Nicol *et al* (2007) found a reduction in wetland plant density and species diversity in their study between grazed and ungrazed section of a wetland.

Do wetlands with different water permanency, as indicated by profile, have distinctly different plant communities?

There is a suggestion that permanency of water may influence plant communities in this study, but the tightness of the groupings differ when paddock plots are removed. More temporary (shallow) wetlands show a tighter grouping than more permanent (deeper) wetlands when only wetland data are explored (Figure 15). The reverse it true when paddock plot data are included (Figure 13). The lower diversity and number of individuals in the submerged treatment suggests that wetlands with greater water permanency would have a different plant community, perhaps having more submerged plants rather than emergent wetland plants.

Do wetlands with different frequently of filling have distinctly different plant communities?

There is a suggestion that frequency of filling does influence plant communities in this study. More frequently filled (low) wetlands show a tighter grouping with or without the inclusion of paddock plot data. The other groupings change depending on whether paddock plot data are included or not (Figure 14 & 16).

Is the density of weeds at a level to cause concern?

The density of weeds was a concern, because even one plant germinating equates to 52.63 plants per square metre. If weeds are similar to other wetland plants, then the number of weed plants germinating per plot in this experiment is an under estimation of the true weed problem.

Summer moist treatments of the two wetland plot types showed a greater diversity of weeds species compared to winter. But the winter samples showed a greater diversity of weeds and density in the samples that had been submerged in summer. Winter paddock submerged showed the greatest difference, having only 2 of 11 sites germinating in summer compared to all 11 sites having germination in winter. This suggests that submerging paddocks for small periods of time will suppress weeds, but will not destroy the viability of the seeds.

Of the Class 4 Noxious weeds, Horehound was found only in the winter experiment, while Paterson's Curse was found in both the winter and summer experiment with a about the same level of representation in samples. Bathurst Burr showed low representation in both summer and winter samples.

Were weed species and densities different between adjoining paddocks and wetlands?

There were more species of weeds (n = 13) in the wetland compared to the paddock (n = 11) plots. Horehound and Black Roly Poly were only found in paddock plots. Red Milfoil, Bathurst Burr and Jo Jo Daisy were only found in wetlands. Those that did occur in both wetland and paddock samples appeared to be more numerous in wetlands.

Were paddocks a source of weeds in wetlands? Or visa versa?

Depending on the weed species and their optimal growing conditions, the verdict could be other way.

Other observations

Soil samples from Toogimbie, which is a lignum swamp, failed to have one lignum plant germinate. This suggests that the lignum plants had not recently flowered or the viability of the seed is lost more quickly than other wetland species.

The soil collected from Bull's Run wetland had remnants of an *Eleocharis sphacelata* tussock in it, but none of the spike rush germinated from this tussock. This might suggest that the vegetative reproductive part was not collected, the tussock was not viable, or this species does not reproduce vegetatively from a rhizome. However this seems rather surprising because other species of *Eleocharis* do show the development of rhizomes.

Conclusion

Wetlands may harbour weeds but whether they are the source or the sink for weed species is hard to determine from this study. Class 4 Noxious weeds did not have a preference for winter or summer, except Horehound which was only found in winter and only in paddock samples.

Results suggest that saturating paddock soils will suppress weeds, but the viability of the seeds is not compromised because they will readily germinate after saturation.

Some wetland plants may not germinate readily from seed as shown by the lack of any plants germinating of Lignum and *Eleocharis sphacelata* even though large numbers of parent plants were present at the time of sampling.

The lack of a distinctive wetland community compared to the surround paddock may be due to a high representation of common floodplain wetlands being present or may be an indication of the decline in the wetland plant community due to the impact of grazing. However, the soil seed bank under experimental conditions may only be a small representation of what actually exists. This might be related to the patchy distribution of wetland plants species and the quick sampling method in this study did not adequately account for this in the design.

Appendix 1: Soil parameters test results

Wetland Name	Plot Type	pH	EC (mm/cm)	Texture Description	Texture Score
Bulgari Lagoon	Low	6.69	216	Light sandy clay loam	5
	High	6.17	95	Sandy clay loam	10
	Paddock	5.92	180	Loam, fine sandy	7
Bulls Run Swamp	Low	5.4	215	Loam, fine sandy	7
	High	5.51	145	Silty clay	11
	Paddock	6.11	115	Silty clay loam	12
Coldene Lagoon	Low	6.05	625	Loam	6
	High	6.43	95	Silty clay	11
	Paddock	6.39	200	Silty clay loam	12
Currawanna Lagoon	Low	5.45	170	Silty loam	13
	High	6.35	55	Silty clay loam	12
	Paddock	6.23	77	Silty clay	11
Dry Lake	Low	6.06	92	Loam, sandy	8
	High	5.69	95	Loam, sandy	8
	Paddock	6.05	160	Silty clay loam	12
Ganmain Station	Low	5.81	380	Loam	6
	High	6.44	220	Silty Loam	13
	Paddock	5.91	250	Medium clay	9
Kurrajong Lagoon	Low	5.79	103	Loam, fine sandy	7
	High	5.47	136	Loam fine sandy	7
	Paddock	5.91	85	Silty clay loam	12
McKennas Lagoon	Low	5.68	315	Silty clay loam	12
	High	5.25	210	Loam	6
	Paddock	6.64	140	Clayey loam	2
Molleys Lagoon	Low	5.64	140	Fine sandy loam	3
	High	6.22	37	Light clay	4
	Paddock	6.02	145	Medium clay	9
Toogambie	Low	6.45	85	Light clay	4
	High	6.56	82	Light clay	4
	Paddock	6.49	92	Clay loam	1
Uri East	Low	5.7	135	Clay loam	1
	High	6.25	65	Light clay	4
	Paddock	5.95	135	Light clay	4

Appendix 2 Species data

Table 2A.1 Species list for wetland seed bank investigation

(Species highlighted in grey were classified as agricultural weeds for this investigation)

Species Code	Common Name	Scientific Name	Weed Class
BLRP	Salt Bush 3/ Black Roly Poly	*Sclerolaena muricata*	
BMed	Burr medic	*Medicago polumorpha var vulgaris*	
CDe	Crassula decumbens	*Crassula decumbens*	
Char	Stonewort Algae	*Chara* sp	
CHel	Swamp Stonecrop	*Crassula helmsii*	
D01	Common sneezeweed	*Centipeda cunninghamii*	
D01c	Spreading sneezeweed	*Centipeda minima var minima*	
D03	Lesser Joyweed	*Alternanthera denticulata*	
D04	Stonecrop sp 2	*Crassula* sp 2	
D06	Mud Dock	*Rumex bidens*	
D08	Creeping Knotweed	*Persicaria prostrata*	
D09	Starfruit	*Damasonium minus*	
D10	Waterwort	*Glossostigma diandrum*	
D12	Slender Carpet Weed	*Glinus oppositifolius*	
D13	Small Knotweed	*Polygonum plebeiujm*	
D14	Wireweed	*Polygonum aviculare*	
D16	Small Crumbweed	*Chenopodium pumilio*	
D18	Jerry Jerry	*Ammannia multiflora*	
D19	Horehound	*Marrumium vulgare*	4
D22	Hyssop Loosestrife	*Lythrum hyssopifolia*	
D23	Hairy Carpetweed	*Glinus lotoides*	
D29	Willowherb	*Epilobium ciliatum*	
D31	Stonecrop sp 3	Crassula sp 3	
D33	Creeping Cudweed	*Gnaphalium gymnocephalum*	
D35	River Red Gum	*Eucalyptus camaldulensis*	
D35a	Black Box	*Eucalyptus largiflorens*	
D37	Fleabane	*Conyza* sp.	
D38	Buttercup sp 1	*Ranunculus* sp 1	
D44	River Cress	*Rorippa eustylis*	
D46	Ferny Buttercup	*Ranunculus pumilio*	
D49	Glinus sp	Glinus oppositifolius	
D52	Jersey Cudweed	*Pseudognaphalium luteoalbum*	
D54	Unknown dicot	Unknown dicot	
D55	Native Sowthistle	*Sonchus oleraceus*	

Species Code	Common Name	Scientific Name	Weed Class
D57	Wahlenbergia species	*Wahlenbergia littoricola*	
D64	Goodenia species	*Goodenia heteromera*	
D65	Mousetails	*Myosurus minimus*	
DLo	Drooping Lovegrass	*Eragrostis leptocarpa*	
HCl	Haresfoot Clover	*Trifolim arvense*	
HP	Hairy Panic	*Panicium effusum*	
JJ	Jo Jo Daisy	*Solvia anthemifolia*	
M01	Hare's Tail Grass	*Lagurus ovatus*	
M02	Floating Pondweed	*Potamogeton tricarinatus*	
M03	Grass sp 1	Grass sp 1	
M04	Grass sp 2	Grass sp 2	
M05	Dirty Dora	*Cyperus difformis*	
M06	Rye Grass	*Lolium perenne*	
M07	Grass sp 3	Grass sp 3	
M08	Juncus sp 1	*Juncus* sp 1	
M10	Couch grass	*Cynodon dactylon*	
M11B	Juncus sp 2	Juncus sp 2	
M12	Common Love grass	*Eragrostis sp.brownii*	
M14	Grass sp. 5	*Grass* sp 5	
M15	Toad Rush	*Juncus bufonius*	
M16	Brome Grass sp.	Bromus sp 1	
M17	Grass sp 6	Grass sp 6	
M18	Meadow Foxtail	*Alopecurus pratensis*	
Mil1	Common Water Milfoil	*Myriophyllum crispatum*	
Nar	Common Nardoo	*Marsilea mutica*	
NTh	Nodding Thistle	*Carduus nutans*	
OxC	Yellow Woodsorrel	*Oxalis corniculata*	
PC	Paterson’s Curse	*Echium plantagium*	4
RC	Red Clover	*Trifolium pratense*	
RivSO	River Sheoak	*Casuarina cunninghamiana*	
RMil	Red Milfoil	*Myriophyllum verucosum*	
RSR	Fine spike rush	*Eleocharis pusilla*	
SBu1	Salt Bush 1	Salt Bush 1	
SBu2	Salt Bush 2	Salt Bush 2	
SlCG	Slender Cupgrass	*Eriochloa procera*	
SR1	Common spike rush	*Eleocharis acuta*	
SR2	Large spike rush	*Eleocharus sphacelata*?	
WCl	White Clover	*Trifolium repens*	
WG	Windmill Grass	*Chloris truncata*	
XSp	Bathurst Burr	*Xanthium spinosum*	4

Table 2A.2 Winter and Summer species list

Species Code	Winter		Summer	
	Wetland	Paddock	Wetland	Paddock
BLRP		2		4
BMed	18	2	3	
CDe	1	22	1	5
Char			4	1
CHel	6	12		
D01	253	40	315	109
D01c	2	1		
D03	1		121	6
D04	12	5	1	1
D06	93	10		2
D08			40	1
D09	3		5	
D10	41		396	2
D12	3	4	12	4
D13	217	1	101	1
D14			10	1
D16			99	16
D18		3	11	
D19		1		
D22	9	11	6	9
D23			35	1
D29	56	22	5	
D31			3	2
D33	3	1	3	
D35			4	
D35a			1	
D37			2	
D38			1	
D44	21	7		
D46	38	31		
D49		3		
D52	71	34		
D54	157	80		
D55	36	15		
D57	16	6		
D64	5			
D65	1			
DLo			155	188
HCl		1	1	
HP	1			1

Species Code	Winter		Summer	
	Wetland	Paddock	Wetland	Paddock
JJ	176		1	
M01	16	7	32	8
M02				
M03	12	5	9	6
M04				
M05	8	17	27	19
M06	88	32	24	7
M07	94	5	4	
M08			1	
M10			30	9
M11B			6	
M12			3	
M14		2		
M15	112	59	10	3
M16	8	2		
M17	8	4		
M18	11	1		
Mil1	10	4	27	1
Nar			1	
NTh		1	4	2
OxC	17	7	1	1
PC	9	1	2	1
RC	1			
RivSO	1			
RMil	2		22	
RSR	278	114	279	1
SBu1				1
SBu2				
SlCG			3	4
SR1	112	124	160	16
SR2			17	
WCl	1		2	
WG	1	1		2
XSp	1		2	

Table 2A.3 Summer species data for plot and treatment

Species Code	Summer Wetland Moist Treatment		Summer Wetland Submerged Treatment		Summer Paddock Plot	
	Low Plot	High Plot	High Plot	Low Plot	Moist Treatment	Submerged Treatment
BLRP					4	
BMed		3				
CDe	1				5	
Char	1				1	
D01	105	178	366	24	109	
D03	108	13	18	14	5	
D04		1			1	
D05	1					
D06					2	
D08	1	39	4	3	1	
D09		1				
D10	1	5			2	
D12	2	10	2		4	
D13	70	31	17	1	1	
D14	9				1	
D16	63	36	10	5	16	
D18	1					
D22	4	2			8	1
D23	27	8	2	4	1	
D29		1				
D31		1			2	
D33	2	1				
D35	1	3				
D35a		1				
D36					1	
D37	1	1				
D38		1				
DLo	145	10	84	50	188	
HCl		1				
HP					1	
JJ	1					
M01					8	
M03	1	8		1	6	
M05	8	12	2	1	15	4
M06	8	16	3	1		
M07	3	1				
M08		1				
M09						
M01	18	14	6			
M10	9	21		4		9
M12		3				
M15	3	7			3	

Species Code	Summer Wetland Moist Treatment		Summer Wetland Submerged Treatment		Summer Paddock Plot	
	Low Plot	High Plot	High Plot	Low Plot	Moist Treatment	Submerged Treatment
Mil1	4	5			1	
NTh	0	4			2	
OxC	1				1	
PC	1	1			1	
RG					7	
RMil	2	5				
RSR	4	141	21	64	1	
SBu1					1	
SlCG	1	2			4	
SR1	44	31	1	9	16	
SR2	8	3	1			
WCl		2				
WG					2	
XSp		2				

Table 2A.4 Winter species data for plot and treatment

Species Code	Winter Paddock Plot		Winter Wetland Submerged Treatment		Winter Wetland Moist Treatment	
	Moist Treatment	Submerged Treatment	Low Plot	High Plot	Moist Plot	Low Plot
BLRP	2					
BMd	1	1	7	2	2	7
CDe	5	17		1		
CHel	9	3	1	1	1	3
D01	17	23	98	29	21	106
D01c	1			2		
D03					2	
D04	4	1	6			6
D06	3	7	3	2	1	876
D08	1				5	4
D10				33	8	
D12	4			3		
D13		1	72		3	142
D18		3				
D19		1				
D22	9	2	1	2	3	4
D29	8	14	18	9	14	17
D33		1	3			
D44	1	6	11	2	3	5
D46	15	16	5	9	9	17
D49		3				
D52	12	22	14	16	22	20
D54	43	37	31	48	36	43
D55	5	10	6	10	9	12
D57	5	1	3	4	2	8
D61	3					
D62					3	
D64			3			2
D65			1			
HCl		1				
HP					1	
JJ			26			150
M01	6	1		76	1	
M03	1	4	8		1	3
M05	14	3		5	3	1
M06	19	13	9.5	18.5	28	33.5
M07		5	44	5	14	34
M14	2					
M15	29	30	12.5	25.5	55	21.5
M16	2		4			4
M17	2	2	1	5		2

Species Code	Winter Paddock Plot		Winter Wetland Submerged Treatment		Winter Wetland Moist Treatment	
	Moist Treatment	Submerged Treatment	Low Plot	High Plot	Moist Plot	Low Plot
M18	1		10			1
Mil1		4		4	3	3
NTh		1				
OxC	5	2	2	6	8	1
PC		1	7		1	1
RC					1	
RivSO						1
RMil			2			
RSR	60	54	127	78	8	66
SR1	60	64		25	29	58
WC					1	
WG		1				1
XSp						1

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