Forest Internship Project

FRST 90035

Winton Wetlands

Identifying the most effective approaches for establishing Cane Grass in wetlands restoration

Final Report

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Contents

Summary

As part of my studies in the Master of Forest Ecosystem Science at The University of Melbourne, I undertook the Forest Internship Project subject. I have an interest in restoration science and I was pleased to be studying a real-life problem at the Winton Wetlands.

Field and glasshouse growth trials of Southern Cane Grass (*Eragrostis infecunda*) were undertaken. Two propagation methods were trialled: transplanting existing plants (sods) and taking cuttings (cuttings). Sods had higher rates of survival in both glasshouse conditions and in the field trials. The project proves that transplanted sods can grow in a target site despite very low soil nutrient levels. Glasshouse trial results indicate that under controlled conditions cuttings can have a much higher survival rate. Glasshouse trials indicate that a planting depth of 150mm will lead to increased rates of growth in the short term. Field plantings may be better starting in warmer conditions in late winter/early spring. After three months of monitoring, flooding caused by a wetter than average year (BOM 2016) ruined the field trials. Follow up monitoring later this year or early next year will determine if any of the plants survived inundation.

Introduction

Project Context: The Winton Wetlands

The Winton Wetlands (WW) are a series of lakes and ponds in the North-East of Victoria near the regional town of Benalla. The system covers over 8,750 ha., consisting of 3,800 ha of wetlands surrounded by 4,950 ha of red gum and grassy box forests (Stoffels, 2014). The WW have a catchment area of approximately 330 sq. km (Barlow 2010). The original wetlands were dammed in 1971 to create a storage reservoir called Lake Mokoan for the provision of irrigation water to the surrounding area for dairy farms, fruit orchards and viticulture (Winton Wetlands Committee of Management 2012).

When the dam was commissioned in 1971, Winton swamp, Green swamp, several other small swamps and over 5,000 ha of farmland were flooded. When full the dam covered 7,890 ha., but had a maximum depth of only 7m. (Stoffels, 2014). The dam was highly inefficient and had evaporation losses of approximately 50,000 ML a year, nearly 14% of its 365,000 ML storage capacity (Stoffels, 2014). These losses, combined with high operating costs and water quality issues eventually led to the decision in 2004 to decommission the dam. Restoration activities have been taking place since the decommissioning of the dam in 2009. The restoration plan for the WW is to restore the ecosystem functions of the WW to their pre-Lake Mokoan state (WWCoM 2006).

Clay for the construction of part of the Lake Mokoan dam wall was taken from a series of sites known as “borrow pits”. These sites were inundated when the dam was operational but have been exposed since the dam was decommissioned. They hold water year-round, the level of which fluctuates with rainfall. The Winton Wetlands Committee of Management (WWCoM) has collectively renamed these pits the Mokoan Ponds.

Students from the University of Melbourne’s Ecological Restoration subject visit the Winton Wetlands each year; I visited with this subject in 2014. That subject is co-ordinated by Dr. Lauren Bennett, the academic supervisor for this project.

The WWCoM have previously hosted University of Melbourne Masters student’s internship projects with good results for all involved. The industry supervisor for the previous project was Lance Lloyd, Aquatic Ecologist at the Winton Wetlands; he is also the industry supervisor for this project. Lance Lloyd contributed to the project design, helped with harvesting and planting the first round of plantings, facilitated my involvement in the Wetlands Restoration Science Forum, and provided advice and support throughout the course of the project.

Due to the severe disturbance that occurred to the Mokoan Ponds during construction of the dam wall they have much less vegetation cover than the rest of the Winton Wetlands. By restoring Southern Cane Grass to the Mokoan Ponds the WWCoM aim to provide habitat for a range of fauna species as well as improve the aesthetics of the site (Barlow 2010).

Target Species: Southern Cane Grass

Southern Cane Grass (*Eragrostis infecunda*), also known as infertile lovegrass, is a member of the Poaceae family. It uses the c4 photosynthetic pathway (Osborne et al., 2014). It has long stalks (canes) that grow horizontally, eventually becoming so long and heavy (at approximately 1m) that they bend and touch the ground, to then root and form mats (Sharp & Simon, 2002). Its natural distribution is throughout Victoria and South Australia and it has also been introduced into the Northern Territory (Lazarides, 1997). Although normally found in freshwater systems it can tolerate saline conditions. It is found on cracking clay, alluvial sandy loams, seasonal floodplains, river beds and on the margins of marshes. It can survive long periods with the majority of the plant underwater (Lazarides, 1997). Southern Cane Grass Southern Cane Grass provides excellent habitat for the young of fish species present in the WW such as Redfin Perch (Perca fluviatlis), Golden Perch (Macquaria ambigua) and Brown Trout (Salmo trutta). (Lloyd Environmental 2014) and terrestrial marsupial species such as the Yellow-footed Antechinus (*Antechinus flavipes*) (Carter 2011).

Propagating *Eragrostis* species using Vegetative propagation has been successful in other field trials (Holm & Sasser, 2008), (du Toit, 2009).

Southern Cane Grass is found throughout the Winton Wetlands but is largely absent from the area immediately surrounding the Mokoan Ponds. The successful restoration of Southern Cane Grass is one of the indicators of an improvement in ecological function at the WW (Barlow 2010). Due to its importance as a habitat species, the WWCoM would like to replant the area around the Mokoan ponds with Southern Cane Grass. However, this is a large area and the most effective propagation technique is currently unknown. The average area that a single plant covers is also unknown; this information is important for determining the number of plants necessary for replanting all of the Mokoan Ponds. The optimum planting distance from the current edge of the water and high water mark in the Mokoan Ponds is also unknown**.** The WWCoM have identified a lack of research on the autecology of Southern Cane Grass as a key knowledge gap (Barlow 2010).

Winton Wetlands management have tested some methods for propagating Southern Cane Grass on a community planting day in 2015, including transplanting established plants and planting cuttings. However, these preliminary tests were limited by poor record keeping including which method was planted where, so the best method for establishing Southern Cane Grass remains largely unknown.

Restoration

Ecological restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (SERA 2004).

The condition that a landscape was in prior to any disturbance in often used as a goal for restoration activities to aim for (Gibbons et al., 2008), (McElhinny, Gibbons, Brack, & Bauhus, 2005). Stoddard, Larsen, Hawkins, Johnson, and Norris (2006) define this as a "historical reference". The WW has the long-term goal to restore the wetlands to their state before the creation of Lake Mokoan, aiming for this historical reference state. Unfortunately there are few records of the condition of the WW prior to the creation of Lake Mokoan with the exception of some unpublished flora surveys by Helen Aston in 1959 and 1962, some historical photos and the memories of locals. Determining the exact conditions to aim for is therefore problematic.

An alternative to deal with severely damaged systems where it is not practical to restore them to their historical state is to aim for a novel state that has no analogue in nature (Chapin & Starfield, 1997). Influential articles by Hobbs (2006, 2009) have promoted this idea, but it is contentious, and has been criticised by Murcia et al. (2014) and Balaguer, Escudero, Martín-Duque, Mola, and Aronson (2014) amongst others (see (Miller & Bestelmeyer, 2016) for more on this discussion).

Choi (2004) suggests that restoration goals take into account the likely climate conditions in the future and plan accordingly, while Harris, Hobbs, Higgs, and Aronson (2006) suggest that historical reference states be used, but resilience to changes in future climate be built into restored systems.

Hilderbrand, Watts, and Randle (2005) caution that although there may be a restoration goal that is being worked towards, systems undergoing restoration are dynamic and may end up in a state other than that being aimed for, such as a hybrid state between a historical reference and a novel ecosystem described by (Hobbs et al., 2009).

While the restoring the ecosystem functions of the WW is an important goal, the WW exists in a complicated social context (Barlow 2010). Hobbs (2007) highlights the need for restoration goals to take the values of the community that the project exists within into consideration to ensure the success of restoration projects.

Adaptive management

The WWCoM are using Conservation Measures Partnership's '*Open Standards for the Practice of Conservation'* adaptive management framework (CMP 2008). Due to a lack to published material on Southern Cane Grass and its restoration, I am using a trial and error approach within this framework. The WWCoM will be able to implement management decisions based on an adaptive assessment of the results of this project.

Project Objectives

By implementing trials of Southern Cane Grass planting methods I aimed to:

- Record the survival rate of each propagation method under both glasshouse and field conditions
- Document key logistical data relevant to each propagation method, including the time taken to harvest plants
- Determine the optimal planting distances from the edge of the water in the Mokoan Ponds
- Determine if the soil chemistry has any effect on the survival rates of the plants
- Gain practical experience in restoration and project management

Method

Study Area

Figure 1. Location of the Winton Wetlands Reserve in Victoria, Austalia.

Figure 2.Location of study site within the Winton Wetlands Reserve.

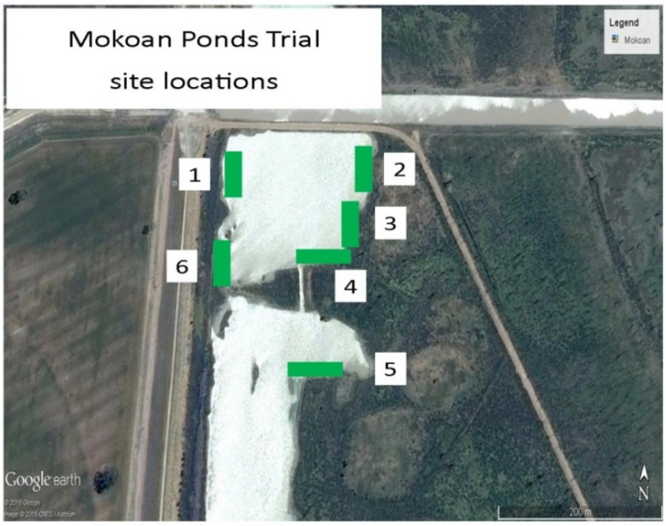

Figure 3. Location of study sites within the Mokoan Ponds.

Locations for sites and plots were chosen in the areas around the Mokoan Ponds in which future restoration works will take place. Locations for sites and plots were chosen where there was the smallest amount of existing vegetation present, however there were no plots without pre-existing vegetation.

Field trial plant material

Plant material for the field trial was harvested in May 2016 from one area in the main body of the Winton Wetlands (-36.439680 N, 146.067430 E), where there is a large body of mature Southern Cane Grass. Clods of earth (20cm by 20cm wide by 10cm deep) containing growing Southern Cane Grass plants in were dug up. The plants in each of these clods were separated into nine smaller plants, and are hereafter referred to as “sods”. In addition, cuttings, of 80-95cm length, were taken from Southern Cane Grass plants that showed signs of growth from the nodes of their canes. In both instances the time taken to harvest each type of plant was recorded.

Glasshouse trial plant material

The plant material for the glasshouse trial was harvested in August 2016 from the same location as that for the field trial using the same methods.

Field trial design

Based on the results of the trial plantings that took place in 2015, it was decided to plant the cuttings and sods two metres apart at 100mm deep (Lloyd, pers. comm. 2016). In the project proposal the plots were to be located two, five and ten meters away from the water's edge, however the water in the ponds was very low at the time of the establishment of the trial due to a long, dry summer (70mm lower than average for Dec-Mar. Rainfall measurements were taken from the B.O.M.'s weather station at Benalla Airport, 12km from the main body of the Winton Wetlands (BOM 2016). It was decided that a more appropriate location for the plots would be on, three metres and eight metres away from the annual high water mark, closer to the water than originally intended (Lloyd, pers. comm. 2016).

The original experimental design included three 'treatments' involving a non-planted control and two propagation methods (detailed below). Treatments were replicated in randomised blocks, which were replicated at each of the three distances from the annual high water mark. Other plant species that were already present in the plots were not removed, which is consistent with the WWCOM (2012) goals to restore the site using both active methods and passive regeneration of native species.

Field trial planting

The first plantings took place on the 24th (sites 1 and 2) and the 25th of May 2016 (remaining sites). Due to delays associated with misplacement and study commitments, the cuttings in plots 11 and 17 were not planted until the 18th of June during a community planting day.

While it was initially hoped that the majority of the first round of plantings would survive due to the success of the trial plantings in 2015, this did not prove to be the case. A contingency plan was enacted, including planting a second round of cuttings (4th July 2016, all cuttings planted on the same day as they were harvested), and implementing a glasshouse trial (as detailed below). In addition, to maximise alignment between the field and glasshouse trials, a third round of field plantings of both sods and cuttings took place on the 9th and 10 of August, immediately before the glasshouse trials were established on the 11th of August.

Field trial monitoring

Plants were assessed for survival and horizontal growth. Under advice from L. Lloyd, the survival of the plants was assessed generously, with any plant that had any part of it showing green being assessed as being living. All sods were assumed to have horizontal dimensions of 50mm by 50mm and all cuttings were assumed to have horizontal dimensions of 10mm by 10mm at the time of planting.

Plants that showed sign of growth from the nodes above ground were recorded as "growing", while several categories of dead plant were used: dead plants were recorded as having dimensions of 0mm by 0mm or "dead", plants that had drowned were recorded as "drowned", plants that had been eaten (presumably by wallabies or kangaroos) were recorded as "eaten" and plants that could not be found (due to being eaten or trampled by wallabies or kangaroos) were recorded as "missing". No plant showed signs of horizontal growth within the monitoring of this project. The effects of kangaroos and wallabies were measured via the "eaten" and "missing" categories in all monitoring rounds.

Glasshouse trial planting

Plants for the glasshouse trial were harvested on the 10th of August. The cuttings for the glasshouse trial were planted on the 11th of August and the sods were planted on the 12th of August. The cuttings were planted first to ensure that they did not dry out. The clods were kept in plastic tubs overnight on the 11th of August and were watered to ensure that they did not dry out.

During the glasshouse trial the opportunity was taken to explore the effects of planting depth on growth. Half of the plants were planted at a depth of 100mm and the other half at 150mm. Due to transport space constraints, more cuttings (n=129) than sods (n=81) were collected for the glasshouse trial.

The glasshouse was kept at a constant 24 degrees C and 55% humidity for the duration of the study. The plants were planted in perlite (course grade), in 60mm by 60mm (width) by 160mm (depth) pots. Each plant received approximately 50mm of water every 3-4 days. Plants were arranged in two blocks, one of each planting depth. Cuttings and sods were randomised within these blocks.

At 70 days into the glasshouse trial a random subset of 25% of all cuttings and sods was selected for harvest. Individual plants were removed from their pots and the perlite and soil (where present) was washed off. They were they cut at the node where root growth started. All samples were then air dried at 40 degrees C for 24 hours and weighed to enable a root vs shoot comparison. The remaining plants will remain in the glasshouse for further growth and will then be returned to the Winton Wetlands for use in restoration activities.

Glasshouse trial monitoring

The monitoring of the glasshouse trial assessed survival and growth from the nodes above and below ground. Plants that were growing from nodes above the ground were recorded as "growing", those that had died as "dead" and the above ground growth (in mm) of nodes below the ground was recorded in a separate category, vertical growth.

Soil testing

A soil bulk density core (133.2 cm^3) was taken from the mid-point (20m) of each of the 40m plots. Five bulk density cores were also taken from the donor site. All of these samples were taken to a depth of 10cm.

Soil samples were assessed for texture by hand using the ribbon method as described in McDonald et al. (1998). They were then air-dried at a temperature of 40 degrees C for 48 hours and weighed before and after. The samples were then ground down to <2mm size. Representative sub-samples of 8g were ground down to <0.02mm for total carbon and nitrogen analyses and representative sub-samples of 40g were taken for all other tests.

Representative sub-samples of 25g were dried at 105 degrees C for 24 hours and weighed to determine the moisture content.

Concentrations of total carbon and nitrogen were assessed through dry combustion using the LECO CHN 2000 analyser (LECO Corp., St Joseph, MI, USA). Soil ph and electrical conductivity were measured in 1:5 water solutions after an hour of agitation using the Meterlab PHM240 and Meterlab CDM230 respectively, both made by Hach Lange (Hach Corp., Loveland, CO, USA). Concentrations of ammonia, nitrate and available phosphorus were tested using the AQ2 discrete analyser (Seal Analytical, Southampton, Hampshire, UK). Available ammonia and nitrate were extracted in 1 M KCl solution at a 1:10 soil:solution ratio after agitation for 1 hour using colorimetric measurement of the phosphate molybdenum blue complex at 882nm. Available phosphorus is measured following Rayment & Higginson (1992) in an ammonium fluoride extraction solution (0.03 *N* NH4F + 0.1 *N* HCl) at a soil: solution ratio of 1:7.

Statistical Analysis

The RStudio software program (Version 0.99.903 – © 2009-2016 RStudio Inc., Boston, MA, USA) was used to perform all statistical analysis. The survival rates of the plants were transformed using arcsine transforms to normalise the data before ANOVA calculations were made.

Results

Monitoring results

Field trial

The sods had a higher rate of survival than the cuttings in all rounds of plantings, 49% in the 1st planting (73.1 to 24.1) and 10.2 % in the 3rd planting (83.3 to 73.1); there were no sods planted in the 2nd planting. All plants showed a decrease in survival in the 3rd monitoring period, except for the 1st round of cuttings. This decrease was due to five of the six plots on the high water mark (all except plot 3) being under approximately 400mm of water. This inundation was the cause of the increased mortality, rather than any other factor.

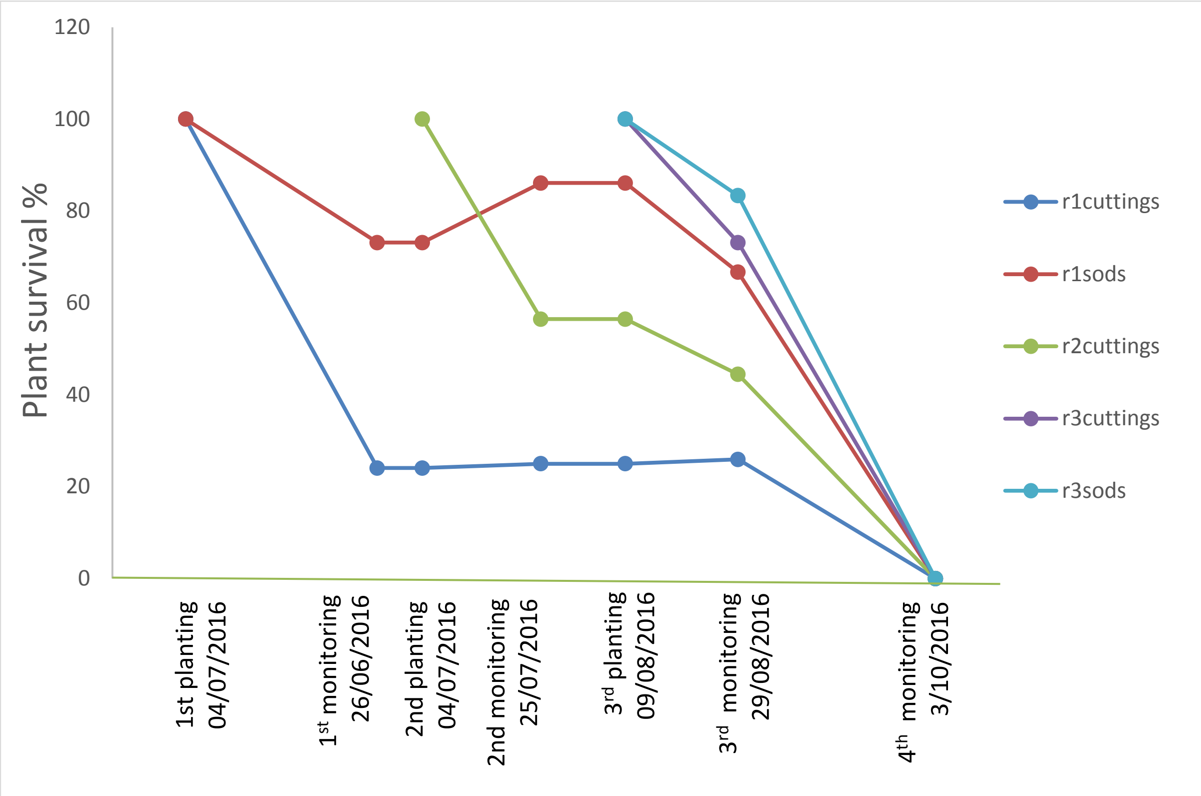

Figure 4. Mean plant survival over time by planting type.

The increase in the survival rate of the cuttings from the 1st round of planting in the 2nd and 3rd monitoring rounds was due to several cuttings which had previously been assessed as dead starting to show signs of green. This is encouraging because it means that cuttings which appear to be dead above ground may still be alive and growing below ground. The delay in planting the cuttings in plots 11 and 17 did appear to have an impact on the results as ten of the twelve cuttings in those two plots survived; the average across all other plots was just one plant surviving. This difference raised the average survival rate to 24.1% from 16.7%.

Effect of distance from high water mark on survival rates

The distance that the plants were planted from the high water mark was found to have no statistically significant effect on the survival rates in the first two monitoring periods. It was found to have an effect in the third round of monitoring as all plots at 0m were inundated and many plants died as a result. This result is important from an operational perspective and will be discussed further in the recommendations section. In the 3rd monitoring the eaten and missing categories made up 2.5% and 3.5% of all plants respectively. The full summary results of the field trial monitoring can be found in Appendix 1.

Glasshouse trials

Both sods and cuttings had higher survival rates in the glasshouse (100% and 82.2% respectively) than in the field. Due to the inundation of the field trial it is not possible to compare the glasshouse results directly to those in the field. A one-way ANOVA test with survival as the dependent variable found that the planting depth did not have a statistically significant effect on the survival of the plants (P=0.656).

The 150mm planting depth had a higher rate of vertical growth in sods than the 100mm planting depth at 71.1% and 53.7% respectively. The 100mm planting depth sods had a higher average vertical growth than the 150mm planting depth sods, at 18cm and 15.3cm respectively. After performing a one-way ANOVA test on the planting depth with the vertical growth as the dependent variable, the planting depth was not found to be statistically significant (P = 0.49). Although the planting depth does seem to have an effect on the root to shoot ratio of the cuttings, this difference is too small for the ANOVA test to detect as significant (P=0.783).

Measurement	150mm	100mmm
Cutting survival (%)	84.48	80.0
Sod survival (%)	100.0	100.0
Cuttings growing from below surface nodes (%)	3.4	9.1
Sods growing from below surface nodes (%)	71.1	53.7
Cuttings growing from above ground nodes (%)	46.6	34.6
Ave. cutting root to shoot ratio	0.145	0.017
Ave. sod root to shoot ratio	2.866	3.376

Table 1. Glasshouse survival and growth monitoring results.

Soil chemistry testing

The relationship between the levels of all the soil chemicals measured, the distance from the high water mark and the survival of the plants was analysed using two-way ANOVA tests. Soil electro-conductivity was the only soil property which was affected by the distance from the high water mark. The density of the soil varied from 3172.8 kg $m^{3\ -1}$ to 4613.5 kg $m^{3\ -1}$. All study plots had heavy clay soils with the exception of plots 6 and 11 which had clay loams. The soil chemistry did not affect the survival of the plants. The full results of the soil testing can be found in Appendix 2.

Chemical	Distance	Survival	Average levels		
	P	P	0m	3m	8m
Ammonia (mg/kg)	0.0632	0.552	4.4	2.8	2.9
Carbon (%)	0.367	0.104	0.5	0.3	0.6
EC (µ Siemens/cm)	**0.0232**	0.613	111.2	64.6	57.4
Nitrate(mg/kg)	0.213	0.681	5.9	2.3	2.3
Nitrogen (%)	0.589	0.645	0.1	0.0	0.1
pH	0.283	0.217	7.6	7.2	7.0
Phosphate (mg/Kg Bray 1)	0.796	0.316	4.5	3.2	3.7

Table 2. Effect of soil chemistry vs distance and survival ANOVA results and average levels at each distance.Significant results are indicated in bold.

Site no.	Distance from high water mark		
	0m	3m	8m
1	3519.8	3874.3	3380.5
2	3630.8	4150.9	3731.1
3	3527.6	3172.8	3452.7
4	4063.7	4314.6	3574.8
5	4044.7	4395.3	4613.5
6	3045.1	3891.2	3977.3

Table 3. Soil bulk density results. Core of 73mm diameter were taken to a depth of 10cm using a stainless steel tube. The tube was cleaned with water in between each sample to prevent cross-contamination. Samples were air dried at 40 degree C for 48 hours, then weighed. The resultant weight was divided by the volume of the tube to give the final result.

	Distance from high water mark		
Site	0m	3m	8m
1	Heavy clay	Heavy clay	Heavy clay
2	Heavy clay	Heavy clay	Heavy clay
3	Heavy clay	Heavy clay	Heavy clay
4	Heavy clay	Heavy clay	Heavy clay
5	Heavy clay	Clay Loam	Heavy clay
6	Clay Loam	Heavy clay	Heavy clay

Table 4. Soil texture by hand (ribbon method as described by McDonald et al. (1998).

Logistical results

First round of plantings

It took two people half an hour to harvest each type of plant, a total of one hour all together. Carrying the clods was physically demanding and it took two people to carry the clods six at a time using a stretcher; one person could easily carry all the cuttings without straining themselves.

Second round of plantings

Taking cuttings for the second round of plantings took one person an hour.

Third round of plantings

By the 9th of August the donor site was inundated with 600mm of water. It did not longer to harvest the plants, but it did take longer to transport them. The sods and cuttings that were harvested in round 3 were in much better condition than those for the first two rounds of plantings- they were generally greener and showing signs of current growth from their above ground nodes.

Discussion

The sods had higher survival rates than the cuttings in both the first and third plantings (no sods 2nd planting) across all monitoring periods. This is likely due to the sods having an established root system as well as higher stem area to photosynthesis from.

The increased survival of the second round of cuttings (56.5%) as compared to the first (25.0%) at the 2nd monitoring was thought to be due to increased soil moisture levels. The cumulative rainfall for the year was 313.6mm at T_1 and 390.6mm at T_2; there was an extra 24.5% cumulative rainfall at T_2 as compared to T_1 (BOM 2016). Insolation levels for the period between the first plantings and the first monitoring (T_0 and T_1) and the first and second monitoring (T_1 and T_2) were 1.98 and 1.99 kW m^{-2} day^{-1} respectively. The average rainfall levels for the same periods were 3.04 to 2.74 mm day^{-1}. The higher survival rate of the cuttings in the 3rd round of plantings (73.1 %) compared to the 1st (25.9%) and 2nd (44.4%) round cuttings at the 3rd monitoring was likely due to this increased soil moisture as well.

The soil nutrient levels did not vary significantly across the different study sites. The low soil nutrient levels did not have an effect on the survival of the plants. The ability of Southern Cane Grass to grow well in low nutrient soils is consistent with the findings of Han, Buckley, and Firn (2012), who found that native Australian grasses *Eragrostis sororia* (woodlands lovegrass) and *Themeda Triandra* (kangaroo grass) grew well in low soil nutrient conditions, even with competition from an invasive species *Eragrostis curvula* (African lovegrass).

Glasshouse propagation methods similar to those used in this study have been found to be effective in other grass species (Holm & Sasser, 2008). Higher survival in glasshouse is due to growing medium and moisture conditions that better suit the plants than field conditions, however plants grown in these conditions may have lower survival rates in the field (Pezeshki, Anderson, & DeLaune, 2000).

The root to shoot ratio of the sods in the glasshouse trial were 2.866 and 3.376 at 150mm and 100mm planting depth respectively. These are much higher values than those reported in a greenhouse study by Olupot et al. (2010) on seedlings of native NSW grasses, also over an eight week period. Their root to shoot ratios ranged from 1.413 to 0.528, with an average of 0.844 (n=5). This difference is probably due to the sods used in my project having a well-developed root system at the start of the project.

The WWCoM (2012) intend on using both active and passive methods of regeneration to restore the WW, however leaving the Mokoan Ponds to regenerate passively may advantage invasive species at the cost of preferred natives (Han et al., 2012). Giving priority to the restoration of Southern Cane Grass may help it to outcompete non-native invasive species and to increase its persistence in the landscape over time (Vaughn & Young, 2015). Werner, Vaughn, Stuble, Wolf, and Young (2016) found that the effect of giving priority to the restoration could last up to eight years in some grass species. Although the WWCoM is working to restore the ecosystem structures that existed prior to the creation of Lake Mokoan, the ecosystem processes may take years or even decades to re-establish themselves. (Matzek, Warren, & Fisher, 2016), (Barlow 2010).

While it has been possible to monitor the progress of this project manually, the size of the WW will make on the ground monitoring of a larger restoration of Southern Cane Grass impossible. LIDAR and multispectral data could be used to monitor the extent of the growth of Southern Cane Grass across the site in the future (Jeong, Mo, Kim, Park, & Lee, 2016).

Limitations of this project

It would have been better to establish the glasshouse trial at start of project; this would have enabled a much better comparison between the plants in the field and those in the glasshouse.

It would also have been better to start the trials earlier in the year when it was warmer to give the plants a chance to establish before winter and to gather more data. Alternatively, another better project schedule would have been to start in early spring and go through to the same time in the following year, however the requirement of the subject to be completed with a university year made this impossible for this project.

Due to time constraints, not all sites were planted on the same day in the first and third rounds of plantings. This had a negative effect on the survival of cuttings in the first round but this effect was not apparent in the third round.

Monitoring did not take place at regular intervals due to university commitments. This lessens the ability to compare the changes over time accurately. The time between the planting and monitoring of the different rounds also varied. This lessens the accuracy of the comparison between rounds. The glasshouse trial was not monitored until 8 weeks after planting. This makes it impossible to compare the survival of the 3rd round plantings with the glasshouse plants at the same time.

Plants in the glasshouse trial were not fully randomised, which lessens the strength of the ANOVA results.

The other vegetation present in the plots in the field trial was not removed. This may have had a confounding effect on the results.

Only one soil sample was taken from each 40m plot. There may be intraplot variation in soil nutrients that effected the survival of the plants that was not measured.

Many plants were damaged, eaten or killed by kangaroos and wallabies. This interference did not confound the results but is important to note for future restoration activities.

Although follow-up monitoring may be possible if any plants survive their current inundation, the fact that individual plants were marked out with bamboo stakes, the colour on which would have washed off, will make it hard to know which plant is which once the water recedes.

The high levels of rainfall in 2016 may have confounded the results of the field trial. The average rainfall at the Benalla Airport monitoring station is 429mm for the year to the end of September; this year has had 654.9mm for the same period (BOM 2016).

Project objectives

All of the objectives of this project were successfully achieved with the exception of the results of field trial, which were ruined by flooding after three rounds of monitoring. The results that were gathered indicate that sods have higher rates of survival than cuttings. The soil nutrient levels did not affect the survival of the plants. Electro-conductivity was found to be negatively correlated with the distance from the high water mark. The harvesting of donor plants took the same amount of time for both sods and cuttings, however transporting the cuttings was much easier work, which would be a major factor to consider in a large-scale restoration. The planting distance from the high water mark did not affect the survival of either type of plant, however the experience of the inundation of the trial site indicates that planting a range of distances from the high water mark would be prudent.

This project has been enjoyable as well as a valuable learning experience. Throughout the course of this project I have increased my knowledge regarding restoration ecology, experimental design, project management, fieldwork techniques, adaptive management and statistical analysis using the RStudio program as well as making industry contacts.

Communications plan

The on-going results of this project have been shared with the Winton Wetlands community at a community planting day on the 18th of June and at the Wetland Restoration Science Forum, hosted by the Winton Wetlands. This report and the accompanying presentation will be passed on to the Winton Wetlands Committee of Management.

I hope to be able to carry out follow-up monitoring next year to assess survival rates after the current inundation recedes and present the results at the Wetland Restoration Science Forum conference next year. I hope to be involved in future planting days and to communicate the finding of this project to others attending.

Recommendations to the Winton Wetlands committee of management

Based on the results of this study, in future restoration plantings of Southern Cane Grass at the Winton Wetlands, I recommend that:

- Sods be planted where possible due to their more reliable survival
- Cuttings be planted where long transport distances are going to make using sods a problem; four cuttings should be planted in each space to ensure that at least one survives.
- Plantings are arranged at a range of distances from the high water mark to mitigate against possible wet years
- Plantings occur during late winter/early spring (August/September) to maximise plant survival
- Planting in areas with high levels of kangaroo and wallaby activity be avoided
- Losses of 6% due to animal activity be factored into future plantings around the Mokoan Ponds

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Appendix 1. Field monitoring results

Plant type	Distance from high water mark 0m	3m	8m
Round 1 sods (%)	75.0	77.8	66.7
Round 1 cuttings (%)	11.1	25.0	36.1

Table 5. 1st Monitoring plant survival results

Plant type	Distance from high water mark 0m	3m	8m
Round 1 sods (%)	83.3	91.7	83.3
Round 1 cuttings (%)	13.9	19.4	41.7
Round 2 cuttings (5)	55.6	50.0	63.9

Table 6. 2nd Monitoring plant survival results.

Plant type	Distance from high water mark 0m	3m	8m
Round 1 sods (%)	25.0	80.6	94.4
Round 1 cuttings (%)	5.6	16.7	55.6
Round 2 cuttings (%)	50.0	47.2	36.1
Round 3 sods (%)	80.6	91.7	77.8
Round 3 cuttings (%)	61.1	69.4	88.9

Table 7. 3rd Monitoring plant survival results.

Plant type	Distance from high water mark 0m	3m	8m
Round 1 sods (%)	0.0	0.0	0.0
Round 1 cuttings (%)	0.0	0.0	0.0
Round 2 cuttings (%)	0.0	0.0	0.0
Round 3 sods (%)	0.0	0.0	0.0
Round 3 cuttings (%)	0.0	0.0	0.0

Table 8. 4th Monitoring plant survival results. All plants were flooded at this time.

Appendix 2. Soil chemistry results

Plot no.	Distance	Ammonia (mg/kg)	Nitrate (mg/kg)	Phosphate (mg/Kg Bray 1)	Carbon (%)	Nitrogen (%)	EC (µ Siemens/cm)	pH
Plot 1	0m	3.39	5.46	5.4	0.46	0.05	108.2	7.282
Plot 2	0m	5.71	8.77	8.16	0.77	0.08	146.9	7.174
Plot 3	0m	2.93	1.69	1.58	0.17	0.03	80.9	7.025
Plot 4	0m	4.65	0.59	0.32	0.05	0.02	80.1	7.142
Plot 5	0m	2.32	1.75	0.82	0.11	0.02	55.8	8.263
Plot 6	0m	7.48	17.12	10.49	1.22	0.12	195	6.99
Plot 7	3m	2.91	3.26	4.24	0.27	0.03	68.4	7.512
Plot 8	3m	2.72	0	4	0.34	0.05	78.7	7.464
Plot 9	3m	3.12	2.18	1.91	0.43	0.05	40.3	7.05
Plot 10	3m	2.73	1.23	0.42	0.15	0.03	54.1	7.272
Plot 11	3m	2.22	2.68	3.65	0.46	0.05	68	6.862
Plot 12	3m	3.29	4.56	4.68	0.24	0.03	78.2	6.889
Plot 13	8m	2.57	1.82	10.56	0.91	0.09	67.8	6.966
Plot 14	8m	2.91	0.56	0.68	0.36	0.04	54.7	6.993
Plot 15	8m	2.41	1.61	1.53	0.58	0.06	44.4	6.872
Plot 16	8m	3.99	2.01	4.13	0.84	0.07	35.9	6.128
Plot 17	8m	2.48	5.55	1.4	0.34	0.03	80.4	7.373
Plot 18	8m	3.18	2.25	3.68	0.42	0.04	61.4	7.067

Table 9. Soil nutrient level results.