Seven years on: a re-survey of the vegetation of Mokoan Reserve, autumn 2017

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COVER PHOTOGRAPH

Edge of Green Swamp at Lake Mokoan storage, March 2008. Photo by Jane Roberts

Executive Summary

Introduction

The vegetation of 61 plots at 61 sites (one 10 x 100m plot per site) at Mokoan Reserve, previously known as Winton Wetlands, was re-surveyed in autumn 2017. These plots had been established seven years previously, in autumn 2010 as a long-term monitoring program to track vegetation recovery following the decommissioning of Lake Mokoan, at the beginning of the restoration project initially known as Winton Wetlands. The monitoring program was designed as a chronosequence, treating elevation as equivalent to time since last flooded. When established in autumn 2010, sites A, B, C, D and M were aged 19, 8, 4, 2 and 1.25 years respectively; and thus were 26, 15, 11, 9 and 8.25 y respectively when re-surveyed in 2017. These sites were distributed across two landforms: Slopes (Sites A, B and C) and Wetlands (Sites D and M). Origins and background to the design of this monitoring program are in "*Lake Mokoan: baseline vegetation monitoring program in March 2010*" (Roberts, Osler and Hale (2010).

Methods

Three sets of vegetation attributes were recorded: *structure*, a broad term for a number of vegetation attributes (cover per stratum, cover of types of ground cover) and presence of features potentially important as habitat for fauna, such as fallen logs; *floristics*, meaning species abundance (as live projective foliage cover or PFC); *regeneration status* of target species, meaning their age structure as determined using age-stages. The target species were Southern Cane Grass *Eragrostis infecunda* and River Red Gum *Eucalyptus camaldulensis*, and their age-stages were Seedling, Young, Established and Patch for Southern Cane Grass, and Germinants, Seedlings, Juveniles and Saplings for River Red Gum. Each 10x100m plot was subsampled (data were the mean of five 5x5m quadrats) for structure and floristics, but for regeneration status, the whole 10x100m plot was censused. A fourth data set, *SET* meaning *Species Ecological Type*, was derived from floristics data. For this, each species was categorised according to its growth form, life-span and origin. The resulting 14 categories used in this study, were coded SET_1 to SET_14.

Structure, floristics and *SET data* were each analysed in two ways, and the two landforms (Slopes and Wetlands) were analysed and presented separately. Most of the analyses were done using multi-variate routines in Primer 7.

The first analysis (analysis using factors) tested if variations in abundance could be explained by any one of the following spatial and temporal factors: Survey (2010 or 2017), Site (A, B, C for Slopes sites; D and M for Wetland sites), Since DD (number of years since submerged by Lake Mokoan), and EMU (for ecological management unit) as recognised in the "*Winton Wetlands. Restoration and Monitoring Strategic Plan"* (Barlow 2011). There were two additional factors describing inundation in 2017 for Wetlands sites: FLDextent and Depth (inundation extent and average depth per plot).

In the second analysis (analysis using empirical groupings), no assumptions were made about factors affecting vegetation: instead sites were grouped based on their similarity to each other. These empirical groups were then used to describe the magnitude and nature of vegetation change from 2010 to 2017, using Bray-Curtis measure of similarity, and transition matrices.

Regeneration status of Southern Cane Grass and of River Red Gum were described using plots and tables to compare counts in 2010 with counts in 2017 of incidence, total numbers, number per age-stage, and age-structure. In addition, for Southern Cane Grass, groups of sites with similar age-stage counts were identified using multi-variate routines, and these groups were then used in a transition matrix to describe change, as described for floristics and SETs above. Change was also described by comparing abundance per site (as live cover, taken from the floristics data set) in the two surveys, and assigning the ratio (abundance 2017/abundance 2010) to one of six categories of vegetation dynamics: COL = colonising, INC = increased, NC = no change, DEC = decrease, LOSS = mortality, and zero = absent in both surveys.

Digital copies of the data files have been forwarded, and details are in Appendix 1.

Results: Overview

A total of 159 species from 42 families (103 being native) were recorded in the 2010 and 2017 surveys. Families with the most species were Poaceae (46 species), and Asteraceae (36 species). Most of the 159 species had seeds with traits usually associated with wind-dispersal: only three species had traits associated with animal dispersal. Also recorded were two species rated 'r' under VROTS: Floodplain Fireweed *Senecio camplylocarpus* and Branching Groundsel *Senecio cunninghamii* var *cunninghamii.* Species turnover was high between the two surveys (33 species recorded only in 2010, and 55 only in 2017), possibly due to contrasting conditions, drought and following good rains, in 2010 and 2017.

Results: Slopes

The analysis of factors for Slopes found that the temporal factor Survey explained far more variation in structure, species composition and SET composition than any of the three other factors tested, and that spatial factors (Site and EMU) had only marginal explanatory importance.

When based on species abundance, the analysis of empirical groups found a complete turnover in groups (ie assemblages) between 2010 and 2017, and a marked tendency for *Phalaris aquatica*, an introduced perennial grass, to be the most dominant species in a group. When based on SET abundance, the analysis of empirical groups showed a decrease through time in herbs, particularly of perennial native herbs, and an increase in graminoids, both native and introduced perennials, and in short-lived annuals. Structure data was too homogenous to be able to detect empirical groups.

Results: Wetlands

As with Slopes data, the analysis of factors for Wetlands found that the temporal factor Survey and the contrasting conditions (ExtentFLD, depth) explained far more variation in structure, species composition and SET composition than the other factors, and that the two spatial factors (Site and EMU) had little to no explanatory importance.

The analysis using empirical groups found a sharp contrast in structure, species composition and in SET composition of vegetation at Wetland sites, between 2010 and 2017. The magnitude of these changes was quite variable, and was influenced by wetland size: thus changes were greatest on the floor of large wetlands, and least for small wetlands.

Results: Target Species

Southern Cane Grass: Census of age-stages from 61 plots on Slopes and in Wetlands found clear evidence of an increase of Southern Cane Grass. The 2017 survey had higher incidence (57% of sites had Southern Cane Grass compared with 43% in 2010), higher total count (1815 compared with 316 in 2010), but had a similar age structure with Seedlings and Young stages being 8.2% and 18.3% in 2017 compared with 7.3% and 22.5% in 2010. Sites favourable for successful recruitment and establishments were localised rather than uniformly distributed at Winton Wetlands. The few sites with high numbers of Seedlings and Established plants were close together, referred to as 'co-located'. No Seedlings were recorded at any small wetland site.

The transition matrix of sites based on age-stages showed that Southern Cane Grass generally increased between 2010 and 2017. Recruitment occurred at 13 of 61 sites, and mortality (ie loss of Southern Cane Grass) was very low, occurring at just one site, leaving just 24 sites where there was no Southern Cane Grass present in either survey. The abundance data (live cover) recorded by subsampling the plots using five 5x5 quadrats per plot showed a similar pattern. A map of these outcomes suggests a non-random distribution in population processes: Southern Cane Grass was generally absent sites in the north-eastern part of Mokoan Reserve, and recruitment was concentrated around two of the larger wetlands, Seargents and Green Swamps. The situation is paradoxical, with Southern Cane Grass, which is considered a wetland plant, persisting and increasing in terrestrial areas (ie on Slopes sites).

River Red Gum: Regenerating River Red Gums were recorded at only five sites in 2017, not much different from 2010 (four sites), and in low numbers, 15 in 2017 compared with five in 2010. Regenerating River Red Gums were only recorded in Slopes sites, and five of the 15 were at just one site. There was no evidence of regeneration occurring in target areas described by Barlow (2011) such as small wetlands, or Edge sites around large wetlands; and no evidence of regeneration occurring in the amounts needed to result in 3000 ha of woodland. A major constraint on passive regeneration of this species is that mature seed-producing trees are set back and distant from the areas targeted for passive regeneration into woodlands. A staged restoration strategy based on nurturing 'mother' trees to by-pass this constraint is outlined.

Species and Trends

This section comments on the abundance and distribution of 20 species, of ecological interest. Fourteen of these are wetland species, but occur also on Slopes. Trends and patterns of these 14 are not readily determined, due to their relatively low abundance and incidence. The other six species are a mix of terrestrial and wetland native and introduced species.

Drooping Cassini*a Cassinia arcuata*, which increased in incidence and abundance from 2010 to 2017, is contributing structural diversity especially to vegetation on Slopes.

Cat's Ear or Flatweed *Hypochaeris radicata*, an introduced perennial herb, is enormously widespread in Australia so it is no surprise it was so common in the surveys of Mokoan Reserve. Its abundance decreased from 2010 at Wetland sites, probably due to the species being flood intolerant: it increased on Slopes sites.

Juncus semisolidus is a native perennial rush that has been a conspicuous part of the self-regenerating vegetation since at least 2006. It is an early coloniser, following water level recession. Its abundance fluctuated between 2010 and 2017, increasing at some wetlands (Green, and small wetlands) and decreasing at others (Sergeants, Winton) and remaining little changed on Slopes sites.

Blown grass *Lachnagrostis filiformis var 1*, a shorter lived native grass and one of only a few in this SET, exemplifies how variable abundance can be due to seasonal conditions. In 2010 it was abundant on the Floor of large wetlands but not in 2017.

Toowomba Canary Grass *Phalaris aquatica*, a naturalised introduced pasture grass, is a serious environmental weed which is clearly expanding. The number of sites where it was recorded nearly doubled in seven years (from 10 to 19), and its abundance has increased by two orders of magnitude in most sites.

Clover *Trifolium* spp, is a group of introduced pasture herbs, rarely considered as an environmental weed. The incidence and abundance of these, and the number of species, is fairly similar in 2017 as it was in 2010.

Trends in the eight SETS covering graminoids and herbs are explored but only one trend for one SET (a decline in longer-lived native herbs) was statistically significant, however two others (increase in shorter-lived introduced graminoids; and decrease in shorter-lived introduced herbs) were marginally significant.

Recommendations Arising

Nineteen recommendations were made, arising out of the analyses of the main results in this report.

Recommendations arising from analysis of Slopes sites (Section 4)

Recommendation 1

Clarify best practice in relation to various uses of the Slopes environment, but specifically in relation to agriculture and conservation.

Recommendation 2

Develop s.m.a.r.t. and spatially-explicit targets for vegetation on Slopes surrounding the Wetlands. This could benefit from further analysis of 2010 and 2017 monitoring data.

Recommendation 3

Establish a system and map of vegetation condition indicators that can be used to guide day-to-day management and decisions in relation to selected threats or issues.

Recommendation 4

Establish a suite of indicators of ecosystem function and condition, as recommended by Barlow (2011), with an emphasis on those that are low cost, amenable to citizen-science or volunteer implementation, and that can be integrated into an appraisal of Mokoan Reserve / Winton Wetlands.

Recommendation 5

Continue with this monitoring program, but sampling every 5 years. A sub-sample of sites could be monitored more frequentl, such as every 2-3 years), in order to distinguish short-term fluctuations from long-term trends.

Recommendation 6

Once spatially explicit targets have been established, review and revise this monitoring program, paying special attention to gaps and redundancies.

Recommendations arising from analysis of Wetland sites (Section 5)

Recommendation 7

Categorise wetlands in terms of their water regime and hydraulic characteristics. The categorisation should be used to recognise sites, areas and wetlands where vegetation is expected to respond similarly. This categorisation will be useful in setting specific vegetation targets, for evaluating feasibility of targets, and for reviewing the scope and representativeness of the current vegetation monitoring program.

Recommendation 8

Determine the actual elevation in m AHD of all monitoring sites, but especially of D sites which appear to be rather variable. Consider the need or otherwise of standardising D sites by elevation for comparability of vegetation response.

Recommendation 9

Increase frequency of vegetation monitoring at Wetlands sites to every five years to link with Slopes sites and retain an overall whole-of-Reserve perspective.

Recommendation 10

Establish a monitoring program that complements the current quadrat-based vegetation monitoring, by providing broad coverage but qualitative data (mapping from aerial photography; permanent fixed photopoints).

Recommendation 11

Establish a staff gauge or water level recording system that can be used to provide water/inundation history for all Wetlands monitoring sites; the necessary data is depth and duration of being flooded, as well as frequency.

Recommendations arising from analysis of Southern Cane Grass (Section 6.2)

Recommendation 12

The vision that Sergeants and Winton Swamps will eventually be dominated by Southern Cane Grass needs to be critically reviewed for ecological feasibility. For this it will be necessary to consider the contemporary hydrologic and hydraulic characteristics of Sergeant's and Winton Swamps (which may have changed since

1960s), and tolerances and requirements of Southern Cane Grass. If necessary, the vision may need to be revised.

Recommendation 13

Knowledge about life cycle and water regime requirements and tolerances of Southern Cane Grass needs to be improved to a level that can inform the long-term vision for Winton Wetlands / Mokoan Reserve. In particular, the depth duration tolerances and sensitivities of different age-stages need to be quantitatively established, preferably using multiple lines of evidence including empirical from existing monitoring sites, from other wetlands, and by experiment, and linked to hydrologic and hydraulic modelling.

Recommendation 14

Continue monitoring recruitment and persistence of Southern Cane Grass at existing sites, using existing methods, but increase the sampling frequency to every 2-3 years for age-stage monitoring. Understanding populations processes would be helped by recording water level and depth history, at some (not necessarily all) sites: see Recommendation 15.

Monitoring should continue at all sites until the restoration objective is achieved or is certainly on track for success, at which point the monitoring program should be reviewed to make it fit for other needs, such as long-term condition monitoring.

Recommendation 15

Develop a means of recording inundation history at monitoring sites that will give essential information on depth and duration of inundation, at precision levels that will allow interpretation of fate of age –stages.

Recommendation 16

Develop a strategic approach for achieving restoration objectives for target species using a mix of natural and assisted regeneration. However, as wetland types, land use, and other factors vary around the Reserve, it would be sensible to develop a suite of strategies, tailoring them to particular wetlands and areas: this is because a single approach is unlikely to suit all areas.

Recommendations arising from analysis of River Red Gums (Section 6.4)

Recommendation 17

Continue to monitor age-stages of River Red Gum at all 61 monitoring sites, at least until spatially-explicit targets are articulated and a revised regeneration strategy has been initiated; increase frequency of monitoring to every 2-3y to align with Southern Cane Grass monitoring.

Recommendation 18

Develop a restoration plan for River Red Gum woodlands at Winton Wetlands /Mokoan Reserve which is spatially explicit and which acknowledges that not all dead woodland was or should be River Red Gum. The plan will need to be sensitive to natural heterogeneity of the Reserve, and should develop and use knowledge of abiotic and biotic constraints on regeneration to different approaches for different areas.

Recommendation 19

Develop a regeneration strategy for River Red Gum that by-passes life-history bottle-necks such as dispersal, germination and early seedling establishment; and that instead invests in more establishing and nurturing more advanced stages, either by planting and/or by locating self-established juveniles. A network of 'mother' trees is suggested.

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Table of Contents

1. VEGETATION SURVEY IN 2017

1.1 Background

The vegetation survey done in autumn 2017 is the first re-survey of a vegetation monitoring program established in autumn 2010, to track the recovery of vegetation largely through passive restoration appraches. At the time, the area was known as Winton Wetlands, a name that was used after it had been Lake Mokoan, a water storage that was de-commissioned in 2010. The name Winton Wetlands is about to be replaced by another name, Mokoan Reserve, that harks back to earlier times. In this report, the terms Winton Wetlands and Mokoan Reserve should be treated as interchangeable labels. The name Winton Swamp, referring to the largest wetland in this wetland complex, remains unchanged.

The 2010 monitoring program was intended to detect the outcome of a management decision, namely to allow vegetation to recover by natural regeneration, so has affinities with *intervention* monitoring, although this was using passive restoration approach. It was also designed with the intention of tracking vegetation development in a landscape that had been submerged for decades by Lake Mokoan storage. Documented examples of vegetation development post-de-commissioning are rare, especially in Australia, hence the monitoring program has affinities with research questions on vegetation succession, and the spatial arrangement is influenced by the concept of space-for-time substitution or *chronosequence*.

A critical assumption was made that, due to prolonged submergence, soil erosion, and sedimentation, there would be no or very little residual viable seed bank in terrestrial or wetland soils. Following from this is the expectation that vegetation development would depend on inward dispersal of seeds and other propagules, and that this would control species composition. The local catchment was expected to be the principal source of propagules, as wind and flowing water are main vectors for dispersing terrestrial and wetland species. Another critical assumption, based on scant case histories in the technical literature, was that vegetation characteristics such as structure, and species composition would change through time, following change in disturbance regime. For a water storage that is being de-commissioned, such as Lake Mokoan, change in disturbance can be equated with no longer being submerged, and thus length of time can be approximated by position (elevation, in metres above Australian Height Dataum, henceforward as m AHD) on the landscape.

Initially, the monitoring design focused on Sergeants Swamp, Winton Swamp and Green Swamp, three large (598, 1792 and 802 ha respectively) and hydrologically connected basins that are effectively a single wetland complex of 3192 ha (areas taken from Hamilton et al 2013). Early versions of the monitoring program had sites around these basins to cover variation in environmental conditions known to affect wetland vegetation such as aspect, exposure to wind and wave action, substrate, and slope.

However, as water levels of Lake Mokoan continued to fall, a number of wetlands were revealed in the north-east, many more than had been expected from the planning documents available. These wetlands are much smaller than the three connected basins, ranging in area from 2.1 ha for Unamed K to 174 h for Boggy Bridge (Hamilton et al 2013). Such size differences suggest that the smaller wetlands would have quite different hydrological characteristics (water retention, maximum depth, rate of fill) from the three main basins and hence would develop different vegetation. This expectation was consistent with the scant evidence of vegetation present prior to commissioning Lake Mokoan, namely the notes made by Helen Aston, and the distribution of dead trees described in Barlow (2011). Moreover, it was also apparent that the north-eastern area, with its mosaic of small wetlands would have a distinctive biodiversity value within this wetlands complex, and therefore these smaller wetlands needed to be included in the vegetation monitoring program.

The decision to use age-stages to monitor the regeneration of two target species Southern Cane Grass *Eragrostis infecunda* and River Red Gum *Eucalyptus camaldulensis* was taken following an observational study of regeneration and establishment of wetland plants around Winton, Green and Sergeants Swamps in March

2008 (Roberts et al 2008). Regeneration monitoring was limited to these two species because they were considered keystone species, and because distinct age-stages could be recognised.

The same observational study provided valuable insights into substrate variability, noting areas of deep sedimentation particularly in parts of Green Swamp, and severe erosion especially along the northern shore. The usefulness of elevation as a surrogate for developmental time and assemblage characteristics was explored using survey information from January 2006 (Ecology Australia 2006), as described in Appendix 4 of Roberts and Hale (2007). The derivation of elevations from storage level, storage level history and a digital elevation model (DEM) that was used is described in Roberts and Hale (2007) and in Roberts et al (2008).

An early version of the vegetation monitoring program is described and baseline data are provided in Roberts and Hale (2008). This was entirely wetland-based. It used variable-length transects, aligned at right angles to the contour: 15 at Winton and Green Swamps, and 6 at Moodie's Swamp (as a control site). This early version was replaced by the current design, given in Roberts et al (2010).

The 2010 monitoring program

As described in Roberts et al (2010), the monitoring program is an unbalanced stratified design, of 61 sites (Table 1.1), with strata being elevation (age), topography, wetland size, and position within wetland. Sites are distributed to cover likely environmental heterogeneity, in substrate and exposure (aspect). A map of the 61 monitoring sites is given below (Figure 1.1). The number of sites was a trade-off between the competing needs of monitoring design, logistics and resources. For a large complex such Winton Wetlands / Mokoan REserve, each site had to serve more than one purpose.

There are five types of sites: A, B, C, D and M. A, B, C and D sites are defined by elevation, which is a surrogate for time elapsed (or age) since being exposed by falling water levels of Lake Mokoan. The elevation for M sites could not be satisfactorily determined by the DEM available at the time, so they are assigned a notional elevation of "<160.5 m AHD", and an approximate age of 1.25 y (treated as 1 y in analyses and presentations).

A, B, and C sites monitor terrestrial vegetation on Slopes. D sites monitor the wetland 'Edge', ie that part of the littoral zone near or at sill level, and are for the main basins (larger wetlands) only. M sites monitor the wetland 'Floor' in large basins and small wetlands, and are deliberately positioned away from the Edge because wetland Edge and wetland Floor typically have different vegetation. Because of the very large size of Green, Winton and Sergeant Swamps, M sites are not central in these three basins but positioned to be accessible on foot. Each site comprised a single unreplicated 10 x 100m plot, aligned parallel to the contour.

Table 1.1: Summary of monitoring program design

	A sites	B sites	C sites	D sites	M sites
Elevation (m AHD)	165.5	164.0	163.5	<161.0	<160.5
Last time inundated	Feb 1991	22nd Mar 2002	14th Mar 2006	6th Mar 2008	29th Dec 2008
Time since exposed (the 2010 baseline)	19 y	8 y	4 y	2 y	1.25y
Landform	Slopes	Slopes	Slopes	Wetland Edge	Wetland Floor
Number of Sites	8	8	8	14	23

Approach

In addition to structure and species composition, a novel ecological grouping system was developed, called Species Ecological Types (SET), for species with similar ecological attributes. This is used to report on vegetation changes, in both aquatic and terrestrial situations. Details are in Methods.

Vegetation data (structure, species composition, SET abundance) was analysed using two approaches. The first, referred to as an *analysis of factors*, tests assumptions of the monitoring program that vegetation will change through time and in response to environmental factors. The second, referred to as an *analysis using empirical groups*, uses groups of samples with similar characteristics and tracks these through time. Details are in Methods.

With only two sampling times, separated by seven years, it is not feasible to identify trends, only temporal contrasts. The chronosequence approach goes part way to mitigating this constraint on interpreting vegetation change.

This Report

This report describes vegetation present in 2017, and interprets the combined 2010 and 2017 survey data to describe differences between the two surveys, and considers changes.

The report is organised as follows:

Section 2. Methods. Description of field conditions, data preparation and analysis.

Section 3. Results: Overview. Description of taxonomic characteristics, species of interest, field observations, and summary of structure, abundance and Species Ecological Types (SET) in 2010 and 2017.

Section 4. Results: Slopes. Role of four factors in vegetation patterns; description of changes in structure, species composition and SET abundance, and trajectory 2010 to 2017; recommendations.

Section 5. Results: Wetlands. Role of six factors in vegetation patterns; description of changes in structure, species composition and SET abundance, and trajectory 2010 to 2017; recommendations.

Section 6. Results: Target species. Regeneration status of Southern Cane Grass and River Red Gum in 2010 and 2017; patterns of change 2010 to 2017, summarised as overall trajectory; summary by location; recommendations.

Section 7. Results: Species and Trends. A summary of changes in wetland and other species from 2010 to 2017, and possible trend in SETs through time.

Section 8. Recommendations Arising. A collection of all recommendations made through the report.

Monitoring Data

A copy of the monitoring data (2010 and 2017), which is the combined 2010 and 2017 data as used in analyses for this report, a copy of the 2010 monitoring report, and of the 2017 monitoring report (2017), with a zip folder of site photographs (autumn 2017) has been provided to the Winton Wetlands Committee.

In addition, the 2017 data and photographs are stored on Biosis archive.

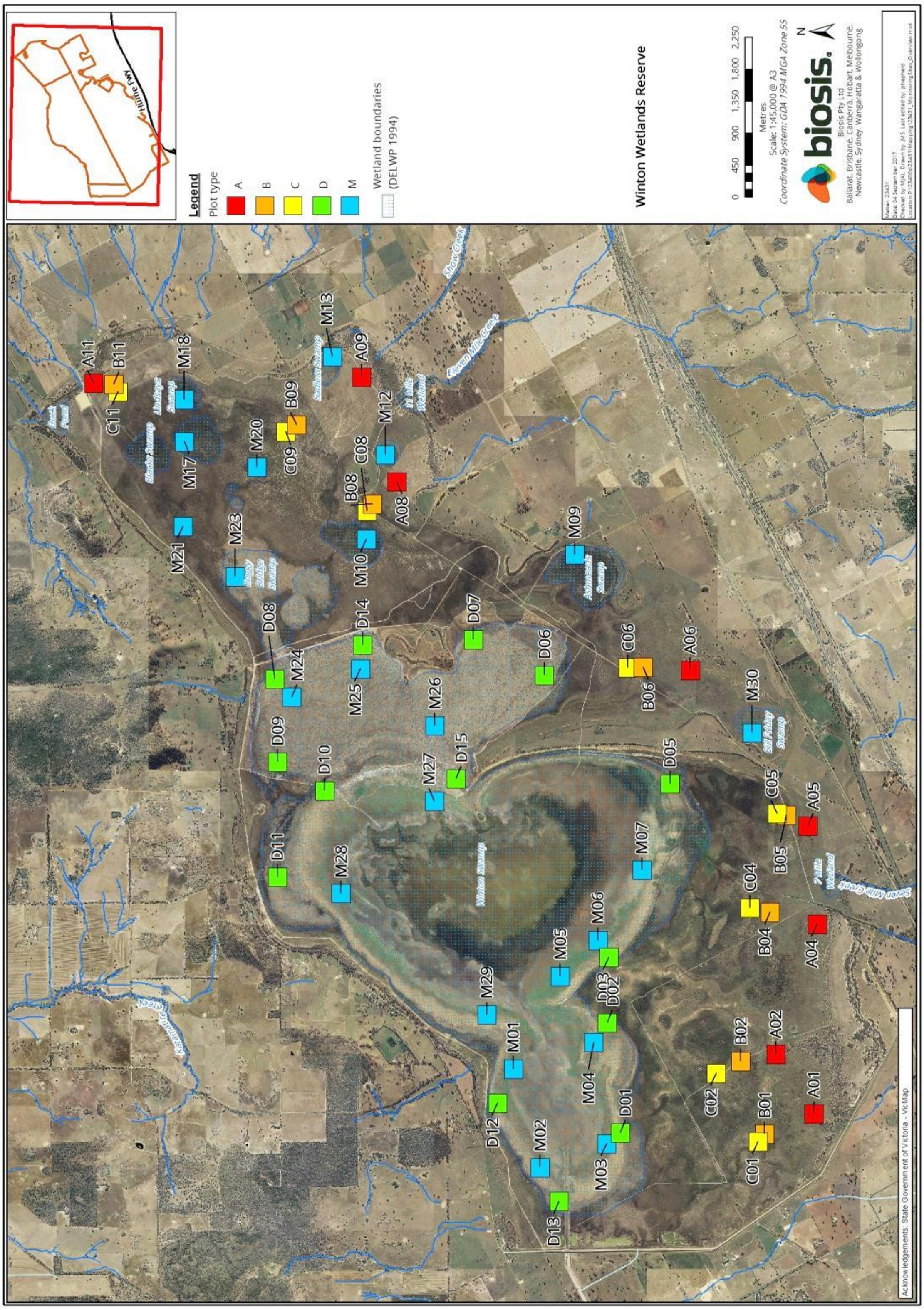


Figure 1.1. Map of 61 vegetation monitoring sites at former Winton Wetlands, scheduled to be re-named Mokoan Reserve

2. METHODS

2.1 Field Conditions for 2010 and 2017 surveys

The first survey was done in autumn 2010, towards the end of the Millennium Drought.

At the time, Winton Wetlands was still officially the Lake Mokoan storage. Water levels in the storage had been receding very gradually during the Millennium Drought, and by April 2009 the storage dried out completely. The main basins then re-flooded (but did not fill) in 2009-2010: drying in autumn 2010 was prevented by heavy rain in March 2010, with 104.8 mm in 4 days recorded at Benalla Airport. This reversed the drying trend in the large wetlands, creating extensive areas of clear shallow water in parts of Winton and Sergeant's Swamps. Run-off and creek in-flow would have inundated the smaller wetlands but there was little evidence of it persisting as the small wetlands were mostly dry when surveyed in 2010 (Roberts et al 2010).

The second survey, in autumn 2017, followed a fairly wet period.

Rainfall in the 12 months prior to the survey was high, with 645.6 mm recorded between April 2016 and March 2017 at Shepparton airport (Station Number 081125, Bureau of Meteorology). Rainfall in September 2016 was twice the monthly average. The following summary was provided by Lance Lloyd, in July 2017.

> *There was a big fill in 2010/2011 of the wetlands which filled the whole site to over 100%, this slowly dried down in 2012 - 2014 and dried completely in Feb 2014. In June/July 2015 there was a fill of the main swamps Winton and Sergeant's and partially of Green Swamp: other wetlands may have received some water but largely all water was gone by November 2015, with drying down proceeding from eastern end (upstream) and Winton being last to dry (being slightly deeper: Sergeant's dried out after Greens and Boggy Bridge.*
>
> *The site started filling around May 2016 with water running down from creeks into east and south, filling Boggy Bridge Swamps and east of there first and then Greens; Winton and Sergeant's took a while but were full by July/August 2016. Boggy Bridge Swamp (and upstream) started drying first and Greens is getting very low now but Sergeants and Winton swamps being about 700mm deep now*.

This summary indicates that all wetlands flooded (and probably also filled) at least twice between the first and second surveys, providing two or more growth and recession phases.

Wetland inundation status in Autumn 2017

At the time of sampling, in autumn 2017, all wetland sites had been flooded and were at various stages of post-flood or recession: some were exposed wetland floor, at various stages of plant colonisation; some were still flooded, but not as deeply as they had been.

The depth and extent (as a percentage) of flooding in each plot was recorded in field notes in autumn 2017, and is summarised below (Table 2.1), using wetland names taken from map in Hamilton et al (2013). Monitoring sites M20 and M10 are assumed to be Unamed C and Unamed E in Hamilton et al (2013).

Out of 37 wetland (D and M) sites, 13 were unflooded, 4 were partly flooded, and 20 were completely flooded. The flooded sites were nearly all in large wetlands (Sergeant's, Winton and Green Swamps) except for one site (M30) in Bill Friday Swamp. Flooding depth and extent in the plots showed a dichotomous pattern: sites were either partly inundated to a shallow depth (20 cm or less) or else were completely flooded and typically much deeper (to 80 cm) (Figure 2.1).

Table 2.1. Inundation status of 37 wetland sites in autumn 2017

Wetland Name	Monitoring Sites	Number of plots per inundatred extent			
		0 % inundated	1-49 % inundated	50-100 % inundatd	Total
Ashmeads	M09	1	0	0	1
Bill Friday	M30	0	1	0	1
Black	M17	1	0	0	1
Boggy Bridge	M23	1	0	0	1
Boggy Bridge North	M21	1	0	0	1
Green	D06, D09, D07, D08, D14 M24, M25, M26	2	2	1 3	8
Humphries	M12	1	0	0	1
Lindsay	M18	1	0	0	1
Sadlers	M13	1	0	0	1
Sergeants	D01, D02, D12, D13 M01, M02, M03, M04	0	0	4 4	8
Unamed C	M20	1	0	0	1
Unamed E	M10	1	0	0	1
Winton	D03, D05, D10, D11, D15 M05, M06, M07, M27, M28, M29,	2	1	4 4	11
TOTALS		13	4	20	37

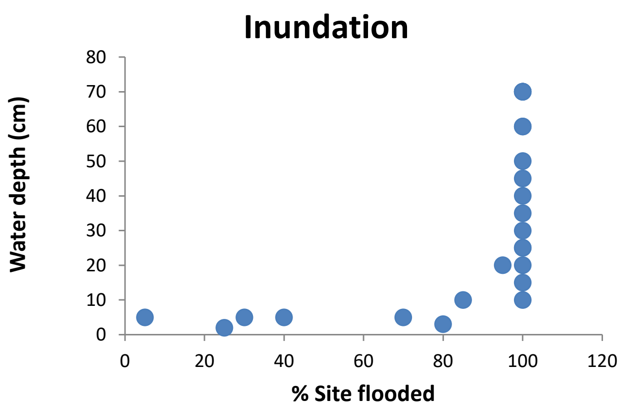


Figure 2.1. Inundation depth and extent for 24 wetland sites in autumn 2017

2.2 Field Survey

All 61 sites were re-located in autumn 2017, and re-surveyed despite water depths of nearly 100 cm in some areas. The field survey was spread over 13 days (not all full days) across an eight-week period starting on 21st March and ending on 30th May 2017. This was longer and later than the first survey, which began on 17th March 2010, and was completed on 31st March 2010, but is nonetheless a good inter-annual match. As shown by the time taken, preparation and field work required a solid time investment. In both surveys, the contractor combined the monitoring project with other commitments in the region.

In 2010, data and field notes were recorded on paper. In 2017, field site locations, data and field notes were loaded and recorded using the ESRI Applications Collector and Survey123 on field tablets. Pre-loading of field sites from the 2010 coordinate set made navigation to field sites relatively simple with the longest walk-ins from a vehicle track being up to 15 minutes, especially for inundated sites. The use of customised electronic forms also made data entry consistent. The customised maps and survey forms were prepared by Biosis and can be made available for future monitoring. The 2017 survey made regular notes on grazing and pugging, and took a geotagged photograph at each site, looking along the centre of the 10 x 100 m plot. Opportunistic photographs were also taken of quadrats and features observed at each monitoring site. Field notes for 2010 make no mention of grazing or pugging.

Future surveys covering all 61 plots and repeating all protocols described below should allow 2 days for data preparation, mapping and field preparation, 10-11 full days in the field, 1 full day for post-fieldwork data curation. Surveys require a 4WD, familiarity or guidance on the track network through the wetland complex, and botanical expertise in temperate grassy ecosystems and wetland flora (Matt Looby, pers. obs.).

Data recorded

As per the 2010 survey, three data sets were recorded as follows:

Structure: Structure as used here means a 3-dimensional record of vegetation present that might possibly influence fauna. Thus for each 5 x 5m quadrat was recorded:

> Cover (%) per layer, for four vegetation layers: upper = taller than 5m, mid = >1m to 5m, lower = 15 cm to 1m, and ground = vegetation <15 cm tall,
> various forms of ground cover: bare, cryptograms (= lichens and mosses), fallen litter (= detached)
> vegetation that could be utilised by fauna, as perches or shelter: standing dead non-woody material, logs and branches >20 cm dbh, standing dead trees >20 cm dbh either in or overhanging the quadrat, and stumps (= dead trees sawn or broken off, up to 1 m tall).

Vegetation layers and overhanging dead trees can overlap, so the sum of all cover variables may (and sometimes did) exceed 100%.

In addition, the 2017 survey recorded cover of rocks per 5x5m quadrat, and extent of flooding (as a percentage of each plot), and estimated average depth of water.

Species composition: The cover (% of 5 x 5 m quadrat) of all live plants was recorded using a pre-loaded master flora species list from the 2010 survey and other sources such as Ecology Australia (2006), Barlow (2011) and a 10 kilometre buffered search from the Victorian Biodiversity Atlas (VBA).

Regeneration of target species: The number of individuals in each age-stage in each 10x100m plot was counted.

Age-stages for Southern Cane Grass are defined by plant habit (see Photo 2:1):

Seedling:	Only stolons, extending over the ground: no erect stems
Young:	Stolons and some erect stems
Established:	Stems erect
Patch:	An established plant covering an area of $5m^2$ or more

Age-stages for River Red Gum are defined by height:

Germinant:	<5 cm tall
Seedling:	5 to 50 cm tall
Juvenile:	>50 to 130 cm tall
Sapling:	>130 to 300 cm tall

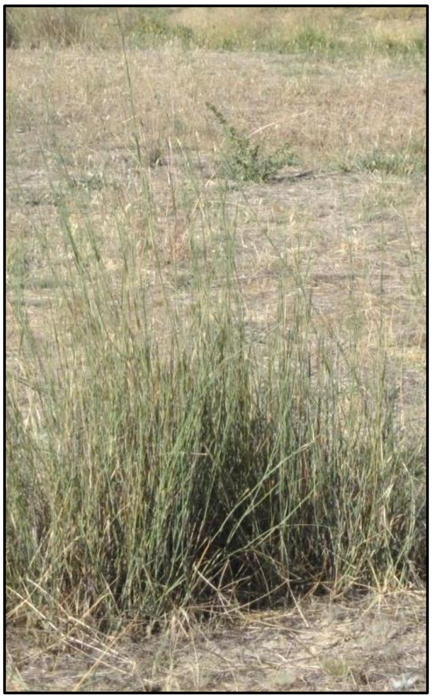


Photo 2.1: Age-stages for Southern Cane Grass. Photos by Jane Roberts

Top: Seedling: stems all prostrate, as runners over the ground. Left: Young: some stems prostrate, some stems erect. Right: Established: stems all erect.

2.3 Data Preparation

Sites are referred to in the text by a letter code and number (eg A08). As there is only one plot at a Site, the terms plot and site are sometimes interchangeable.

Analyses are done at the scale of the plot. For abundance as cover, species abundance is the average of the three subsamples. Each plot site ID (eg A08) with survey year (s10, s17) giving a six-character alphanumeric label (eg A08s10 or C11s17). This six alphanumeric is a unique identifier, and is how the data are stored in the spreadsheet. However for plots and dendrograms, survey year is abbreviated to '10' or '17 rather than 's10' for brevity.

Conventions: Conventions used in this monitoring report

Sample means the data set collected from a particular site at a particular time.

The term 'abundance ' is used in a general sense, and applied to clive cover, numbrs present, counts.

Factors are capitalised, to make then easily recognised, and as an alert to the reader.

Structure

The 2010 survey did not record rocks, extent of flooding or depth of water. In 2017, rocks were recorded at just one site at very low cover (0.2% at Site B04) so were excluded from analysis. Extent of flooding and depth of flooding were treated as zero for 2010 survey.

Inundation complicated the analysis and interpretation of wetland sites. In deep water, when the plot is submerged, the cover of submerged structural variables could not readily be estimated, so were scored as zero. Extent and depth of flooding are therefore considered as explanatory variables, and flooding depth is included as a factor in the analysis of factors.

Species

Plant species were identified to species level in the field, or were this was not possible they were given a field name, collected and later identified to genus or species level. Taxonomic nomenclature for the 2017 survey follows the VBA standard set by the Department of Environment, Land, Water and Planning (Victoria).

For analysis, 'monggg' and dicggg' were added to the species list to cover unidentified monocot seedlings, and unidentified dicot seedlings. Four records, recorded once and identified to genus only, were assigned to a species based on distribution within the study area (Winton Wetlands, Mokoan Reserve): thus *Austrostipa* sp. was assigned to *Austrostipa scabra subsp. falcata*, *Cheilanthes* sp. to *Cheilanthes austrotenuifolia*, *Lactuca* sp. to *Lactuca saligna*, and *Sonchus* sp. to *Sonchus oleraceus*.

In the text, plants are referred down to level of species only. Full names to subspecies level or variety are given in the complete List of species (Appendix 2).

Species Ecological Types (SET)

A system of Species Ecological Types (SET) was developed for this project, based on three attributes for which information is readily available: growth form, origin, and longevity. Information on each attribute was taken from the web version of Flora of Victoria, and from PlantNet, the web version of Flora of New South Wales. Attributes such as growth form and longevity were simplified, and resulted in the following:

Longevity: 2 categories. Shorter-lived (for species described as annual, annual/biennial, biennial). Longer-lived (for species described as perennial)

Growth form: 5 categories. Fern and liverwort (FL); Graminoid for grasses, sedges, rushes (GR); Herb, including species described as subshrubs (HB); Shrub (S); Tree (T).

Origin: 2 categories. Native; Introduced, for species described as introduced or naturalised.

The three attributes were combined to give a single ecological type. The total number of types possible is 16, which is less than the maximum combination of three attributes (2 x 5 x 2), because two attribute combinations do not exist (e.g. short-lived shrubs, short-lived trees).

This analysis uses 14 SETS (Table 2.2), comprising thirteen combinations and one for species with incomplete, uncertain information or uncertain identification. The floating fern *Azolla filiculoides* is treated as shorter-lived, to parallel the liverwort *Ricciocarpus natans*.

Each species was assigned to a SET. The floristics data was then re-compiled to give the number of species and sum of their covers for each plot. SET species richness means the number of species per SET for a particular array of plots. SET abundance means the total %cover of all species in that SET.

Table 2.2. Species Ecological Types (SETs)

SET	Code	Code in full
1	FL_long_native	Ferns or liverworts, long-lived, Australian
2	FL_short_native	Ferns or liverworts, short-lived, Australian
3	GR_long_native	Graminoid, long-lived, Australian
4	GR_long_intro	Graminoid, long-lived, introduced
5	GR_short_native	Graminoid, short-lived, Australian
6	GR_short_intro	Graminoid, short-lived, introduced
7	HB_long_native	Herb, long-lived, Australian
8	HB_long_intro	Herb, long-lived, introduced
9	HB_short_native	Herb, short-lived, Australian
10	HB_short_intro	Herb, short-lived, introduced
11	SB_long_native	Shrub, long-lived, Australian
12	SB_long_introduced	Shrub, long-lived, introduced
13	TR_long_native	Tree, long-lived, Australian
14	Uncertain	

Merging 2010 and 2017 data sets

Species names for 2010 survey were updated to be consistent with 2017 survey. In all cases, this was straightforward, simply a matter of revision, with no splitting or lumping. Data sets were merged manuallyor via the VLOOKUP function in Excel.

2.4 Analysis

There are three lots of analyses, done using different parts of the data set, as described below:

[i] Structure, Floristics and SET (Slopes sites reported in Section 4, Wetland sites in Section 5)
[ii] Regeneration of Target Species (reported in Section 6)
[iii] Species and Trends (reported in Section 7).

Multi-variate analyses (clustering, ordination) were done using routines in PRIMER v7 (Clarke and Gorley 2015); one-way analysis of variance and significance tests were done using MiniTab 18.1. Data were prepared, manipulated and plotted on spreadsheets in Excel.

Significance levels used for Global R, the test statistic in ANOSIM analyses, were: 0.1% = Significant, 0.2% = marginally significant, and >0.2% = Not Significant (NS)

Significance levels used for F ratio and p values in 1-way ANOVA, were: <0.001 = highly significant (***); <0.01-0.001 = significant (**), <0.2-0.1 = significant (*), <0.5-0.2 = marginally significant, and >=0.5 = not significant (NS).

Structure, Floristics, and SET

Structure, species composition and SET abundance data were analysed separately using the same methods. Slopes (24 sites) were analysed separately from Wetlands (37 sites).

Data analysis is in two stages. The first, *Analysis using Factors*, tests if any of a number of factors (equivalent to *a priori* assumptions) can account for variations between samples. Factors (explained below) are chosen to determine if the vegetation is changed through time (Survey) or in response to other environmental variables (EMU, Depth, ExtentFLD) and to test assumptions implicit in the design (Site, SinceDD). The second, *Analysis using empirical groupings*, makes no *a priori* assumptions about influences on the data.

Analysis using Factors

Analysis of Slopes samples uses four factors (Survey, Site, SinceDD, EMU) and analysis of Wetland samples uses six factors (the additional two being Depth and ExtentFLD). Each factor has various levels.

- **Survey** has two levels (2010 and 2017) for the two surveys separated by seven years.
- **Site** has five levels (A, B, C, D and M), defined by elevation and corresponding to different topographic positions (Table 1.1). Analysis for Slopes uses three levels (Sites A, B, and C) and analysis for Wetlands uses two levels (Sites D and M).
- **SinceDD** has six levels for Slopes analysis (4y, 8y, 11y, 15y, 19y, and 26y), and four levels for Wetlands analysis (1y, 2y, 7y and 9y). This tests the assumption that vegetation characteristics develop through time.
- **EMU,** an abbreviation for Ecological Management Unit, is a surrogate for edaphic, topographic, and land use heterogeneity. Eight EMU were proposed by Barlow (2011) but only five have monitoring sites: Southern Plains (SP), Eastern Rises (ER), North Eastern Swamps (NE), Sergeants and Winton Swamps (SW), and Green Swamp (GS). Analyses for Slopes use three levels (SP, ER and NE) and four (WS, NE, GS, ER) for Wetlands.
- **Depth** has three levels (none, shallow, and deep). None means 0 cm, shallow means 5 to 30 cm, and deep means >30 cm to 70 cm.
- **ExtentFLD** has three levels (none, some, and most). None means 0% of site is covered by water, some means 1 to 50%, and most means >50% to 100%.

Each level in the factors Survey, Site and SinceDD have equal sample sizes (24, 16, and 8 respectively), but sample sizes are uneven for the other factors. For EMU on Slopes, sample sizes are ER = 18, NE = 6, SP = 24, and for Wetlands are ER = 8, GS = 16, NE = 12 and SW = 38. For ExtentFLD, most -21, some = 3, and none = 30, and for Depth, deep = 9, shallow = 15, and none = 30.

Vegetation data (structure, species and SET) were square root transformed and a resemblance matrix prepared using Bray-Curtis measure of similarity. The likelihood of a factor being significant was first explored, graphically, by overlaying all levels of a factor onto a 2-dimensional plot of nMDS ordination of the resemblance matrix; then tested using the ANOSIM routine, with 999 permutations. A factor was considered significant if the Global R test statistic output by ANOSIM was significant at 0.1% level, and the factor levels that were significantly different were determined using the R-statistic for pairwise comparisons. Where differences were significant, the SIMPER routine was used to determine their average percentage dissimilarity, and which variables (structure, species or SET) were contributing.

Analysis using Empirical Groups

Homogeneous groups of samples were identified based on sample values, with no pre-conceptions, using SIMPROF ("similarity profiles") routine. This tests for evidence of structure (ie of heterogeneity) using permutations of randomised data and compares the resulting similarity profile with actual data (Clarke and Gorley 2015). The homogeneous groups are referred to as clusters in this report, and labelled 'clust 5%' in diagrams.

Cluster analysis was used in conjunction with the SIMPROF routine to show the configuration of clusters. For this, vegetation data (structure, species, SET) were square root transformed, a resemblance matrix constructed using the Bray-Curtis measure of similarity, and clusters formed using group average linkage. The SIMPROF routine determines the number and sample composition of each cluster, using 999 permutations of randomised data, and tests each cluster for evidence of heterogeneity, with significance level set to 5%. This procedure avoids the arbitrary definition of clusters that results from drawing a line across a dendrogram.

Individual clusters were characterised using time and locations (Survey, Site) and inundation status (wetlands only), and also characterised based on vegetation attributes. The first characterisation was used to make a qualitative appraisal of the importance of time (ie Survey) in vegetation change.

The change in structure, species composition and SET abundances between 2010 and 2017 was described for each site using the Bray-Curtis measure of similarity (between the two surveys) and by comparing its 2010 cluster to its 2017 cluster. Sites were compiled by location, and the resulting tabulation for Slopes (Sites A, B and C), and for Wetlands (Edge of large wetlands, Floor of large wetlands and small wetlands) used to describe spatial variations in vegetation changes.

Finally, the extent and magnitude of vegetation change was explored using the clusters and a cluster transition matrix. Patterns of change were interpreted based on the number of pathways, patterns of convergence and divergence, and instances of stability. The magnitude of change for each cluster transition was quantified using the dissimilarity between cluster pairs, estimated as part of the SIMPER routine, and presented with the following colour-coding: average dissimilarity coloured red (40 to 59% dissimilar), yellow-brown (60 to 79% dissimilar), or green (80 to 100%).

Regeneration of Target Species

The regeneration status of Southern Cane Grass and River Red Gum is described using counts per age-stage for each species. These counts were for the 10m x 100m monitoring plot at each site, in 2010 and 2017. Slopes and Wetlands sites were analysed together.

For Southern Cane Grass, changes were explored using three approaches. The first was descriptive, and used counts to describe spatial changes (site incidence), changes in abundance (total count per plot), age-stage profile (counts per age-stage or age structure), and details about Seedling stage (numbers, occurrence). The second used groups of statistically-similar plots ("clusters") and a cluster transition matrix, as described above for Structure, Species Composiiton, and SET. For this, count data were standardised by age-stage, then samples were square-root transformed. Samples with no Southern Cane Grass present were excluded from analyses in Primer 7, but were re-introduced as a cluster (of absences) in order to complete the transition matrix. The third approach used abundance data (mean percentage cover) for each plot to give an overall summary of change across all sites. For this, survey in 2017 and 2010 were compared, as a ratio (abundance in 2017 / abundance in 2010), and the ratio interpreted as follows:

COL (= colonisation, recruitment) if abundance is 0% in 2010, and more than 0% in 2017;
INC (= increase) if abundance is higher in 2017 than 2010, and the ratio for 2017/2010 is >=1.20;
NC (= no change) if the abundance ratio lies between 0.8 and 1.2;
DEC (= decrease) if abundance is lower in 2017 than 2010, and the abundance ratio is <0.8;
LOSS (=Loss) if abundance falls to 0% in 2017;
Zero (=zero) if abundance is zero in 2010 and zero in 2017.

The number of sites per change category is used to infer demographic dynamics on Slopes and Wetlands. The definition of No change as an abundance ratio of 0.8-1.2 was a qualitative means of ensuring small changes did pr even field errors did not get tallied as major population dynamic.

For River Red Gum, analyses were limited to descriptions based on counts and abundance (% cover).

Species and Trends

Individual Species

The dynamics of six species were described using incidence and mean abundance per survey for six locations: three locations on Slopes (A, B, C), and three locations in Wetlands (D sites or Edge of large wetlands; Floor of large wetlands; Floor of small wetlands). Species were selected to cover specific points of interest and management issues.

Trends in SETs

Space-for-time substitution was used to describe changes in the abundance of individual SETs on Slopes sites. First, plots of mean % cover for 4y, 8y, 11y, 15y, 19y and 26y (six levels of factor SinceDD) were used to show (graphically) general trends. One-way Analysis of variance was used to test for differences between levels, and pair-wise comparisons was done using Fishers LSD method. Data were not transformed as variances were not heterogeneous (Barlett's test, Levene's test).

2.5 Archive

Copies of plot information and field data from 2010 and 2017 were provided to Winton Wetlands Committee of Management via Lance Lloyd, on 31st August 2019.

A description of the data files supplied is given in Appendix 1.

3. RESULTS: OVERVIEW

3.1. General Information

Taxonomic Perspective

The two surveys (2010 and 2017) recorded 159 species in 42 families, with another 17 taxa not identified to species level. Of these, 103 species are native.

Very few families were species-rich (Figure 3.1). The two richest families were Poaceae (grasses) with 46 species, and Asteraceae (daisies) with 36 species. Other families that were relatively species-rich were Cyperaceae (sedges) with 12 species, Polygonaceae (knotweeds and docks) with 9 species, Fabaceae (pea and clovers) with 8 species, and Juncaceae (rushes) with 6 species. Collectively these 6 families account for 66% of all species.

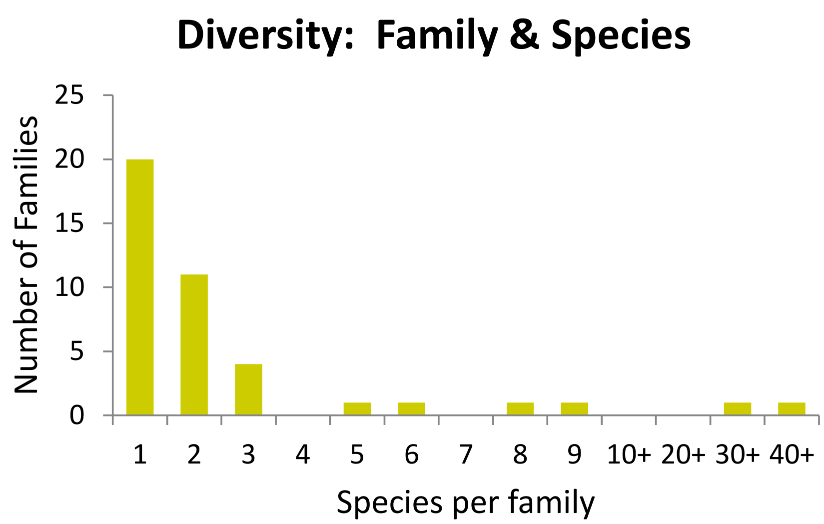


Figure 3.1. Taxonomic diversity of species recorded in autumn 2010 and 2017

Most of the species had seed traits well-suited for wind dispersal, and longer distances (eg Vittoz and Engler 2007). Almost all species had small dry fruits, such as *capsules* and *schizocarps* that split open to release seeds, or *cypselas* often with pappus, or seeds that were generally small, with some even being described as 'minute'. Only three species had fruits with characteristics conventionally considered as adaptations for animal-dispersal - hooks in the case of *Xanthium spinosum*, and fleshy fruit in the cases of *Rosa rubiginosum* and *Solanum nigrum* – and these species were recorded infrequently (1, 1 and 7 times respectively).

Two species of conservation interest are Floodplain Fireweed *Senecio campylocarpus* and Branching Groundsel *Senecio cunninghamii var. cunninghamii*, both listed as 'r' (rare) under VROTS (a government listing of species classified as vulnerable, rare or threatened, in Victoria). These species were recorded in both surveys, seven years apart, but with differing frequencies. Branching Groundsel was recorded at two sites in 2017 (Sites C02 and C06) and at two sites in 2010 (C02 and C05), both in the Southern Plains EMU. Floodplain Fireweed was recorded at one site on the edge of Sergeants Swamp in 2017 (D02) but from 16 sites in 2010: four around Sergeants Swamp (including D02), five dryland sites on the Southern Plains EMU, two dryland sites in the northern part of Eastern Rises EMU and three small wetlands (Humphries, Sadlers, and Bill Friday).

An unexpected record for 2017 was an orchid *Microtis unifolia*, recorded at two sites (C04, B09) in Southern Plains.

Species Turnover

The general pattern of floristics described above was similar in both surveys. The 2017 survey recorded 140 taxa in 37 families, of which 80 (57.1%) were native, compared with 121 taxa in 33 families in 2010, of which 74 (61.2%) were native. In 2017, the six species-rich families comprised 51 species that were native (36.4%) and 54 that were long-lived (38.6%); in 2010, the same six families comprised 46 species that were native (38%) and 53 that were long-lived (43.8%).

However, this similarity in family profile, nativeness and longevity masks considerable species turnover between 2010 and 2017, with 37 taxa (31% of 2010 total) from 2010 not being re-recorded in 2017, and 55 taxa (39% of 2017 total) being new records in 2017.

The 37 taxa that were not re-recorded came from 19 families, but mostly from Asteraceae (8 taxa) and Poaceae (7 taxa). Most were incidental records, from just one or two sites, however eight occurred frequently, and were recorded at 5 to 26 sites: *Wahlenbergia ?multicaulis* at 26 sites, *Paspalum distichum* at 17 sites, *Erodium criniticum* at 7 sites, *Pseudoraphis spinescens* at 6 sites, and *Cassinia aculeata*, *Gamochaeta americana*, *Vittadinia gracilis* and *Digitaria sanguinalis* all at 5 sites. All eight are distinctive and straightforward to identify, making it likely that their apparent absence in 2017 is due to an undetermined mix of genuine change and re-randomisation of quadrats within each plot.

The 55 taxa that were recorded for the first time in 2017 were from 23 families, mostly Poaceae (17 taxa) with some Asteraceae (5), Cyperaceae (5), and Fabaceae (4). Although many (22 or 40%) were recorded from just one site, thirteen were recorded at 5 or more sites: *Briza minor* at 25 sites, *Lotus subbiflorus* and *Juncus bufonius* at 18 sites, *Bromus hordeaceus* at 17 sites, *Trifolium subterraneum* at 16 sites, *Romulea rosea* and *Ricciocarpus natans* at 11 sites, *Azolla filiculoides*, *Erodium botrys* and *Vulpia spp* at 9 sites, *Eleocharis pusilla* at 8 sites, *Typha orientalis* at 6 sites, and *Mentha pulegium* at 5 sites. Some of these new records are likely to be in response to wetter conditions (eg *Briza minor*) and some are aquatic plants responding to flooding (eg *Ricciocarpus natans, Azolla filiculoides).*

Species Ecological Types (SET)

The fourteen SETs are listed below, showing their family and species richness, and giving several species as examples (Table 3.1). 'Species' is applied strictly here, and excludes taxa identified to genus level only.

The three most species-rich SET across both surveys is the longer-lived native graminoids (SET 3) with 36 species, mainly in Poaceae, Cyperaceae and Juncaceae; longer-lived native herbs (SET 7), the most diverse SET, with 20 families and 32 species; and shorter-lived introduced herbs (SET 10) with 11 families and 30 species, with slightly more than half (17 species) being in family Asteraceae. The two fern and liverwort SETs (1 and 2) and the three woody SETs (11, 12 and 13) are species-poor.

Table 3.1. Fourteen SETs, with family and species richness

	Code	Number of		Examples
		Families	Species	
1	FL_long_native	1	2	*Cheilanthes austrotenuifolia*
2	FL_short_native	2	2	*Ricciocarpus natans, Azolla filiculoides*
3	GR_long_native	4	36	*Amphibromus nervosus, Chloris truncata, Eleocharis acuta, Eragrostis infecunda, Juncus semisolidus, Rytidospermum uttonianum, Walwhalleya proluta, Typha orientalis*
4	GR_long_intro	2	9	*Cynodon dactylon, Cyperus eragrostis, Paspalum distichum, Phalaris aquatica*

	Code	Number of		Examples
		Families	Species	
5	GR_short_native	3	4	*Juncus bufonius, Eragrostis parvifolia, Lachnagrostis filiformis*
6	GR_short_intro	2	14	*Avena barbata, Briza minor, Isolepsis marginata, Lolium rigidum, Vulpia bromoides*
7	HB_long_native	20	32	*Alternanthera denticulata, Centipeda cunninghamii, Euchiton involucratus, Persicaria prostrata, Epilobium hirtigerum, Myriophyllum verrucosum, Oxalis perennans*
8	HB_long_intro	6	13	*Aster subulatus, Hypochaeris radicata, Mentha pulegium, Rumex crispus*
9	HB_short_native	8	12	*Euchiton sphaericus, Dysphania glomulifera, Lythrum hyssopifolia, Glinus lotoides, Polygonum plebeium*
10	HB_short_intro	11	30	*Cirsium vulgare, Lactuca saligna, Rorippa palustris, Trifolium subterraneum, Erodium botrys, Polygonum aviculare*
11	SB_long_native	2	3	*Cassinia arcuata, Calytrix tetragona*
12	SB_long_inroduced	1	1	*Rosa rubiginosa*
13	TR_long_native	2	2	*Eucalyptus camaldulensis, Acacia sp.*
14	Unknown		6	"monggg" (= unidentified monocot seedlings), Iridaceae

Synthesis

The flora occurring in the 61 sites is predominantly non-woody dryland and wetland species that have self-established through wind or water dispersal since being exposed by falling water level. The 177 taxa recorded to date from the monitoring sites are not a comprehensive list of all plant species at this wetland complex (see also Ecology Australia 2006, Davidson and Mann 2010, Hamilton Environmental Services 2013) but are probably a reliable indication (rather than a structured representation) of taxonomic and ecological characteristics of plant species present.

Previous projects and investigations have recorded a larger number of rare and threatened species, including three that are nationally listed (Ecology Australia 2006), several that are regionally depleted (Davidson and Mann 2010), and larger number of plant records (252) for the Lake Mokoan area between 1968-2008 (Ecology Australia 2006).

The two species recognised as rare in Victoria have both self-established and appear to have different trajectories, following drawdown of Lake Mokoan. Floodplain Fireweed *Senecio campylocarpus* was initially frequent, but appears to have undergone a contraction: it was recorded at four localities in January 2006 (Ecology Australia 2006), and 16 sites in March-April 2010, but only one site in March-April 2017. Branching Groundsel *Senecio cunninghamii var. cunninghamii* appears to have established later than Floodplain Fireweed, and at only a few localities. It was not recorded in January 2006 (Ecology Australia 2006) or September-October 2010 (Davidson and Mann 2010) but was present at two sites in March-April 2010 and appears to have persisted at one site, at least.

3.2 Field Observations

Grazing

Observations made in autumn 2017 (Table 3.2) indicate the presence of native herbivores (kangaroos) and livestock (cattle, sheep) at 16 out of 61 monitoring sites. Field observations from the first survey make no mention of grazing effects, or livestock presence.

Table 3.2. Observations from autumn 2017 related to grazing

Site	Observation
A01	Grazed by sheep
A02	Grassland with some Cassinia grazed
A05	Phalaris and Cassinia grazed
A06	Heavy kangaroo grazing, high weed invasion, Cassinia recruitment
A08	Recent cattle grazing
A09	Currently gazed by cattle
B04	Seasonally damp with Phalaris, cane grass and eucs to 8 m tall, grazed
B05	Phalaris dominated and grazed
B06	Kangaroo disturbance, Cassinia recruitment
B09	Grazed
B11	Grazed and pugged
C02	Lots Cassinia regen and kangaroo grazing
C05	Phalaris Cassinia grazed
C09	Recent grazing
C11	Temp fence has excluded cattle from last third of transect (ie plot). Sig difference in grazing levels
M13	Heavily grazed and pugged.

All sites (Table 3.2) were on Slopes, except for one (M13), which was quite deeply but not extensively pugged when visited (Photograph 3.1). There was no indication that rabbits or deer were active at any sites.

Fire

No information is available on recent fires in Winton Wetlands Reserve, and field notes from 2017 survey make no observations of recent fire, therefore it is assumed none of the sites was burnt between 2010 and 2017. In autumn 2010, seven sites had been recently burnt (D06, D07, D08, D09, D15, M24 and M25), all in Green Swamp. A satellite image showing extent of this burn is given in Figure 3 of Roberts et al (2010).

Sedimentation

Two years before the first survey, areas with deep (to 30 cm), soft and poorly consolidated, often reddish sediment were noted, particularly around Green Swamp (see Figure 20 in Roberts et al 2008). It was assumed that this sediment had been eroded by wave action when Winton Wetlands was still a storage, from exposed areas such as the northern shoreline of Winton Swamp and the western side of The Spit (see Figure 19 in Roberts et al 2009) and then deposited in the relative shelter of Green Swamp, on the eastern side of The Spit.

In terms of plant regeneration, this sediment provides a type of substrate that is quite different from the cracking grey clay at most wetland sites, and almost certainly devoid of viable propagules within it.

In autumn 2010, field notes from the first survey recorded sediment at seven sites in Green Swamp (D06, D07, D08, D09, D14, M24 and M25) as well as in some smaller wetlands (M09, M17, M18 and M20) and larger basins (D02, D03). Sediment deposits were not recorded in the second survey.

Photograph 3.1. Early morning at site M13 on 30th March 2017. Photo by Biosis

3.3 Comparison 2010 and 2017

This section summarises structural attributes, species composition and SET composition for 2010 and 2017 samples. Slopes and wetland samples are presented separately.

Vegetation Structure

Slopes

Mean (SE) cover and incidence (number of sites where recorded) for structure for 2010 and 2017 samples for Slopes sites (n = 24) are summarised below (Table 3.2) and shown in Figure 3.2. Terms were explained in Section 2.2.

Table 3.2. Structural attributes for 2010 and 2017 samples for 24 Slopes sites

	Vegetation Layers (cover %)				Other cover (%)				Features		
	Upper	Mid	Lower	Ground	Bare	Crypto -grams	Litter	St. Dead	Logs	Dead Trees	Stumps
2010 Mean	0.17	0.78	32.1	22.9	15.2	5.59	20.8	7.3	0.06	0.02	0

	Vegetation Layers (cover %)				Other cover (%)				Features		
	Upper	Mid	Lower	Ground	Bare	Crypto-grams	Litter	St. Dead	Logs	Dead Trees	Stumps
(SE)	(0.17)	(0.39)	(1.90)	(2.27)	(1.83)	(1.30)	(1.17)	(0.85)	(0.04)	(0.02)	
Incidence	1	6	24	24	24	20	24	24	2	1	0
2017 Mean (SE)	0.21 (0.21)	2.8 (0.39)	23.8 (2.64)	24.1 (2.91)	25.3 (1.89)	2.6 (0.41)	13.2 (0.97)	14.6 (0.68)	0.06 (0.04)	0.04 (0.04)	0.14 (0.14)
Incidence	1	13	24	24	24	24	24	24	3	1	1

Vegetation height is broadly similar in 2010 and 2017. Most of the sites have vegetation 1m tall or less (lower + ground layers = 55% of sites in 2010, and 48% in 2017), with very few that are taller than 1m. Only one of the 24 sites (A11 in both surveys) has an upper layer (>5m). The number of sites with a mid layer doubles from 6 in 2010 to 13 in 2017. This increased occurrence, combined with a very high cover at one site (29% at C02), results in the mid layer for 2017 being considerably higher, relative to 2010. At all other sites, mid layer cover ranges from 0.2% to 11.8%.

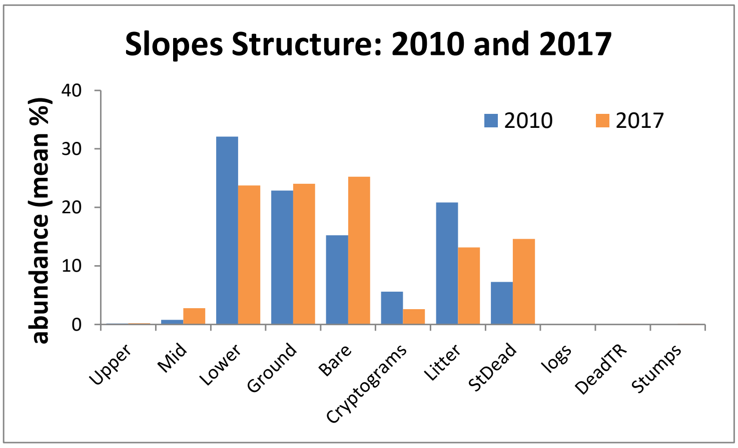


Figure 3.2. Structure at Slopes sites: abundance of 11 variables

Features that increase habitat heterogeneity for fauna, such as logs (meaning logs or fallen branches more than 20 cm dbh) and dead trees (more than 20 cm dbh), occur very infrequently and have low cover. Logs are in 2 and 3 sites only in 2010 and 2017 (including A11 in both surveys), and dead trees at only one site (C08 in both years). Stumps and boles to 1m tall were recorded only in 2017.

There is a marked contrast between 2010 and 2017 in the distribution of litter and standing dead, collectively dead material. In 2010, towards the end of the Millennium Drought after years of poor growing conditions, most of the dead material is present as fallen litter rather than as standing dead (29.8% and 7.3%), whereas in autumn 2017 after good growing conditions in preceding spring-summer, dead material is present in fairly equal amounts of standing dead and fallen litter (14.6% and 13.2%). Standing dead and fallen litter can be interpreted as different age classes of dead material, with fallen litter being older and standing dead being more recent. In 2010, fallen litter acted as a protective cover under which cryptograms were observed.

Wetlands

Mean (SE) for cover of 11 structural attributes for 2010 and 2017 samples for Wetland sites (n=37) sites are summarised below (Table 3.3) and plotted in Figure 3.3. Extent of flooding is included, and upper layer (zero cover in both surveys) is excluded, due to space constraints. Terms were explained in Section 2.2.

Table 3.3. Structural attributes for 2010 and 2017 samples for 37 Wetland sites

	Cover (%)	Vegetation Layers			Other Cover (%)				Features		
	Flood Extent	Mid	Lower	Ground	Bare	Crypto-grams	Litter	St. Dead	Logs	Dead Trees	Stumps
2010 Mean (SE)	0	1.6 (0.57)	22.8 (2.66)	8.7 (1.51)	31.3 (5.26)	6.4 (3.02)	31.2 (4.37)	8.1 (1.15)	0.85 (0.18)	0.19 (0.06)	0.07 (0.03)
Incid-ence	0	13	34	36	35	11	37	37	22	11	5
2017 Mean (SE)	54.9 (7.72)	0	13.2 (2.17)	13.3 (2.19)	13.2 (2.18)	0.6 (0.10)	5.5 (0.90)	4.1 (0.68)	1.5 (0.24)	0.54 (0.09)	0.24 (0.04)
Incid-ence	24	0	34	23	20	16	22	37	26	23	20

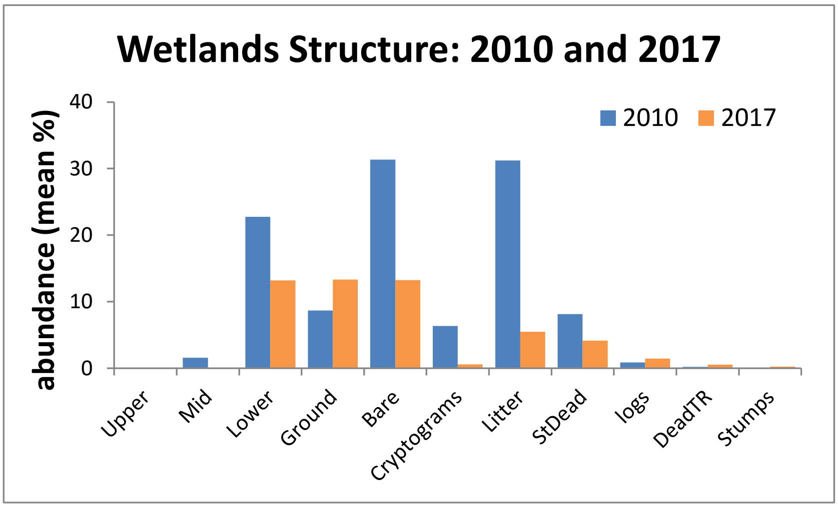


Figure 3.3. Structure at Wetland sites: abundance of 11 variables

Unlike Slopes samples, only two structure variables were recorded at all sites: litter and standing dead in 2010, and standing dead in 2017. The incidence of features such as logs, dead trees and stumps is much higher than for Slopes sites, and tends to be higher in 2017 samples than 2010 samples.

Vegetation height was shorter in 2017 due to having no mid layer and a much reduced lower layer (Table 3.3). Both vegetation (mid + lower + ground layers) and dead material (fallen litter + standing dead) are higher in 2010 samples: 33.1% compared with 26.5% for vegetation, and 39.3% compared with 9.6% for dead material.

Differences between 2010 and 2017, such as lower cover, cannot be solely attributed to a lapse of seven years, as on-site conditions are also relevant. In 2017 sampling was done after recent and extensive spring-summer inundation. At the time of sampling, 24 out of 37 wetland sites were still flooded, and 7 of these were under more than 50 cm water (Table 2.1, Figure 2.1). Inundation and water movement is assumed to have had a number of effects on vegetation such as: accelerating mechanical breakdown; flushing out litter; accelerating decomposition of submerged litter and standing dead material; causing stress and mortality, especially in terrestrial plants, due to submergence and water-logging. Recession has exposed mudflats, some of which have remained bare, and some of which have been extensively covered by seedlings.

Photographs below illustrate different stages of inundation and recession in relation to vegetation at wetland sites (Photographs 3.2).

Photographs 3.2: Inundation and recession

Top Left: Inundated (more than 50 cm): mainly tall emergent wetland plants recorded. Top Centre: Water levels receding. Top Right: Water level has recently receded, no germination yet evident on exposed mudflats. Bottom Left: Post-recession: wetland plants stranded on mudflats. Bottom Centre: Post recession: extensive near mono-specific cover of young plants. Bottom Right: Post recession: dense cover becoming taller.

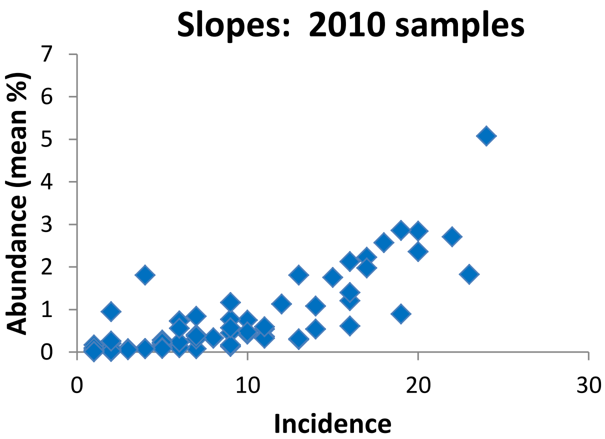
All photographs taken during field survey in March-April-May 2017 by Biosis.

Species Composition

Slopes

A total of 94 species occurred in 2010 samples, and 119 species in 2017 samples. The relationship between species abundance and incidence was similar in both surveys, and followed the expected pattern of many species with low abundance and low incidence, and fewer species with high abundance and high incidence (Figure 3.4). The proportion of species with very low abundance, taken here as having a mean of 0.1% or less for 24 samples, was 40% for 2010 samples, and 50% for 2017 samples. Species with such low abundances are important for ecological diversity but contribute little to the analyses of spatial and temporal pattern described in Section 4.

The relationship between incidence and abundance is noisy, and part of this variability can be attributed to growth form. For example: two species with abundances higher than general trend for 2010, *Avena barbata* and *Rytidosperma fulvum* (4 occurrences with 1.7% abundance; 2 occurrences with 1.0% abundance respectively) are both erect grasses; two species with abundances lower than the general trend in 2017 are *Persicaria prostrata* and *Juncus bufonius* (21 occurrences, only 0.6% abundance; 18 occurrences, only 0.3% abundance), which are both low-growing or short.



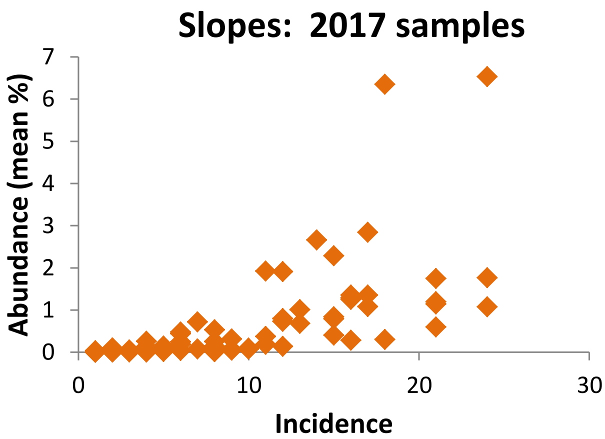


Figure 3.4. Incidence and abundance in 2010 and 2017 Slopes samples

Species abundance is summarised below (Table 3.4). In 2010, total abundance per sample (sum of all plant species present) averaged 55.7%, and species richness per sample averaged 28.9: in 2017, total abundance was slightly lower (50.9%) and species richness slightly higher (32.6).

The ten most abundant species per survey was nearly completely different in 2017 compared with 2010, with the exception of *Hypochaeris radicata* which topped the list in both surveys (Table 3.4). *Hypochaeris radicata*, commonly known as Flatweed, is an introduced herb (Asteraceae), and one of the most widely distributed species in Victoria. It had the highest incidence of any species recorded in the monitoring program, being the only species recorded in all 24 samples in 2010; and in 2017, it was one of three species recorded in all 24 samples, the others being *Briza minor* and *Lythrum hyssopifolia*. As shown by the scatter plots above (Figure 3.4), abundance tends to be a function of incidence, hence most of these ten species occur frequently in samples, although they were not necessarily the most frequently recorded species. In both surveys, the ten most abundant species comprised a mix of grasses and herbs, annuals and perennials, and native and introduced species, however the 2017 list was distinctive in having more grass species (six instead of four), only one native herb, and included a native shrub *Cassinia arcuata*.

Table 3.4. Species composition for 2010 and 2017 samples for 24 Slopes sites

	2010			2017		
Total Abundance per sample						
	Mean (SE)	55.7% (2.21)		Mean (SE)	50.9% (2.03)	
	Range	38-73%		Range	35-68%	
Species Richness per sample						
	Mean (SE)	28.9 (1.05)		Mean SE	32.6 (0.84)	
	Range	20-41 %		Range	27-40	
Rank	Ten most abundant species (for all 24 samples)					
	2010	Mean % (SE)	Inci-dence	2017	Mean % (SE)	Inci-dence
1	*Hypochaeris radicata*	5.1 (0.74)	24	*Hypochaeris radicata*	6.5 (1.24)	24
2	*Cirsium vulgare*	2.9 (0.96)	19	*Phalaris aquatica*	6.5 (1.93)	18
3	*Amphibromus nervosus*	2.8 (0.83)	20	*Eragrostis infecunda*	2.8 (0.91)	17
4	*Cynodon dactylon*	2.7 (0.56)	22	*Cassinia arcuata*	2.7 (1.09)	14
5	*Walwhalleya proluta*	2.6 (0.77)	18	*Rytidosperma duttoniana*	2.3 (0.76)	15
6	*Eragrostis parvifolia*	2.4 (0.56)	20	*Rytidosperma setaceum*	1.9 (0.76)	11
7	*Conyza bonariensis*	2.2 (0.80)	17	*Trifolium subterraneum*	1.9 (0.65)	12
8	*Euchiton sphaericus*	2.1 (0.61)	16	*Lythrum hyssopifolia*	1.8 (0.24)	24
9	*Senecio quadridentatus*	2.0 (0.53)	17	*Chloris truncata*	1.7 (0.32)	21
10	*Persicaria prostrata*	1.8 (0.25)	23	*Bromus hordeaceus*	1.4 (0.38)	17

Wetlands

Despite very different field conditions, the number of species was similar in the two surveys, with 75 in 2010 samples, and 72 in 2017 samples. The number of species was considerably lower than in Slopes samples, despite wetlands having more sites.

The relationship between species abundance and incidence for wetland samples (Figure 3.5) was similar to Slopes samples, however the proportion of species with very low abundances (meaning 0.1% cover or less) was considerably higher: 61.3% for 2010 samples, and 68.1% for 2017 samples. This leaves a relatively small number of species contributing to the analysis of wetland samples in Section 5.

Species with abundances higher than the general trend (Figure 3.5) were *Amphibromus nervosus*, a tall erect grass (four occurrences, 1.7% mean abundance in 2010); species with abundances less than the general trend in 2017 are *Glinus lotoides*, a near prostrate herb (12 occurrences, 0.7% mean abundance), and *Eragrostis infecunda*, a grass that can be erect or spreading depending on its age-stage (13 occurrences, 0.6% mean abundance).

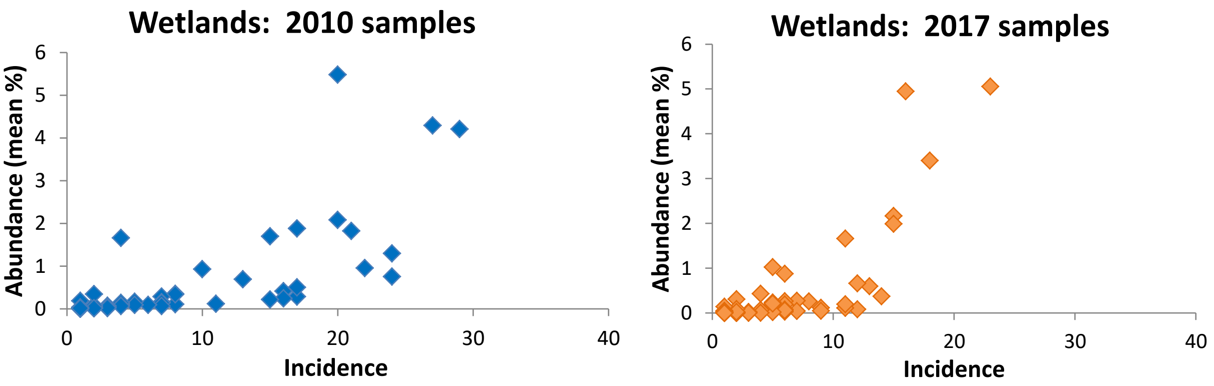


Figure 3.5. Species incidence and abundance in 2010 and 2017 Wetland samples

Abundance and richness for 2010 and 2017 from 37 Wetland sites are summarised below (Table 3.5). The average total abundance per sample was 33.1% in 2010, and 26.5% in 2017: this was considerably lower than in Slopes samples. A fairly high proportion of 2017 samples (15 out of 37) had less than 10% cover (Figure 3.6), including three samples had zero abundance (sites D05, D12 and M07).

There was a strong spatial pattern in the occurrence of low (10% cover and less) and very high abundance (at least 80% cover). All 20 low abundance samples (five from 2010, 15 from 2017) were Edge and Floor sites around the three large wetlands (none from small wetlands), whereas all four very high abundance samples were for small wetlands (sites M13 and M30 in 2010, M17 and M18 in 2017). High abundance is due to diverse wetland plants, mostly native, except for M13 in 2010 which had short-lived, opportunistic herbs, dominated by Spear Thistle *Cirsium vulgare* with 39% cover.

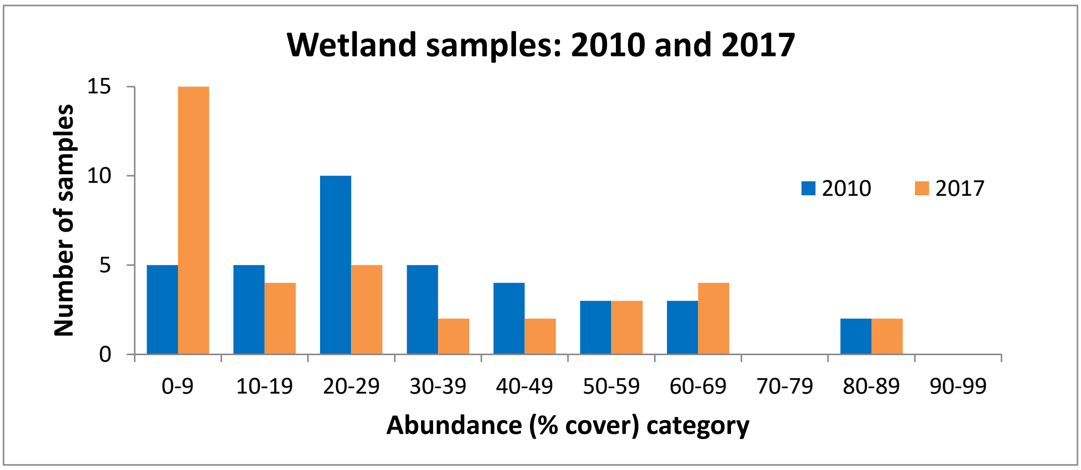


Figure 3.6. Abundance categories for Wetland samples: 2010 and 2017

Despite very different antecedent conditions, the list of ten most abundant species (Table 3.5) was fairly similar in 2010 and 2017, with only moderate differences. Four species were on both lists: *Juncus semisolidus*, *Persicaria lapathifolia, Alternanthera denticulata*, and *Dysphania pumilio*, all native wetland plants. The 2010 list comprised a mix of graminoids and herbs, including four introduced terrestrial herbs *Cirsium vulgare, Lactuca serriola, Conyza bonariensis, Hypochaeris radicata*: these are opportunistic or invasive and commonly occur in wetlands and on floodplains in dry phase. In contrast, the 2017 list comprised only native wetland plants.

Mean abundances (Table 3.5) were slightly lower in 2017 whereas incidences were considerably lower, suggesting where these species did occur, their abundance was quite high.

Table 3.5. Species composition in 2010 and 2017 samples for 37 Wetland sites

Total abundance per sample						
	2010			2017		
	Mean % (SE)	33.1 (3.55) .		Mean % (SE)	26.5 (4.43)	
	Range	2.5-80.0		Range	0-86.9	
Species Richness per sample						
	Mean % (SE)	13.4 (0.77)		Mean % (SE)	9.3 (1.58)	
	Range	3 - 25		Range	0 - 34	
Rank	Ten most abundant species in 37 samples					
	2010	Mean % (SE)	Incidence	2017	Mean % (SE)	Incidence
1	*Dysphania pumilio*	5.5 (2.11)	20	*Juncus semisolidus*	5.1 (1.24)	23
2	*Lachnagrostis filiformis*	4.3 (0.82)	27	*Alternanthera denticulata*	4.9 (1.51)	16
3	*Juncus semisolidus*	4.2 (1.23)	29	*Persicaria lapathifolia*	3.4 (1.64)	18
4	*Persicaria lapathifolia*	2.1 (0.61)	20	*Centipeda cunninghamii*	2.2 (0.71)	15
5	*Cirsium vulgare*	1.9 (1.15)	17	*Dysphania pumilio*	2.0 (0.62)	15
6	*Lactuca serriola*	1.8 (0.74)	21	*Ricciocarpos natans*	1.7 (0.78)	11
7	*Conyza bonariensis*	1.7 (0.57)	15	*Typha orientalis*	1.0 (0.58)	5
8	*Amphibromus nervosus*	1.7 (1.28)	4	*Eleocharis acuta*	0.9 (0.62)	6
9	*Alternanthera denticulata*	1.3 (0.37)	24	*Glinus lotoides*	0.7 (0.45)	12
10	*Hypochaeris radicata*	1.0 (0.24)	22	*Eragrostis infecunda*	0.6 (0.25)	13

SET abundance

Slopes

SET abundances for 24 Slopes sites (Table 3.6) were broadly similar in the two surveys. The surveys had a similar number of SETS (11 in 2010, 12 in 2017) and similar profiles: in 2010, eight SETS occurred frequently and three were uncommon (ie incidence less than 10) compared with 2017 when nine SETS occurred frequently and three were uncommon. In both surveys, the most abundant SET was GR_long_native (15.1% and 16.5%). Low abundant SETs were GR_short_native, and very low abundance were FL_long_native, TR_long_native, and both SB_long SETS.

SET abundance was similar in both surveys, and for most SETs, the difference in abundance between the two surveys was 2% or less, with a few exceptions: HB_long_native decreased from 7.5% in 2010 to 1.5% in 2017, and GR_long_intro increased from 5.3% to 8.1%.

Aggregating SETs according to origin, longevity and growth form (lower part of Table 3.6) showed that both native and herb SETS had lower abundance in 2017 than in 2010 and, conversely, that both graminoid and woody SETS had higher abundances.

Table 3.6. SET abundance in 2010 and 2017 samples for 24 Slopes sites

		2010		2017	
SET No.	SET name	Mean % (SE)	Incidence (max=24)	Mean % (SE)	Incidence (max=24)
1	FL_long_native	0.02 (0.01)	2	0.01 (0.003)	3
2	FL_short_native	0	0	0	0
3	GR_long_native	15.1 (1.78)	24	16.5 (1.54)	24
4	GR_long_intro	5.3 (1.10)	23	8.1 (1.85)	24
5	GR_short_native	2.5 (0.55)	21	1.5 (0.30)	24
6	GR_short_intro	1.9 (1.01)	7	3.8 (0.61)	24
7	HB_long_native	7.5 (0.90)	24	1.5 (0.30)	23
8	HB_long_intro	5.9 (0.76)	24	7.2 (1.17)	24
9	HB_short_native	3.7 (0.66)	22	1.9 (0.29)	24
10	HB_short_intro	9.3 (1.74)	24	7.6 (0.74)	24
11	SB_long_native	0.8 (0.38)	15	2.7 (1.09)	14
12	SB_long_intro	0	0	0.01 (0.01)	1
13	TR_long_native	0.2 (0.17)	1	0.002 (0.001)	2
14	Uncertain	3.5 (0.76)	21	0.09 (0.04)	6
	Groups of SETs	Mean % (SE)		Mean % (SE)	
	Native	29.8 (1.69)		24.0 (2.07)	
	Longer-lived	34.8 (2.23)		35.9 (2.02)	
	Graminoid	24.8 (2.52)		29.9 (1.59)	
	Herb	26.4 (1.98)		18.3 (1.24)	
	Woody	0.99 (0.40)		2.7 (1.09)	

Wetlands

SET abundances for 37 Wetland sites (Table 3.7) showed that both surveys had a similar number of frequently-occurring SETs (eight in 2010, seven in 2017) and a similar number of SET that were uncommon (three in both surveys). In both surveys, GR_long_native and HB_short_native were among the most abundant, and GR_short_intro, HB_long_intro and SB_long_native were the least abundant. Individually, most SET had similar abundances in both surveys, typically differing by 2% or less, except for GR_short_native and HB_short_intro which decreased by 4% and 6.6% respectively, and HB_long_native which increased by 4.6%. Aggregating SET according to origin, longevity and growth form (lower part of Table 3.7) showed a slight increase in native and longer-lived SET in 2017, and a decrease in graminoid and herb SET.

Table 3.7. SET abundance in 2010 and 2017 samples for 37 Wetland sites

		2010		2017	
SET	SET	Mean % (SE)	Incidence (max=37)	Mean % (SE)	Incidence (max=37)
1	FL_long_native	0	0	0	0
2	FL_short_native	0	0	1.8 (0.78)	14
3	GR_long_native	6.9 (1.92)	32	8.6 (1.58)	34
4	GR_long_intro	0.3 (0.12)	15	0.2 (0.12)	9
5	GR_short_native	4.4 (0.71)	27	0.4 (0.13)	14
6	GR_short_intro	0.2 (0.14)	5	0.04 (0.02)	5
7	HB_long_native	3.1 (1.61)	36	7.7 (2.14)	19
8	HB_long_intro	1.8 (0.33)	32	0.6 (0.21)	16
9	HB_short_native	7.9 (2.12)	31	6.3 (2.09)	19
10	HB_short_intro	7.3 (1.43)	34	0.7 (0.33)	17
11	SB_long_native	0.04 (0.03)	2	0.003 (0.002)	3
12	SB_long_intro	0	0	0	0
13	TR_long_native	0.01 (0.03)	1	0	0
14	Uncertain	1.3 (0.46)	13	0.1 (0.14)	2
SET	Groups of SETs	Mean % (SE) (n=24)		Mean % (SE (n=24)	
	Native	22.2 (2.62)		24.7 (4.32)	
	Longer-lived	12.0 (2.50)		17.1 (2.93)	
	Graminoid	11.7 (2.44)		9.3 (1.60)	
	Herb	20.1 (2.51)		15.3 (3.77)	
	Woody	0.04 (2.45)		0.003 (0.002)	

4. RESULTS: SLOPES

4.1. Analysis using Factors

Structure

The ordination plot of non-metric MDS for 48 structure samples produced a dispersed cloud, with a stress of 0.17 in 2-dimensions. Overlaying the four factors (Survey, Site, SinceDD, EMU) onto this plot (Figure 4.1) showed separation between levels for Survey, but not for the other three factors.

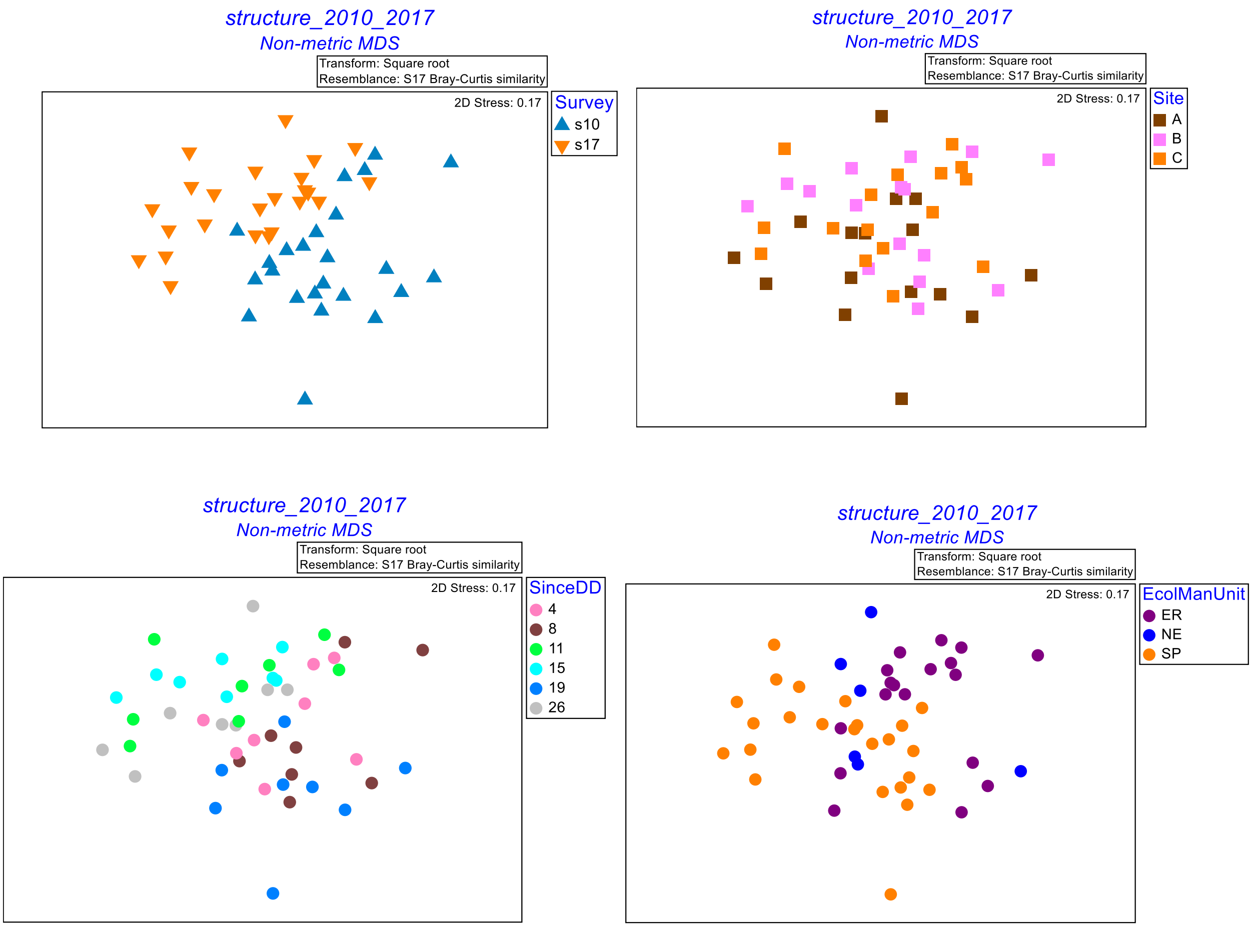


Figure 4.1. Ordination of Slopes structure with factors overlain
Top Left: Factor is Survey with two levels, 2010 and 2017. Top Right: Factor is Site, with three levels, A, B, and C. Bottom left: Factor is SinceDD, with six levels, 4y, 8y, 11y, 15y, 19y and 26y. Bottom Right: Factor is EMU with three levels, SP, ER and NE.

The significance of Survey as a factor explaining variation in structural characteristics of 48 Slopes samples was confirmed by ANOSIM routine (Table 4.1). The factors SinceDD and EMU were only marginally significant (at 0.2%), and Site was not significant.

Table 4.1. Significance of four factors on Slopes structure

Factor & levels	Global R	Significance level of sample statistic	Outcome	Pairwise comparison
Survey	0.268	0.1%	Significant	n.a.
Site	-0.005	53.4%	Not significant	n.a.
SinceDD	0.155	0.2%	Marginally significant	4y and 8y not different 8y and 11y not different 11y and 15 y not different 15y and 19y marginally different 19y and 26y marginally different
EMU	0.199	0.2%	Marginally significant	SP and ER marginally different NE and ER not different NE and SP not different

Differences between factor levels

For Survey, the average dissimilarity between 2010 and 2017 was 20.5% (ie not very great), and this small difference was largely due to 2017 samples having more bare ground, more ground layer and standing dead matter, and less lower layer and cryptogram cover than 2010 samples. Mean values for structure for 2010 and 2017 are in Table 3.3.

Species Composition

Overlaying the four factors onto the ordination plot of species composition (Figure 4.2) showed clear separation between levels for Survey, and possible separations for SinceDD (26y) and EMU (SP), but no separation for Site as A, B and C sites overlapped in ordination space.

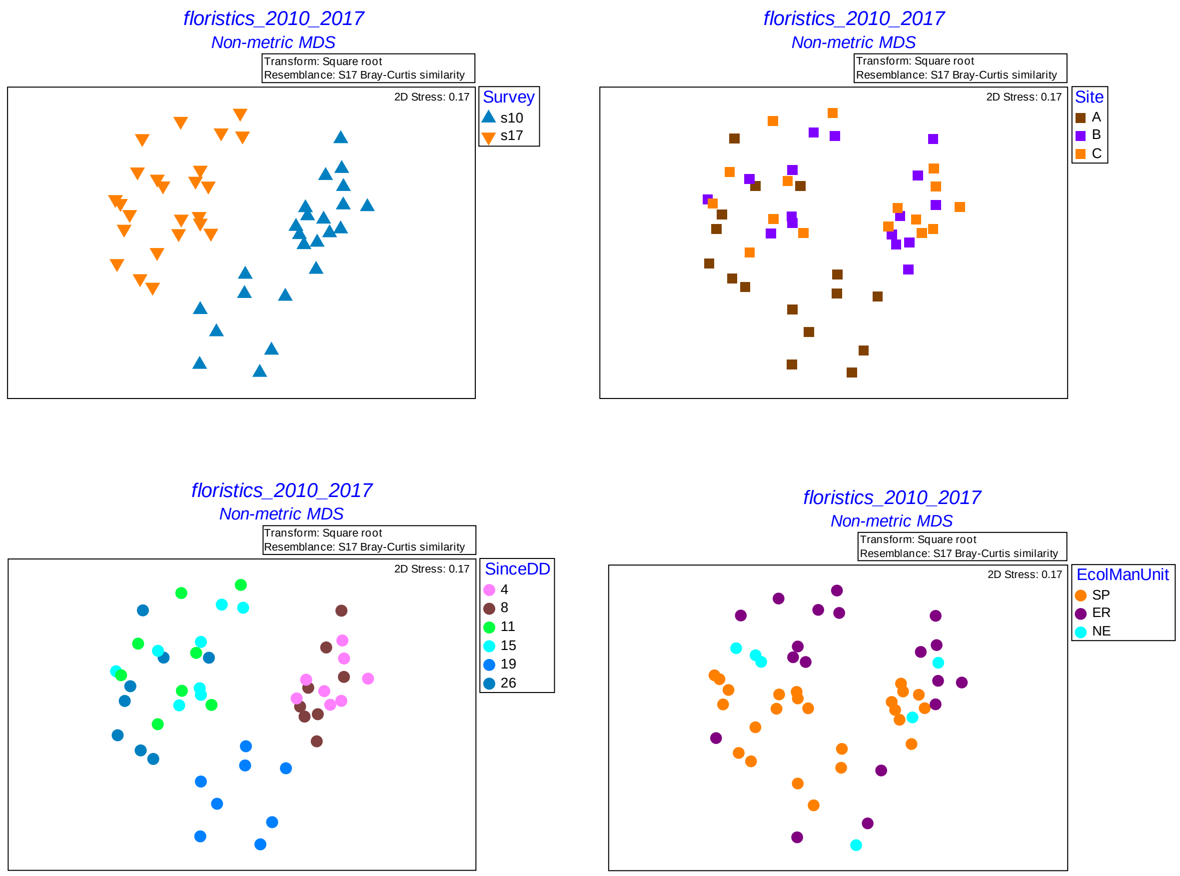


Figure 4.2. Ordination of species composition for Slopes with factors overlain
Top Left: Factor is Survey with two levels, 2010 and 2017. Top Right: Factor is Site, with three levels, A, B, and C. Bottom left: Factor is SinceDD, with six levels, 4y, 8y, 11y, 15y, 19y and 26y. Bottom Right: Factor is EMU with three levels, SP, ER and NE.

The ANOSIM routine showed that all four factors were significant (Table 4.2), although not all levels of each factor (right-hand column in Table 4.2).

Table 4.2. Significance of four factors on species composition

Factor	Global R	Significance level of sample statistic	Outcome	Pairwise comparisons
Survey	0.668	0.1%	Significant	n.a.
Site	0.201	0.1%	Significant	A different from B A different from C B and C not different
SinceDD	0.488	0.1%	Significant	4y and 8y not different 8y and 11y differ 11y and 15y not different 15y and 19y differ 19y and 26y differ
EMU	0.259	0.1%	Significant	SP and NE differ SP and ER differ ER and NE not different

Differences between factor levels

For all factors, the dissimilarity between levels was due to small differences in abundance of many species (typically more than 30 taxa), rather than large differences in just a few species. This is challenging to summarise, and hence the differences reported for factor levels are limited to the 'top ten' species, meaning those identified by SIMPER routine as contributing most to the dissimilarity.

For Survey, the average dissimilarity between 2010 and 2017 was 73.3%, and was due to differences in the abundance of 38 species, of which 20 increased and 18 decreased. The 2017 samples had higher abundance of *Phalaris aquatica, Eragrostis infecunda, Hypochaeris radicata* and *Cassinia arcuata*; and lower abundance of *Eragrostis parvifolia, Cirsium vulgare, Walwhalleya proluta, Conyza bonariensis, Euchiton sphaericus* and *Amphibromus nervosus*. These species all feature in the 'top ten' abundant species summary for 2010 and 2017 (Table 3.4).

For Site, the average dissimilarity between A sites and B sites was 68.8%, and was largely due to A sites having higher abundance of *Phalaris aquatica, Rytidosperma setaceum, Hypochaeris radicata, Chloris truncata, Walwhalleya proluta* and *Rytidosperma duttoniana*, and lower abundances of *Juncus semisolidus, Amphibromus nervosus, Cirsium vulgare, Eragrostis infecunda* and *Cassinia arcuata*. Similarly, the average dissimilarity between A sites and C sites was 71.4%, largely due to A sites having higher abundance of *Rytidosperma setaceum*, *Phalaris aquatica*, *Chloris truncata*, *Hypochaeris radicata, Walwhalleya proluta* and *Cassinia arcuata*, and lower abundance of *Eragrostis infecunda, Conyza bonariensis, Juncus semisolidus* and *Amphibromus nervosus*.

For the factor SinceDD, it is the temporal sequence from 4y to 26y that is of interest so the comparisons are for sequential years. Table 4.3 below shows the average dissimilarity (abbreviated to "ave dis") between sequential years, and gives the species contributing to this, but only when "ave dis" is significant.

Table 4.3. Factor SinceDD and species differences between sequential years

Years (ave dis)	Species with higher abundance in later year	Species with lower abundance in later year
4y and 8y		
8y and 11y 72.6%	11y has higher abundance than 8y of: *Phalaris aquatica, Trifolium subterraneum, Eragrostis infecunda*	11y has lower abundance than 8y of: *Cirsium vulgare, Euchiton sphaericus, Amphibromus nervosus, Eragrostis parvifolia, Conyza bonariensis*, monocot seedlings
11y and 15y		
15y and 19y 71.6%	19y has higher abundance than 15y of: *Rytidosperma setaceum, Avena barbata, Hypochaeris radicata*, monocot seedlings, *Walwhalleya proluta*.	19y has lower abundance than 15y of: *Phalaris aquatica, Eragrostis infecunda, Juncus semisolidus, Cassinia arcuata, Rytidosperma duttonianum*
19y and 26y 69.4%	26y has higher abundance than 19y of: *Phalaris aquatica, Rytidosperma setaceum, Briza minor, Rytidosperma duttonianum, Lotus subbiflorus*	26y has lower abundance than 19y of: *Avena barbata, Hypochaeris radicata, Walwhalleya proluta*, monocot seedlings, *Eragrostis infecunda*.

For EMU, the average dissimilarity between SP and ER was 68.9%, and was largely due to SP having higher abundance of *Eragrostis infecunda, Hypochaeris radicata, Cassinia arcuata* and *Rytidosperma setaceum* and lower abundance of *Phalaris aquatica, Amphibromus nervosus, Juncus semisolidus, Walwhalleya proluta, Rytidosperma duttoniana* and *Cirsium vulgare*. Similarly, the average dissimilarity between SP and NE was 68.3%, and was largely due to SP having higher abundance of *Hypochaeris radicata, Eragrostis infecunda, Cassinia arcuata, Walwhalleya proluta* and *Eragrostis parvifolia* and lower abundance of *Phalaris aquatica, Rytidosperma setaceum, Cirsium vulgare, Avena barbata* and *Lactuca saligna*.

Species Ecological Types (SET)

Overlaying the four factors (Survey, Site, SinceDD and EMU) onto the ordination plot of SET abundance (Figure 4.3) resulted in patterns that are broadly similar to species (Figure 4.2), although not as clearly defined.

With the factor Survey, 2010 and 2017 samples were closer together in ordination space than for species: there was some overlap between 2010 and 2017, and 2010 samples were scattered, with outliers. With Site, Sites A, B and C were intermingled and Site A was not as well-separated from Sites B and C as it was for species (Figure 4.2). With SinceDD, although the individual years tend to occupy specific areas of the ordination space (4y and 8y on the right, 26y towards the lower left) there was considerable overlap between them. With EMU, the three tended to occupy particular parts of ordination space and differed in how dispersed or compact they were.

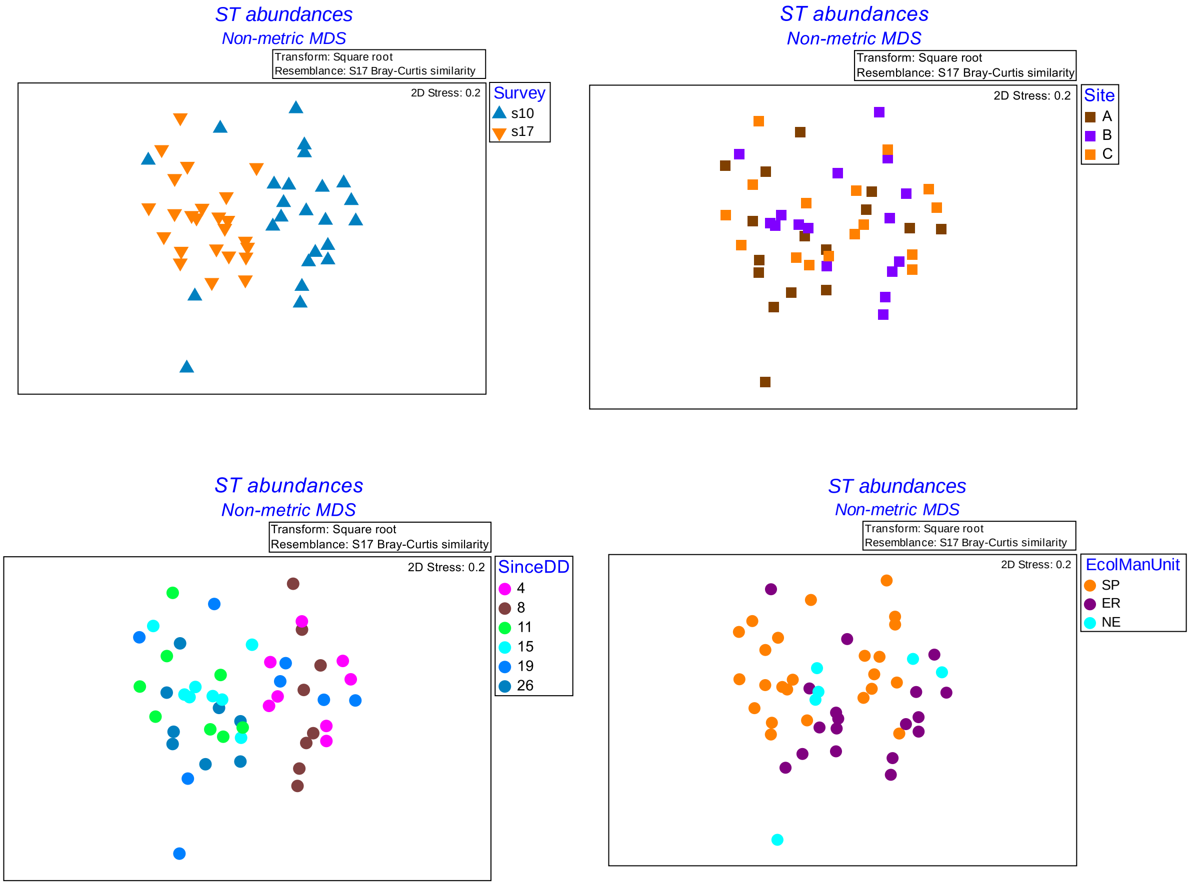


Figure 4.3. Ordination of SET abundances with factors overlain

Top Left: Factor is Survey with two levels, 2010 and 2017. Top Right: Factor is Site, with three levels, A, B, and C. Bottom left: Factor is SinceDD, with six levels, 4y, 8y, 11y, 15y, 19y and 26y. Bottom Right: Factor is EMU with three levels, SP, ER and NE.

The significance of these four factors in accounting for variability in SET abundance was summarised below (Table 4.4). Only two factors, Survey and SinceDD were significant at 0.1% level, EMU was marginally significant, and Site was not significant.

Table 4.4. Significance of four factors on SETs

Factor	Global R	Significance level of sample statistic	Outcome	Pairwise comparison
Survey	0.489	0.1%	Significant	n.a.
Site	0.006	39.5%	Not significant	n.a.
SinceDD	0.338	0.1%	Significant	8y and 11y differ 15y and 19y marginally differ 19y and 26y differ
EMU	0.214	0.2%	Marginally significant	SP and ER differ SP and NE differ ER and NE not different

Differences between factor levels

For all factors, the average dissimilarity between levels was fairly low, ranging from 24 to 35%, and was largely due to differences in graminoid and herb SETs (GR and HB), and only rarely due to shrubs (SB). The two fern and liverwort SETS (FL) did change but were of low abundance and made little contribution to dissimilarity.

For the factor Survey, the difference between 2010 and 2017 samples was due to 2017 samples having higher abundance of three of the four graminoid SETs (GR_short_intro, GR_long_intro, GR_long_native) and of one herb SET (HB_long_intro), and lower abundance of two herb SETs (HB_long_native and HB_short_intro). Overall this pointed to an increase in graminoids and in longer-lived species from 2010 to 2017. Mean abundances for each SET in 2010 and 2017 are summarised in Table 3.6.

For SinceDD, it is the temporal sequence from 4y to 26y that is of particular interest, and the comparisons presented here (Table 4.5) are limited to sequential years that are significant.

For EMU, the difference between SP and ER was due to SP samples having higher abundance of introduced Graminoids (SET 4 and SET 6), longer-lived Herbs (SET 7 and SET 8) as well as native Shrubs (SET 11), and lower abundance of longer-lived native Graminoids (SET 3) and shorter-lived introduced Herbs (SET 10). The difference between SP and NE was due to SP having higher abundance of longer-lived introduced Herbs (SET 8), longer-lived Graminoids (SET 3 and SET 4), and of native shrubs (SET 11).

Table 4.5. Factor SinceDD and SET differences between sequential intervals

Years (ave dis)	SETs with higher abundance in later year	SETs with lower abundance in later year
4y and 8y		
8y and 11y 34.9%	11y has higher abundance than 8y of: GR_short_intro, GR_long_intro, and GR_long_native	11y has lower abundance than 8y of: Unknown, HB_long_native, and HB_short_native
11y and 15y		
15y and 19y		
19y and 26y 32.9%	26y has higher abundance than 19y of: GR_short_intro, HB_long_intro, HB_short_intro, and SB_long_native	26y has lower abundance than 19y of: GR_long_intro and GR_long_native

4.2. Analysis using Empirical Groupings

Structure

The dendrogram resulting from cluster analysis of 48 samples (Figure 4.4) showed all clusters joining at 73% similarity, which is high. The SIMPROF routine identified only one cluster, an outcome that was not expected but is consistent with high similarity among samples. The outcome was the same despite testing with other data transformations, and applying more stringent criteria for defining clusters (1% and 0.5%). The planned analysis could not be progressed, as the statistical procedure found no evidence of empirical groupings.

This re-enforces the point made earlier (Table 3.1, Section 4.1) that of a high level of similarity in structure among Slopes samples.

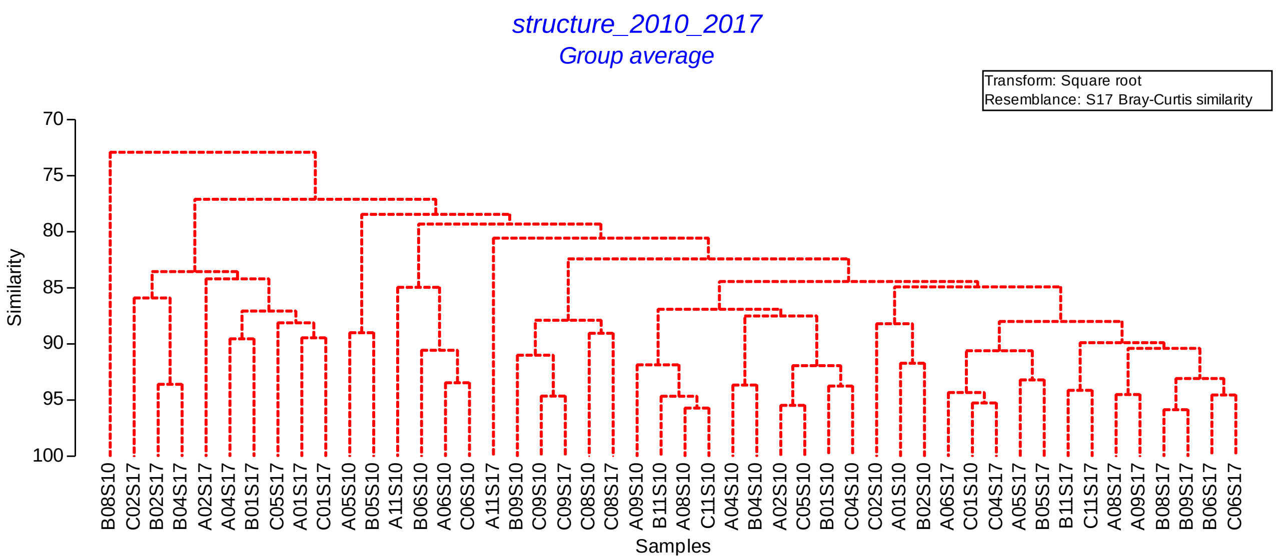


Figure 4.4. Dendrogram showing clusters based on structure for Slopes samples

Species Composition

Cluster analysis of species abundances resulted in the recognition of 13 clusters at the 5% level, as indicated by the solid black lines (Figure 4.5). The clusters joined at a fairly low level of similarity, 27%.

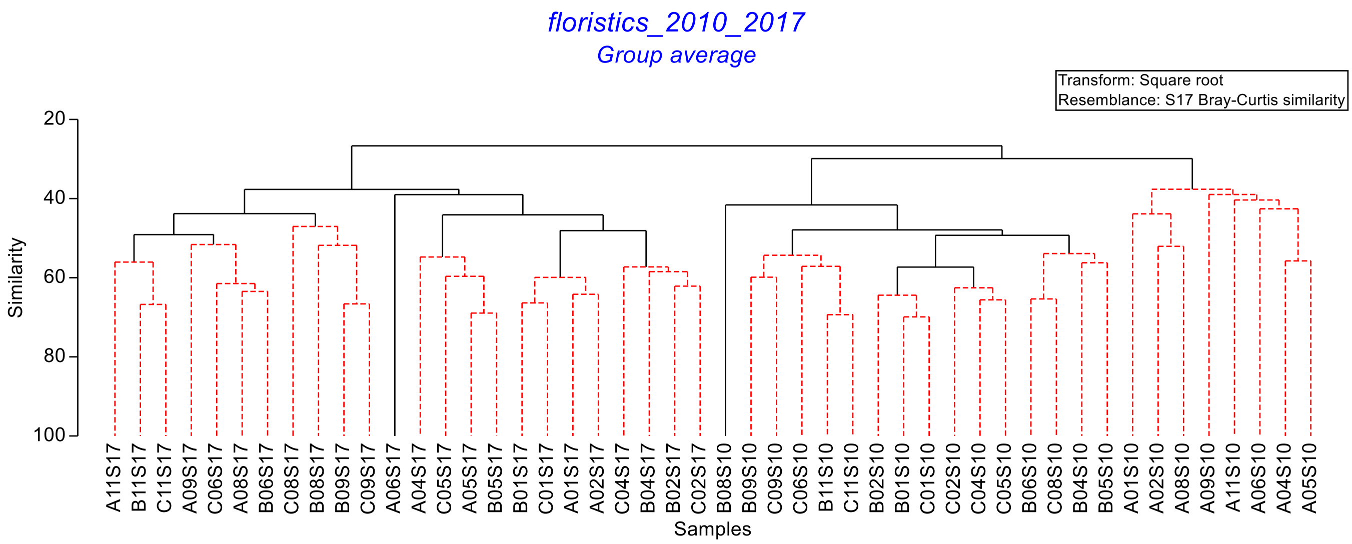


Figure 4.5. Dendrogram showing clusters based on species abundance for Slopes samples

Ordination plot of species abundances with the 13 clusters overlaid is shown below (Figure 4.6). The two hollow circles are singletons (clusters comprising just one sample). Most clusters were fairly compact, and only a few are dispersed, notably cluster m.

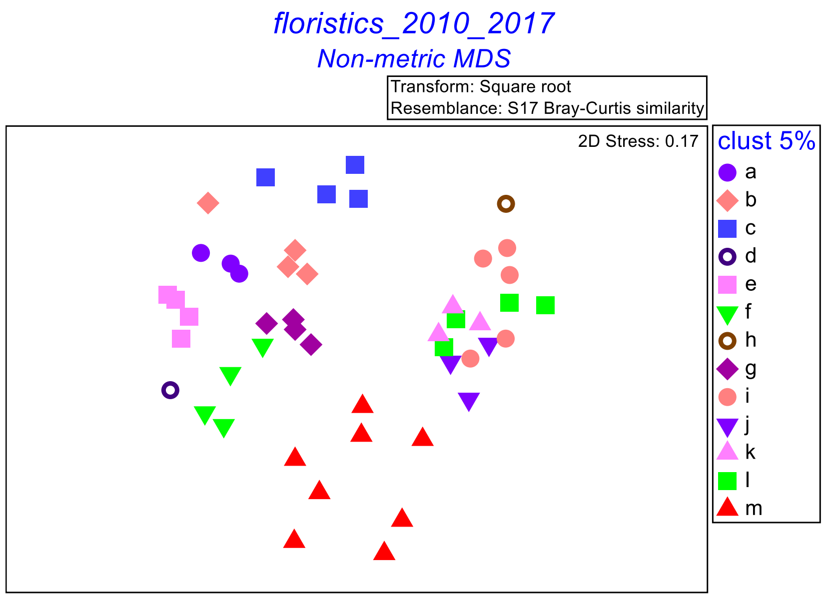


Figure 4.6. Ordination of Slopes species abundance with 13 clusters imposed

Cluster characteristics

Cluster size was generally small, ranging from just 1 to 8 samples, however most had 4 or 5 (Table 4.6), indicating heterogeneity. Each cluster comprised samples from just one Survey, either 2010 or 2017, and were mix of Sites. Thus four clusters were a mix of A, B and C sites (clusters a, b, e and f), five clusters were B and C Sites only (clusters c, g, i, j and l), and four clusters were just one Site (clusters a, h, k and m). Co-location, meaning Sites that are closer to each other (Figure 1.1) than to any other Sites, was evident in six clusters: for example, all samples in cluster a have the same number (A11, B11 and C11), and samples in cluster g not only shared a number but were 'neighbours' on the landscape (B04 and C04, B05 and C05). This suggested fine-scale spatial patterning

Table 4.6. Characteristics of clusters based on Slopes species composition

Cluster	Cluster size (samples)s	Survey	Location	Notes
a	3	2017	A, B and C sites	Co-location
b	4	2017	A, B and C sites	
c	4	2017	B and C sites	Co-location
d	1	2017	A site	
e	4	2017	A, B, and C sites	Co-location
f	4	2017	A, B, and C sites	Co-location
g	4	2017	B and C sites	Co-location
h	1	2010	B site	
i	5	2010	B and C sites	
j	3	2010	B and C sites	Co-location
k	3	2010	C sites	
l	4	2010	B and C sites	
m	8	2010	A sites only	

Species characteristics of each cluster are summarised below (Table 4.7), and the following is evident.

Sample abundance per cluster (all species summed) was fairly uniform, 42.5 to 61.3% cover per cluster with no extreme highs or lows. Abundance was lowest in clusters a, c and h (42.5-44.5%), and highest in clusters e, l and m (59.4-61.3%). Species richness per sample was also quite uniform, ranging from 26.9 (cluster m) to 34.3 (cluster g). Similarity between clusters (not shown) was moderate to high, ranging from 42.7% (between clusters k and j) to 86.8% (between clusters h and d). Within a cluster, abundance of individual species was skewed: most species had low (1-2%) to very low (<1% cover) abundances, and only a few had high abundance. Only four of the 149 taxa averaged more than 10% per cluster: *Eragrostis infecunda* in cluster g, *Hypochaeris radicata* in cluster f, *Phalaris aquatica* in cluster e, and *Cirsium vulgare* in cluster h. A further 14 species averaged 5% or more (not shown).

What really distinguished the clusters was which species was most abundant: four grasses in seven clusters, and four herbs in six (Table 4.7). The four grasses comprised two introduced *Phalaris aquatica* and *Cynodon* *dactylon* for clusters a, c and e, and cluster j respectively (and *Phalaris aquatica* is second most abundant in cluster b), and two native *Eragrostis infecunda* and *Rytidosperma duttonianum* in clusters g and k, and cluster b, respectively. The four herbs comprised three introduced *Hypochaeris radicata* (clusters f and m), *Cirsium vulgare* (cluster h and l), and *Plantago lanceolata* (cluster d), and one native *Euchiton sphaericus* (cluster i).

Table 4.7. Species characteristics of clusters for Slopes samples

Cluster	The four most abundant species, total abundance and species richness (mean and SE per sample)
a	*Phalaris aquatica* (5.9%), *Rytidosperma duttonianum* (2.9%), *Eragrostis infecunda* (2.9%), *Lachnagrostis filiformis* (2.7%). Mean (SE) abundance per sample = 44.0% (5.78) Mean (SE) species richness per sample = 33.3 (SE 3.28)
b	*Rytidosperma duttonianum* (8.9%), *Phalaris aquatica* (4.6%), *Lotus subbiflorus* (3.7%), *Lythrum hyssopifolia* (3.5%). Mean (SE) abundance per sample = 52.3% (3.06) Mean (SE) species richness per sample = 33.3 (1.49)
c	*Phalaris aquatica* (8.9%), *Juncus semisolidus* (3.6%), *Hypochaeris radicata* (3.4%), *Juncus flavidus* (3.3%). Mean (SE) abundance per sample = 42.3% (2.36) Mean (SE) species richness per sample =32.3 (3.09)
d	*Plantago lanceolata* (6.4%), and *Chloris truncata, Romulea rosea* and *Rytidosperma setaceum* (each is 5.8%), *Briza minor* (3.6%). Mean abundance per sample = 54.6% Mean species richness per sample = 34
e	*Phalaris aquatica* (18.5%), *Hypochaeris radicata* (6.2%), *Trifolium subteraneum* (5.6%), *Cassinia arcuata* (4.6%) Mean (SE) abundance per sample = 59.4% (1.65) Mean (SE) species richness per sample = 28.5 (0.5)
f	*Hypochaeris radicata* (17.8%), *Rytidosperma setaceum* (6.7%), *Chloris truncata* (2.9%), *Trifolium subterraneum* (3.0%). Mean (SE) abundance per sample = 53.7% (6.02) Mean (SE) species richness per sample = 33.8 (2.17)
g	*Eragrostis infecunda* (10.2%), *Hypochaeris radicata* (8.5%), *Cassinia arcuata* (7.2%), *Trifolium subterraneum* (2.6%). Mean (SE) abundance per sample = 50.9% (7.44) Mean (SE) species richness per sample = 34.3 (1.70)
h	*Cirsium vulgare* (10.0%), *Juncus semisolidus* (8.0%), *Typha domingensis* (6.0%), *Lactuca serriola* (4.8%). Mean abundance per sample = 44.5%

Cluster	The four most abundant species, total abundance and species richness (mean and SE per sample)
	Mean (SE) species richness per sample = 24
i	*Euchiton sphaericum* (5.8%), *Conyza bonariensis* (5.0%), *Amphibromus nervosus* (3.5%), *Hypochaeris radicata* (3.3%). Mean (SE) abundance per sample = 51.5% (2.88) Mean (SE) species richness per sample = 29.2 (2.06)
j	*Cynodon dactylon* (8.9%), *Eragrostis parvifolia* (6.1%), *Hypochaeris radicata* (5.0%), *Euchiton sphaericus* (2.7%); and unidentified monocot seedlings (4.5%). Mean (SE) abundance per sample = 50.8% (3.02) Mean (SE) species richness per sample = 32.0 (1.00)
k	*Eragrostis infecunda* (5.4%), *Hypochaeris radicata* (4.9%), *Senecio quadridentata* (4.1%), *Pseudoraphis spinescens* (3.7%). Mean (SE) abundance per sample = 51.3% (0.59) Mean (SE) species richness per sample = 29.7 (0.67)
l	*Cirsium vulgare* (9.7%), *Amphibromus nervosus* (9.3%), *Walwhalleya proluta* (4.7%), *Hypochaeris radicata* and *Trifolium angustifolium* (both 3.6%). Mean (SE) abundance per sample = 61.3% (7.96) Mean (SE) species richness per sample = 31.0 (4.30)
m	*Hypochaeris radicata* (7.4%), *Avena barbata* (5.3%), *Walwhalleya proluta* (3.7%) and *Rytidosperma setaceum* (3.4%). Mean (SE) abundance per sample = 60.5% (4.34) Mean (SE) species richness per sample = 26.9 (1.82)

Changes

Change in species composition between the two surveys is summarised below for individual sites organised by location (Tables 4.8, 4.9, and 4.10) using Bray-Curtis measure of similarity (%s), and showing which cluster each site belonged to in each Survey , ie in 2010 and 2017.

Overall, the percentage similarity between surveys was low to moderate, ranging from 21.9% to 49.7% for individual sites, which indicated moderate to high changes in species composition. The three locations had an average similarity of 38.1% for A sites, 33.6% for B sites, 32.6% for C Sites, showing that the magnitude of change was fairly uniform for Slopes sites regardless of time since exposure.

Table 4.8. Change in A sites

	A01	A02	A04	A05	A06	A08	A09	A11
%s	49.7	42.0	36.6	39.6	40.8	37.2	27.6	31.4
S10	m	m	m	m	m	m	m	m
S17	f	f	e	e	d	b	b	a

Table 4.9. Change in B sites

	B01	B02	B04	B05	B06	B08	B09	B11
%s	36.9	40.9	40.8	21.9	26.6	31.2	40.1	30.6
S10	j	j	l	l	l	h	i	i
S17	f	g	g	e	b	c	c	a

Table 4.10. Change in C sites

	C01	C02	C04	C05	C06	C08	C09	C11
%s	30.2	48.5	31.0	23.3	37.0	22.7	37.6	30.6
S10	j	k	k	k	i	l	i	i
S17	f	g	g	e	b	c	c	a

The matrix of cluster transitions (Figure 4.7) shows six clusters in 2010 (clusters h to m) and seven in 2017 (clusters a to g). No cluster occurred in both surveys, indicating a substantial turnover between the two surveys.

The matrix has 17 transitions. None of these was dominant, instead each transition involved only 1 or 2 sites, indicative of multiple changes with no uniformity. However reference to species characteristics of the clusters (Table 4.7) shows this was not strictly true. Five of the 2010 clusters (h, i, k, l and m) transition to three 2017 clusters (a, c and e) and although these differ in species composition, they all have *Phalaris aquatic*a as the most abundant species.

Divergence, meaning what was one cluster in 2010 transitions to multiple clusters in 2017. This was most evident with cluster m, which was all A sites in 2010 and transitioned to five clusters in 2017 (clusters a, b, d, e and f). Similarly cluster i transitioned to three clusters (a, b and c). Species characteristics show these two clusters underwent a similar type of change, becoming clusters with extensive *Phalaris aquatica* (clusters a, b, c, d, e) or extensive *Trifolium subterraneum* (clusters e, f, g).

In contrast, cluster convergence, meaning several sites from different clusters transition to the same cluster, was not evident, as the largest cluster size in 2017 was only 4 sites.

The transition matrix also showed the difference between net change (a simple contrast between 2010 and 2017) and the actual changes involved. Southern Cane Grass *Eragrostis infecunda* was the most abundant species at three sites in 2010 (cluster k), and at four sites in 2017 (cluster g): however this was not a simple increase as only two of the three3 cluster k sites actually transitioned to cluster g.

		Survey in 2017													Total
		a	b	c	d	e	f	g	h	i	j	k	l	m	**2010**
Survey	a														
in	b														
2010	c														
	d														
	e														
	f														
	g														
	h			1											**1**
	i	2	1	2											**5**
	j						2	1							**3**
	k					1		2							**3**
	l		1	1		1		1							**4**
	m	1	2		1	2	2								**8**
Total for 2017		**3**	**4**	**4**	**1**	**4**	**4**	**4**							**24**

Figure 4.7. Matrix of cluster transitions, 2010 to 2017: Species on Slopes

The dissimilarity matrix (Figure 4.8) for cluster transitions shows that all 17 transitions are in the moderate to high range, ie undergo a change of a similar magnitude.

		Survey in 2017												
		a	b	c	d	e	f	g	h	i	j	k	l	m
Survey	a													
in	b													
2010	c													
	d													
	e													
	f													
	g													
	h			66.1										
	i	76.5	71.4	67.5										
	j						69.6	66.2						
	k					78.2		61.4						
	l		71.9	71.1		79.8		68.3						
	m	71.9	71.5		69.4	73.5	66.9							

Figure 4.8. Average dissimilarity per cluster transition

Species Ecological Groups (SET)

Cluster analysis combined with the SIMPROF routine for SET abundance resulted in just three clusters (Figure 4.9), as indicated by the solid black lines. Effectively, however, there were just two clusters, as one of these three was a singleton outlier, site A11 in 2010 (to extreme left of dendrogram in Figure 4.9)).

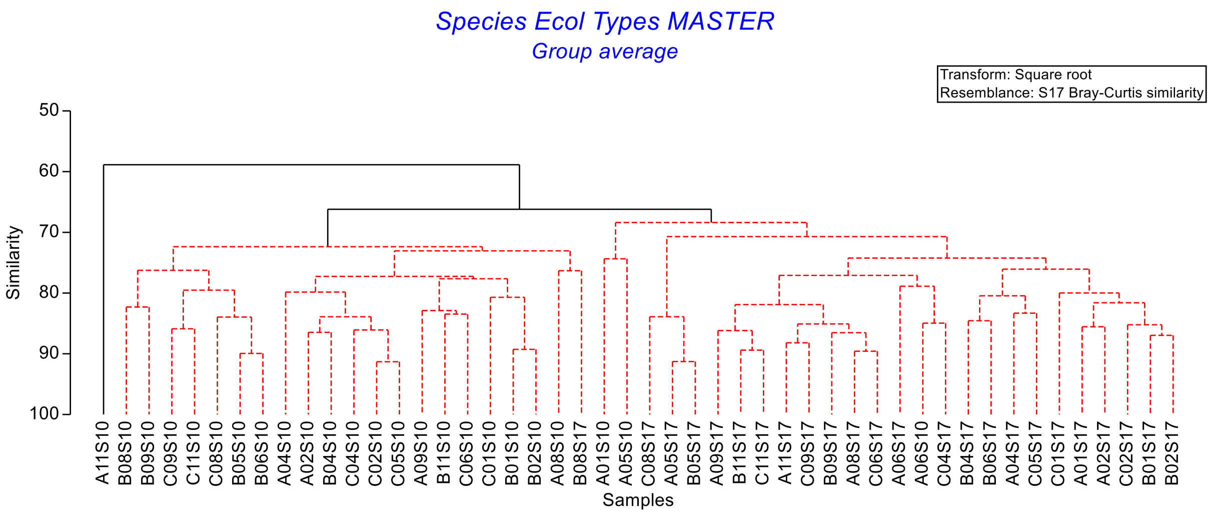


Figure 4.9. Dendrogram showing clusters based on SET for Slopes samples

Ordination plot of SET abundance with the three clusters overlain (Figure 4.10) showed two large loose but separated clusters with the singleton cluster underneath.

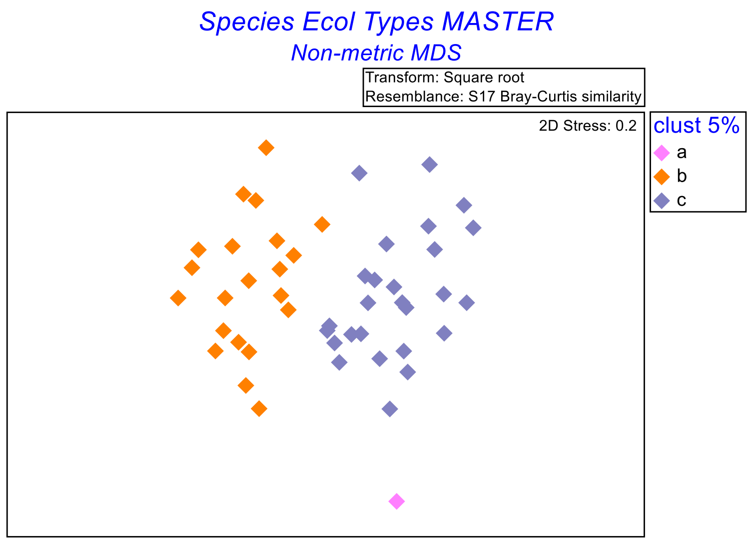


Figure 4.10. Ordination of Slopes SET abundances with 3 clusters imposed

Cluster Characteristics

Clusters were quite variable in size, with the two largest clusters comprising 21 and 26 samples respectively. Cluster characteristics, summarised below (Table 4.11) showed that the clusters were defined mainly by Survey: thus cluster b is almost entirely 2010 samples, with one exception (B08 from 2017) and cluster c was almost entirely 2017 samples, except for three from 2010 (A01, A05, A06). Both large clusters were a mix of A, B and C sites.

Table 4.11. Characteristics of clusters based on SET

Cluster	Number of samples	Survey	Sites
a	1	2010	A
b	21	All except one are 2010	Mix of A, B and C
c	26	All except 3 are 2017	Mix of A, B, and C

The SET characteristics for each cluster (Table 4.12) show mean abundance per SET, as well as total abundance per cluster, and percentage of total abundance that is native, graminoid (GR) or herb (HB).

Cluster a, the singleton, was characterised by high total abundance (64.4% cover) of which a very high proportion was graminoids (81.5%) and only a little was herbs (7.8%). The most abundant SET was SET 3 (GR_long_native) with an abundance of 31.9% (the highest for any site), followed by SET 6 (GR_short_intro) at 19.0%: all other SETS were less than 2%.

Cluster b had a moderate total abundance (52.6%) of which just over half was herbs (51.7%) and less than half was graminoids (39.9%). The most abundant SETs were SET 3 (GR_long_native) with 13.4%, and SET 10 (HB_short_intro), at 10.2%. This cluster was distinctive for having a high abundance of SET 7 (HB_long_native), at 8.1%.

Cluster c also had a moderate total abundance (53.5%) but with a graminoid-herb composition that was markedly different from cluster b, with 58.8% of total abundance being graminoid and only 35.7% being herb. The most abundant SETs were SET 3 (GR_long_native) at 17.1% and SET 4 (GR_long_intro) at 8.3%. This cluster had the highest cover for SET 8 (HB_long_intro) at 8.1% and SET 11 (SB_long_native) at 2.8%.

Table 4.12. Characteristics of clusters based on SET composition

	SET	Cluster a (n=1)	Cluster b (n=21)	Cluster c (n= 26)
Abundance (mean % cover, SE)				
1	FL_long_native	0	0.01 (0.01)	0.01 (0.01)
2	FL_short_native	0	0	0
3	GR_long_native	31.9	13.4 (1.58)	17.1 (1.57)
4	GR_long_intro	1.2	5.0 (0.94)	8.3 (1.81)
5	GR_short_native	0.4	2.6 (0.58)	1.6 (0.35)
6	GR_short_intro	19.0	0.07 (00.01)	4.5 (0.71)
7	HB_long_native	1.2	8.1 (0.94)	1.6 (0.39)
8	HB_long_intro	1.2	4.9 (0.52)	8.1 (1.13)
9	HB_short_native	1.5	3.9 (0.67)	2.0 (0.38)
10	HB_short_intro	1.1	10.2 (1.90)	7.3 (0.71)
11	SB_long_native	0	0.6 (0.25)	2.8 (1.03)

	SET	Cluster a (n=1)	Cluster b (n=21)	Cluster c (n= 26)
Abundance (mean % cover, SE)				
12	SB_long_intro	0	0	0.01 (0.01)
13	TR_long_native	4	0	0
14	Uncertain	2.9	3.8 (0.85)	0.1 (0.05)
Total (% abundance)		64.4	52.6	53.5
Longer-lived as % of total		59.8	60.9	71.0
Native as % of total		60.6	54.3	47.0
GR as % of total		81.5	39.9	58.8
HB as % of total		7.8	51.7	35.7
Richness (number of SET)		9 (5 native)	10 (6 native)	11 (7 native)

Changes

Changes in SET abundance between 2010 and 2017 are summarised below for individual sites organised by location (Tables 4.13, 4.14 and 4.15) as for species composition (above).

Overall, the similarity between surveys was moderate to high, ranging from 51 to 74.9% for individual sites, indicating only moderate to little changes in SET abundance. The three locations had an average similarity of 68.8%, 67.2% and 65.4% for A, B and C sites respectively, showing that the magnitude of change was fairly similar for Slopes sites, regardless of time since exposure.

Table 4.13. Change in A sites

	A01	A02	A04	A05	A06	A08	A09	A11
%s	74.9	73.0	61.8	77.8	73.6	65.9	64.0	60.0
S10	c	b	b	c	c	b	b	a
S17	c	c	c	c	c	c	c	c

Table 4.14. Change in B sites

	B01	B02	B04	B05	B06	B08	B09	B11
%s	64.7	69.1	67.9	55.5	69.4	68.4	71.3	71.3
S10	b	b	b	b	b	b	b	b
S17	c	c	c	c	c	b	c	c

Table 4.15. Change in C sites

	C01	C02	C04	C05	C06	C08	C09	C11
%s	63.2	72.8	71.4	63.7	69.0	51.0	65.8	65.9
S10	b	b	b	b	b	b	b	b
S17	c	c	c	c	c	c	c	c

The matrix of cluster transitions (Figure 4.11) shows three clusters for 2010 and only two for 2017. Cluster a, with high abundance and very high proportion of graminoids, occurred only in 2010. Four sites (17% of monitoring sites on Slopes) did not change cluster, indicating a degree of stability through time.

The transition matrix has only 4 pathways, two of them being no change (the boxed diagonal in Figure 4.11). The most prevalent pathway was from cluster b to cluster c, with 19 sites and was a high proportion of the 24 Slopes monitoring sites (79%). Cluster characteristics (Table 4.13) showed this was a shift to lower herb cover and lower native cover, with more longer-lived introduced herbs (SET 8) and more native shrubs (SET 11).

		Survey in 2017			Total
		a	b	c	in 2010
Survey	a			1	**1**
in	b		1	19	**20**
2010	c			3	**3**
Total in 2017			**1**	**23**	**24**

Figure 4.11. Matrix of cluster transitions, 2010 to 2017: SET on Slopes

However, the level of dissimilarity between clusters was generally low (Figure 4.12), showing that the change described above, from cluster b to cluster c, although a marked trend was minor.

		Survey in 2017		
		a	b	c
Survey	a			38.7
in	b		0	33.8
2010	c			0

Figure 4.12. Dissimilarity of cluster transitions, 2010 to 2017.

4.3 Synthesis

Analysis using Factors

The four factors used in the analysis are potential influences on vegetation, at temporal and spatial scales ranging from fine to coarse, exemplified by 7 year contrast for Survey, compared with up to 26 y for SinceDD. Factors Survey and EMU are temporal, and spatial respectively, whereas Site and SinceDD are confounded. Site has both spatial and temporal interpretations, referring either to topographic position (A, B and C sites), or to age as lapsed time since the drawdown of Lake Mokoan (Table 1.1). SinceDD is Site x Survey so has similar spatial and temporal interpretations.

The influence of these four factors (tested individually) varied with vegetation attribute (Table 4.16). Species composition was significantly affected by all four factors, which is consistent with the large number of clusters identified in the Analysis using empirical groups (Section 4.2), and with the combinations of Site and Survey that characterised the 13 clusters (Table 4.6). In contrast structure was significantly influenced only by one temporal factor Survey, showing that the 7-year contrast applies across all 24 sites, whereas SET abundance was significantly influenced by Survey and SinceDD, indicating two temporal scales. Overall, the temporal factors (Survey and SinceDD) had more influence on variations in Slopes vegetation than the spatial factors EMU and Site.

Table 4.16. Summary of analysis using factors
S = Significant, NS = Not Significant, and ms = marginally significant

	Survey	Site	SinceDD	EMU
Structure	S	NS	ms	ms
Species Composition	S	S	S	S
SET abundance	S	NS	S	ms

The average dissimilarity between 2010 and 2017 was much higher for species composition (73.3%) than for structure and SET abundance, 20.5% and 33.2% respectively. These dissimilarity values were so low that they can be interpreted as showing no change and minor change respectively.

Overall, the analysis showed the nested nature of the vegetation attributes: although species composition changed, this had no effect on structure, and very little effect on SET.

Grazing as a Factor

An additional factor analysis was done using the same methods, comparing species composition of 2017 samples not in a grazing lease (n = 11) with samples in a grazing lease (n = 13). There was no significant difference between these (ANOSIM statistics: Global R = 0.152, significant at 2.1% level, which is not statistically significant).

Spatial Influences

Site and EMU partition the Winton landscape in quite different ways. Site partitions the slopes landscape down to the wetlands into a series of horizontal bands, equivalent to different development ages regardless of their substrate and topographical characteristics, whereas EMU partitions the landscape into areas based on broad substrate and topographic similarity so includes different developmental age.

The diverse effect of these two spatial factors on the three vegetation attributes (Table 4.16) showed influences operating at different spatial scales. Structure and SET abundance, which were not influenced by spatial partitioning of the Mokoan landscape, must therefore be controlled by factors such as regional climate. Species composition was influenced by both Site and EMU, implying that it was responding to fine-scale influences that nested within levels of both Site and EMU.

This fine-scale influence becomes evident by intersecting findings for Site with findings for EMU, using two grasses. A sites had higher abundance of *Phalaris aquatica* and lower abundances of *Eragrostis infecunda* than did B or C sites; and sites in ER and NE had more abundant *Phalaris aquatica* and less abundant *Eragrostis infecunda* than did SP sites. Combining these indicates that A sites in NE and SR were patches of high abundance for *Phalaris aquatic*a, and that B and C sites in SP were patches of high abundance for *Eragrostis infecunda*. This fine-scale patchiness was also evident as co-location, noted above, and in species-based clusters. Nearly all similarly-numbered B and C sites in the summary of changes (Tables 4.8, 4.9 and 4.10) were in the same species cluster in 2017, although not in 2010.

The relative importance of site characteristics versus land management history in determining differences in species composition could be disentangled, and could provide feedback useful to land managers. This would require site-specific information on physical characteristics and land management history.

Changes identified using empirical groups

Vegetation changes identified using empirical groups and transition matrices ranged from no change in structure, to minor changes in SET abundances, and moderate to major changes in species composition. This is parallel to, but not identical, the change gradient detected in the analysis using factors (Table 4.16). The finding of no change for vegetation structure contrasts with the summary values (Table 3.2) where differences between means (SE) suggest there will be significant differences for individual variables such as mid layer, ground layer, bare ground, litter, standing dead and cryptogram cover.

SET abundance changed, showing an increase in longer-lived graminoids and in introduced graminoids, a decrease in herbs and native species, and an increase in the cover of longer-lived species. Individual SETS also changed: there was a reduction in SET 7 HB_long_native, and increases in SET 8 HB_long_intro, SET 3 GR_long_native, SET 6 GR_short_intro, and SET 11 (SB_long_native) (Table 4.12, Figure 4.7). These changes are minor because most SETs changed by relatively few percent. However, although minor in terms of abundance, the changes have ecological implications as collectively they point to an increase in longer-living species, and in introduced species. The only indication of a response to the wet seasonal conditions of autumn 2017 was the increase in SET 6 GR_short_intro, characterised by *Briza minor, Lolium rigidum* and *Avena barbata* (Table 3.1).

With species composition, there was a major shift, as indicated by the complete turnover in clusters (Figure 4.7). This analysis treats clusters as distinct assemblages, which is a simplifying tactic, however cluster characteristics (Table 4.7) showed that several of the 2017-specific clusters shared species, and were dominated by *Phalaris aquatica*, an invasive problematic agricultural grass that is also an environmental weed. More on abundance and incidence of select species including *Phalaris aquatica* is in Section 7.2.

Relevance to Restoration Plan

This monitoring program describes the vegetation in 2010 and in 2017, and compares the two surveys for most of the Slopes area around Winton Swamp, with the exception of the steeper northern margins. The findings provide only limited direct feedback on the vegetation-related objectives for Slopes areas that are set out in the Restoration and Monitoring Strategic Plan (Barlow 2011) and confirmed as current for Winton Wetlands by the Project Manager Lance Lloyd. This arises because the objectives refer to habitats (creek lines) not covered by this monitoring program, and to management activities at designated – but not known - areas (objectives 2.2, 2.5, 2.7, 3.4) or to management objectives which are general and broad-scale (objective 2.9).

However the finding that the *Phalaris aquatica* is now the dominant (most abundant) species in several assemblages (ie clusters) and that the cover of introduced long-lived species has increased since 2010 is directly relevant to several restoration objectives about non-native vegetation on the Slopes, and particularly about Phalaris (eg objectives 2.7, 3.2, 3.4, 3.5, 3.6, 3.7), presumed to mean *Phalaris aquatica*. Whether these increases should be a trigger for action is another matter, which cannot be resolved without knowing the triggers or thresholds for intervention, or conditions prior to intervention.

All the principal objectives (Section 2.4 in Barlow 2011) are strategic; and all (not just ones relevant to Slopes vegetation) will need to be re-worked if they are to be used as vegetation targets. Current practice in Victoria is for targets to be “s.m.a.r.t.” that is specific, measureable, achievable, realistic, and time-specific.

4.4. Recommendations Arising

Recommendation 1

Clarify best practice in relation to various uses of the Slopes environment, but specifically in relation to agriculture and conservation.

Recommendation 2

Develop s.m.a.r.t. and spatially-explicit targets for vegetation on Sopes surrounding the Wetlands. This could benefit from further analysis of 2010 and 2017 monitoring data.

Recommendation 3

Establish a system and map of vegetation condition indicators that can be used to guide day-to-day management and decisions in relation to selected threats or issues.

Recommendation 4

Establish a suite of indicators of ecosystem function and condition, as recommended by Barlow (2011), with an emphasis on those that are low cost, amenable to citizen-science or volunteer implementation, and that can be integrated into an appraisal of Mokoan Reserve / Winton Wetlands.

Recommendation 5

Continue with this monitoring program, but sampling every 5 years. A sub-sample of sites could be monitored more frequentl, such as every 2-3 years), in order to distinguish short-term fluctuations from long-term trends.

Recommendation 6

Once spatially explicit targets have been established, review and revise this monitoring program, paying special attention to gaps and redundancies.

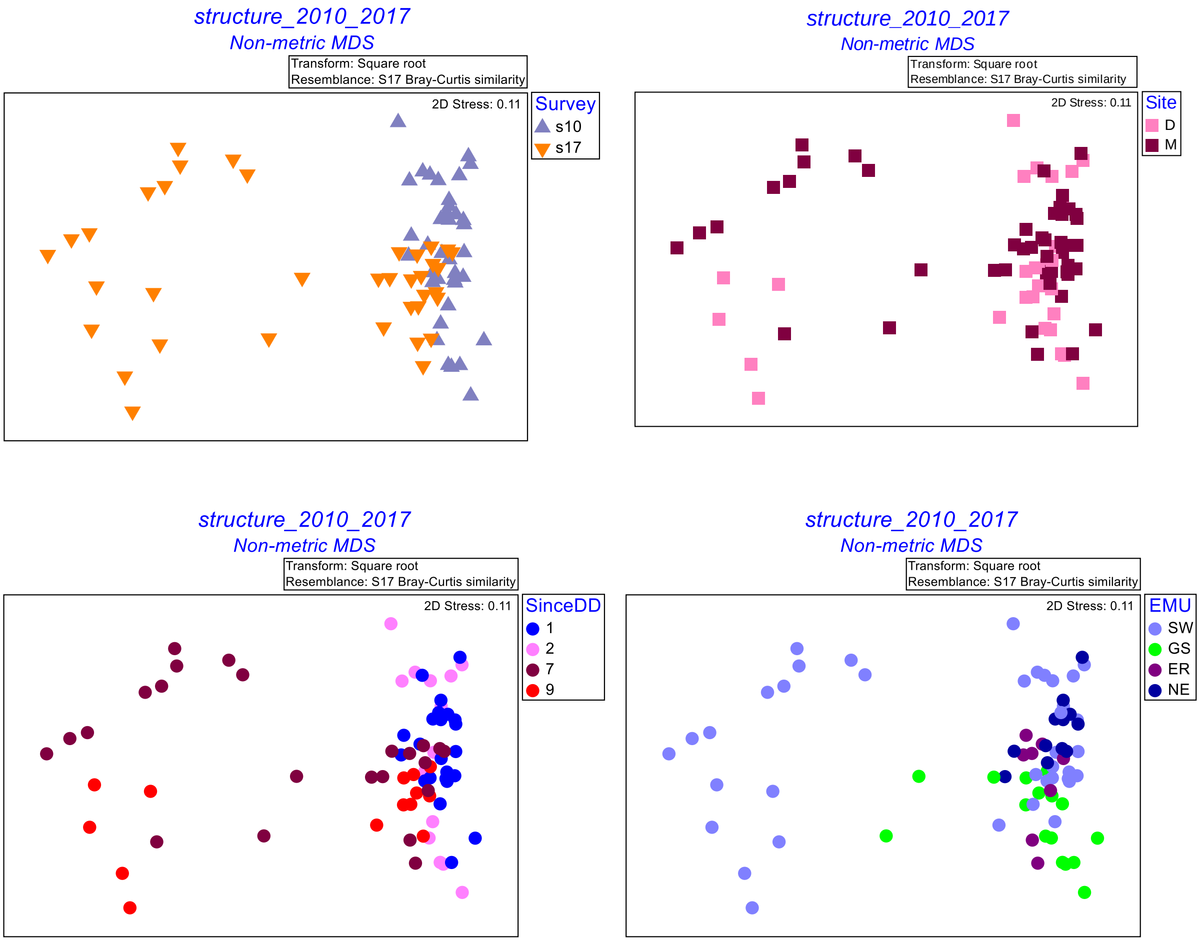
5. RESULTS: WETLANDS

There are 74 wetland samples (37 sites, each sampled twice) but because three samples from 2017 (D05, D12 and M07) had no live plants, only 71 samples are used in analyses of species composition and SET abundance.

5.1 Analysis using Factors

Structure

Non-metric MDS of wetland structure samples produces an elongated clump on the right, and a dispersed cloud on the left, with a stress of 0.11 in two dimensions. Ordination plots with six factors (Survey, Site, SinceDD, EMU, ExtentFLD and Depth) overlaid are shown below (Figure 5.1).



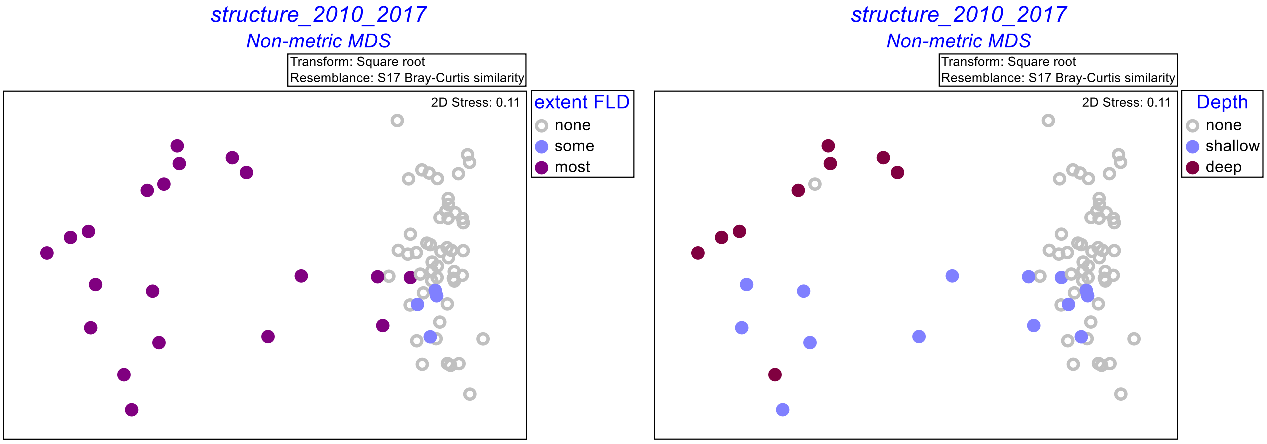


Figure 5.1. Ordination of wetland structure with factors overlain

Top Left: Factor is Survey with two levels, 2010 and 2017. Top Right: Factor is Site, with two levels, D and M. Centre left: Factor is SinceDD, with four levels, 1y, 2y, 7y, 9y. Centre right: Factor is EMU with four levels, Sergeants and Winton Swamps (SW), Green Swamp (GS), Eastern Rises (ER) and North Eastern (NE). Bottom left: Factor is ExtentFLD with three levels, none, some, most. Bottom Right: Factor is Depth, with three levels: none, shallow, deep.

The significance of each factor in accounting for the variation in structure of Wetland vegetation, as determined by ANOSIM routine, is summarised below (Table 5.1). Three factors (Survey, ExtentFLD and Depth) were significant. The factor SinceDD was not considered significant, despite the value and significance level of the sample statistic, because pairwise comparisons of the four levels (1y, 2y, 7y, and 9y) showed that none of the comparisons of interest (1y v 2y, 2y v 7y, 7y v 9y) were significant.

Table 5.1. Significance of six factors on wetland structure

Factor	Global R	Significance level of sample statistic	Outcome	Pairwise comparison
Survey	0.214	0.1%	Significant	n.a.
Site	0.03	18.3%	Not Significant	n.a.
SinceDD	0.206	0.1%	Treated as Not Significant	1y and 2 y not different 2y and 7y not different 7y and 9y not different
EMU	-0.038	74%	Not Significant	n.a.
ExtentFLD	0.651	0.1%	Significant	None and most differ Some and most differ None and some not different
Depth	0.63	0.1%	Significant	None and shallow differ Shallow and deep differ None and deep differ

Differences between factor levels

The structural variables contributing most to the difference between levels, for all three factors, as determined by the SIMPER routine, were bare ground, litter, lower layer and ground layer.

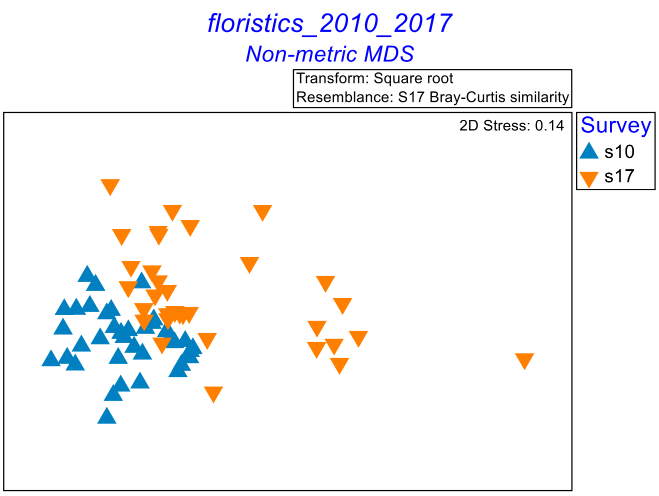
For the factor Survey, the average dissimilarity between 2010 and 2017 was 55.7%, which is moderate, with litter, lower layer and ground layer all much higher in 2010 than in 2017. Structural characteristics of 2010 and 2017 samples are summarised above (Table 3.3).

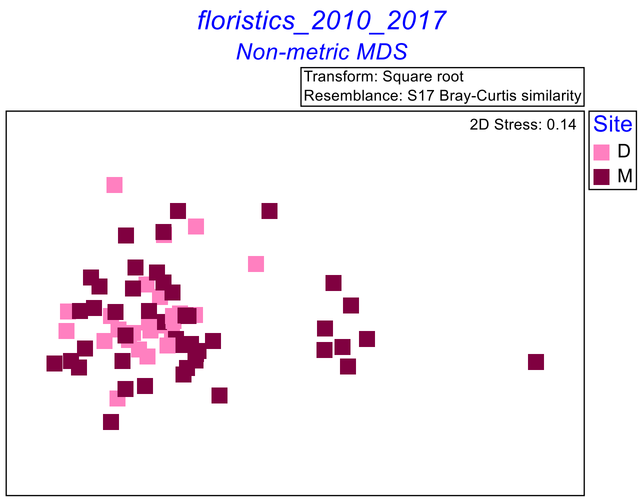
For the factor ExtentFLD, the average dissimilarity between level none and level most was 71.5%, which is high, with bare ground, litter, lower layer and ground layer being considerably higher in level none (not shown).

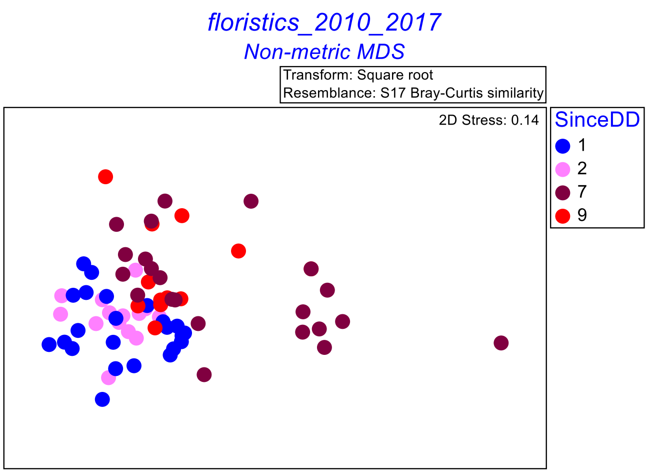
With the factor Depth, average dissimilarity between levels ranged from 55.6% (for levels none v shallow) to 78.5% (for none v deep). The level none had higher values for bare ground, litter, lower layer and ground layer (not shown).

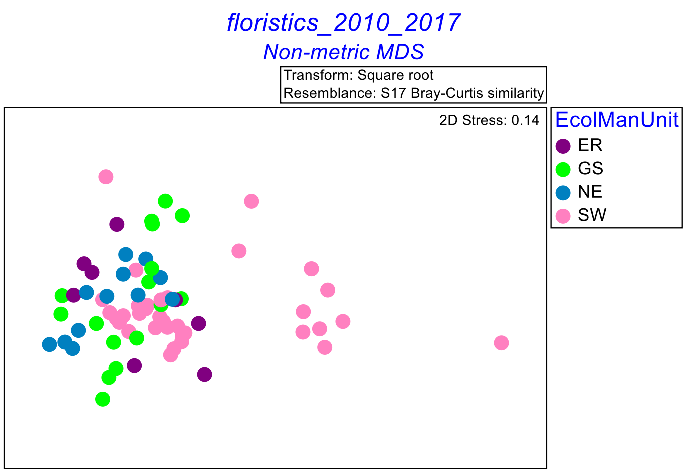
Species Composition

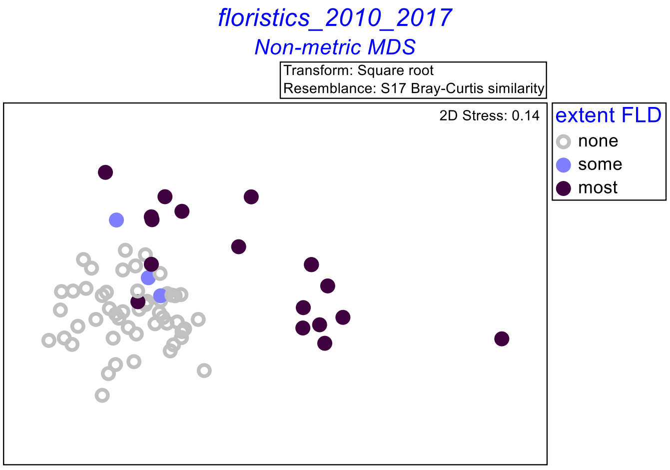
Non-metric MDS of wetland species composition produced a clump of samples on the left, with a smaller clump on the right and an outlier on the extreme right, with a stress of 0.14 in 2 dimensions. Ordination plots with the six factors overlain (Survey, Site, SinceDD, EMU, ExtentFLD and Depth) are shown below (Figure 5.2).











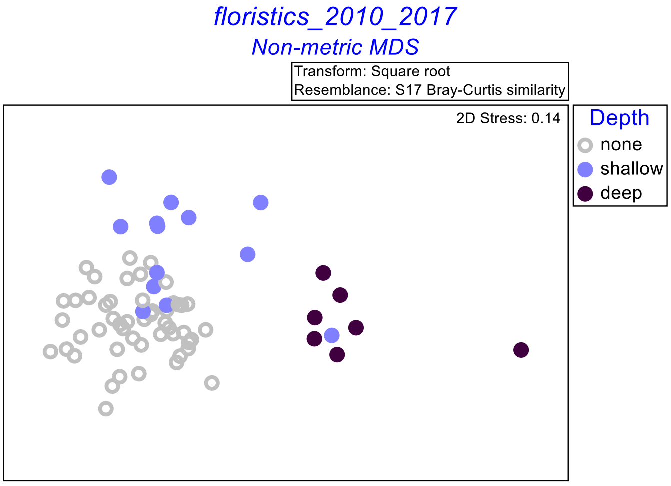


Figure 5.2. Ordination of wetland species abundances with factors overlain
Top Left: Factor is Survey with two levels, 2010 and 2017. Top Right: Factor is Site, with two levels, D and M. Centre left: Factor is SinceDD, with four levels, 1y, 2y, 7y, 9y. Centre right: Factor is EMU with four levels, Sergeants and Winton Swamps (SW), Green Swamp (GS), Eastern Rises (ER) and North Eastern (NE). Bottom left: Factor is ExtentFLD with three levels, none, some, most. Bottom Right: Factor is Depth, with three levels: none, shallow, deep.

As with wetland structure, the factors Survey, ExtentFLD and Depth were significant in accounting for the variation in species composition (Table 5.2) but not Site, or EMU. The factor SinceDD is treated as not significant, as was described above for wetland structure.

Table 5.2. Significance of six factors on species abundance in wetland samples

Factor	Global R	Significance level of sample statistic	Outcome	Pairwise comparisons
Survey	0.271	0.1%	Significant	n.a.
Site	-0.066	99.2%	Not Significant	n.a.
SinceDD	0.147	0.2%	Treated as Not significant	1y and 2 y not different 2y and 7y not different 7y and 9y not different
EMU	0.106	4.8%	Not Significant	n.a.
ExtentFLD	0.61	0.1%	Significant	none and most differ
Depth	0.655	0.1%	Significant	None and shallow differ None and deep differ Shallow and deep differ

Differences between factor levels

Average dissimilarity between levels was mostly high (see next paragraphs). Differences between levels are due to many species (as many as 17) each making a small contribution (<10%), rather than to a few species making a substantial contribution.

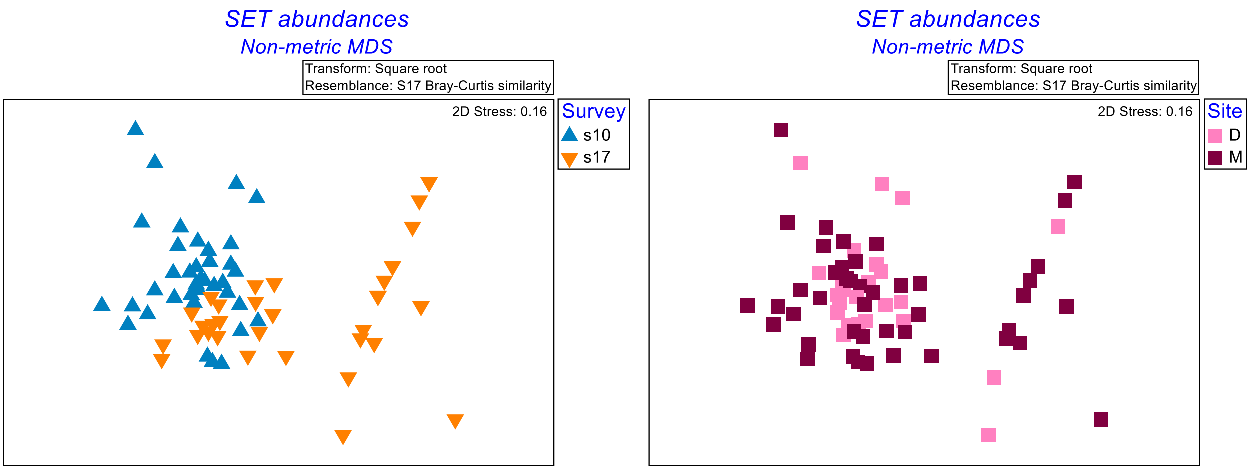
For the factor Survey, the average dissimilarity between levels was 85%, which is very high. The difference between 2010 and 2017 levels was primarily due to 2017 samples having higher abundances of *Juncus semisolidus, Alternanthera denticulata, Persicaria lapathifolia, Centipeda cunninghamii, Ricciocarpos natans, Eragrostis infecunda* and *Typha orientalis* (all native wetland species), and lower abundances of *Lachnagrostis filiformis, Dysphania pumilio, Lactuca serriola, Conyza bonariensis, Hypochaeris radicata, Cirsium vulgare, Aster subulatus, Lactuca saligna* and *Rorippa palustris* (all short-lived species, nearly all introduced, some terrestrial). Floristic characteristics of 2010 and 2017 samples are summarised above (Figure 3.6, Table 3.5).

For the factor ExtentFLD, the average dissimilarity between levels none and most was 92.7%, which is very high. It is due to the level most having higher abundances of *Ricciocarpos natans*, *Eragrostis infecunda* and *Typha orientalis* and lower abundances of *Juncus semisolidus* and *Lachnagrostis filiformis* as well as very low abundances in ten other species (not shown).

For the factor Depth, the average dissimilarity between levels was very high, ranging from 90.6% (shallow v deep) to 98.8% (none v deep). The difference between levels shallow and deep was due to shallow samples having higher abundances of *Juncus semisolidus* and *Ricciocarpos natans* and lower abundances of *Typha orientalis* and *Eragrostis infecunda*. The difference between none and shallow, and between none and deep was due to large changes in abundance of 14 to 17 species respectively (not shown).

Species Ecological Types (SET)

Non-metric MDS of wetland SET samples produced a distinctive ordination plot showing a large loose clump on the left, and a diagonal on the right, with a stress of 0.16 in two dimensions. Overlaying the six factors (Survey, Site, SinceDD, EMU, ExtentFLD and Depth) onto this plot (Figure 5.3) suggests only Survey, ExtentFLD and Depth are likely to explain variations in wetland SET composition.



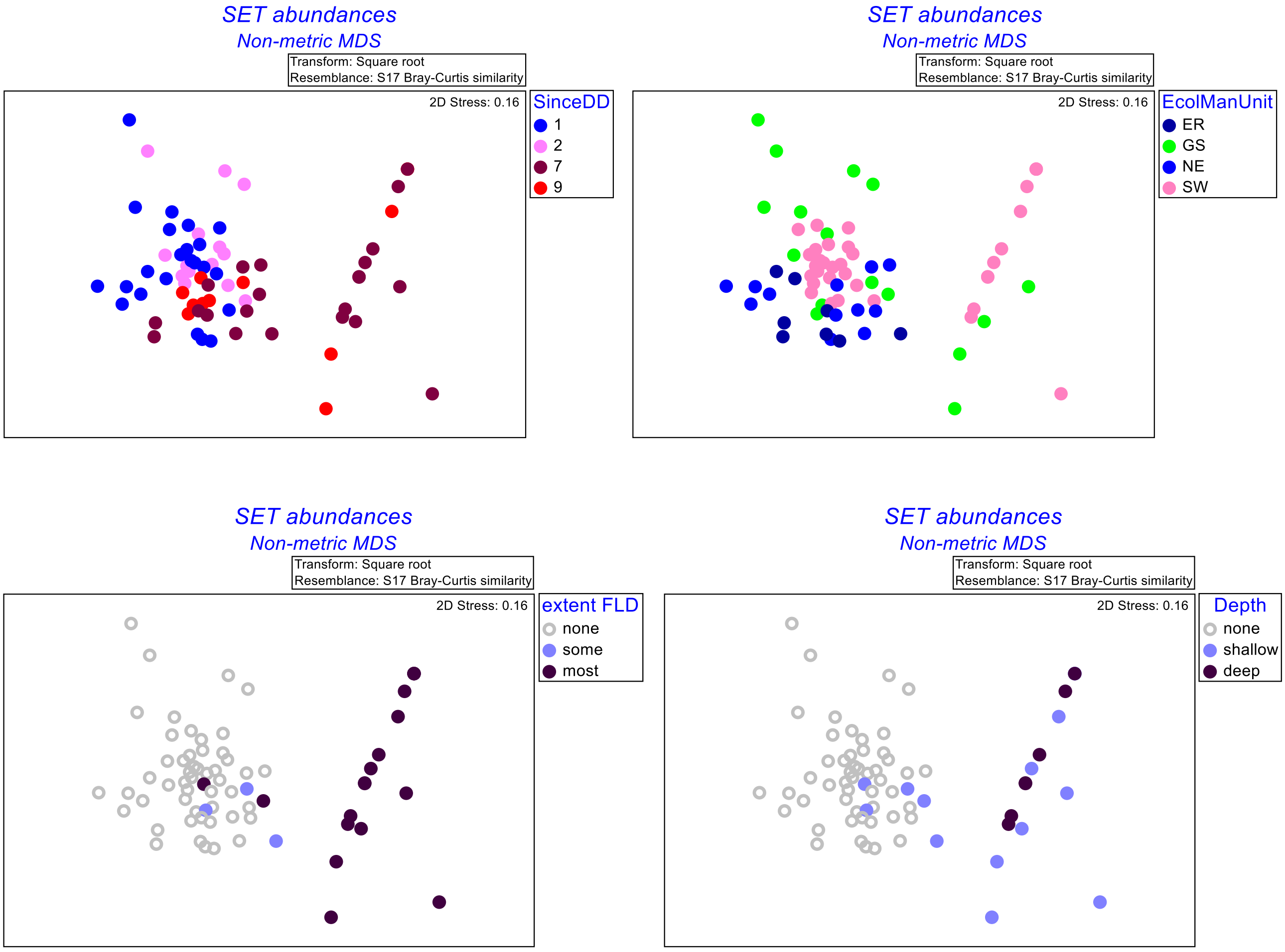


Figure 5.3. Ordination of SET abundances for Wetland samples with factors overlain

Top Left: Factor is Survey with two levels, 2010 and 2017. Top Right: Factor is Site, with two levels, D and M. Centre left: Factor is SinceDD, with four levels, 1y, 2y, 7y, 9y. Centre right: Factor is EMU with four levels, Sergeants and Winton Swamps (SW), Green Swamp (GS), Eastern Rises (ER) and North Eastern (NE). Bottom left: Factor is ExtentFLD with three levels, none, some, most. Bottom Right: Factor is Depth, with three levels: none, shallow, deep.

The ANOSIM routine (Table 5.3) confirmed that Survey, ExtentFLD and Depth were significant, and that Site and EMU were not. As with structure and species composition, and for the same reasons, the factor SinceDD is treated as not significant.

Table 5.3. Significance of six factors on SET abundances for Wetland samples

Factor	Global R	Significance level of sample statistic	Outcome	Pairwise comparisons
Survey	0.286	0.1%	Significant	n.a.
Site	-0.038	85.1%	Not significant	n.a.
SinceDD	0.198	0.1%	Treated as not significant	1y and 2y not different 2y and 7y not different 7y and 9y not different

Factor	Global R	Significance level of sample statistic	Outcome	Pairwise comparisons
EMU	0.088	6.9%	Not significant	n.a.
ExtentFLD	0.664	0.1%	Significant	none and most differ
Depth	0.651	0.1%	Significant	none and shallow differ none and most differ

Differences between factor levels

The difference between factor levels is due to five SETs, each making a similar contribution (typically in the order of 20-10%), rather than to a few SETs making a large contribution.

For the factor Survey, average dissimilarity between 2010 and 2017 levels was 67.4%. The level 2017 had higher abundances of GR_long_native and lower abundances of HB_short_native, HB_short_intro, HB_long_native and GR_short_native than the 2017 level. A summary of SET characteristics for 2010 and 2017 is given above (Table 3.7).

For the factor ExtentFLD, the average dissimilarity between levels none and most was high, 80.9%. The level most had much lower abundances than level none of HB_short_intro, HB_short_native, GR_long_native, HB_long_native and GR_short_native (not shown).

For the factor Depth, the average dissimilarity between levels ranged from 67.7% (shallow v most) to 73.5% and 82.8% (none v shallow, none v most). The difference between shallow and deep levels was due to GR_long_native (more abundant in deep) and FL_short_native (more abundant in shallow). The difference between levels none and shallow, and between levels none and deep was due to the level none having higher abundances of GR and HB SETs (not shown) with the exception of GR_long_native which was slightly more abundant in level deep.

5.2. Analysis using Empirical Groups

Structure

Cluster analysis of wetland samples combined with the SIMPROF routine recognised four clusters (a to d) at the 5% level (see black lines in Figure 5.4). This is in marked contrast to the analysis of Slopes structure, where no subgroups could be statistically identified. Samples in these four clusters are joined at a 20% similarity.

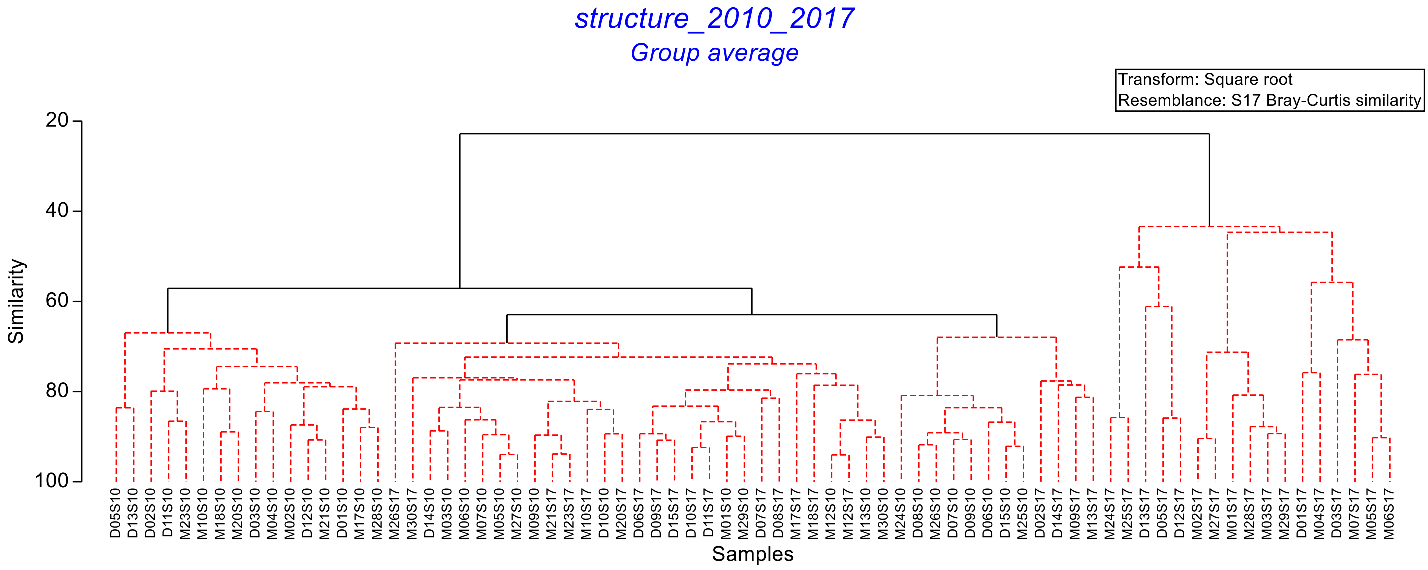


Figure 5.4. Dendrogram showing clusters based on wetland structure

When overlain onto the ordination plot of wetland structure, these four clusters are seen to have distinct and non-overlapping distributions in 2-dimensional space (Figure 5.5). Clusters a, b and c are close together and fairly compact, whereas cluster d is separate and forms an open group. The clearly-defined and separated groupings evident here are in marked contrast to the less well-defined groupings shown by overlaying factors (Figure 5.1).

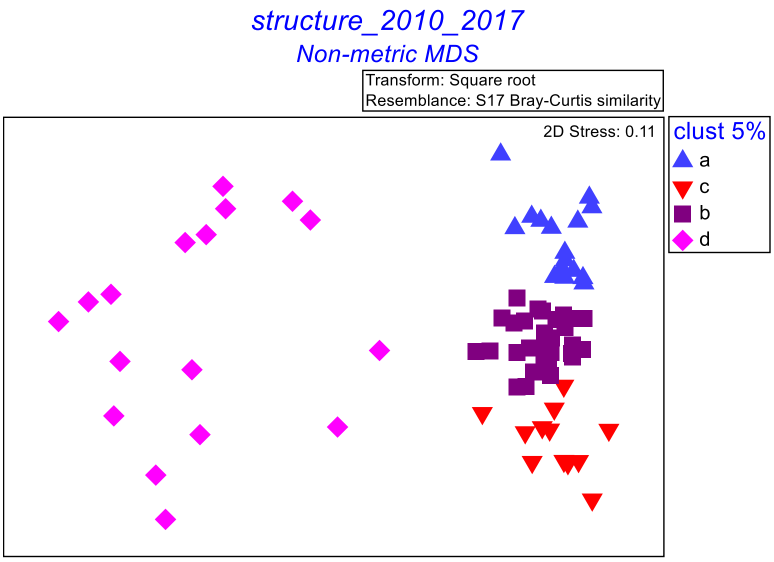


Figure 5.5. Ordination of Wetland samples with 4 structure clusters imposed

Cluster characteristics

Cluster size was moderate, ranging from 12 to 29 samples (Table 5.4), and each cluster was a specific combination of survey, location, wetland size, and inundation.

Two clusters (a, d) comprised samples for one survey only (2010, 2017 respectively), and the other two (b, c) were a mix of 2010 and 2017 samples. In terms of location, all four clusters were a mix of Edge and Floor samples (D and M sites), three clusters (a, b and c) were samples from small and large wetlands, and cluster d was large wetlands only. Nearly all samples in cluster d were inundated at the time of sampling, compared with none in cluster a, and a few in clusters b and c.

Clusters were not separated by site position around large wetlands: D and M sites occur in all clusters.

Table 5.4. Characteristics of clusters based on structure for Wetland samples

			Large wetlands			Small wetlands	
Cluster	Survey	Inundation	Name	Edge (D sites)	Floor (M sites)	(M sites)	Total
a	2010	Not flooded	Mostly Sergeants (6 sites): Winton (4)	7	3	6	16
b	2010 & 2017	Mostly not flooded (5 shallow)	Mostly Winton (9) and Green (6), a few Sergeants (2)	9	8	12	29
c	2010 & 2017	Mostly not flooded (2 shallow)	Mostly Green (8)	7	3	2	12
d	2017	Nearly all flooded (7 shallow, 9 deep, 1 none)	Mostly Sergeants (7) and Winton (8), a few Green (2)	5	12	0	17

The structural characteristics of each cluster are summarised below (Table 5.5).

Cluster a was distinctive in being the tallest (Table 5.5), and in having the most fallen litter, standing dead matter and cryptograms, and relatively little bare ground. Cluster b was distinctive in having the most abundant lower and ground layers, with moderate amounts of bare ground. Cluster c was distinctive in having the highest values for bare ground and more ground layer than lower layer. Cluster d was distinctive for its very low values generally, associated with all sites being inundated (Table 5.4).

Woody items such as fallen logs, stumps and dead trees are obvious features in the landscape that had been submerged by the former Lake Mokoan, and are expected to be important in providing structurally diverse habitat for fauna. Despite these being so conspicuous to visitors, the cover of woody items was low in all clusters: clusters b and c had a higher incidence of fallen logs than did clusters a and d (in 83% and 93% of sites, compared to 44% and 35%) and hence higher cover per cluster.

Table 5.5. Structure characteristics of Wetland clusters

	Cluster a mean (SE)	Cluster b mean (SE)	Cluster c mean (SE)	Cluster d mean (SE)
Upper layer (> 5m)	0	0	0	0
Mid layer (1m to 5 m)	3.6% (1.14)	0.05% (0.04)	0	0
Lower layer (15cm to 1 m)	20.7% (2.37)	30.9% (3.36)	3.1% (1.51)	3.8% (1.42)
Ground layer (<15 cm)	6.6% (1.88)	19.3% (3.17)	12.1% (3.59)	0.25% (0.15)
Bare ground	5.6% (1.11)	25.1% (2.54)	69.4% (7.57)	0
Cryptograms	14.2% (6.58)	0.9% (0.32)	0.4% (0.27)	0
Litter	56.4% (5.06)	14.0% (1.64)	4.0% (0.57)	0.2% (0.13)
Standing Dead	11.9% (1.92)	6.5% (1.22)	4.7% (0.90)	1.2% (0.13)
Dead Tree	0.2% (0.07)	0.5% (0.09)	0.4% (0.21)	0.4% (0.17)
Fallen log	0.3% (0.11)	1.8% (0.29)	1.9% (0.62)	0.4% (0.14)
Stumps	0.04% (0.03)	0.2% (0.07)	0.2% (0.09)	0.2% (0.06)

Changes

Changes in structural characteristics at 37 wetland sites between the two surveys are summarised below for each site individually (Tables 5.6, 5.7 and 5.8), using percentage similarity (%s) between 2010 and 2017, and showing which cluster each site belonged to in 2010 and 2017.

The summary shows structural change was highly variable. Similarity between surveys ranged from less than 20% (which was very low and indicated large change) at six sites, all in large wetlands (three Edge and three Floor sites) to more than 70% at six sites (three Edge, and three small wetlands). The magnitude of change varied with location. It was greatest for Floor sites in large wetlands (average similarity = 29.3%, SE = 6.84), and least for small wetlands (average similarity = 69.1%, SE = 3.84): Edge sites around large wetlands were intermediate (average similarity = 46.9%, SE = 3.50).

Table 5.6. Large wetlands: changes in Edge sites

	Sergeants				Winton					Green				
	D01	D02	D12	D13	D03	D05	D15	D10	D11	D06	D07	D14	D08	D09
%s	16.2	50.0	9.9	26.9	19.1	8.2	71.2	80.9	57.3	69.0	67.4	70.4	61.9	49.1
S10	a	a	a	a	a	a	c	b	a	c	c	b	c	c
S17	d	c	d	d	d	d	b	b	b	b	b	c	b	b

Table 5.7. Large wetlands: changes in Floor sites

	Sergeants				Winton						Green		
	M01	M02	M03	M04	M05	M06	M07	M27	M28	M29	M26	M25	M24
%s	22.8	36.0	27.9	24.1	15.3	11.9	9.0	40.0	29.3	23.9	53.6	51.8	34.7
S10	b	a	b	a	b	b	b	b	a	b	c	c	c
S17	d	d	d	d	d	d	d	d	d	d	b	d	d

Table 5.8. Small wetlands: changes in sites

	BFS	AS			SS		LS		BBN	BBS
	M30	M09	M10	M12	M13	M20	M18	M17	M21	M23
%s	69.3	63.4	69.6	94.0	59.6	79.0	57.7	67.8	72.2	58.1
S10	b	b	a	b	b	a	a	a	a	a
S17	b	c	b	b	c	b	b	b	b	b

The matrix of cluster transitions (Figure 5.6) shows three clusters for 2010 and three for 2017. Only two clusters (b and c) occurred in both surveys: clusters a and d were specific to 2010 and to 2017 respectively. Three sites (all in cluster b) did not change, showing only 8% stability.

The transition matrix has 8 pathways, the four most prevalent being cluster a to b (7 sites), cluster a to d (8 sites), cluster b to d (7 sites) and cluster c to b (6 sites). The transitions showed both divergence and convergence. Divergence was evident in the 16 sites of cluster a in 2010 which transitioned to three clusters (b, c and d) in 2017, and in the 13 sites in cluster b which transitioned to two clusters (c and d). Convergence was evident in the 16 sites of cluster b in 2017, that had transitioned from clusters a, b and c in 2010; and the in 17 sites in cluster d, with origins in clusters a and c.

Reference to the structural characteristics (Table 5.5) showed that the loss of cluster a was a change away from taller vegetation with high amounts of litter. Convergence to cluster b was a change to more abundant lower and ground layers. The convergence to cluster d was a major reduction in cover and litter and standing dead material: this was due to flooding, and ws primarily associated with large wetlands.

		Survey in 2017				Total
		a	b	c	d	2010
Survey	a		7	1	8	**16**
in	b		3	3	7	**13**
2010	c		6		2	**8**
	d					
Total for 2017			**16**	**4**	**17**	**37**

Figure 5.6. Matrix of cluster transitions, 2010 to 2017: structure in wetlands

The matrix of transition dissimilarity (Figure 5.7) shows that transitions on the divergence paths for clusters a and c had dissimilarity ranging from low to high, whereas the convergence paths were more uniform, being either low (convergence to cluster b) or high (convergence to cluster d).

		Survey in 2017			
		a	b	c	d
Survey in 2010	a		37.9	55	78.7
	b		0	37.1	75.8
	c		37.1		78.7
	d				

Figure 5.7. Average dissimilarity per cluster transition: structure

Species Composition

Cluster analysis combined with the SIMPROF routine of species composition for 71 wetland samples resulted in 14 clusters, a to n (Figure 5.8). Clusters are shown as black lines: the red lines show how samples are joined to form clusters, and what the composition of each cluster is. Three of the 14 clusters are singletons (ie have just one sample each): M13 and M30 in 2017 (extreme left of dendrogram) and M20 in 2017 (centre left of dendrogram).

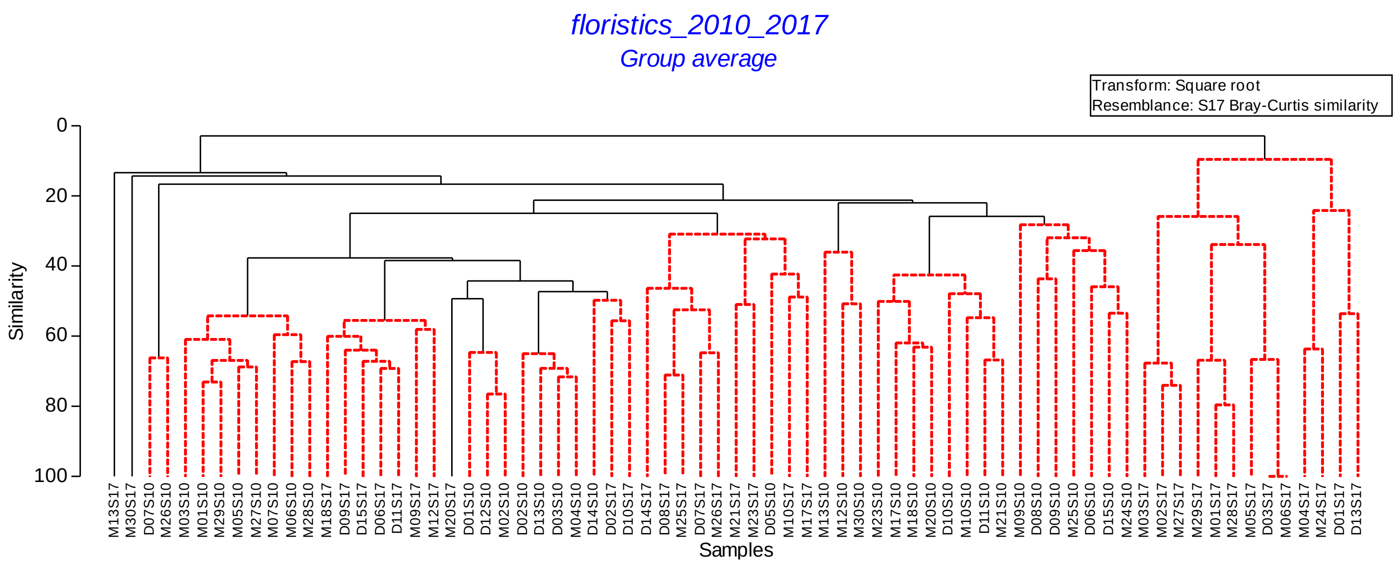


Figure 5.8. Dendrogram showing clusters based on Wetland species abundance

The ordination plot of species composition with the 14 clusters overlaid is shown below (Figure 5.9). Clusters h, g and e were quite compact and close together, in contrast cluster n was somewhat separate from other clusters, and formed an open elongated group on the right. The three singletons were clusters a, b and f, shown as hollow circles. This approach disaggregated species into many clusters, and contrasts with analysis using factors (Figure 5.2).

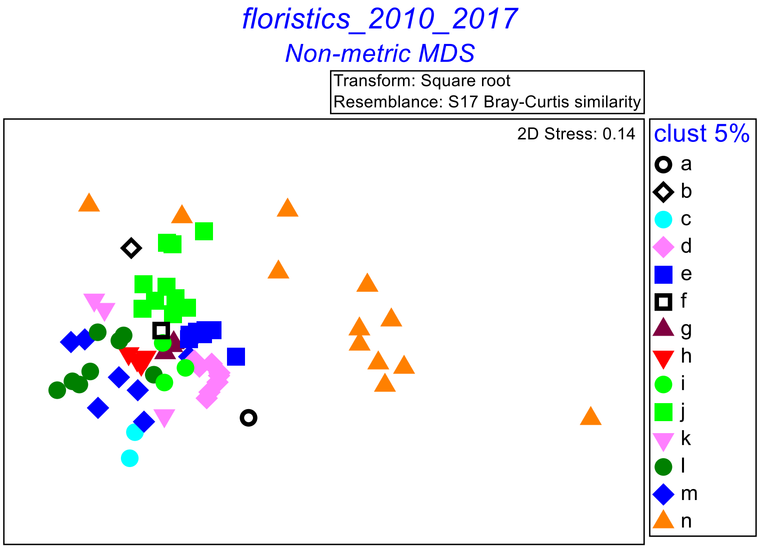


Figure 5.9. Ordination of Wetland species abundances with 14 clusters imposed

Cluster characteristics

Cluster characteristics are summarised below (Table 5.9). This table has 15 clusters, as it includes the three sites with no live plants as an additional cluster (cluster o), even though this was not part of the analyses.

Cluster size tended to be small, ranging from 1 to 13 samples per cluster. Clusters were characterised by survey, inundation and, to a lesser extent, by wetland size and sample location. All clusters except two (cluster i and j) comprised samples from either 2010 or 2017: clusters i and j had samples from both surveys. Clusters tended to be either unflooded at time of survey (clusters a, c, d, f, g, h, k, l and m) or flooded (clusters b, n, and o); only a few had a mix of flooded and unflooded samples (clusters e, i and j). Clusters were a mix of locations, being only Edge (cluster i), Edge and small wetlands (clusters e and l), Edge and Floor of large wetlands (cluster c, g, h, n and o) or all three locations (clusters j and m). The three singletons (clusters a, b, and f) are all small wetlands.

Co-location, meaning samples from sites that are locally close to each other such as D and M sites, is unusual in wetland clusters (unlike Slopes) with only one instance: cluster c, where the D and M sites in Green Swamp are the closest to each other.

Site M13 (cluster a) was the only wetland site where grazing was noted during 2017 survey (Section 3.2. Field Notes).

Table 5.9. Characteristics of clusters based on Wetland species composition

			Large wetlands			Small wetlands	
Cluster	Survey	Flooded	Name	Edge (D sites)	Floor (M sites)	(M sites)	Total
a	2017	no		0	0	1	1
b	2017	flooded		0	0	1	1
c	2010	no	Green	1	1	0	2
d	2010	no	Winton (mostly) and Sergeants	0	8	0	8
e	2017	Mostly flooded	Green, Winton	4	0	3	7
f	2017	no		0	0	1	1
g	2010	no	Sergeants	2	1	0	3
h	2010	no	Mostly Sergeants	3	1	0	4
i	Mostly 2017	Unflooded and flooded	Sergeants, Winton, Green	3	0	0	3
j	Mostly 2017	Flooded and unflooded	Mostly Green	4	2	4	10
k	2010	no		0	0	3	3
l	2010	no	Winton	2	0	6	8
m	2010	no	Mostly Green	4	2	1	7
n	2017	all	Mostly Sergeants, and Winton	3	10	0	13
o	2017	flooded	Sergeants, Winton	2	1	0	3

The species characteristics of each cluster are summarised below (Table 5.10) showing mean (SE) abundance for the four most abundant species per cluster (five, if one of those was an unidentified taxon), and mean (SE) species richness per cluster.

Abundance ranges quite widely from 0% to 76.5% cover. Most clusters are in the range 20-50%; four are lower than 20% (clusters c, m, n and o) and two are higher than 60% (e, k). Species richness ranged from 0 to 26.3 per cluster, and tended to increase with abundance ($r^2 = 0.54$). Most clusters had between 10 to 20 species. Species richness departed from the general trend for cluster k, the most abundant cluster, which had a mean species richness of only 17.7 per sample, and cluster i, the most species-rich cluster, which had an average abundance of 36.5%.

There was considerable overlap between clusters in their four most abundant species, as some species occurred in several clusters (Table 5.10). For example, *Juncus semisolidus* occurred in nine clusters, *Lachnagrostis filiformis* in seven clusters, *Alternanthera denticulata* and *Persicaria lapathifolia* in six clusters each, and *Dysphania pumilio* in five clusters. A consequence of this overlap was that only 23 species comprise the four most abundant, far short of the potential maximum of 60 (4 spp x 15 clusters). These 23 species comprised a mix of wetland perennials (*Juncus semisolidus, Eleocharis acuta, Typha orientalis, Eragrostis infecunda*), aquatic plants (*Lemna disperma, Ricciocarpos natans, Potamogeton cheesemanii*), terrestrial opportunistic introduced herbs (*Conyza bonariensis, Lactuca serriola, Lactuca saligna, Hypochaeris radicata, Cirsium vulgare*), and herbs that flourish following falling water levels and here called 'recession' plants (*Persicaria lapathifolia, Dysphania pumilio, Centipeda cunninghamii, Alternanthera denticulata*).

Nearly all clusters were assemblages dominated by recession plants with the following exceptions: clusters b and n which were dominated by aquatics, and clusters l and m which had some opportunistic introduced terrestrial herbs dominating.

Table 5.10. Species characteristics of Wetland clusters

Cluster	The four most abundant species (mean % cover per sample)
a	*Lotus subbiflorus* (11.4%), *Dysphania pumilio* (7.4%), *Cynodon dactylon* (1.0%), *Persicaria lapathifolia* (0.8%) Mean (SE) abundance per sample = 21.5% Mean (SE) species richness = 11
b	*Eleocharis acuta* (21.4%), *Lemna disperma* (5.2%), *Juncus semisolidus* (3.8%), *Potamogeton cheesemanii* (3.02%) Mean (SE) abundance per sample = 36.3% Mean (SE) species richness = 10
c	*Lachnagrostis filiformis* (3.2%), unidentified dicot seedlings (1.0%), *Alternanthera denticulata* (0.5%), *Persicaria prostrata* (0.4%), *Rumex tenax* (0.1%) Mean (SE) abundance per sample = 5.3% (2.10) Mean (SE) species richness = 4.5 (1.50)
d	*Dysphania pumilio* (22.5%), *Lachnagrostis filiformis* (8.8%), *Alternanthera denticulata* (3.8%), *Eragrostis infecunda* (1.5%) Mean (SE) abundance per sample = 44.2% (6.36) Mean (SE) species richness = 14.9 (1.06)
e	*Alternanthera denticulata* (22.5%), *Centipeda cunninghamii* (8.9%), *Dysphania pumilio* (7.7%), *Juncus semisolidus* (7.2%) Mean (SE) abundance per sample = 64.0% (4.89) Mean (SE) species richness = 18.1 (3.14)
f	*Persicaria lapathifolia* (16.0%), *Juncus semisolidus* (13.8%), *Alternanthera denticulata* (5.4%), *Lachnagrostis filiformis* (2.2%) Mean (SE) abundance per sample = 49.1% Mean (SE) species richness = 20

Cluster	The four most abundant species (mean % cover per sample)
g	*Juncus semisolidus* (12.0%), *Lachnagrostis filiformis* (11.9%), *Persicaria lapathifolia* (5.7%), *Dysphania pumilio* (1.3%) Mean (SE) abundance per sample = 36.1 % (10.55) Mean (SE) species richness = 11.7 (0.67)
h	*Persicaria lapathifolia* (9.4%), *Juncus semisolidus* (2.3%), *Lachnagrostis filiformis* (2.2%), *Alternanthera denticulata* (2.1%) Mean (SE) abundance per sample = 26.6% (3.97) Mean (SE) species richness = 18.0 (0.82)
i	*Alternanthera denticulata* (7.0%), *Centipeda cunninghamii* (3.9%), *Lachnagrostis filiformis* (3.5%), *Dysphania pumilio* (3.5%) Mean (SE) abundance per sample = 36.0% (11.44) Mean (SE) species richness = 26.3 (5.49)
j	*Juncus semisolidus* (12.8%), *Persicaria lapathifolia* (6.3%), *Ricciocarpus natans* (5.7%), *Carex tereticaulis* (1.4%) Mean (SE) abundance per sample = 30.8% (7.23) Mean (SE) species richness = 10.6 (1.45)
k	*Amphibromus nervosus* (20.3%), *Cirsium vulgare* (19.5%), *Juncus semisolidus* (6.8%), monocot seedlings (4.3%), *Eleocharis acuta* (3.0%). Mean (SE) abundance per sample =76.5% (8.10) Mean (SE) species richness = 17.7 (0.33)
l	*Juncus semisolidus* (7.7%), *Conyza bonariensis* (6.7%), *Lactuca serriola* (5.3%), unidentified dicot seedlings (3.9%), *Lactuca saligna* (2.5%) Mean (SE) abundance per sample = 35.6% (4.47) Mean (SE) species richness = 14.4 (1.58)
m	*Lachnagrostis filiformis* (3.2%), *Lactuca serriola* (1.9%), *Persicaria lapathifolia* (1.5%), *Hypochaeris radicata* (1.2%) Mean (SE) abundance per sample = 11.7% (3.09) Mean (SE) species richness = 9.0 (1.48)
n	*Typha orientalis* (2.9%), *Eragrostis infecunda* (1.4%), *Ricciocarpos natans* (0.2%), *Juncus semisolidus* (0.1%). Mean (SE) abundance per sample = 4.6% (1.74) Mean (SE) species richness = 1.5 (0.14)
o	Mean (SE) abundance per sample = 0 Mean (SE) species richness = 0

Changes

Changes in species composition at 37 wetland sites between the two surveys are summarised below for the three locations for eah site individually (Tables 5.11, 5.12 and 5.13), using the Bray-Curtis measure of similarity (%s) to indicate change.

There were considerable differences in species composition in 2017 compared with 2010. Percentage similarity between surveys was generally low or sometime moderate, ranging from 0 to 50.4%. A similarity of 0%, which indicates completely different in 2017 compared to 2010, occurred at ten of the 37 sites, nine of them in large wetlands, and one in a small wetland (M23). For the large wetladns, six were Floor sites and three were Edge sites. Average similarity was low for all three locations, particularly for Floor sites of large wetlands (6.3%, SE = 1.92). Average similarity for Edge sites was 18.0% (SE = 4.60) and for small wetlands was 17.1% (SE = 3.26).

Table 5.11. Large wetlands: changes in Edge sites

	Sergeants				Winton					Green				
	D01	D02	D12	D13	D03	D05	D15	D10	D11	D06	D07	D14	D08	D09
%s	7.8	42.7	0	7.8	0	0	36	50.4	35.5	22.0	25.8	8.5	7.0	8.2
S10	g	h	g	h	h	j	m	l	l	m	c	i	m	m
S17	n	i	o	n	n	o	e	i	e	e	j	j	j	e

Table 5.12. Large wetlands: changes in Floor sites

	Sergeants				Winton						Green		
	M01	M02	M03	M04	M05	M06	M07	M27	M28	M29	M26	M25	M24
%s	11.8	0	0	0	0	5.1	0	17.6	17.3	9.1	13.3	5.3	0
S10	d	g	d	h	d	d	d	d	d	d	c	m	m
S17	n	n	n	n	n	n	o	n	n	n	j	j	n

Table 5.13. Small wetlands: changes in sites

	BFS	AS			SS		LS		BBN	BBS
	M30	M09	M10	M12	M13	M20	M18	M17	M21	M23
%s	23.7	10.8	26.7	20.5	14.8	20.4	8.8	10.1	35.6	0
S10	k	m	l	k	k	l	l	l	l	l
S17	b	e	j	e	a	f	e	j	j	j

The matrix of cluster transitions (Figure 5.10) showed the same pattern of widespread and considerable change between the two surveys. There was no stability: all sites changed cluster from 2010 to 2017.

The matrix shows nine clusters in 2010, and eight in 2017. Seven clusters were specific to 2010 (clusters c, d, g, h, k, l and m), and six were specific to 2017 (clusters a, b, e, f, n and o): only two clusters (i and j) occurred in both surveys. There were nineteen transitions: none of them occurred frequently, and several occurred just once (n = 10). The most prevalent pathways tended to be associated with a specific location: for example, the transition from cluster d to cluster n occurred at seven sites, all Floor sites in large wetlands. Similarly the transition from cluster l to j, and from cluster m to e occurred at four sites each, all small wetlands, and mostly at large wetlands respectively.

Divergence was evident: clusters l and m (two of the largest clusters in 2010) transitioned to four and three clusters respectively in 2017. Convergence was also evident: clusters j and n (the two largest clusters in 2017) were both from four 2010 clusters: also cluster o (with no live plants when sampled). Recent inundation history is implicated as the mechanism forcing convergence (Table 5.9).

		Survey in 2017															Total
Survey		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	**2010**
in	a																
2010	b																
	c										2						**2**
	d														7	1	**8**
	e																
	f																
	g														2	1	**3**
	h									1					3		**4**
	i										1						**1**
	j															1	**1**
	k	1	1			1											**3**
	l					2	1			1	4						**8**
	m					4					2				1		**7**
	n																
	o																
Total for 2017		**1**	**1**			**7**	**1**			**2**	**9**				**13**	**3**	**37**

Figure 5.10. Matrix of cluster transitions, 2010 to 2017: Species in wetlands

The dissimilarity of the nineteen transitions ranged from 52.7 to 100% (Figure 5.11), ie from moderate to complete dissimilarity. Flooding accounted for the most extreme change in species, as shown by very high dissimilarity for cluster b, e, j, n and o (Table 5.9). The most prevalent pathways all showed very high dissimilarity. There was one transition with a moderate dissimilarity (site D02), which moved from one recession assemblage to another.

Survey in 2010	Survey in 2017: a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
a															
b															
c										90.3					
d														94.73	**100**
e															
f															
g														97.9	**100**
h									52.7					98.3	
i										75.4					
j															**100**
k	88.4	82.6			79.6										
l					82.6	73.7			68.2	82					
m					93.3					83.8				96.5	
n															
o															

Figure 5.11. Average dissimilarity per cluster transition: species composition

Species Ecological Types (SET)

The SIMPROF procedure recognised eight clusters, a to h, as shown by the black lines in the dendrogram below (Figure 5.12), joined at moderate similarity. Cluster d is a singleton: site M17 in 2017.

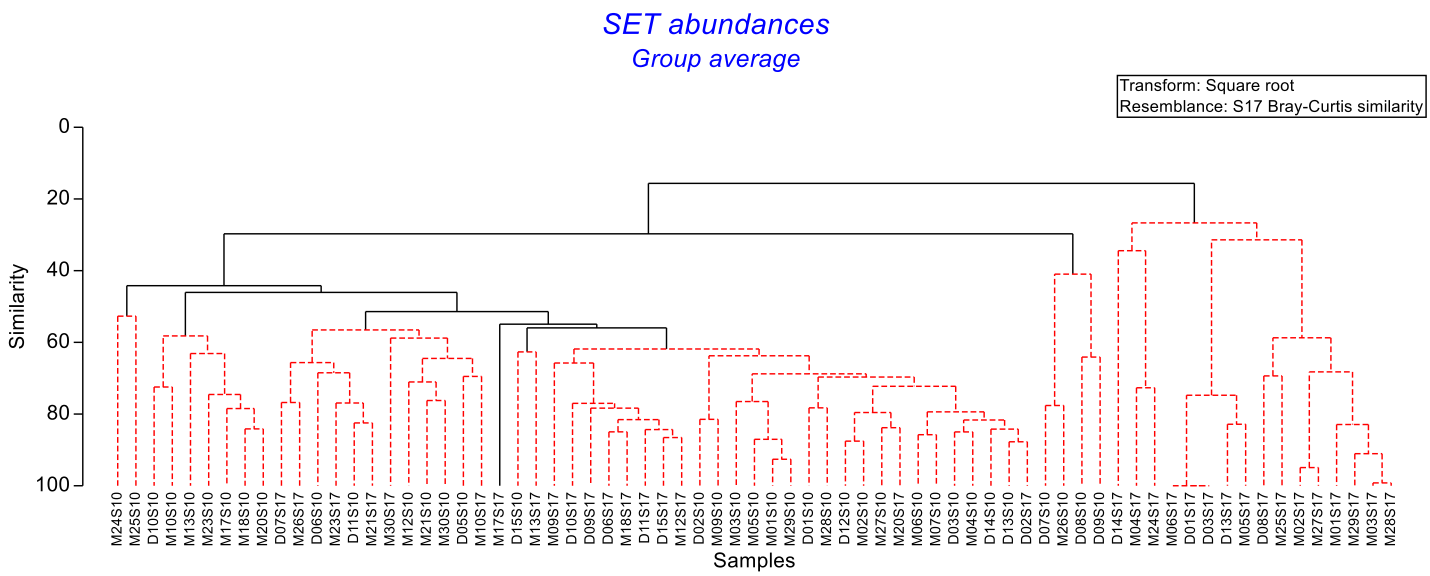


Figure 5.12. Dendrogram showing clusters based on SET

Overlaying the eight clusters onto the ordination plot of SET abundance (Figure 5.13) showed the outlying spine of sites in the lower right as one cluster (cluster h), the small dispersed group in the top left as another (cluster g), and a central clump of the other clusters, which were mostly fairly well separated in two-dimensional space.

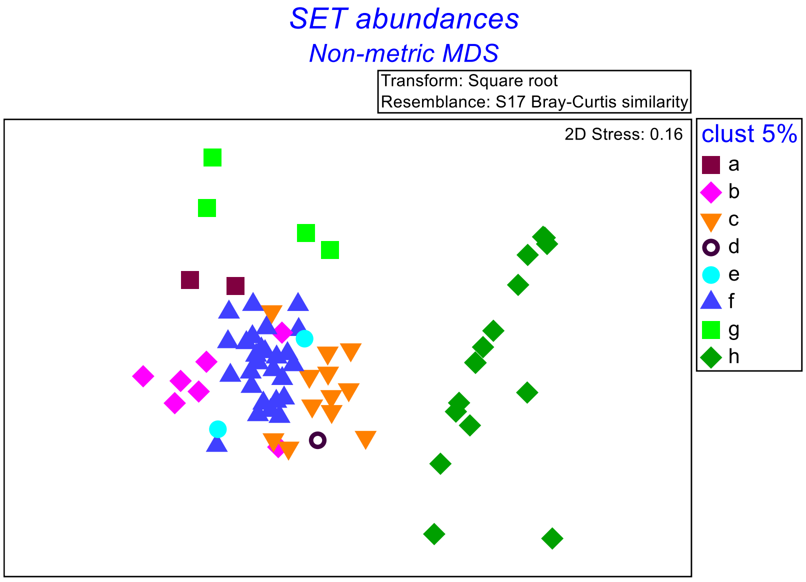


Figure 5.13: Ordination of wetland SET abundances with 8 clusters imposed

Characteristics of clusters

Cluster characteristics are summarised below (Table 5.14). This table has nine clusters, as it includes the three sites with no live plants as cluster i, even though these were not part of the analyses.

Cluster size was quite variable, ranging from 1 to 27 samples: the three largest clusters (c, f and h) accounted for 74% of samples. Clusters were characterised by Survey, whether flooded when sampled, and wetland size. Site location (Edge or Floor) did not appear to be relevant in characterising SET clusters. Six clusters (a, b, d, g, h and i) comprised samples from just one survey, and typically these were the smallest clusters: two of the biggest clusters, cluster c and f (n= 12 and 27 respectively) were a mix of surveys. Five clusters (mostly smaller ones) were not flooded when sampled: clusters that were flooded are clusters h and i with all samples were flooded, and clusters c and f, with just a few samples flooded. Four clusters (a, g, h, and i) were specific to large wetlands, and four were a mix of samples from large and small wetlands (b, c, e, f). Small wetlands were concentrated in three clusters (b, c and f): the singleton, M17 in 2017 (cluster d) was a small wetland.

Table 5.14. Characteristics of clusters based on wetland SET abundance

			Large wetlands			Small wetlands	
Cluster	Survey	Flooded	Name	Edge (D sites)	Floor (M sites)	(M sites)	Total
a	2010	no	Green Swamp		2		2
b	2010	no	Winton Swamp	1		6	7
c	2010, 2017	Mostly not (3 shallow)	Green & Winton	4	1	7	12
d	2017	no				1	1
e	2010, 2017	no	Winton	1		1	2
f	2010, 2017	Mostly not (2 shallow)	Sergeants, Winton, Green	12	10	5	27
g	2010	no	Green Swamp	3	1		4
h	2017	Mostly flooded (9 shallow, 7 deep)	Sergeants, Winton, Green	5	11		16
i	2017	Flooded	Winton, Sergeants	2	1		3

The SET characteristics for each cluster are summarised below (Table 5.15), showing the two most abundant SET, and total SET abundances (mean, SE per sample). The most abundant cluster was, by far, cluster d (singleton, M17) with total abundance of 86.5%, followed by clusters f and b with 44.3% and 40.4% respectively. Five clusters had low total abundance (less than 20%), and three of these were very low (less than 10%): clusters h, g and i had abundances of 7.5%, 4.5% and 0% respectively. Individual SETs with high abundance (ie average more than 20% per cluster) were GR_long_native (22.0% in cluster d), HB_short_native (58.6% in cluster d) and HB_short_intro (23.2% in cluster b). Such high abundances were unusual: individual SETs generally averaged much less than 10%.

The combined list of two most abundant SETs feature seven SETs, with the most frequent being HB_short_intro (in clusters a, b, c and e) and HB_short_native (in clusters d, e and f).

Table 5.15. SET characteristics of Wetland clusters

Cluster	Two most abundant SET (mean, SE) Total SET abundance (mean, SE per sample)
a	Most abundant SET are: GR_short_native (8.8%), HB_short_intro (3.6%) Total abundance averages 14.1% (7.9)
b	Most abundant SET are: HB_short_intro (23.2%), unknown (6.0%) and HB_long_intro (4.8%) Total abundance averages 40.4% (8.03)
c	Most abundant SET are: FL_short_native (23.1%), HB_short_intro (5.0%) Total abundance averages 36.9% (10.7)
d	Most abundant SET are: HB_short_native (58.6%), GR_long_native (22.0%) Total abundance averages 86.5%
e	Most abundant SET are: HB_short_intro (7.0%), HB_short_native (5.6%) Total abundance averages 16.9% (4.7)
f	Most abundant SET are: HB_short_native (16.0%), HB_long_native (9.6%) Total abundance averages 44.3% (3.7)
g	Most abundant SET are: GR_short_native (1.9%), HB_long_native (1.0%) Total abundance averages 4.1% (1.1)
h	Most abundant SET are: GR_long_native (5.0%), FL_short_native (2.5%) Total abundance averages 7.5% (2.3)
i	Total abundance averages 0%

Changes

Changes in SET composition are summarised below (Tables 5.16, 5.17 and 5.18) for individual sites grouped by location, using the same metrics as for species composition and structure.

For individual sites, similarity between surveys was highly variable, ranging from 0 (4 sites in large wetlands) to at least 70% (3 sites in large wetlands). Similarity varied with location, with the biggest changes (ie lowest similarity) being Floor sites of large wetlands. Here similarity between surveys averaged only 14.8% (SE = 3.53), compared Edge sites and small wetlands (mean = 30.4%, SE=7.38; and mean = 46.6%, SE = 4.18, respectively). Change was not uniform within a location, as shown by standard error and the range of values for Edge sites (Table 5.16): the between survey similarities are quite variable for Edge sites, were consistently low for Floor sites, and consistently moderate for small wetlands with no extreme high or low values.

Table 5.16. Large wetlands: changes in Edge sites

	Sergeants				Winton					Green				
	D01	D02	D12	D13	D03	D05	D15	D10	D11	D06	D07	D14	D08	D09
%s	9.6	70.4	0	13.9	6.1	0	57.1	70.0	72.2	49.8	30.4	12.5	10.4	23.4
S10	f	f	f	f	f	c	e	b	c	c	g	f	g	g
S17	h	f	i	h	h	i	f	f	f	f	c	h	h	f

Table 5.17. Large wetlands: changes in Floor sites

	Sergeants				Winton						Green		
	M01	M02	M03	M04	M05	M06	M07	M27	M28	M29	M26	M25	M24
%s	18.8	42.6	14.1	2.1	8.7	6.7	0	29.0	28.0	18.4	17.0	7.0	0
S10	f	f	f	f	f	f	f	f	f	f	g	a	a
S17	h	h	h	h	h	h	i	h	h	h	c	h	h

Table 5.18. Small wetlands: changes in sites

	BFS	AS			SS		LS		BBN	BBS
	M30	M09	M10	M12	M13	M20	M18	M17	M21	M23
%s	58.2	56.9	46.5	61.9	49.0	33.5	30.5	31.8	63.7	34.3
S10	c	f	b	c	b	b	b	b	c	b
S17	c	f	c	f	e	f	f	d	c	c

The matrix of cluster transitions (Figure 5.14) showed the same mixed pattern of variability. Four of the 37 sites (11%) were stable (ie same cluster in both surveys), and of these three were in small wetlands, and one was an Edge site: none was from the Floor of a large wetland.

Although the matrix showed six clusters for 2010, and six for 2017, they were not exactly the same six, and there was cluster turnover: clusters a, b and g were specific to 2010, and clusters d, h and i were specific to 2017. Only two clusters (c and f), both fairly abundant (Table 5.15), occurred in both surveys. There were thirteen transitions, of which six were individual (ie only one site made that transition). The most prevalent transition was from cluster f in 2010 to cluster h in 2017 (n = 13 sites), indicating a shift from a moderately abundant herb-dominated plant assemblage to a low abundance assemblage, characterised by perennial native grasses and floating-leaved aquatics (Table 5.15). This transition occurred only in large wetlands, and mostly in Floor sites (Table 5.16). There was no prevalent transition path for small wetlands, instead these showed diversity, with a range of transitions (seven for ten sites), including no change (3 out of 10 sites).

Survey in 2010	Survey in 2017									Total
	a	b	c	d	e	f	g	h	i	2010
a								2		**2**
b			2	1	1	3				**7**
c			2			3			1	**6**
d										
e						1				**1**
f						2		13	2	**17**
g			2			1		1		**4**
h										
i										
Total in 2017			**6**	**1**	**1**	**10**		**16**	**3**	**37**

Figure 5.14. Matrix of cluster transitions, 2010 to 2017: SET in wetlands

The dissimilarity matrix (Figure 5.15) shows that the divergent path of cluster b and the convergent path to cluster f are moderate changes in SET composition, whereas the convergent path to cluster h is one of substantial (near complete) change in SET composition.

Survey in 2010	Survey in 2017								
	a	b	c	d	e	f	g	h	i
a								95.5	
b			53.6	69.9	54.8	53.4			
c			0			48			**100**
d									
e						44			
f						0		84.9	**100**
g			70.2			69.9		90.7	
h									
i									

Figure 5.15. Average dissimilarity per cluster transition: SET abundance

5.3. Synthesis

Analysis using Factors

The six factors used in the analysis of Wetlands samples are the same spatial and temporal influences on vegetation as for Slopes samples but with the addition of two inundation-related factors, ExtentFLD and Depth.

Only three of the six factors, Survey, ExtentFLD and Depth, were significant in accounting for variation in wetland vegetation (Table 5.19). All vegetation attributes were equally influenced, unlike Slopes samples where species composition was more sensitive (Table 4.16). All three factors were to do with inundation, even Survey. The levels in the factor Survey were not simply a temporal contrast, as with Slopes samples (ie seven years later), but were also contrasting inundation phases. The 2017 samples were for the recession phase after extensive and persistent flooding whereas the 2010 samples were from a phase between inundations (Section 2.1). ExtentFLD and Depth focus on different consequences of inundation (water-logging and submergence respectively), and for both these, the level "none" was a temporal mix of samples from 2010 with samples from 2017.

Neither of the two spatial factors, Site (with two levels: D and M) or EMU (with four levels: SW, GS, ER, NE), was significant. This was an unexpected finding. In the case of Site, differences were expected between D (Edge) and M (Floor) sites because wetlands in 2010 had a vegetation fringe that was visually very different from the wetland floor, and this was the reason for sampling Edge and Floor separately. In the case of EMU, differences were expected between EMU characterised by large wetlands (SW) and EMU with only small wetlands (NE and ER), due to differences in water regime (depth and duration of flooding), and time since last flooded.

Table 5.19. Summary of analyses using factors

	Survey	Site	SinceDD	EMU	ExtentFLD	Depth
Structure	S	NS	NS	NS	S	S
Species Composition	S	NS	NS	NS	S	S
SET abundance	S	NS	NS	NS	S	S

Changes identified by Analysis using empirical groups

Vegetation changes identified using percentage similarity and transition matrices ranged from effectively no change to complete change, with the magnitude of change dependent on vegetation attribute, and on location. All vegetation attributes changed, but vegetation structure changed the least and species composition changed the most, with SET abundance being intermediate. Changes occurred at all three locations, but were most extreme for Floor sites of large wetlands, and least for Floor sites of small wetlands, with Edge sites being intermediate. This is summarised below (Table 5.20).

Table 5.20. Mean (SE) similarity (%s) between surveys by location

	Large wetlands Floor	Large wetlands Edge	Small wetlands Floor
Structure	29	47	69
Species Composition	6	18	17
SET abundance	15	30	46

Relevance to Restoration Plan

Vegetation objectives for wetlands in the Restoration and Monitoring Strategy Plan (Barlow 2011) are expressed quite broadly, "extensive areas dominated by emerging River Red Gum, Common Spike-sedge, Southern Cane-grass and Plains Rush" so have broad rather than specific targets. Only two of these four species, Southern Cane-grass and Plains Rush, appear likely to meet the target by the preferred process, which is by "demonstrated natural recruitment". Two of the four species, Southern Cane Grass and River Red Gum, are target species in this monitoring program, and their regeneration status is discussed in Section 6 (Results:

Target Species). The status of the other two, Common Spike-sedge and Plains Rush, is considered in Section 7 (Results: Dynamics).

This report recognises large and small wetlands as being ecologically-distinct systems, not just because of the differences in area which range through an order of magnitude (Hamilton Environmental Services 2013) but because size affects hydraulic characteristics notably depth and duration patterns as well disturbance intensity (fetch, wave action). In turn, these determine vegetation responses and wetland functioning. Because of this, large and small wetlands should have vegetation objectives specific to them.

The Restoration and Monitoring Strategy Plan (Barlow 2011) does not distinguish between large and small wetlands, and refers to both as *ephemeral*, a term used by some professionals in wetland ecology for wetlands that are inundated briefly, and can only support short-lived aquatic life (Table 1.2 in Boulton et al 2014).

5.4. Recommendations arising

Recommendation 7

Categorise wetlands in terms of their water regime and hydraulic characteristics. The categorisation should be used to recognise sites, areas and wetlands where vegetation is expected to respond similarly. This categorisation will be useful in setting specific vegetation targets, for evaluating feasibility of targets, and for reviewing the scope and representativeness of the current vegetation monitoring program.

Recommendation 8

Determine the actual elevation in m AHD of all monitoring sites, but especially of D sites which appear to be rather variable. Consider the need or otherwise of standardising D sites by elevation for comparability of vegetation response.

Recommendation 9

Increase frequency of vegetation monitoring at Wetlands sites to every five years to link with Slopes sites and retain an overall whole-of-Reserve perspective.

Recommendation 10

Establish a monitoring program that complements the current quadrat-based vegetation monitoring, by providing broad coverage but qualitative data (mapping from aerial photography; permanent fixed photopoints).

Recommendation 11

Establish a staff gauge or water level recording system that can be used to provide water/inundation history for all monitoring sites in wetlands; the necessary data is depth and duration of being flooded, as well as frequency.

See also Recommendations Arising in Sections 6.2 and 6.4.

6. RESULTS: TARGET SPECIES

6.1 Southern Cane Grass

Census data: Counts

Incidence

The percentage of the 61 plots where Southern Cane Grass was recorded was 43% for 2010, and 57% for 2017. A breakdown by age-stage shows incidence was higher for all age-stages in 2017 (see total columns, Table 6.1), and was higher for Slopes than Wetlands. Southern Cane Grass was not present in any plots in small wetlands in 2010 or 2017, although recorded from several in 2012-13 (Hamilton et al 2013).

There are two exceptions to this general pattern. In 2017, fewer Slopes plots had Patches than in 2010 (9 in 2017, compared with 12 in 2010), and fewer Floor plots of large wetlands had Seedlings and Young (0 and 0 in 2017, compared with two and fivein 2010, respectively). Fewer Slopes plots with Patches can be assumed to be due to patch mortality, speculatively attributed to drying out. Fewer Wetland Floor plots with Seedlings and Young is attributed to either mortality (as a result of being submerged for too long in recent flooding) or maturing into Established or Patches. Wetland plant species are known to vary in their sensitivity to and tolerance of being submerged. Within a species, younger stages are generally less tolerant of physiological stresses such as submergence or desiccation. Wetland plants that typically have foliage in the air respond to being submerged I various ways: by dying, negative growth rates, shoot extension or re-allocation of resources into emergent foliage (Blanch et al 1999, Greet et al 2015, Vivian et al 2014). Submergence is thus a strong selective filter, and water depth and depth-duration are critical parts of a water regime.

Table 6.1. Incidence of Southern Cane Grass by location, in 2010 and 2017

			Large Wetlands		Small wetlands (n=10)	Total number of plots	Total (% of 61)
Age-stage	Survey	Slopes (n=24)	Edge (n=14)	Floor (n=13)			
Seedlings	2010	1	1	2	0	4	6.6
Young	2010	4	2	5	0	11	18.0
Established	2010	11	1	4	0	16	26.2
Patch	2010	12	0	1	0	13	21.3
Seedlings	2017	6	2	0	0	8	13.1
Young	2017	15	3	0	0	18	29.5
Established	2017	18	8	8	0	34	55.7
Patch	2017	9	1	5	0	14	23.0

Total Count

The total count (meaning the sum of all age-stages) was 1815 for 2017, far exceeding the total count for 2010, which was only 316.

Several of the 2017 samples with very high total counts were co-located, meaning the plots occurred close to each other (Figure 1.1). Examples of co-location are: plots B04 and C04 (with total counts of 277 and 209); plots A02, B02 and C02 (with total counts of 255, 99, 87); and plots D15 and D10 (with total counts of 261 and 180). Some of these were also high in 2010 (relatively high, that is, compared with other plots in 2010), notably three Slopes plots (A02, B04 and C04, with total counts of 20, 24 and 30 respectively) and one Edge plot D15 (total count = 17). Plots with high total counts in both surveys, seven years apart, indicate areas that are particularly favourable for establishment and survival of Southern Cane Grass, and that these favourable conditions recur or persist through time. However, favourable conditions did not always persist: four plots from the northern shoreline that had high totals in 2010 (plots M27, M28, M29 and M01 with 75, 28, 17 and 23 respectively) had very low totals in 2017 (12, 5, 6 and 18).

Age-Stage Counts

The number per age-stage (mean, SE) varied with age-stage, with location, and survey (Table 6.2), but was particularly high for Established in 2017 (41.75) at Slopes plots. The highest counts from a single 10x100m plot were 109 for Seedlings (at D15 in 2017), 61, 65 and 95 for Young (at B04, A02 and D15 respectively, all in 2017), and 120, 180, 180 and 206 for Established (at D10, A02 and C04, and B04 respectively, all in 2017).

Table 6.2. Number (mean count + SE per sample) per age-stage of Southern Cane Grass

Age-stage	Survey	Slopes (n=24)	Edge (n=14)	Floor (n=13)	Small wetlands (n=10)
Seedlings	2010	0.08 (0.08)	0.36 (0.36)	1.23 (0.84)	0
Young	2010	0.25 (0.12)	1.29 (1.08)	3.62 (1.79)	0
Established	2010	3.17 (0.95)	0.14 (0.14)	5.54 (4.73)	0
Patch	2010	2.46 (0.83)	0	1 (1.00)	0
Seedlings	2017	1.17 (0.55)	8.64 (7.70)	0	0
Young	2017	7.83 (3.59)	10.29 (7.32)	0	0
Established	2017	41.75 (12.80)	14.14 (9.07)	5.0 (2.17)	0
Patch	2017	1.88 (0.70)	0.07 (0.07)	1.77 (0.79)	0

Age Structure

Despite differences in total counts, the age structure for Southern Cane Grass was broadly similar in both surveys (Figure 6.1). The proportion of total count in Seedling and Young stages was comparable (7.3% and 22.5% in 2010, and 8.2% and 18.3% in 2017), and in both surveys the Established stage was by far the largest. In 2017, the Established stage was a considerably bigger proportion of the total count than in 2010, being 69.7% compared with only 47.5%. The age structure was unusual in having progressively bigger counts of sequential age-stages from Seedling to Young to Established (Figure 6.1). It is more common for numbers to progressively decrease with sequential stages. Knowledge of Southern Cane Grass demography is not good enough to determine if this age structure is a species attribute and what the ecological implications might be, or whether it is an artefact of the method (how age-stages are defined). Nonetheless, it was notable that age-structure was similarly shaped in both surveys, ven though they were seven years apart.

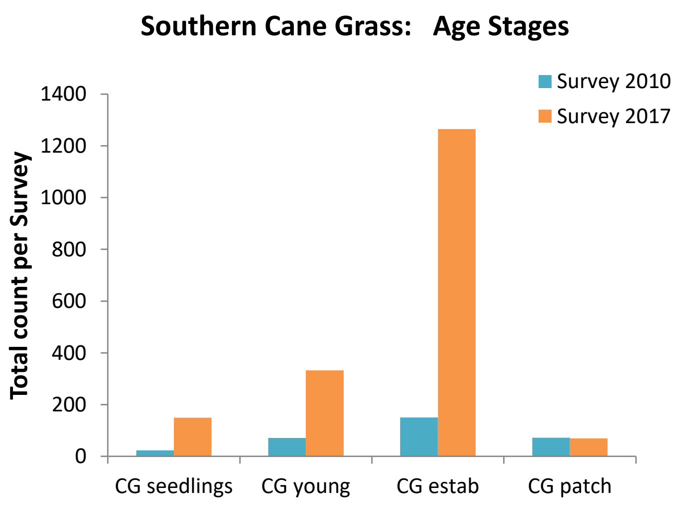


Figure 6.1. Southern Cane Grass: Counts per age-stage for 2010 and 2017

Seedlings

Seedlings are strong evidence that regeneration is occurring, though not necessarily that it is successful. Seedlings were present in greater numbers and in more samples in 2017 than in 2010 (Table 6.1, Table 6.2), indicating that regeneration had been more abundant and more widespread in 2017. However the proportion of plots with Seedlings was low, less than 15%: only four plots in 2010 (three large Wetlands, one Slopes) and only eight plots in 2017 (6 Slopes, 2 Edge plots). Mean number of Seedlings per plot for those four plots was 5.8 (SE = 1.49) in 2010, and for the eight plots in 2017 was 18.6 (SE = 12.87). The 2017 average was high due to one exceptionally high count of 108 Seedlings at plot D15. If site D15 is treated as anomalous and excluded, then the mean for 2017 is 5.9 (SE = 1.74) which similar to 2010.

Plots with seedlings in 2017 tended to be plots with high total counts (Figure 6.2), indicating multiple age-stages were present and co-occurrence of high counts of different age-stages. This suggests these eight plots had been favourable for Southern Cane Grass over several years. Of these eight plots, six were Slopes (plots A02, B02, C02; B04; B11) and two were wetland Edge (plots D10, D15).

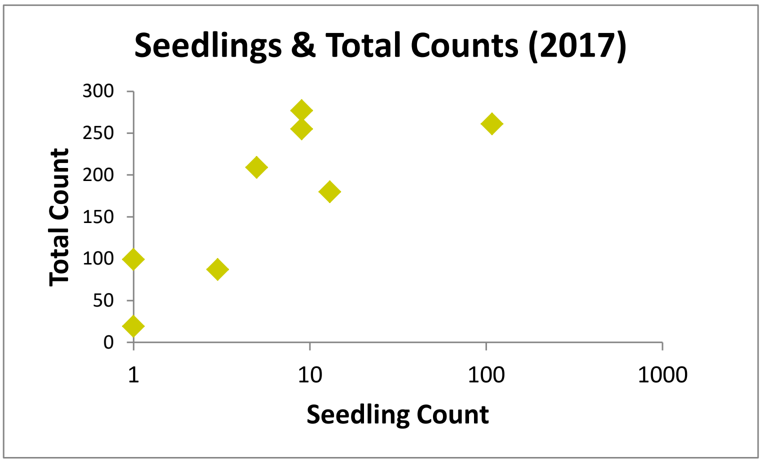


Figure 6.2. Southern Cane Grass: high Seedling and high total counts, in 2017

Transitions using clusters

Cluster analysis (all data: 2010 and 2017, Slopes and Wetlands combined) of age-stage counts for 60 plots which had Southern Cane Grass present using SIMPROF as described above (Analysis for empirical groups, Section 2.4) resulted in 5 clusters (a to e). Overlaying these onto nMDS ordination of age-stages showed the five clusters were clearly separated in 2-dimensional ordination space, and varied in size and compactness (Figure 6.3).

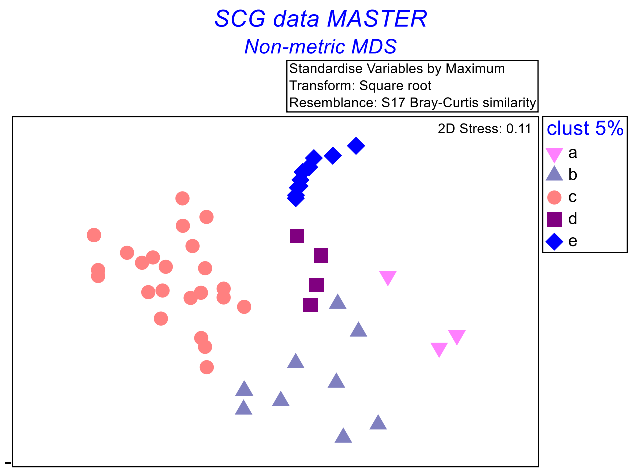


Figure 6.3. Ordination of age-stages of Southern Cane Grass with 5 clusters overlain

Characteristics of these five clusters and cluster x are given below (Table 6.3, Table 6.4). Cluster x is the 62 samples with no Southern Cane Grass that were excluded from the multi-variate analyses.

With the exception of cluster d, clusters had a non-distinctive mix of survey, location and flooding characteristics, and were not readily definable by these attributes (Table 6.3). This was in marked contrast to cluster characteristics described above (Section 4.2, Section 5.2) where survey, plot and flooding were important.

Table 6.3. Cluster characteristics

Cluster	Survey	Location	Flooded
a (n=4)	Mostly 2010 (2010 = 3 samples)	Large Wetlands, mostly: (Slopes = 1 sample) Large Wetlands: a mix of Edge and Floor (D = 1 sample)	None flooded
b (n=10)	Mix of surveys (2010 = 5 samples)	Large Wetlands, mostly: (Slopes = 3 samples) Large Wetlands: a mix of Edge and Floor (D = 4 samples)	Mostly not (1 Shallow)
c (n=25)	Mix of Surveys (2010 = 14 samples)	Slopes, mostly: (large wetlands = 6 samples) Large Wetlands: only Floor	Mostly not (4 Deep)
d (n=4)	All one survey, 2017	Slopes, mostly: (Large Wetlands = 1 sample)	Mostly not (1 Shallow)
e (n=17)	Mostly 2017 (2017 = 13 samples)	Mix of Large Wetlands and Slopes (Slopes = 7 samples) Large Wetlands: a mix of Edge and Floor (D = 5 samples)	Mix (6 Shallow, 3 Deep)
x (n=62)	Mix of Surveys (2010 = 35 samples)	Mix of locations (Slopes = 15 samples) (Large Wetlands = 27 samples) (Small Wetlands = 20 samples) Large Wetlands: (Green Swamp = 15 samples)	Mostly not (10 shallow)

Clusters differed in size (from 4 to 62 samples), total count (mean ranges from 0 to 117.9), which age-stage was characteristic (this being the one identified by SIMPER routine as contributing most to within cluster similarity) and in what abundance, and which age-stages were present and absent (Table 6.4). Mean total count ranged from zero and very low (cluster x, and clusters a and e) to high (cluster b), with clusters c and d being moderately high. Most of the clusters were characterised by Young and/or Established age-stages, with low, moderate or high counts, whereas cluster c was characterised by low number of Patches. Seedlings were mostly in cluster b.

Table 6.4. Cluster characteristics

Cluster	Total Counts	Characteristic age-stage	Notes
a (n=4)	Range = 1-3 Mean = 1.8	Young (mean = 1.5)	No Seedlings No Patches
b (n=10)	Range = 8-277 Mean = 117.9	Young (mean = 34.7) Established (mean = 66.9)	Seedlings mostly present (mean = 16) Almost no Patches
c (n=25)	Range = 2-209 Mean = 30.6	Patch (mean = 5.5)	Almost no Seedlings Established (mean = 23.0)
d (n=4)	Range = 13-38 Mean = 24.8	Established (mean =22.8)	No Seedlings No Patches
e (n=17)	Range = 1-10 Mean = 4.7	Established (mean = 4.7)	No Seedlings No Young No Patches
x (n=62)	Range = 0 Mean = 0	n.a.	No Seedlings No Young No Established No Patches

The matrix of cluster transitions (Figure 6.3) shows five clusters in 2010 and six in 2017, the difference being cluster d in 2017. All other clusters were in both surveys.

There are 14 transitions, the three most prevalent being x – x, x – e, and c – c. In contrast to the transition matrices for structure, species and SETs for Slopes and Wetlands (Figures 4.7, 4.11, 5.6, 5.10, 5.14) the age-stage transition matrix shows considerable stability. More than half the plots (37 out of 61) did not change cluster between 2010 and 2017, although most of these were in cluster x, that is plots with no Southern Cane Grass present. Of the plots that did change, the most prevalent transition was cluster x-e (n=9), implying colonisation had occurred and Seedlings had become Established.

Colonisation since 2010 was evident at 11 plots. Interpreting these transitions using characteristics above (Table 6.4) shows these 11 plots changed from having no Southern Cane Grass (cluster x) in 2010 to having only Young (cluster a) or only Established plants (cluster e, cluster d) (Figure 6.3) in 2017, with low to moderate counts. As none of these colonisation plots had Seedlings, colonisation is assumed to be not recent. These 11 plots indicate areas where conditions had been favourable for germination and/or persistence since 2010. Most were in Sergeant's Swamp (4 Edge and 2 Floor), but there was also a favourable area on the Slopes, indicated by plots that were co-located (B06 and C06).

Mortality occurred, but was limited to just 2 plots: one wetland Floor, and one Slopes (M02, A05). These two plots suffered complete mortality, changing from low counts of Patches or Established plants to none. Recent flooding (submergence) may have been the cause for mortality at plot M02: reasons for mortality at A05 are not known, but in 2010 it had only one Established plant.

Only six plots changed clusters in ways consistent with Southern Cane Grass maturing and ageing: cluster a (mainly Young plants) transitioned to clusters d and e (mainly Established plants), and cluster b (Young and Established plants) transitioned to cluster c (Patches).

Except for the stable plots which had very low dissimilarity, transitions were moderately to completely dissimilar (not shown).

		Survey in 2017						Total in 2010
		a	b	c	d	e	x	
Survey in 2010	a				1	2		**3**
	b		2	3				**5**
	c		3	8	2		1	**14**
	d							
	e					3	1	**4**
	x	1			1	9	24	**35**
Total in 2017		**1**	**5**	**11**	**4**	**14**	**26**	**61**

Figure 6.3. Matrix of cluster transitions from 2010 to 2017: Southern Cane Grass

Quadrat data: Abundance

Abundance data, measured as percentage live cover in five 5x5m quadrats used to subsample the fixed 10 x 100 m plot, was quite variable (Table 6.5) and showed the same trends as count data (not surprisingly), with Southern Cane Grass more abundant in 2017, and more abundant in Slopes than Wetlands (Figure 6.4). The breakdown of Slopes into A, B and C plots revealed that the increase to 2017 was at B and C plots only, whereas at A plots there was a decrease.

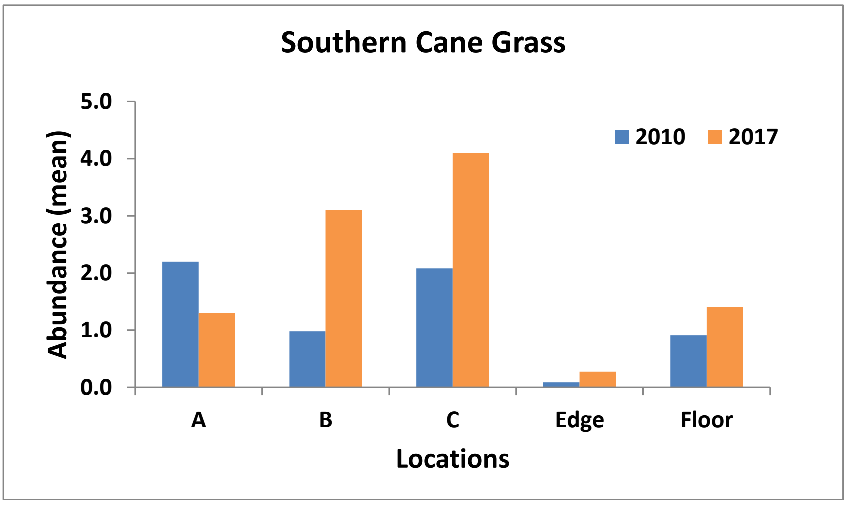


Figure 6.4. Southern Cane Grass: Abundance at five locations

The number of samples with Southern Cane Grass increased from 23 in 2010, to 30 in 2017 (Table 6.5). (Numbers do not match count data exactly, due to differences in method.) Incidence and abundance generally increased in all locations between 2010 and 2017 (Table 6.5), a trend that parallels the age-stage counts described above (Table 6.1). The increase for the Floor of large wetlands was largely due to five plots in Winton Swamp. These increased from 1.63% (SE = 0.98) to 2.5% (SE = 1.18), an increase that was associated with a shift in age-stages, from Seedling and Young in 2010 to Established and Patches in 2017.

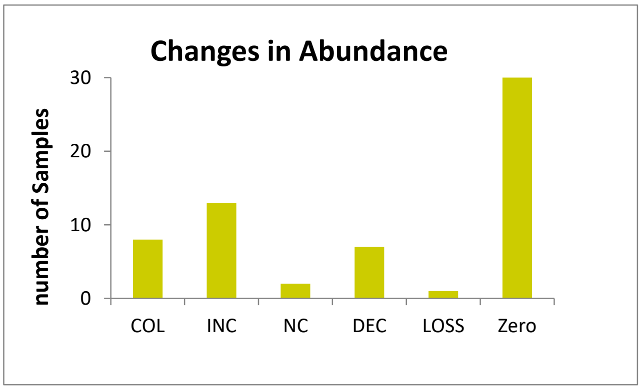
The maximum abundance at a plot was similar in both surveys, with 12.8% being highest in 2010, and 15% the highest in 2017, with both of these being Slopes plots (A02 and C04). Only a few plots had high abundances in both surveys, notably Plot C02 on Slopes (11.8% in 2010, and 14.4% in 2017) and Plot M27 on northern shore of Winton Swamp (6.4% in 2010, and 5.6% in 2017). This re-emphasises that small-scale influences appear to be important in determining the success of Southern Cane Grass, as noted with counts.

Table 6.5. Southern Cane Grass: incidence and abundance

		Survey 2010		Survey 2017	
Location	Plots	Plots with SCG	% cover (mean, SE)	Plots with SCG	% cover
Slopes	A sites (n = 8)	4	2.2 (1.55)	5	1.3 (0.93)
Slopes	B sites (n = 8)	7	0.98 (0.40)	7	3.1 (1.14)
Slopes	C sites (n = 8)	4	2.08 (1.43)	5	4.1 (2.33)
Edge: Large wetlands	D sites (n = 14)	2	0.09 (0.06)	5	0.27 (0.18)
Floor: Large wetlands	M sites (n=13)	6	0.91 (0.49)	8	1.4 (0.63)
Small Wetlands	M sites (n = 10)	0	0	0	0

Abundance changes

As described in methods (Section 2.4), abundance can change in six ways. The most frequent, other than the category Zero, was INC (n=14 plots), and the least frequent were NC and LOSS (Figure 6.5: left). Low mortality and losses combined with colonisation at eight plots resulted in a net increase in number of plots where Southern Cane Grass was present. The colonisation finding parallels the changes described above using cluster transition matrix, and the growth finding parallels the total count data, reported above. A map of these changes is given below (Figure 6.6).



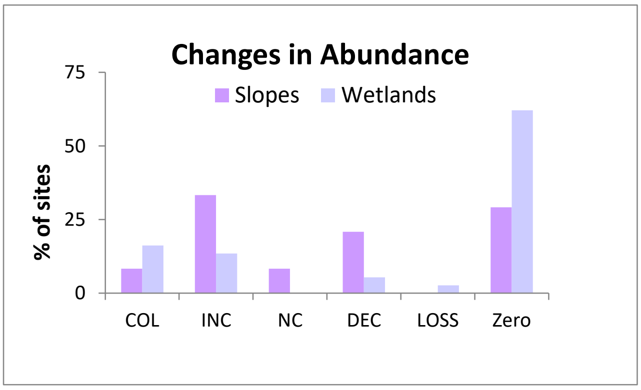


Figure 6.5. Southern Cane Grass: Frequency of specific changes
Left: all plots combined. Right: Slopes plots and Wetlands plots shown separately. Key to type of change: COL = colonisation (plot now has Southern Cane Grass); INC = increase (2017 abundance is more than 2010); NC = no change: abundance is same in both surveys; DEC = decrease (2017 is less than 2010); LOSS = loss (from in 2010) to zero abundance in 2017; Zero = plots with no Southern Cane Grass in both surveys.

Disaggregating the results into Slopes and Wetlands (Figure 6.5: right) illustrates similarities and differences between the two landforms in population processes: colonisation (COL) was lower on Slopes (there were few plots left to colonise); more Slopes plots showed growth than contraction and death (INC was greater than DEC and LOSS); Wetlands plots had a higher proportion of plots without Southern Cane Grass. Overall, these data suggest that Slopes landform has been a more vigorous habitat for Southern Cane Grass than Wetlands.

Synthesis

Expansion and Increase

Comparison of the two surveys showed more Southern Cane Grass in 2017 than in 2010. 'More' means Southern Cane Grass was present at more plotss (higher incidence), in greater numbers (higher total counts) and in greater abundance (higher cover). However, the magnitude and rate of this increase across 61 monitoring plots was fairly small. There was a net increase of only 9 plots in 7 years, made up of 11 'new' plotss and 2 losses (Figure 6.3), thus equivalent to an average expansion of 1-2 plots per annum. Total count increased from 316 to 1815, equivalent to 214 per annum, or 3+ per plot per annum, and abundance (as %cover) increased from an average per plot of 0.9% (SE = 0.30) to 1.5% (SE = 0.41), equivalent to less than 0.1% per year. With data from only two points in time and separated by seven years, it is impossible to make valid assumptions as to whether Southern Cane Grass increased incrementally or exponentially or episodically.

The trend was even lower for the Wetland landform, and was for only Edge and Floor plots (n=19, D and M plots) in Sergeant's and Winton Swamps. Incidence increased from 8 to 14 plots; total count increased from 173 to 552, and abundance increased from 0.7% (SE = 0.40) to 1.2% (SE = 0.53). If these rates of colonisation and expansion are indicative, then it will take decades for Southern Cane Grass to achieve dominance across these two wetlands.

However, with perennial wetland plants, colonisation and growth are unlikely to change in a linear fashion with smooth annual increments but instead be influenced by wetland inundation, by frequency of regeneration opportunities, and capacity to persist. These differed between the two landforms. Slopes plots showed that Southern Cane Grass was quite drought hardy once established. For Wetlands landform, periodic inundation (submergence) probably limited recruitment on the Floor of large wetlands. The estimates given above of average annual colonisation and expansion give a spatial and temporal perspective on net changes since 2010, and help frame the restoration challenge. In the last seven years, there may have been significant pulses of recruitment and periods of loss, but these are not detectable when dealing with samples from just two points in time (2010 and 2017). From a management perspective, bottlenecks, due to dispersal, germination and seedling establishment, can be by-passed by planting, provided the water regime is suitable, as shown by the recent student project (Richter-Martin 2016).

Restoration by Natural Regeneration

Restoration by natural regeneration is a passive approach that deliberately does not utilise interventions such as seeding or planting (Roberts et al 2017, McDonald et al 2016). Natural regeneration is the current approach for restoring Southern Cane Grass in Sergeant's and Winton Swamps. The success of this approach depends on perspective. For example, it is successful, when considering total counts per survey (Figure 6.1); however, it is not successful everywhere, an appears to be rathr slow.

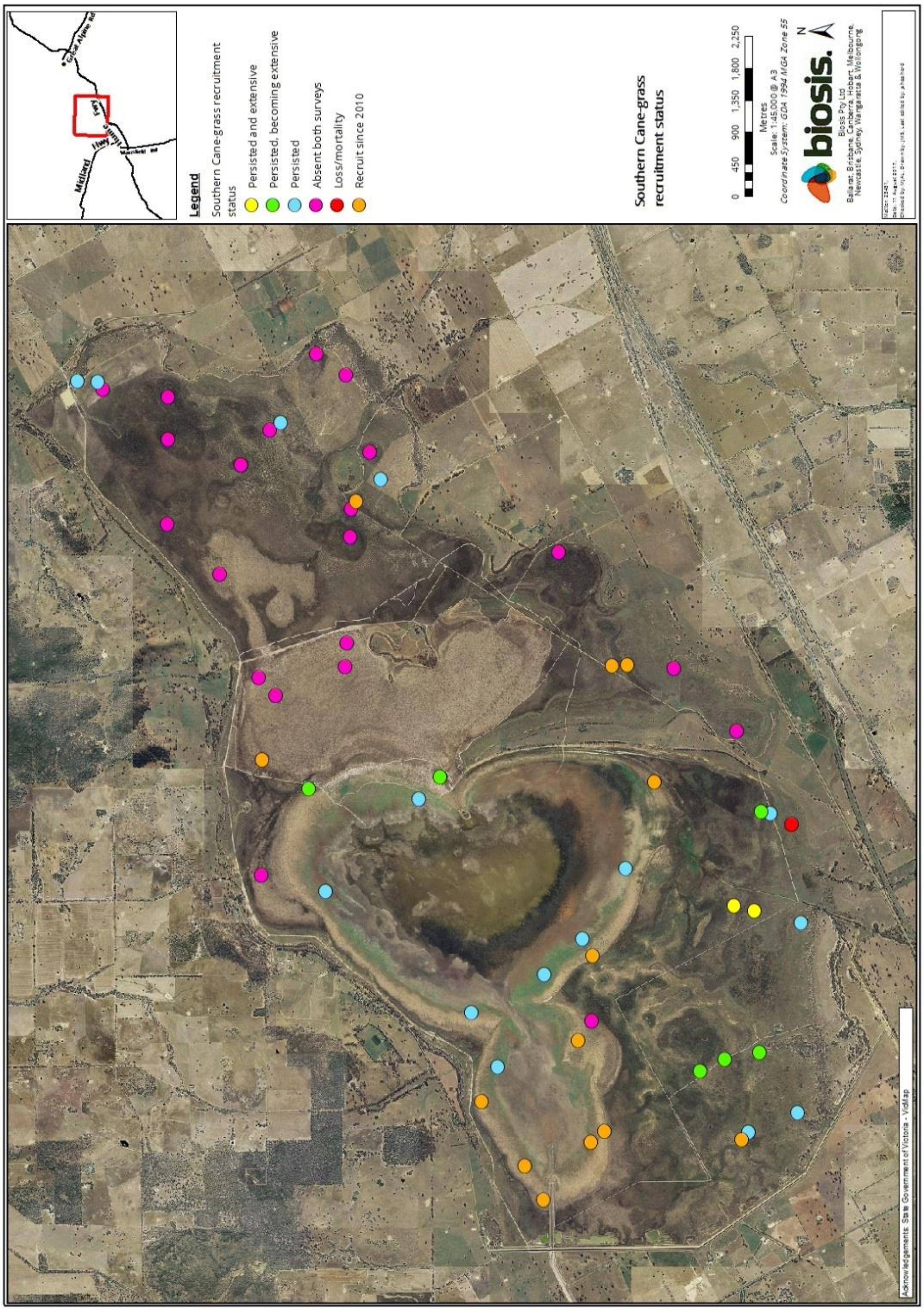


Figure 6.6. Status of Southern Cane Grass in 2017, based on changes 2010 to 2017
Key to dots: Yellow = persisted and extensive; Green = persisted, becoming extensive; Blue = persisted; Pink = absent in 2010 and 2017; Red = loss/mortality; Orange = recruit since 2010.

Variability in total counts and other measures show the regeneration of Southern Cane Grass was spatially variable (Figure 6.6). For example, the total count for individual Edge and Floor plots around Sergeant's and Winton Swamps ranged from 0 to 261, showing that a passive restoration strategy had indeed been successful, but only at some plots. This variability was evident at different spatial scales: between Slopes and Wetlands; between locations within a Wetland (Edge and Floor); and at a finer scale, referred to as co-location. The co-location of plots with high counts revealed three areas where regeneration had been successful. Only one of these was in a target area for Southern Cane Grass restoration, and this was on the north-east margin of Winton Swamp (Plots D10 and D15), straddling the connection between Winton and Green Swamp (Figure 1.1): (the other two were on Slopes south of Sergeant's Swamp. This area had previously been reported as having high counts and/or having Seedlings (autumn 2010; autumn 2008, see Figure 9 in Roberts et al 2008). Possible explanations for this area being favourable are to do with its position w.r.t. prevailing winds: it could be that water body seiches gently irrigate the shoreline on down-wind plots, or that these plots are an accumulation point for wave-distributed propagules, or that the substrate is particularly suitable.

In contrast, the Floor (M plots) of Sergeant's and Winton Swamps had only low-moderate total counts in autumn 2017. These had a skewed age-structure with the two youngest age-stages (Seedlings, Young) completely missing, and instead ag-structure comprised either Established with a few Patches (Sergeants Swamp, northern shore of Winton Swamp) or Established and no Patches (southern shore Winton Swamp). In autumn 2010, these areas were actively regenerating (albeit in low numbers) and had either Seedlings and/or Young age-stages, indicating that regeneration was indeed feasible at these plots.

Without more information on plot-specific histories, it is not feasible to retrospectively establish reasons for there being no Seedlings or Young age-stages at Wetland Floor plots, however the recent inundation history, with its prolonged high water levels, is a plausible mechanism. Both younger age-stages have prostrate stems, resting on the ground surface, and hence vulnerable to being submerged: and it is only the later stages that have erect stems, able to poke through water into atmosphere.

Wider context for restoration objectives

The Winton Wetlands Restoration and Monitoring Strategic Plan expects that "*Sergeant's and Winton Swamps will remain treeless (except for margins) and eventually become dominated by Southern Cane-grass, this being the original dominant prior to Lake Mokoan.*" (p11 in Barlow 2011).

This expectation makes three assumptions. The first is that abiotic conditions post-Mokoan will be similar to abiotic conditions pre-Mokoan. The second is that the water regime post-Mokoan will match the life-cycle (regeneration and maintenance) requirements and tolerances of Southern Cane Grass: ie it assumes no change to precipitiaiton pattersn or to rainfall run-off behaviour in the catchment. The third is that regeneration will not be limited by availability of viable seed.

In relation to the first assumption, there is both historical and contemporary evidence to suggest that the post-Mokoan water regime of Sergeant and Winton Swamps is unlikely to be the same as pre-Mokoan. The historical information (admittedly somewhat scant) comes from field observations made by botanist Helen Aston (Barlow 2011; reported in Appendix 2 and Figure 6 in Roberts and Hale 2008) and an aerial photomosaic dated 1941. Helen Aston noted extensive cover of Southern Cane Grass in February 1959, estimated that water depth was equivalent to 75 cm, and took a photograph showing flooded vegetation in which the water looks less than 1 m deep. The 1941 photomosaic shows no evidence of tussocky vegetation across Sergeants and Winton Swamps.

In relation to the second assumption, the contemporary evidence for both hydrologic and hydraulic change since commissioning Lake Mokoan includes land use and infrastructure changes in the catchment, a myriad of small modifications to surface water, altered sill level (outlet structure), and sedimentation (Barlow 2011, Hamilton et al 2013, Figure 20 in Roberts et al 2008). Hydraulic changes, in particular changes to depth and depth-duration characteristics, are particularly important for wetland plants, which are sensitive to small modifications that are inconsequential for fauna or system-scale volumes. If depth-duration characteristics have changed such that the tolerances of Southern Cane grass are likely to be exceeded, then this is highly significant for restoration of Southern Cane Grass.

In relation to the third assumption, results from the monitoring program show that this assumption of viable seed being produced is valid: seedlings are present and new areas are being colonised, albeit in low numbers.

Southern Cane-grass Eragrostis infecunda

Despite its importance for Mokoan Reserve / Winton Wetlands, there is very little factual information about Southern Cane Grass. Based on slender evidence, it has been surmised that its life cycle and ecological characteristics are probably similar to the closely-related Cane Grass *Eragrostis australasica*, a plant of intermittent wetlands in semi-arid eastern Australia. This species is considered drought hardy, responding rapidly to rain or flooding, intolerant of sustained flooding, and known to germinate on muds exposed by falling water levels but not under water (Roberts and Marston 2011).

Results from the monitoring program support this as a general picture of Southern Cane Grass. Counts show it is drought hardy, as it has persisted at terrestrial plots receiving only rainfall (count of 45 Patches in 2017 compared with 59 in 2010). It does appear to be intolerant of being submerged, as shown by the complete lack of the youngest age-stages from floor of recently flooded and/or still flooded wetlands (count of 63 Seedlings and Young in 2010 compared with 0 in 2017 at M plots), though this could be due to Seedlings progressing to next age-stages. A recent study reported that water depth of 40 cm may be lethal to recent plantings (Richter-Martin 2016) though, critically, it was not stated if the plants had been overtopped. Regeneration may require only saturated soils (assuming temperature is correct) as shown by high numbers in terrestrial plots after above average spring-summer (count of 216 Seedlings and Young at A, B and C plots in 2017 compared with only 8 in 2010). Field observations suggest a possible association between gilgai soils and regeneration of Southern Cane Grass (M. Looby, pers. obs.): this could be worth confirming if management decides to move towards an interventionist approach. .

The findings from the monitoring program are not perfectly aligned with the water regime described for EVC 291 Cane Grass Wetland (Frood and Papas 2016), which is for a 'wetter' habitat (ie flooding longer, deeper, and more frequently) than implied by the count data for Sergeant's and Winton Swamps. Clearly, some quantitative data on life cycle and hydro-ecology of Southern Cane Grass are needed in order to inform restoration of large wetladns in the Reserve.

6.2. Recommendations arising

Recommendation 12

The vision that Sergeants and Winton Swamps will eventually be dominated by Southern Cane Grass needs to be critically reviewed for ecological feasibility. For this it will be necessary to consider the contemporary hydrologic and hydraulic characteristics of Sergeant's and Winton Swamps (which may have changed since 1960s), and tolerances and requirements of Southern Cane Grass. If necessary, the vision may need to be revised.

Recommendation 13

Knowledge about life cycle and water regime requirements and tolerances of Southern Cane Grass needs to be improved to a level that can inform the long-term vision for Winton Wetlands / Mokoan Reserve. In particular, the depth duration tolerances and sensitivities of different age-stages need to be quantitatively established, preferably using multiple lines of evidence including empirical from existing monitoring plots, from other wetlands, and by experiment, and linked to hydrologic and hydraulic modelling.

Recommendation 14

Continue monitoring recruitment and persistence of Southern Cane Grass at existing plots, using existing methods, but increase the sampling frequency to every 2-3 years for age-stage monitoring. Understanding *populations processes would be helped by recording water level and depth history, at some (not necessarily all) plots: see Recommendation 15.*

Monitoring should continue at all plots until the restoration objective is achieved or is certainly on track for success, at which point the monitoring program should be reviewed to make it fit for other needs, such as long-term condition monitoring.

Recommendation 15

Develop a means of recording inundation history at monitoring sites that will give essential information on depth and duration of inundation, at precision levels that will allow interpretation of fate of age –stages.

Recommendation 16

Develop a strategic approach for achieving restoration objectives for target species using a mix of natural and assisted regeneration. However, as wetland types, land use, and other factors vary around the Reserve, it would be sensible to develop a suite of strategies, tailoring them to particular wetlands and areas: this is because a single approach is unlikely to suit all areas.

6.3. River Red Gum

Census data: Counts

Incidence

The incidence of regenerating Rivr Red Gums was low in both surveys. Regenerating stages of River Red Gums occurred in only five monitoring plots in 2017, and only four plots in 2010. Regrettably, in 2010, due to an error, age-stages were not recorded, resulting in blanks in the compilation (Table 6.6). Two plots, both on Slopes, had regenerating stages in 2010 and 2017, and are presumably the same individuals.

Table 6.6. Incidence of River Red Gum by location, in 2010 and 2017

			Large Wetlands		Small wetlands (n=10)	Total	Total (% of 61)
Age-stage	Survey	Slopes (n=24)	Edge (n=14)	Floor (n=13)			
Germinant	2010	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Seedling	2010	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Juvenile	2010	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Sapling	2010	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total		3	1	0	0	4	6.6%
Germinant	2017	0	0	0	0	0	0
Seedling	2017	1	0	0	0	1	1.6%0
Juvenile	2017	2	0	0	0	2	3.2%
Sapling	2017	2	0	0	0	2	3.2%0
Total		5	0	0	0	5	8.2%

Total Count

The total count (the sum of all regenerating stages) was low in both surveys, being 15 in 2017 which was an increase from five in 2010 (Figure 6.6). The count per plot was low in both surveys, although marginally higher in 2017. In 2010, the total count of five was from four plots (an average of 1.25 per plot); in 2017 the total count of 15 was from five plots (an average of 3 per plot). None of the 2017 plots with regenerating River Red Gums had multiple age-stages.

Age-Stage Counts

All regenerating stages in 2017 were on Slopes plots, whereas in 2010 one of the four regenerating plots was a wetland Edge (plot D10) (Table 6.6). The highest count at a plot was five for Seedlings (plot A04), seven for Juveniles (Plot A09) and one for Sapling (Plots A06 and B06). The count for Germinants in both surveys was zero.

Age Structure

The age structure in 2017 (Figure 6.6) showed more Juveniles than Seedlings. This plot is included as a visualisation only, as the counts are too low to be a reliable indication of age-structure.

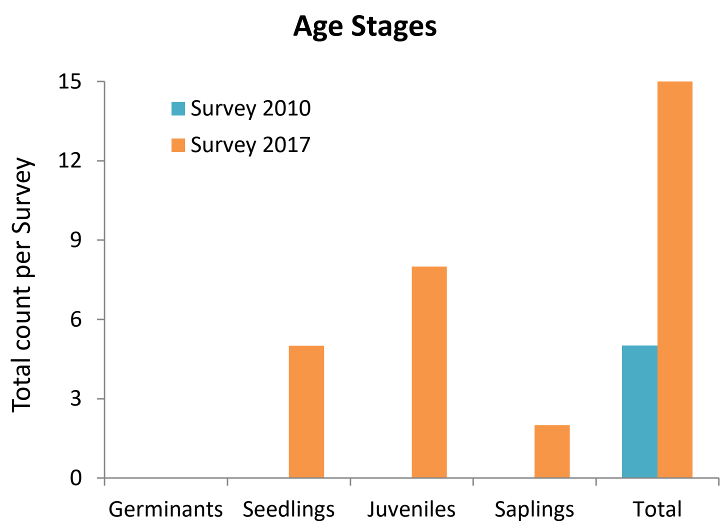


Figure 6.6. River Red Gum: Counts per age-stage for 2017

Germinants and Seedlings

The presence of Germinants and/or Seedlings at a site is strong evidence that conditions are, or have been recently, favourable for River Red Gum regeneration.

In 2017, there were no records of Germinants, and all five Seedlings were recorded from just one plot (A04) on Slopes. Field notes for this plot referred to the presence of a young (10m tall) River Red Gum nearby, as is evident in the plot photograph (Photograph 6.1). If there were any Germinants and Seedlings present in Wetland plots (D and M plots) in winter 2016 and prior to floods of spring-summer 2016-17, they would have been submerged during high inundation, and would have died.

Photograph 6.1. Plot A04 showing central 100m tape and young River Red Gum nearby in 2017. Photo by Biosis.

Quadrat data: Abundance

Incidence and abundance of River Red Gums as recorded by subsampling each plot are summarised below (Table 6.7). Both incidence and abundance were very low in 2010, being recorded from two plots only, with a cover of 4% and 0.2% respectively, but were even lower in 2017, at one plot only, with a cover of 0.02%. These incidence data are lower than incidence data reported above, a difference that can be attributed to their different sampling methods (census versus subsampling).

As with census data, there were more records of River Red Gums in A sites on Slopes than in small wetlands or around large wetlands.

Table 6.7. River Red Gums: abundance by survey and location

		Survey 2010		Survey 2017	
Location	Sites	Plots with RRG	% cover (mean, SE)	Plots with RRG	% cover
Slopes	A sites (n = 8)	1	0.5 (0.5)	1	0.003 (0.003)
Slopes	B sites (n = 8)	0	0	0	0
Slopes	C sites (n = 8)	0	0	0	0
Edge: Large wetlands	D sites (n = 14)	1	0.014 (0.019)	0	0
Floor: Large wetlands	M sites (n=13)	0	0	0	0
Small Wetlands	M sites (n = 10)	0	0	0	0

Synthesis

Regeneration Strategy of eucalypts

The regeneration strategy of most eucalypts is to produce a very large number of very small seeds, almost annually. Eucalypt forest and woodlands produce an estimated 1 to 49 million seed ha^{-1} (Booth 2017). Nature River Red Gums, known to be a 'heavy-seeding species', can produce 5-10 kg of seed per tree, with an average of 6052 seeds per 10 g (George 2004).

Very few of these seeds become seedlings. Jacobs (1955) boldly estimated an outlay of 100,000,000 – 150,000,000 seeds before a replacement tree was established. Central Murray foresters, who rely on natural regeneration, work hard at improving these odds when regenerating floodplain forest, for example through bed preparation for falling seed (eg Dexter 1978). For riverine and riparian species, such as River Red Gums, floods further reduce the odds through secondary dispersal of seeds to a safe plot (such as a debris pack) that is favourable for germination and establishment (Pettit and Froend 2001).

Eucalypt seeds are small, with no adaptation such as a pappus to keep them airborne, so have a low aerial dispersal distance. Dispersal distance is determined by tree height, canopy width and wind strength, thus most seeds fall less than one canopy height equivalent away from the parent tree (Booth 2017), possibly with a longer dispersal kernel on the side away from prevailing winds. However, in the case of riverine and riparian eucalypts, dispersal distance is greatly increased by flowing water, and especially by floods, so long-distance dispersal is principally in a downstream direction.

This eucalypt regeneration strategy has implications for landscape-scale restoration such as at Winton Wetlands / Mokoan Reserve. First, as most of the living River Red Gums are in a terrestrial situation away from creek lines and lake edges, regeneration is most likely to be in the vicinity of these already established reproductively-mature trees, as was hinted at in the results (and see Photograph 6.1), or the occasional River Red Gum that has established closer to the large wetlands. Second, because of where seeding trees are located, the opportunity for dispersal and re-distributioon by flowing water is limited. In addition, the Reserve is not a riverine site, but a lacustrine one. Third, relying on natural regeneration to achieve the restoration target of 3000 ha of terrestrial woodlands by 2025 (page 10, in Barlow 2011) means playing a very high numbers game, given the attrition rates for germination and seedling establishment.

Regeneration Findings

The findings of the monitoring program are consistent with this perspective of eucalypt regeneration. Regeneration was rare, with regenerating River Red Gums in less than 10% of plots. Regeneration was also sparse, with a total count across all 61 plots of just 15 regenerants in plots, compared with 1815 for Southern Cane Grass. The occurrence of regeneration was spatially skewed, being mostly on Slopes, which is a non-target area for River Red Gum woodlands (Barlow 2011). In 2017, there were no records of any Germinants, Seedlings, Juveniles or Saplings in any wetland Edge or Floor plots (D and M plots), pointing to a spatial mismatch between where regeneration is occurring and where it is needed. The data are too sparse to be absolutely conclusive, but regeneration is occurring high up on the Slopes, at plots that have young trees nearby or are near trees that established close to Full Supply Level while Mokoan was operating as a storage.

The findings that regeneration of River Red Gum is rare and sparse, and apparently limited by seed supply, and effective dispersal, are not a surprise. They re-affirm what has been known since the shoreline survey (Roberts et al 2008, Figure 14) and lend substance to the restoration issues raised by Barlow (2011). They are also the reason for the aerial seeding and broad-cast seeding trials previously undertaken at Winton Wetlands; these two interventions targeted seed supply and dispersal constraints.

Future Monitoring

As far as River Red Gum regeneration is concerned, the monitoring program has served its primary purpose of documenting River Red Gum regeneration status (low and sparse), and shown the limitations of relying on natural regeneration.

Although it has served its primary purpose, the monitoring program should not be automatically abandoned. Continuing this monitoring program will help to understanding of the natural recovery processes of a keystone species characterised by low aerial dispersal distance and high seed volumes. The 2010 survey provided a 61-plot benchmark, the age-stages are simple to use and not time consuming to sample when done at the same times as the rest of the vegetation monitoring, and the data returned is informative. The sections above on results and interpretation of Southern Cane Grass and River Red Gum give a number of options for analysis and indicators. Abundance data is not as informative about species demography or process of recovery as the age-stage counts; and cover data (on its own) is ambiguous. For example, does a low value mean lots of seedlings (eg Photograph 6.2) or a small overhanging branch ?

Photograph 6.2. Seedling at Plot A04 in 2017 showing how little cover a Seedling has. Photo by Biosis.

On the other hand, the current 61 monitoring plots are not positioned to sample the target areas for woodland restoration. The vision of 3000 ha of woodland makes the same three assumptions as for Southern Cane Grass, and the same evaluations are needed. Thus it is worth establishing whether plot water regime is likely to provide regeneration opportunities needed, and whether the water regime post-Lake Mokoan is similar to the water regime prior to Lake Mokoan, again focussing on depth and depth-duration. Field observations by Hamilton Environmental Services (2013) showed that most of the small wetlands have had some kind of hydrological change, for example to in-flow volume, out-flow volume, sill position and /or retention characteristics. The same considerations apply to the larger basins. Whether or not such changes limit regeneration or compromise seedling establishment needs to be determined.

It is clear that natural regernation is progressing very slowly and that interventions are needed if 3000 ha of woodland are to be achieved within a given time frame. This will mean using interventions with a high ‘success’ rate. In turn, this means intervention should deliberately by-pass the dispersal, germination and seedling phases, and instead invest in establishing advanced plants at later life-cycle stages.

The two interventions used to date, aerial seeding in August 2014, and a broadcast seeding in December 2016 respectively (Farnsworth 2017), both aimed to address seed supply and dispersal constraints, and neither has been enormously successful. The lack of success with aerial seeding has been attributed to ant predation and inappropriate moisture and inundation conditions, and low success with broadcast seeding has been attributed to density, soil characteristics, competition (Farnsworth 2017, p12). However, many other possibilities could be at play: for example Dexter (1968) listed hard soils (ie not cultivated), seedling desiccation, slow recession, and heat girdling of seedlings. Future interventions should aim to by-pass these natural bottlenecks, and instead focus on establishing future seed trees, either by planting and protecting advanced tubestock or by protecting ones that have self-established.

A strategic approach, one that builds on investing in advanced plants, is to use ‘mother’ trees. The aim is to establish a network mother trees, isolated or in small patches, and for these to be the sources of seed that will lead to young trees self-establishing nearby into the future. The mother trees should be distributed sparsely around the large wetlands and in target areas for River Red Gum woodlands, and be positioned to maximise their dispersal kernels (the spatial envelope around the tree where seeds are likely to fall) by considering prevailing winds. An example of this is given in Photograph 6.3.

This strategic approach to regeneration combines assisted and natural processes, in three clear stages. The first stage is to define optimum locations and carefully establish a network of mother trees; the second stage requires nurturing seedlings and seedling patches that have self-established around the mother trees, through selective watering, and protection against grazing. The third stage is to plant into gaps as these become evident. Each stage is about a decade. The outcome will be a mixed-age woodland.

Photograph 6.3. A natural example of a mother tree, with nearby juveniles. March 2008. Photo by Jane Roberts

6.4. Recommendations arising

Recommendation 17

Continue to monitor age-stages of River Red Gum at all 61 monitoring sites, at least until spatially-explicit targets are articulated and a revised regeneration strategy has been initiated; increase frequency of monitoring to every 2-3y to align with Southern Cane Grass monitoring.

Recommendation 18

Develop a restoration plan for River Red Gum woodlands at Winton Wetlands /Mokoan Reserve which is spatially explicit and which acknowledges that not all dead woodland was or should be River Red Gum. The plan will need to be sensitive to natural heterogeneity of the Reserve, and should develop and use knowledge of abiotic and biotic constraints on regeneration to different approaches for different areas.

Recommendation 19

Develop a regeneration strategy for River Red Gum that by-passes life-history bottle-necks such as dispersal, germination and early seedling establishment; and that instead invests in more establishing and nurturing more advanced stages, either by planting and/or by locating self-established juveniles. A network of 'mother' trees is suggested.

7. RESULTS: SPECIES AND TRENDS

This section presents temporal changes of individual species, and of species groups using SETs. The metric used vary as follows: incidence only was used for selected wetland species, as several of these had limited distribution; incidence and abundance were used for species with wider distribution; and abundance (as % cover) was used for SETs.

7.1. Wetland Species of Interest

A list of 11 native wetland plants was provided by the Project Manager, Lance Lloyd, as being species of particular interest: information on these would assist management and restoration. Two species on this list were not recorded in the surveys (*Persicaria decipiens* and *Persicaria praetermissa*), so two other *Persicaria* species, *Persicaria lapathifolia* and *Persicaria prostrata*, were substituted. A further three wetland species were added as likely to be of interest (*Potamogeton cheesemanii, Typha domingensis* and *Typha orientalis*). One species, *Vallisneria australis* was removed as it was not recorded in either survey, without replacement. The final list of interest was thus 14 species. *Vallisneria australis* was of interest because it formed extensive beds in the former Lake Mokoan in the early 1980s (p1 in AWT 2000).

The sites where these species occurred is tabulated below (Table 7.1), organised by survey and by location, with location being Slopes (A, B and C sites combined), Wetland Edge (D sites) and Wetland Floor (M sites).

Table 7.1. Incidence of 14 wetland species of interest

	2010			2017		
Species	Slopes max = 24	Edge max=14	Floor max = 23	Slopes max = 24	Edge max=14	Floor max = 23
Alternanthera denticulata	14	8	16	3	8	8
Carex tereticaulis	0	0	3	0	1	3
Centipeda cunninghamii	9	8	8	6	8	7
Eleocharis acuta	10	0	7	6	1	5
Myriophyllum crispatum	0	0	1	0	2	0
Myriophyllum verrucosum	0	0	5	0	0	1
Persicaria lapathifolia	0	8	12	21	9	9
Persicaria prostrata	23	7	10	21	2	3
Potamogeton cheesemanii	0	0	2	0	0	2
Pseudoraphis spinescens	6	0	0	0	0	0
Triglochin procera	0	0	0	1	0	0
Typha domingensis	2	0	7	0	1	0
Typha orientalis	0	0	0	1	0	5
Vallisneria australis	0	0	0	0	0	0

The compilation shows the variability in the incidence of wetland species (Table 7.1). Seven species (*Carex tereticaulis*, *Myriophyllum crispatum, Myriophyllum verrucosum, Potamogeton cheesemanii, Pseudoraphis* *spinescens*, *Triglochin procera, Typha orientalis, Typha domingensis*) were recorded 10 times or fewer. The occurrence hints at particular patterns and possible habitat preferences. Some occurred mainly on the wetland Floor, and some only in wetlands of a particular size. *Carex tereticaulis* was only recorded from three small wetlands (M10, M12, M21) whereas *Myriophyllum verrucosum* was only from the large wetlands and mainly from Winton Swamp. Four species, all recession herbs (*Alternanthera denticulata, Centipeda cunninghamii, Persicaria lapathifolia, Persicaria prostrata*), were recorded frequently in all three locations, and across both surveys.

Nine of these wetland species occurred in sites on Slopes (Table 7.1), ie in terrestrial habitats. This suggests that the 10 x 100m plot at these sites was probably topographically heterogeneous. It may have had small localised depressions where rain or run-off could pond so providing habitat patches suitable for wetland species to germinate and establish. This is likely the case for site B08, where four of these species were recorded. However, the high incidence of *Pseudoraphis spinescens* on Slopes, recorded in A04, A05, B05, C01, C04, C05 but only in 2010, seems anomalous, raising the possibility of misidentification.

Two species of *Typha* were recorded, *Typha domingensis* mostly in 2010 and *Typha orientalis* only in 2017 (Table 7.1). These were recorded at same sites in sequential surveys (site B08 on Slopes; and sites M02, M03, M05 and M27 and M29 on south-western and northern areas of large wetlands) raising the question of identification, as the two species can be difficult to tell apart. An alternative interpretation is that there has been a species replacement: *Typha domingensis* is more of a pioneer species that can establish in 'new' and temporary habitats, whereas *Typha orientalis* is likely to occur in more 'reliable' or permanent habitats (Finlayson et al 1983). These habitat preferences are consistent with the conditions in 2010 and in 2017.

7.2 Individual Species

This section summarises incidence and abundance of individual species or groups, in order to show temporal and spatial patterns from the two surveys. The choice of these is a subjective but they have been chosen for diverse ecological reasons.

Cassinia arcuata

Drooping Cassinia *Cassinia arcuata* is a terrestrial native shrub, and is one of only three native shrubs recorded (Table 3.1) during the 2010 and 2017 surveys, and is the most abundant.

Cassinia arcuata is widely perceived as a problem, being an invasive native species that has established over thousands of hectares (eg Campbell 1990). However, it is beginning to be appreciated as a pioneer species, establishing on disturbed land, especially on infertile soil patches, and is achieving recovery of native vegetation by natural regeneration at spatial scales that far exceed any planting program (Geddes et al 2011). In former grazing land in Central Victoria, *Cassinia* patches have developped into shrublands, and eventually developed into some eucalypt patches. The area increased in a two-stage process: first stage being one of incremental increases, for two decades; followed by a more rapid increase.

Two species of Cassinia were recorded in autumn 2010 (*C. arcuata* and *C aculeata*) but only *C. arcuata* in autumn 2017. The inflorescences and foliage of these two shrubs are distinctively arranged so the lack of *Cassinia aculeata* in 2017 is here considered a genuine change and not a case of misidentification in 2010.

At the study site, *Cassinia arcuata* occurred mostly in Slopes sites, where it provided structural diversity (a higher stratum). This layer is expected to become important for fauna (shade, shelter and perching opportunities) in what would otherwise be fairly uniform relatively low vegetation. It has also established in Edge sites in some wetlands but died following wetland inundation: these dead shrubs were already being used by waterbirds for nesting (Photograph 7.1). In 2012-13, it was recorded at 8 out of 30 wetlands (Hamilton et al 2013).

Between 2010 and 2017, incidence of this Cassinia increased from 12 to 17 sites, and its abundance (as mean percentage cover) increased ten-fold at B and C sites. Rather than being seen as an invasive species, it could be seen as providing structural diversity, especially on Slopes, and a transitional stage to more complex vegetation. Long-term monitoring will reveal if it develops as an extensive mono-specific shrub patches or functions as a nurse site for other species.

Photograph 7.1. Bird nest in a dead *Cassinia arcuata* bush, autumn 2017. Photo by Biosis.

Table 7.2. *Cassinia arcuata*

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Slopes	A sites (n = 8)	4	1.15	4	1.83
Slopes	B sites (n = 8)	4	0.20	6	2.55
Slopes	C sites (n = 8)	3	0.28	4	3.60
Edge: Green	D sites (n = 5)	0		1	0.01
Edge: Sergeant's	D sites (n = 4)	1	0.05	1	0.01
Edge: Winton	D sites (n = 5)	0		1	0.01
Floor: Green	M sites (n = 3)	0		0	
Floor: Sergeant's	M sites (n = 4)	0		0	
Floor: Winton	M sites (n = 6)	0		0	
Small Wetlands	M sites (n = 10)	1	0.12	0	

Hypochaeris radicata

Flatweed or Cat's Ear *Hypochaeris radicata* is a terrestrial perennial herb, introduced to Australia and now widespread and naturalised. In the SET classification (Section 2.3), it is #8, HB_long_intro.

Hypochaeris radicata occurred in terrestrial and wetland locations. In 2012-2013, it was recorded in 16 out of 30 wetlands (Hamilton et al 2013).

Between 2010 and 2017 incidence fell from 45 sites in 2010 to 30 sites in 2017. This was mainly due to fewer occurrences in wetlands, as incidence in Slopes sites was unchanged. Over the same period, abundance increased in B and C sites on Slopes, and decreased in wetlands. The decrease in incidence and in abundance in wetlands is attributed to recent flooding befor the 2017 survey: with drier conditions, both incidence and abundance of this species is likely to increase.

Table 7.3. *Hypochaeris radicata*

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Slopes	A sites (n = 8)	8	7.35	8	7.13
Slopes	B sites (n = 8)	8	3.90	8	5.88
Slopes	C sites (n = 8)	8	3.98	8	6.60
Edge: Green	D sites (n = 5)	4	1.18	1	0.04
Edge: Sergeant's	D sites (n = 4)	1	0.15	1	0.25
Edge: Winton	D sites (n = 5)	4	2.32	3	1.09
Floor: Green	M sites (n = 3)	0	0	0	0
Floor: Sergeant's	M sites (n = 4)	1	0.1	0	0
Floor: Winton	M sites (n = 6)	1	0.03	0	0
Small Wetlands	M sites (n = 10)	10	1.64	1	0.04

Juncus semisolidus

Plains Rush *Juncus semisolidus* is a native perennial rush, and a common wetland plant. In the SET classification (Section 2.3), rushes are treated as graminoid (grass-like) and it is #3, GR_long_native.

Juncus semisolidus is an early coloniser following drawdown. Dense bands were present along northern shore-of Winton Swamp in autumn 2008, and on depositional areas on the south-eastern shore (Roberts et al 2008). Although it is a wetland plant, *Juncus semisolidus* occurs in terrestrial and wetland habitats, and within wetlands in Edge and Floor sites. It has been well-established at the wetlands for some time. It was widely recorded in 2006 (Carr and Conole 2006) and in 2012-23 was present in 29 of the 30 wetlands surveyed, mostly in moderate to high abundance (Hamilton et al 2013).

The incidence of Plains Rush decreased slightly from 45 sites in 2010 to 39 sites in 2017, but the pattrn of decrease was not uniform across locations. Incidence fell to zero in 2017 for sites on Floor of Sergeants and Winton Swamp, presumably a casualty of the flooding: dead tussocks of Plain Rush were noted in flooded areas during autumn 2017. Fluctuations in abundance parallelled the variations in incidence.

Abundancechanged very little on Slopes sites, decreased in the two large wetlands Sergeants and Winton Swamps, and increased at Green Swamp and in small wetlands (Table 7.4).

Table 7.4. ***Juncus semisolidus***

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Slopes	A sites (n = 8)	1	0.03	3	0.13
Slopes	B sites (n = 8)	8	2.60	7	2.08
Slopes	C sites (n = 8)	7	1.58	6	1.55
Edge: Green	D sites (n = 5)	4	0.36	5	6.36
Edge: Sergeant's	D sites (n = 4)	4	4.95	3	1.05
Edge: Winton	D sites (n = 5)	5	9.00	3	6.76
Floor: Green	M sites (n = 3)	1	0.10	3	7.13
Floor: Sergeant's	M sites (n = 4)	4	6.05	0	0
Floor: Winton	M sites (n = 6)	4	0.83	0	0
Small Wetlands	M sites (n = 10)	7	5.96	9	9.58

Lachnagrostis filiformis

Blown or Fairy Grass *Lachnagrostis filiformis* var 1 is a native shorter-lived (annual-perennial) grass, usually living for up to a year but persisting for up to three years if soil conditions (moisture) remain suitable. In the SET classification (Section 2.3) it is #5, GR_short_native, a species-poor group (Table 3.1).

Populations and abundances of this species can fluctuate enormously, depending on seasonal conditions and opportunity (eg dried lake beds). Detached inflorescences (referred to as seed heads) can be a major nuisance, if they form large accumulations against fences, trees and buildings (Warnock et al 2013).

At the Reserve*, Lachnagrostis filiformis* occurred in both terrestrial and wetland locations. In 2012-13, it was recorded in 30 out of 30 wetlands surveyed (Hamilton et al 2013).

Although overall incidence is only marginally higher in 2017 (28 and 31 sites in 2010 and 2017 respectively), it shifted habitat. In 2010, nearly all records were from wetland sites, whereas in 2017 it was recorded from a mix of Slopes and Wetland sites. Abundance was correspondingly variable between surveys, however abundance in 2017 did not reach levels recorded in 2010 (Table 7.5).

Table 7.5. ***Lachnagrostis filiformis***

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Slopes	A sites (n = 8)	0	0	4	0.58

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Slopes	B sites (n = 8)	0	0	6	0.96
Slopes	C sites (n = 8)	2	0.1	7	1.71
Edge: Green	D sites (n = 5)	5	2.86	2	0.48
Edge: Sergeant's	D sites (n = 4)	3	6.60	1	0.60
Edge: Winton	D sites (n = 5)	4	1.08	3	0.78
Floor: Green	M sites (n = 3)	2	8.50	1	0.14
Floor: Sergeant's	M sites (n = 4)	4	8.90	0	0.0
Floor: Winton	M sites (n = 6)	6	8.40	0	0.0
Small Wetlands	M sites (n = 10)	2	0.70	7	0.46

Phalaris aquatica

Toowoomba Canary Grass *Phalaris aquatica* is an introduced naturalised perennial grass, found in terrestrial and riparian ecosystems. It is widely recognised as a significant environmental weed on account of its on-site persistence and dominance, and as a fire hazard on account of its high biomass. In the SET classification (Section 2.3), it is #4, GR_long_intro.

Phalaris aquatica occurred in most parts of Mokoan Reserve / Winton Wetlands. It was most prevalent in Slopes sites but occurred also in Edge sites around large wetlands, and on Floor of small wetlands. In 2012-13 it was recorded in 20 out of 30 wetlands surveyed (Hamilton et al 2013). It was well-established in the area over a decade ago, and recognised as a looming management issue (Carr and Conole 2006).

The incidence of *Phalaris aquatica* nearly doubled in 7 years, from 10 sites in 2010 to 19 in 2017 (Table 7.6). Cover increased on Slopes sites, doubling at highest elevations (A sites) and increasing by two orders of magnitude at lower elevations (B sites). In contrast, incidence and cover decreased in the littoral zone (Edge sites), which is attributed to recent long duration flooding. Although young plants of *Phalaris aquatica* are known to be tolerant of being inundated (flooded but not submerged) for two weeks (Ploschuk et al 2017), the species is generally considered a terrestrial forage plant and therefore unlikely to persist if flood duration lasts a few months, especially if the live plant is overtopped, or flooded during its growing season.

Table 7.6. *Phalaris aquatica*

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Slopes	A sites (n = 8)	5	2.43	5	5.68
Slopes	B sites (n = 8)	1	0.05	7	6.95
Slopes	C sites (n = 8)	1	0.05	6	6.43
Edge: Green	D sites (n = 5)	0		0	

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Edge: Sergeant's	D sites (n = 4)	2	0.15	0	0
Edge: Winton	D sites (n = 5)	0		0	
Floor: Green	M sites (n = 3)	0		0	
Floor: Sergeant's	M sites (n = 4)	0		0	
Floor: Winton	M sites (n = 6)	0		0	
Small Wetlands	M sites (n = 10)	1	0.04	1	0.18

Trifolium spp.

Four species of clover occurred in monitoring sites (*T. angustifolium, T. campestre, T. dubium* and *T. subterraneum*), possibly more as some plants could only be identified only to genus (*Trifolium* sp.). The four species belong to SET #10, HB_short_intro, and the taxa identified to genus only are assigned to SET #14, Uncertain, because longevity could not be established.

The number of Trifolium species recorded varied between years and locations. Two taxa were recorded in 2010 (*T. angustifolium* and *Trifolium* sp.) and five in 2017, compared with three in 2012-2013 in 30 wetlands (*Trifolium angustifolium, Trifolium fragiferum*, and *Trifolium subterraneum*: Hamilton et al 2013). Of these, the most frequently recorded was *Trifolium angustifolium*, with an incidence of 15 sites in 2010 (all Slopes), 16 wetlands in 2012-13, and 22 sites in 2017 (of which 21 were Slopes).

Incidence of *Trifolium* (here meaning presence of any one of the five taxa) was higher in 2017 than 2010, 26 sites compared with 20, and were nearly all on Slopes sites (Table 7.7). Abundance (the sum of all five taxa per site) more than doubled at A and C sites, decreased at B sites, and was generally low in or around wetlands.

Table 7.7. ***Trifolium spp.***

		Survey 2010		Survey 2017	
Location	Sites	Sites present	% cover (mean)	Sites present	% cover (mean)
Slopes	A sites (n = 8)	6	0.93	8	2.96
Slopes	B sites (n = 8)	6	2.64	8	1.77
Slopes	C sites (n = 8)	7	1.53	7	4.59
Edge: Green	D sites (n = 5)	1	0.04	1	0.01
Edge: Sergeant's	D sites (n = 4)	0		0	
Edge: Winton	D sites (n = 5)	0		2	0.09
Floor: Green	M sites (n = 3)	0		0	
Floor: Sergeant's	M sites (n = 4)	0		0	
Floor: Winton	M sites (n = 6)	0		0	
Small Wetlands	M sites (n = 10)	0	0	2	0.004

7.3 Trends in SETs

This section presents data on SETS for Slopes sites in relation to the factor SinceDD, but in greater detail than given in Section 4. As in Section 4, the three ages from each survey are treated as a composite time line, with sites ranging in age from 4y to 26y. This is not strictly how a chronosequence is established. As understood in the ecological literature, the x-axis (time) of a chronosequence is a series of sites of different ages (ideally replicated) sampled at a single point in time, whereas in this presentation, the x-axis (time) is a composite of sites (unreplicated) that have been sampled at two points in time, seven years apart. Sites aged 4y, 8y and 19y from the first survey in 2010, are combined with sites aged 11y, 15y and 26y from the second survey in 2017, and placed on a common axis.

The plots below are to assist in the development of vegetation trajectories and ecosystem functioning, as per Objectives 2.9 and 2.10 in Barlow (2011). The relevant statistical analyses of SinceDD are given in Section 4.

Graminoids and Herbs

Plots of mean SET abundance with age since drawdown (Figure 7.1, next page) show diverging trends in SETS. Several graminoid SETs appeared to increase (eg SETs 3, 4, 6 for graminoids, and SETS 8 for herbs) and two herb SETS appeared to decrease (eg SETs 7 and 10).

However, testing the significance of each of these trends by 1-way ANOVA (Table 7.8, next page) showed that only one of the trends (Figure 7.1) was significant, and two were marginal. The one trend found to be significant ws the decrease in longer-lived native herbs (SET 7); the two trends of marginal significance were an increase in shorter-lived introduced graminoids (SET 6), and decline in shorter-lived introduced herbs (SET 10).

These patterns were consistent with changes for Slopes sites described for empirical groupings (eg Table 4.12) and for individual species such as *Phalaris aquatica* (Section 7.2).

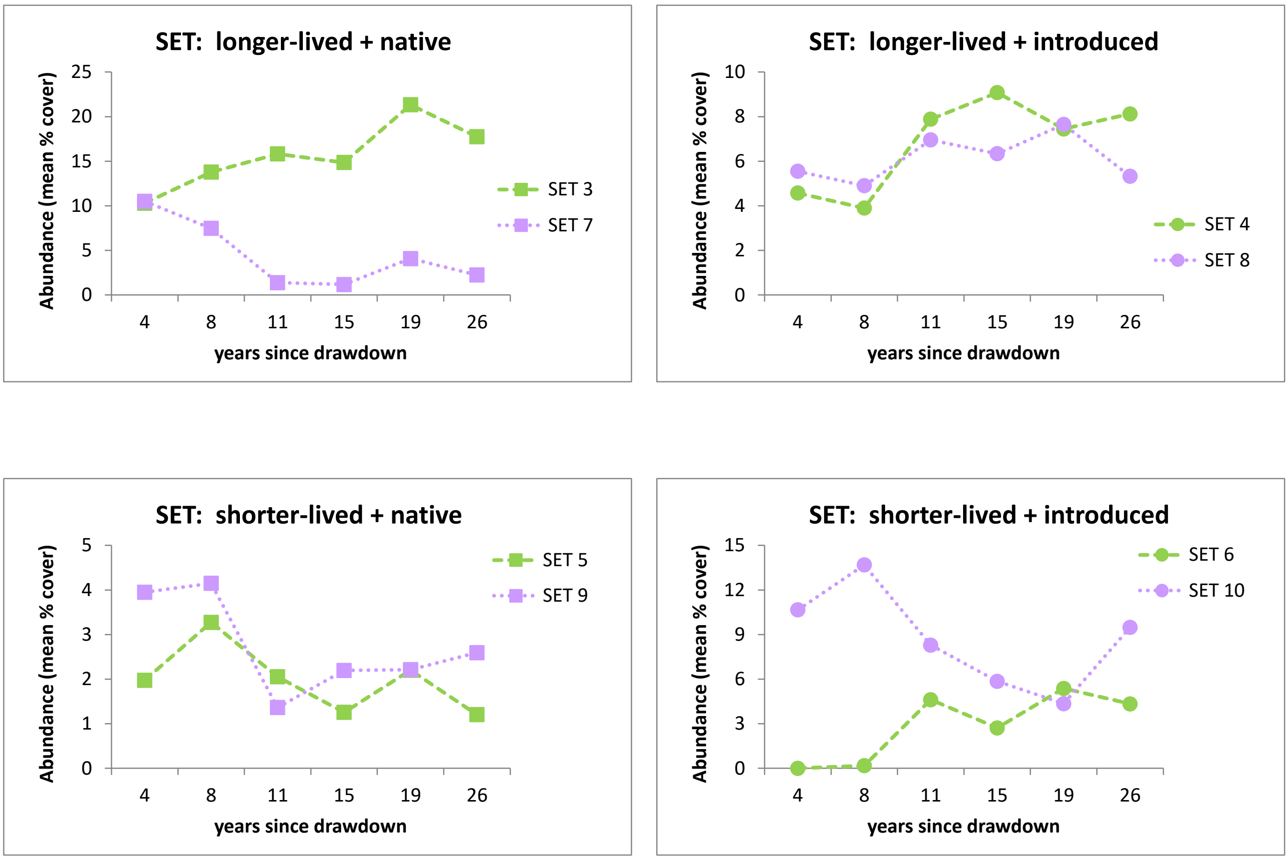


Figure 7.1 Trends in groups of Graminoids and Herbs

Trends in abundance of graminoids and herbs, for differing vegetation attributes. Top Left: longer-lived and native graminoids and herbs; Top Right: longer-lived and introduced graminoids and herbs; Bottom left: shorter-lived and native graminoid and herbs; Bottom Right: shorter-lived and introduced graminoids and herbs. Key: Green = Graminoids, Purple = Herbs. SET numbers are as given in Table 2.2.

Table 7.8.

SET	P value	outcome
3: GR_long_native	0.098	NS
4: GR_long_intro	0.738	NS
5: GR_short_native	0.455	NS
6: GR_short_intro	0.024	marginal
7: HB_long_native	<0.001	***
8: HB_long_intro	0.851	NS
9: HB_short_native	0.197	NS
10: HB_short_intro	0.051	marginal

Further analysis of the one trend that is significant, by pairwise comparison of the means for the six levels of SET 7 HB_long_native using Fishers LSD, showed that two youngest age-classes (4y and 8y) are statistically distinct from each other and from the other age groups, whereas the older age classes (11y, 15y, 19y and 26y) were not (Table 7.9). The implication is that native perennial herbs may establish well following drawdown but are unable to persist.

Table 7.9. Grouping SinceDD for SET 7: HB_long_native

SinceDD	Mean	Grouping
4y	10.51	A
8y	7.48	B
11y	1.388	C D
15y	1.173	D
19y	4.088	C
26y	2.230	C D

Longer-Lived and Nativeness

Similarly, the plots for SETS combined to show vegetation attributes shows that the cover of longer-lived species (sum of SETs 3, 4, 7, 8, 11, 12 and 13) also appeared to increase, but not the cover of native SETS (Figure 7.2). The cover of woody SETS can be interpreted as support for the idea of lag and threshold, as described above for *Cassinia arcuata*.

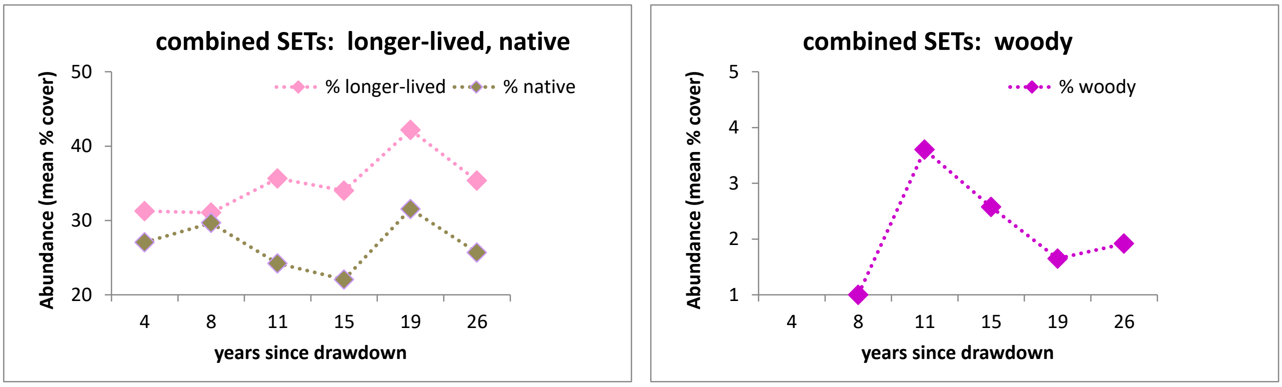


Figure 7.2: Combined SETS and years since drawdown

8. All Recommendations

This is a compilation of the 19 recommendations made arising out of the analyses of the results presented in this report. There are no recommendations arising from Results – Overview (Section 3) or Results – Species and Trends (Section 7).

Recommendations arising from analysis of Slopes sites (Section 4)

Recommendation 1

Clarify best practice in relation to various uses of the Slopes environment, but specifically in relation to agriculture and conservation.

Recommendation 2

Develop s.m.a.r.t. and spatially-explicit targets for vegetation on Slopes surrounding the wetlands. This could benefit from further analysis of 2010 and 2017 monitoring data.

Recommendation 3

Establish a system and map of vegetation condition indicators that can be used to guide day-to-day management and decisions in relation to selected threats or issues.

Recommendation 4

Establish a suite of indicators of ecosystem function and condition, as recommended by Barlow (2011), with an emphasis on those that are low cost, amenable to citizen-science or volunteer implementation, and that can be integrated into an appraisal of Mokoan Reserve / Winton Wetlands.

Recommendation 5

Continue with this monitoring program, but sampling every 5 years. A sub-sample of sites could be monitored more frequentl, such as every 2-3 years), in order to distinguish short-term fluctuations from long-term trends.

Recommendation 6

Once spatially explicit targets have been established, review and revise this monitoring program, paying special attention to gaps and redundancies.

Recommendations arising from analysis of Wetland sites (Section 5)

Recommendation 7

Categorise wetlands in terms of their water regime and hydraulic characteristics. The categorisation should be used to recognise sites, areas and wetlands where vegetation is expected to respond similarly. This categorisation will be useful in setting specific vegetation targets, for evaluating feasibility of targets, and for reviewing the scope and representativeness of the current vegetation monitoring program.

Recommendation 8

Determine the actual elevation in m AHD of all monitoring sites, but especially of D sites which appear to be rather variable. Consider the need or otherwise of standardising D sites by elevation for comparability of vegetation response.

Recommendation 9

Increase frequency of vegetation monitoring at Wetlands sites to every five years to link with Slopes sites and retain an overall whole-of-Reserve perspective.

Recommendation 10

Establish a monitoring program that complements the current quadrat-based vegetation monitoring, by providing broad coverage but qualitative data (mapping from aerial photography; permanent fixed photopoints).

Recommendation 11

Establish a staff gauge or water level recording system that can be used to provide water/inundation history for all monitoring sites in wetlands; the necessary data is depth and duration of being flooded, as well as frequency.

Recommendations arising from analysis of Southern Cane Grass (Section 6.2)

Recommendation 12

The vision that Sergeants and Winton Swamps will eventually be dominated by Southern Cane Grass needs to be critically reviewed for ecological feasibility. For this it will be necessary to consider the contemporary hydrologic and hydraulic characteristics of Sergeant's and Winton Swamps (which may have changed since 1960s), and tolerances and requirements of Southern Cane Grass. If necessary, the vision may need to be revised.

Recommendation 13

Knowledge about life cycle and water regime requirements and tolerances of Southern Cane Grass needs to be improved to a level that can inform the long-term vision for Winton Wetlands / Mokoan Reserve. In particular, the depth duration tolerances and sensitivities of different age-stages need to be quantitatively established, preferably using multiple lines of evidence including empirical from existing monitoring sites, from other wetlands, and by experiment, and linked to hydrologic and hydraulic modelling.

Recommendation 14

Continue monitoring recruitment and persistence of Southern Cane Grass at existing sites, using existing methods, but increase the sampling frequency to every 2-3 years for age-stage monitoring. Understanding populations processes would be helped by recording water level and depth history, at some (not necessarily all) sites: see Recommendation 15.

Monitoring should continue at all sites until the restoration objective is achieved or is certainly on track for success, at which point the monitoring program should be reviewed to make it fit for other needs, such as long-term condition monitoring.

Recommendation 15

Develop a means of recording inundation history at monitoring sites that will give essential information on depth and duration of inundation, at precision levels that will allow interpretation of fate of age –stages.

Recommendation 16

Develop a strategic approach for achieving restoration objectives for target species using a mix of natural and assisted regeneration. However, as wetland types, land use, and other factors vary around the Reserve, it would be sensible to develop a suite of strategies, tailoring them to particular wetlands and areas: this is because a single approach is unlikely to suit all areas.

Recommendations arising from analysis of River Red Gums (Section 6.4)

Recommendation 17

Continue to monitor age-stages of River Red Gum at all 61 monitoring sites, at least until spatially-explicit targets are articulated and a revised regeneration strategy has been initiated; increase frequency of monitoring to every 2-3y to align with Southern Cane Grass monitoring.

Recommendation 18

Develop a restoration plan for River Red Gum woodlands at Winton Wetlands /Mokoan Reserve which is spatially explicit and which acknowledges that not all dead woodland was or should be River Red Gum. The plan will need to be sensitive to natural heterogeneity of the Reserve, and should develop and use knowledge of abiotic and biotic constraints on regeneration to different approaches for different areas.

Recommendation 19

Develop a regeneration strategy for River Red Gum that by-passes life-history bottle-necks such as dispersal, germination and early seedling establishment; and that instead invests in more establishing and nurturing more advanced stages, either by planting and/or by locating self-established juveniles. A network of 'mother' trees is suggested.

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Appendix 1: Data Files

Two Excel data files have been provided.

1: Plot_meta_regen_data_20170726.xlsx

This file has just one worksheet giving co-ordinates for the 10x100m plots (n=61), and regeneration data for Southern Cane Grass and River Red Gum from the 2017 autumn re-survey.

Site ID (column C)

Site Bearing, name and co-ordinates (columns G to N)

Genera site notes from field in 2017 (column R)

Water conditions in plot in 2017 (columns S and T) (column Z)

Notes on soil made in 2017 (columns U, V, W X and Y)

Regeneration status of River Red Gum in 2017 (columns AA to AD) and notes (column AF): counts per age-stage per plot

Regeneration status of Southern Cane Grass in 2017 (columns AE to AI) and notes (column AJ): counts per age-stage per plot

2: MASTER file 2010_2017 vegetation data Winton Mokoan.xlsx

This file has six worksheets:

MASTER structure

MASTER floristics

MASTER SET abundance

MASTER Southern CG

MASTER River Red Gum

MASTER List Species Code SET

<u>MASTER Structure:</u> this worksheet has a data matrix of values for ten structural variables for all 61 plots as recorded in 2010 and in 2017 (columns B to DS). Underneath the data matrix is a second matrix, giving ten environmental or other variables for each plot X survey. The data is set out as used in analysis in Primer.

Plot X survey is a six-character alpha-numeric that combines plot number (such as A08) with survey year (s10 or s17) to give a unique identifier such as B04s10 or M13s17 etc.

For the data matrix:

Unique ID for Plot X survey (61 plots in 2 surveys) is in row 2, columns B to DS.

Ten structural variables (from Upper to DeadTR) are on rows 3 to 12. (see main body of report for definitions)

For the environmental etc matrix underneath: Environmental information for each plot in each survey is on rows 14 to 23. The variables are as follows:

Survey = year when survey was done (s10 or s17);

Site = site as per original design (A, B, C, D, M);

SinceDD = years lapsed between time of survey and when last submerged by watrs of the storage Lake Mokoan, and is roughly equivalent to age. (19, 8, 4, 2 and 1 for s10 and 26, 15, 11, 9 and 8 for s17). The value 8 for s10 is shown as 8.5 to distinguish from s17.

EcoManUnit = Ecological Management Unit as given in Barlow (2011) (ER, SP, GW, NE or SW);

%flooded and depth cm;

whether plot was sedimented;

extent of flooding of plot;

Site x Survey (B_17);

STUMPS = presence of stumps

MASTER floristics 2010, 2017 worksheet: This has a data matrix of plot X survey by species abundance, and underneath it an 'environmental matrix' of attributes. Species abundance = mean % live PFC per plot, and is the average of five 5 x 5 m quadrats used to subsample each plot.

The species abundance matrix comprises plot X survey (61 plots x 2 survey years) (= 122 columns from B to DS) and 175 "species" (not all are strictly species) in rows (rows 3 to 177).

The environmental matrix underneath the data matrix comprises 14 variables or categorical variables used in analyses, in rows 179 – 192.

Survey = year when survey was done (s10 or s17);

Site = site as per original design (A, B, C, D, M);

SinceDD = years lapsed between time of survey and when last submerged by watrs of the storage Lake Mokoan, and is roughly equivalent to age. (19, 8, 4, 2 and 1 for s10 and 26, 15, 11, 9 and 8 for s17). The value 8 for s10 is shown as 8.5 to distinguish from s17.

EcoManUnit = Ecological Management Unit as given in Barlow (2011) (ER, SP, GW, NE or SW);

%flooded = what percentage of plot was flooded at time of survey

Deep = categorical variable (none, shallow, deep)

depth cm = average depth (cm) of water in plot (estimated);

sedimented

extentFLD = categorical variable (none, some, most)

Site x Survey = site type, whether A, B, C, D, or M, per survey (B_17, M_10)

landform = a broad categorisation (slopes, wetlands)

wetland = a broad categorisation (oth for other = the small wetlands, gr = Green Swamp, win =Winton Swamp, ser = Sergeants Swamp, no = not a wetland).

In GRZ lease = plot was or was not located in a grazing lease

GRZ_EVID = whether grazing was evident or not, from incidental field notes (not systematically recorded).

MASTER SET abundances: this has a data matrix of SET abundances by plot X survey. SET abundances are species abundances re-combined (aggregated) according SET. Underneath this data matrix is an environmental etc matrix, identical to the one given above for floristics.

Worksheet uses only SET names. It does not use SET number (see MASTER List Species Code SET)

MASTER Southern CG: this has a simple data matrix, of counts per age-stage by plot X survey. The age-stages are: Seedling, Young, Established, Patch (defined in report).

Field notes for Southern Cane Grass in 2017 are in column AJ in **Plot_meta_regen_data_20170726.xlsx**

MASTER River Red Gum: this has two lists, one for 2010 and one for 2017. There are no age-stages for 2010, only for 2017: instead, 2010 has a total count of regenerants.

Field notes for River Red Gum in 2017 are in column AE in **Plot_meta_regen_data_20170726.xlsx**

MASTER List Species Code SET: this has a list of all species recorded in 2010 and 2017, showing also family, the six-letter code, attributes used to generate each SET (longevity, origin, growth-form), SET number and SET full name.

Six letter code is made up from the first three letters of the genus name and the first three letters of the species name, thus *Chloris truncata* is coded as **chltru**. Plants identified to genus only have 'spx' for their species name, thus *Acaena sp* is coded as **acaspx**. Seedlings that could only be identified as either monocots or dicots are coded as **monggg** and **dicggg** respectively.

CAUTION: an alphabetical list of taxa recorded (given as genus + species) does not fully correspond to an alphabetical list of the six-letter code. For example, an alphabetical list of species names would be in the following sequence "*Cassinia arcuata, Centaurium erythraea, Centipeda cunninghamii*" but an alphabetical list of the six-letter code is in this sequence "casarc, cencun, cenery" . There are only a few instances of this.

Appendix 2: Taxa recorded in 2010 and 2017 surveys

List of all taxa recorded in 2010 and 2017 surveys, given using the name used in 2017. Also shown are the three attributes used to assign Species Ecological Type (SET) and SET number and name. Definitions of three attributes are in Section 2.4 Data preparation.

Family	Species	Longevity	Origin	Growth form	SET	SET name
Adiantaceae	*Cheilanthes austrotenuifolia*	longer	Aus	fern & liverwort	1	FL_long_native
Adiantaceae	*Cheilanthes sieberi subsp. sieberi*	longer	Aus	fern & liverwort	1	FL_long_native
Adiantaceae	*Cheilanthes sp.*	longer	Aus	fern & liverwort	1	FL_long_native
Amaranthaceae	*Alternanthera denticulata s.l.*	longer	Aus	herb	7	HB_long_native
Araliaceae	*Hydrocotyle spp.*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Arctotheca calendula*	short	intro	herb	10	HB_short_intro
Asteraceae	*Aster subulatus*	longer	intro	herb	8	HB_long_intro
Asteraceae	*Cassinia aculeata*	longer	Aus	shrub	11	SB_long_native
Asteraceae	*Cassinia arcuata*	longer	Aus	shrub	11	SB_long_native
Asteraceae	*Centipeda cunninghamii*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Chondrilla juncea*	longer	intro	herb	8	HB_long_intro
Asteraceae	*Cirsium vulgare*	short	intro	herb	10	HB_short_intro
Asteraceae	*Conyza bonariensis*	short	intro	herb	10	HB_short_intro
Asteraceae	*Dittrichia graveolens*	short	intro	herb	10	HB_short_intro
Asteraceae	*Euchiton involucratus s.l.*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Euchiton japonicus s.s.*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Euchiton sphaericus*	short	Aus	herb	9	HB_short_native
Asteraceae	*Euchiton spp.*	uncertain	Aus	herb	14	uncertain
Asteraceae	*Gamochaeta americana*	short	intro	herb	10	HB_short_intro
Asteraceae	*Gamochaeta calviceps*	short	intro	herb	10	HB_short_intro
Asteraceae	*Gamochaeta purpurea s.l.*	short	intro	herb	10	HB_short_intro
Asteraceae	*Helichrysum luteoalbum*	short	Aus	herb	9	HB_short_native
Asteraceae	*Helminthotheca echioides*	longer	intro	herb	8	HB_long_intro
Asteraceae	*Hypochaeris glabra*	short	intro	herb	10	HB_short_intro
Asteraceae	*Hypochoeris radicata*	longer	intro	herb	8	HB_long_intro
Asteraceae	*Lactuca saligna*	short	intro	herb	10	HB_short_intro
Asteraceae	*Lactuca serriola*	short	intro	herb	10	HB_short_intro

Family	Species	Longevity	Origin	Growth form	SET	SET name
Asteraceae	*Lactuca sp.*	short	intro	herb	10	HB_short_intro
Asteraceae	*Leontodon taraxacoides subsp. taraxacoides*	longer	intro	herb	8	HB_long_intro
Asteraceae	*Scorzonera laciniata var. laciniata*	short	intro	herb	10	HB_short_intro
Asteraceae	*Senecio biserratus*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Senecio campylocarpus*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Senecio cunninghamii var. cunninghamii*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Senecio quadridentatus*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Senecio runcinifolius*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Sonchus asper s.l.*	short	intro	herb	10	HB_short_intro
Asteraceae	*Sonchus oleraceus*	short	intro	herb	10	HB_short_intro
Asteraceae	*Sonchus sp.*	short	intro	herb	10	HB_short_intro
Asteraceae	*Tragopogon porrifolius*	short	intro	herb	10	HB_short_intro
Asteraceae	*Vittadinia cuneata var. cuneata*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Vittadinia gracilis*	longer	Aus	herb	7	HB_long_native
Asteraceae	*Xanthium spinosum*	short	intro	herb	10	HB_short_intro
Azollaceae	*Azolla filiculoides*	uncertain	Aus	fern & liverwort	2	FL_short_native
Boraginaceae	*Echium plantagineum*	short	intro	herb	10	HB_short_intro
Boraginaceae	*Heliotropium europaeum*	short	intro	herb	10	HB_short_intro
Brassicaceae	*Lepidium africanum*	longer	intro	herb	8	HB_long_intro
Brassicaceae	*Rorippa palustris*	short	intro	herb	10	HB_short_intro
Campanulaceae	*Lobelia pratioides*	longer	Aus	herb	7	HB_long_native
Campanulaceae	*Wahlenbergia ?multicaulis*	longer	Aus	herb	7	HB_long_native
Campanulaceae	*Wahlenbergia spp.*	longer	Aus	herb	7	HB_long_native
Caryophyllaceae	*Moenchia erecta*	short	intro	herb	10	HB_short_intro
Caryophyllaceae	*Spergularia spp.*	longer	Aus	herb	7	HB_long_native
Caryophyllaceae	*Stellaria caespitosa*	short	Aus	herb	9	HB_short_native
Chenopodiaceae	*Dysphania glomulifera ssp. glomulifera*	short	Aus	herb	9	HB_short_native
Chenopodiaceae	*Dysphania pumilio*	short	Aus	herb	9	HB_short_native
Convolvulaceae	*Convolvulus angustissimus subsp. Angustissimus*	longer	Aus	herb	7	HB_long_native

Family	Species	Longevity	Origin	Growth form	SET	SET name
Convolvulaceae	*Convolvulus sp.*	longer	Aus	herb	7	HB_long_native
Cucucurbitaceae	*Cucumis myriocarpus*	short	intro	herb	10	HB_short_intro
Cyperaceae	*Baumea arthrophylla*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Bolboschoenus medianus*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Carex appressa*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Carex inversa*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Carex tereticaulis*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Cyperus eragrostis*	longer	intro	graminoid	4	GR_long_intro
Cyperaceae	*Cyperus exaltatus*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Cyperus gymnocaulos*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Eleocharis acuta*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Eleocharis pusilla*	longer	Aus	graminoid	3	GR_long_native
Cyperaceae	*Isolepis marginata*	short	intro	graminoid	6	GR_short_intro
Cyperaceae	*Schoenus apogon*	short	Aus	graminoid	5	GR_short_native
Elatinaceae	*Elatine gratioloides*	short	Aus	herb	9	HB_short_native
Fabaceae	*Lotus sp*	uncertain	UNK	herb	14	uncertain
Fabaceae	*Lotus subbiflorus*	short	intro	herb	10	HB_short_intro
Fabaceae	*Swainsona procumbens*	longer	Aus	herb	7	HB_long_native
Fabaceae	*Trifolium angustifolium var. angustifolium*	short	intro	herb	10	HB_short_intro
Fabaceae	*Trifolium campestre var. campestre*	short	intro	herb	10	HB_short_intro
Fabaceae	*Trifolium dubium*	short	intro	herb	10	HB_short_intro
Fabaceae	*Trifolium spp.*	uncertain	intro	herb	14	uncertain
Fabaceae	*Trifolium subterraneum*	short	intro	herb	10	HB_short_intro
Gentianaceae	*Centaurium erythraea*	short	intro	herb	10	HB_short_intro
Geraniaceae	*Erodium botrys*	short	intro	herb	10	HB_short_intro
Geraniaceae	*Erodium crinitum*	short	Aus	herb	9	HB_short_native
Geraniaceae	*Erodium sp.*	longer	Aus	herb	7	HB_long_native
Geraniaceae	*Geranium solanderi var. solanderi*	longer	Aus	herb	7	HB_long_native
Geraniaceae	*Geranium sp.*	uncertain	UNK	herb	14	uncertain
Goodeniaceae	*Goodenia gracilis*	longer	Aus	herb	7	HB_long_native
Haloragaceae	*Myriophyllum crispatum*	longer	Aus	herb	7	HB_long_native

Family	Species	Longevity	Origin	Growth form	SET	SET name
Haloragaceae	*Myriophyllum verrucosum*	longer	Aus	herb	7	HB_long_native
Hypericaceae	*Hypericum gramineum spp. agg.*	longer	Aus	herb	7	HB_long_native
Hypericaceae	*Hypericum perforatum subsp. veronense*	longer	intro	herb	8	HB_long_intro
Iridaceae	*Iridaceae spp.*	longer	UNK	herb	14	uncertain
Iridaceae	*Romulea rosea*	longer	Aus	herb	7	HB_long_native
Juncaceae	*Juncus bufonius*	short	Aus	graminoid	5	GR_short_native
Juncaceae	*Juncus flavidus*	longer	Aus	graminoid	3	GR_long_native
Juncaceae	*Juncus gregiflorus*	longer	Aus	graminoid	3	GR_long_native
Juncaceae	*Juncus holoschoenus*	longer	Aus	graminoid	3	GR_long_native
Juncaceae	*Juncus semisolidus*	longer	Aus	graminoid	3	GR_long_native
Juncaceae	*Juncus subsecundus*	longer	Aus	graminoid	3	GR_long_native
Juncaginaceae	*Triglochin procera s.l.*	longer	Aus	herb	7	HB_long_native
Lamiaceae	*Marrubium vulgare*	longer	intro	herb	8	HB_long_intro
Lamiaceae	*Mentha pulegium*	longer	intro	herb	8	HB_long_intro
Lamiaceae	*Mentha satureoides*	longer	Aus	herb	7	HB_long_native
Lemnaceae	*Lemna disperma s.l.*	uncertain	Aus	herb	14	uncertain
Lythraceae	*Lythrum hyssopifolia*	short	Aus	herb	9	HB_short_native
Mimosaceae	*Acacia spp.*	longer	Aus	tree	13	TR_long_native
Molluginaceae	*Glinus lotoides*	short	Aus	herb	9	HB_short_native
Molluginaceae	*Glinus oppositifolius*	short	Aus	herb	9	HB_short_native
Myrtaceae	*Calytrix tetragona*	longer	Aus	shrub	11	SB_long_native
Myrtaceae	*Eucalyptus camaldulensis*	longer	Aus	tree	13	TR_long_native
Onagraceae	*Epilobium billardierianum subsp. cinereum*	longer	Aus	herb	7	HB_long_native
Onagraceae	*Epilobium hirtigerum*	longer	Aus	herb	7	HB_long_native
Orchidaceae	*Microtis unifolia*	longer	Aus	herb	7	HB_long_native
Oxalidaceae	*Oxalis perennans*	longer	Aus	herb	7	HB_long_native
Plantaginaceae	*Plantago lanceolata*	short	intro	herb	10	HB_short_intro
Poaceae	*Aira elegantissima*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Amphibromus nervosus*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Aristida behriana*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Aristida ramosa*	longer	Aus	graminoid	3	GR_long_native

Family	Species	Longevity	Origin	Growth form	SET	SET name
Poaceae	*Austrostipa scabra subsp. falcata*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Austrostipa spp.*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Avena barbata*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Bothriochloa macra*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Briza maxima*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Briza minor*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Bromus diandrus*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Bromus hordeaceus subsp. hordeaceus*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Chloris truncata*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Cortaderia selloana*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Cynodon dactylon var. dactylon*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Deyeuxia quadriseta*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Digitaria divaricatissima*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Digitaria sanguinalis*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Echinochloa crus-galli*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Enteropogon acicularis*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Eragrostis brownii*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Eragrostis elongata*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Eragrostis infecunda*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Eragrostis parviflora*	short	Aus	graminoid	5	GR_short_native
Poaceae	*Holcus lanatus*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Hordeum hystrix*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Lachnagrostis filiformis var. 1*	short	Aus	graminoid	5	GR_short_native
Poaceae	*Lolium rigidum*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Microlaena stipoides var. stipoides*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Panicum capillare*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Panicum effusum*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Paspalum dilatatum*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Paspalum distichum*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Phalaris aquatica*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Pseudoraphis*	longer	Aus	graminoid	3	GR_long_native

Family	Species	Longevity	Origin	Growth form	SET	SET name
	spinescens					
Poaceae	*Rytidosperma caespitosum*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Rytidosperma duttonianum*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Rytidosperma fulvum*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Rytidosperma racemosum var. racemosum*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Rytidosperma setaceum var. setaceum*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Rytidosperma spp.*	longer	Aus	graminoid	3	GR_long_native
Poaceae	*Setaria parviflora*	longer	intro	graminoid	4	GR_long_intro
Poaceae	*Vulpia bromoides*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Vulpia myuros*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Vulpia spp.*	short	intro	graminoid	6	GR_short_intro
Poaceae	*Walwhalleya proluta*	longer	Aus	graminoid	3	GR_long_native
Polygonaceae	*Acetosella vulgaris*	longer	intro	herb	8	HB_long_intro
Polygonaceae	*Persicaria lapathifolia*	short	Aus	herb	9	HB_short_native
Polygonaceae	*Persicaria prostrata*	longer	Aus	herb	7	HB_long_native
Polygonaceae	*Polygonum aviculare s.l.*	short	intro	herb	10	HB_short_intro
Polygonaceae	*Polygonum plebeium*	short	Aus	herb	9	HB_short_native
Polygonaceae	*Rumex brownii*	longer	Aus	herb	7	HB_long_native
Polygonaceae	*Rumex conglomeratus*	longer	intro	herb	8	HB_long_intro
Polygonaceae	*Rumex crispus*	longer	intro	herb	8	HB_long_intro
Polygonaceae	*Rumex tenax*	longer	Aus	herb	7	HB_long_native
Potamogetonaceae	*Potamogeton cheesemanii*	longer	Aus	herb	7	HB_long_native
Ricciaceae	*Ricciocarpos natans*	short	Aus	fern & liverwort	2	FL_short_native
Rosaceae	*Rosa rubiginosa*	longer	intro	shrub	12	SB_long_intro
Rubiaceae	*Sherardia arvensis*	short	intro	herb	10	HB_short_intro
Scrophulariaceae	*Glossostigma elatinoides*	longer	Aus	herb	7	HB_long_native
Solanaceae	*Solanum nigrum s.l.*	longer	intro	herb	8	HB_long_intro
Typhaceae	*Typha domingensis*	longer	Aus	graminoid	3	GR_long_native
Typhaceae	*Typha orientalis*	longer	Aus	graminoid	3	GR_long_native