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Establishment success and benefits to the aquatic plant community of planting *Schoenoplectus validus* around the shorelines of lakes Alexandrina and Albert 2013–2014

Jason Nicol, Susan Gehrig and Kate Frahn

SARDI Publication No. F2013/000414-2
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SARDI Aquatics Sciences
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July 2014

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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Establishment success and benefits to the aquatic plant community of planting *Schoenoplectus validus* around the shorelines of lakes Alexandrina and Albert-2014

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Cover Photo: Shoreline of Lake Alexandrina at Raukkan showing *Phragmites australis*, *Typha domingensis* and *Schoenoplectus validus* (Regina Durbridge).

South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024
Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

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Authors: Jason Nicol, Susan Gehrig and Kate Frahn

Reviewers: Chris Bice (SARDI) and Sacha Jellinek (DEWNR)

Approved by: Assoc Prof Qifeng Ye
Science Leader – Inland Waters & Catchment Ecology

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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EXECUTIVE SUMMARY

Schoenoplectus validus is a large, native, perennial, rhizomatous sedge that grows to 2–3 m high in water up to 1.5 m deep and is a common emergent species around the edges of the Lower Lakes (lakes Alexandrina and Albert). Unlike other large emergent species present in the Lower Lakes (e.g. *Phragmites australis* and *Typha domingensis*), it does not form dense monospecific stands and usually grows in deeper water than the aforementioned species, often in association with aquatic taxa such as *Myriophyllum* spp., *Potamogeton* spp. *Ceratophyllum demersum* and *Vallisneria australis. Schoenoplectus validus* is a robust species; often growing on shorelines subjected to wave action and providing sheltered areas where less robust species can persist. These characteristics have resulted in *Schoenoplectus validus* being planted extensively around the edges of lakes Alexandrina and Albert, primarily to reduce shoreline erosion.

Despite *Schoenoplectus validus* being extensively planted there has been little monitoring to evaluate the survivorship, density and extent of the planted stands. Furthermore, vegetation surveys were not undertaken at planting sites prior to planting and there is little information regarding the benefits of planting *Schoenoplectus validus* on the aquatic plant community. This project was designed to address these data deficiencies and had four aims:

- To compare the survivorship, density, height and extent of *Schoenoplectus validus* plantings in lakes Alexandrina and Albert between 2013 and 2014.
- To compare the density, height and extent of *Schoenoplectus validus* between shorelines that were planted and areas where it occurs naturally.
- To investigate the effect of *Schoenoplectus validus* planting on the aquatic plant community by comparing the plant community in planted and non-planted areas and where *Schoenoplectus validus* is naturally present.
- To establish and survey paired planted and control sites where *Schoenoplectus validus* may be planted in the future to gain baseline information regarding the aquatic plant communities.

Survivorship, stand width, stem density and maximum and mean stem height of *Schoenoplectus validus* were assessed at seven planted shoreline sites (n = 4 old plantings, 7 to 8.5 years old; and n = 3 new plantings, 1.5 to 2.5 years old) in lakes Alexandrina and Albert in autumn 2013 and 2014, and at three shoreline sites where *Schoenoplectus validus* is present naturally in

autumn 2014 (age unknown, herein referred to as “natural shorelines”; *n* = 3). These parameters were compared between old plantings, new plantings and natural shorelines in autumn 2014, whilst change in these parameters between autumn 2013 and 2014 was assessed at all planted sites. The benefits of planting to the aquatic plant community were assessed by comparing the plant community at planted, adjacent unplanted (control) shorelines (in 2013 and 2014), natural shorelines and shorelines that are potential future planting sites (in 2014).

Between autumn 2013 and 2014, there were significant increases in i) stand width (e.g. Meningie Foreshore) and ii) stem density (e.g. Raukkan) at most planted sites and iii) an increase in the calculated total number of stems present at each 100 m surveyed section of shoreline at all sites. In contrast, with the exception of the old planting at Nurra Nurra Point, stem height decreased significantly at all sites planted prior to 2007. In autumn 2014, *Schoenoplectus validus* stands at the natural sites were characterised by greater stand width than planted sites (old and new) and stem densities lower than shorelines planted prior to 2007 but similar to shorelines planted after 2010. Stem height was similar at natural and all planted shorelines.

A diverse aquatic plant community was generally present at shorelines planted prior to 2007, compared to the control sites, which were generally devoid of aquatic vegetation. The aquatic plant community at shorelines planted after 2010 were similar to the control shorelines (with the exception of Meningie Foreshore). The plant community at natural shorelines was distinct but most similar to shorelines planted prior to 2007. When the plant community was divided into high (+0.8 and +0.6 m AHD) and low (+0.4, +0.2 and 0 m AHD) elevations the differences between the planted, natural and unplanted shorelines at the high elevations was less distinct but the shorelines planted prior to 2007 were still most similar to the natural shorelines. At low elevations there were distinct differences between the plant community at the natural, planted and unplanted shorelines with shorelines planted prior to 2007 becoming more similar to the natural shorelines between autumn 2013 and 2014.

Results showed that planted *Schoenoplectus validus* survived at all sites and there was evidence that it was expanding due to the increase in the calculated number of stems recorded at all shorelines, even in areas where no statistically significant increases in stand width or stem density were detected. Comparisons between planted and natural stands suggested that the planted stands could expand a considerable distance into lakes Alexandrina and Albert and it is unlikely that maximum stem density has been reached at planted sites.

Data collected in autumn 2014 further supported the hypothesis that *Schoenoplectus validus* provides a “breakwater” protecting the shoreline from waves and creating a low energy environment where aquatic, amphibious, floating and submergent plants can establish. There is also evidence that the plant communities at shorelines planted prior to 2007 are becoming more similar to the plant community at natural shorelines through time. Therefore, the natural shorelines may be used as a target to evaluate the success of the planting program.

1. INTRODUCTION

1.1. Background

Schoenoplectus validus is large, native, perennial, rhizomatous sedge that grows 2–3 m in height (up to 5 m in very favourable conditions) in water up to 1.5 m deep (Cunningham *et al.* 1992; Sainty and Jacobs 2003). Ecosystem services provided by *Schoenoplectus validus* include erosion control, waterbird habitat, fish habitat, sediment and water column aeration and water quality improvement (Sainty and Jacobs 2003). It is a common emergent species around the edges of lakes Alexandrina and Albert but unlike the other two large emergent species present in the Lower Lakes, *Phragmites australis* and *Typha domingensis*, it does not form dense monospecific stands (Gehrig *et al.* 2011; 2012; Frahn *et al.* 2013). *Schoenoplectus validus* usually grows in deeper water than *Typha domingensis* and *Phragmites australis* (Sainty and Jacobs 2003) and in the Lower Lakes is often associated with submergent taxa such as *Myriophyllum* spp., *Potamogeton* spp. *Ceratophyllum demersum* and *Vallisneria australis* (Gehrig *et al.* 2011; 2012; Frahn *et al.* 2013; Nicol *et al.* 2013).

The ability of *Schoenoplectus validus* to tolerate wave action has resulted in it being planted extensively around the edges of lakes Alexandrina and Albert in water depths up to 1 m, primarily to control shoreline erosion (Goolwa to Wellington Local Action Planning Board *et al.* no date). Nearly all aquatic (and riparian) erosion control planting programs involve planting trees or shrubs on shorelines or river banks (e.g. Abernethy and Rutherfurd 1998; Raulings *et al.* 2007; Watson 2009); hence, planting an emergent aquatic species in the water is a novel approach.

Results of monitoring undertaken in autumn 2013 showed that plants persisted during the period of low water levels (2007 to 2010), probably as rhizomes, and established once water levels were reinstated (Nicol *et al.* 2013). Furthermore, there was evidence that plantings benefitted the aquatic plant community by providing a sheltered area where submergent and less robust emergent species could establish (Nicol *et al.* 2013).

1.2. Objectives

Despite *Schoenoplectus validus* being planted extensively around the shorelines of lakes Alexandrina and Albert, there has since been just one monitoring event (autumn 2013) to evaluate the survivorship, density and extent of the planted stands. Furthermore, vegetation surveys were not undertaken prior to planting, with only data collected in autumn 2013 available to assess the benefits (or negative impacts) of planting *Schoenoplectus validus* on the aquatic plant community. Finally, quantitative comparisons of the aquatic plant community between shorelines planted with *Schoenoplectus validus* and shorelines where the species occurs naturally have not been undertaken. This project was designed to address these data deficiencies and had four aims:

- To compare the survivorship, density, height and extent of *Schoenoplectus validus* plantings in lakes Alexandrina and Albert between 2013 and 2014.
- To compare the density, height and extent of *Schoenoplectus validus* between shorelines that were planted and areas where it occurs naturally.
- To investigate the effect of *Schoenoplectus validus* planting on the aquatic plant community by comparing the plant community in planted and non-planted areas and where *Schoenoplectus validus* is present naturally.
- To establish and survey paired planted and control sites where *Schoenoplectus validus* may be planted in the future to gain baseline information regarding the aquatic plant communities.

2. METHODS

2.1. Study sites

A total of 11 shorelines were surveyed in 2014 (Table 1, Figure 1). Seven were established in 2013 at locations where *Schoenoplectus validus* had been planted (two in Lake Alexandrina; Wellington Lodge and Raukkan, and five in Lake Albert; Dumandang, Lake Albert Rd, Meningie Foreshore and Nurra Nurra Point) (Figure 1) and surveyed in autumn 2013 and 2014 (Table 1). Control sites, for assessing changes in the aquatic plant community, were established adjacent to all planted sites except Lake Albert Road and Meningie Foreshore (Figure 1). At Lake Albert Road the planting extended a considerable distance along the shoreline, resulting in the adjacent shoreline being too close to the Narrung Narrows at the western end of the planting and at the eastern end at the inlet of Waltowa Swamp. Both these areas were considerably different to the planted area; hence, a control site was established at the northern end of Brown Beach (Figure 1). The shoreline adjacent to the Meningie Foreshore site was also different to the planted shoreline. The shoreline to the south was highly modified (jetties and the boat ramp) and extensive erosion control works had been undertaken on the shoreline to the north hence a control site was established at the southern end of Brown Beach (Figure 1). In 2014, three potential future planting sites (Wellington Lodge, Poltalloch and Point Sturt) and three sites where *Schoenoplectus validus* grows naturally (Hindmarsh Island Bridge, Loveday Bay and Bremer Mouth) (Figure 1) were established and surveyed (Table 1). GPS coordinates of sites and the year *Schoenoplectus validus* was planted at each location are presented in Appendix 1.

Table 1: List of locations, their planting status, stand age category and when the stands were planted and surveyed.

Location	Planting Status	Age	Year Planted	Years Surveyed
Dumandang	Planted (+Control)	Old	2003, 2004 and 2006	2013 and 2014
Raukkan	Planted (+Control)	Old	2006	2013 and 2014
Wellington Lodge	Planted (+Control) and potential future planting	Old	2007	2013 and 2014
Nurra Nurra Point	Old Planted, New Planted (+Control)	Old and New	2006, 2012 and 2013	2013 and 2014
Meningie Foreshore	Planted (+Control)	New	2012	2013 and 2014
Lake Albert Road	Planted (+Control)	New	2013	2013 and 2014
Loveday Bay	Natural	NA	NA	2014
Bremer Mouth	Natural	NA	NA	2014
Hindmarsh Island Bridge	Natural	NA	NA	2014
Poltalloch	Potential future planting	NA	NA	2014
Point Sturt	Potential future planting	NA	NA	2014

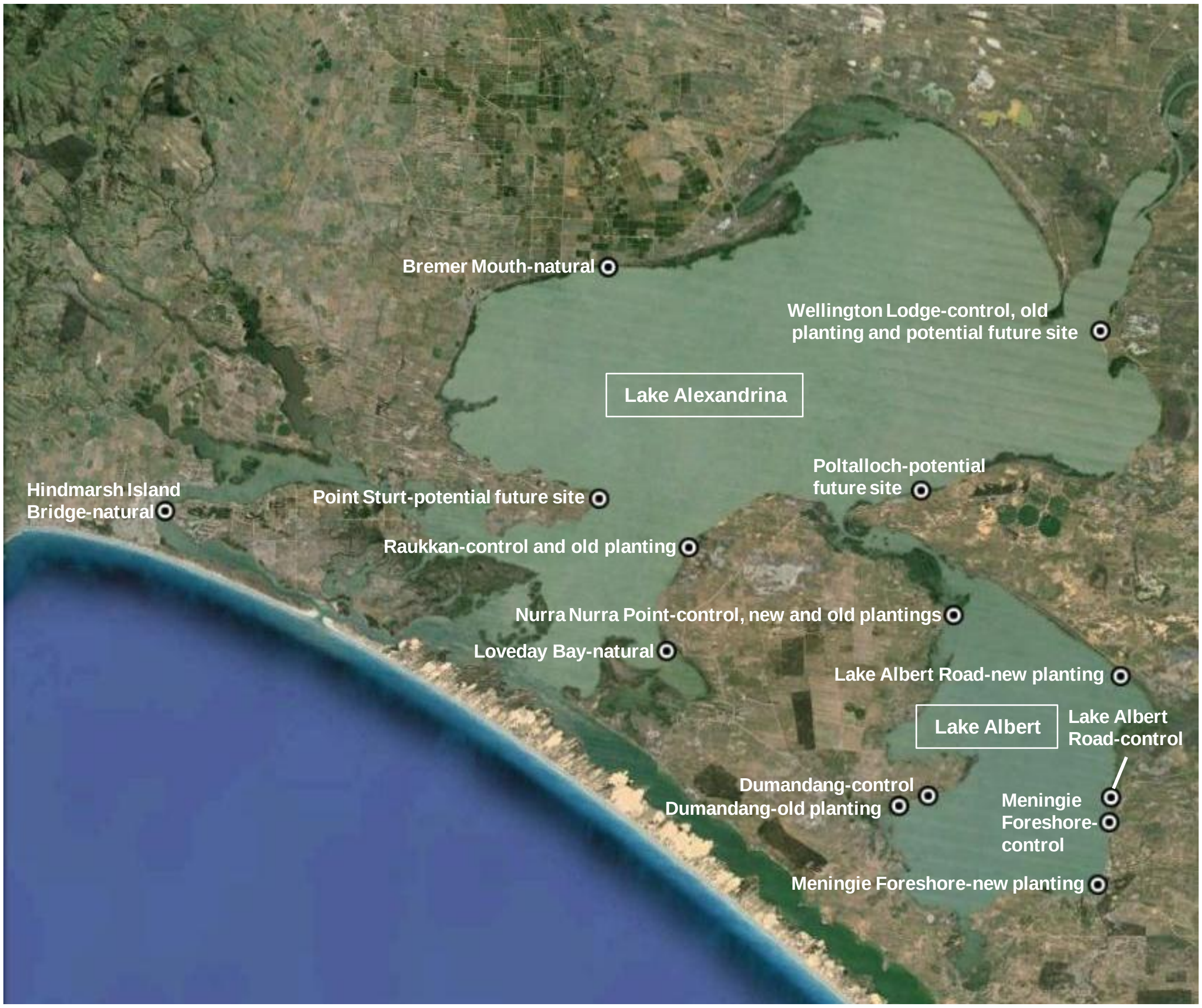

Figure 1: Aerial photograph of lakes Alexandrina and Albert showing the survey locations.

At each site, a 100 m section of shoreline in the centre of the planted stand was selected where the survivorship, stem density, stem height and extent (stand width) of planted or natural *Schoenoplectus validus* and the aquatic plant community were assessed.

2.2. Survivorship, density, height and extent of *Schoenoplectus validus* stands

Stem density (no. stems m^{-2}), stem height (maximum and mean) and extent (stand width) of planted *Schoenoplectus validus* stands was assessed at each of the planted sites (n = 7) (Table 1, Figure 1). Measurements were undertaken at five random points along the 100 m section of surveyed shoreline (determined using a random number generator between 0 and 99 and taking measurements at the corresponding metre mark on a 100 m measuring tape) (Figure 2) in autumn 2013 and 2014 (Table 1). Random numbers were generated for each survey to avoid repeated measures. The same measurements were undertaken on natural *Schoenoplectus validus* (n = 3) stands in autumn 2014.

Stem density was measured by recording the number of stems in a 1 x 1 m quadrat and stand width measured along the left hand edge (facing the shoreline) of the quadrat (Figure 2). The tallest stem in the quadrat and the height of ten random stems were measured from the lake bed. In addition, water depth was measured at each quadrat to determine emergent height, although this was not reported because planting depth was consistent across sites (<5 cm range between sites).

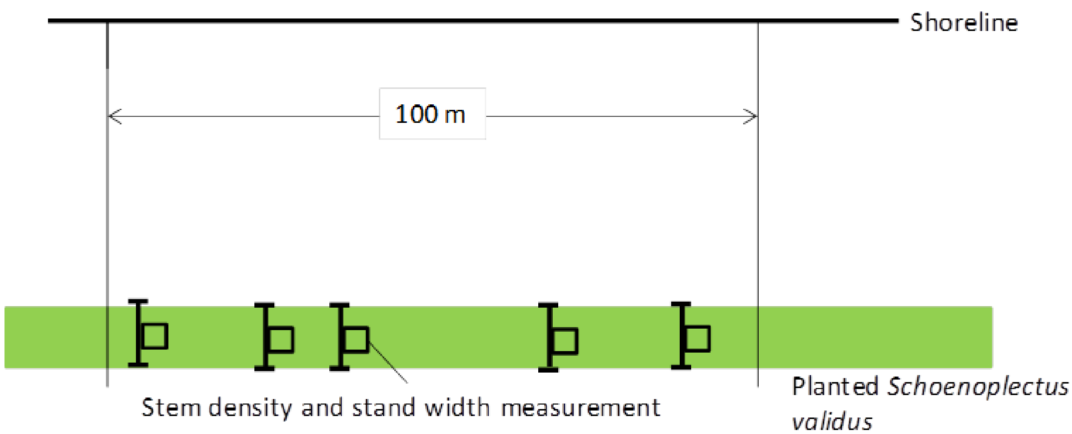

Figure 2: Plan view of a planted shoreline section showing the stand width measurement and quadrats within which stem density and height measurements were undertaken.

2.3. Benefit of *Schoenoplectus validus* plantings for the aquatic plant community

The vegetation monitoring protocol used the same methods as TLM (*The Living Murray*) lake shore vegetation condition monitoring for lakes Alexandrina and Albert (Frahn *et al.* 2013). This will enable quantitative comparison of data with that collected as part of the TLM vegetation condition monitoring, if required. At each site, three transects were established perpendicular to the shoreline, at each end and in the middle of the 100 m shoreline section at planted and control locations (Figure 3). Two locations were established at Point Sturt and Poltalloch (potential future planting sites) with one to be planted and the other the control but only one location at Wellington Lodge because a control site was established in autumn 2013 (Nicol *et al.* 2013). At sites where *Schoenoplectus validus* occurs naturally one location was established.

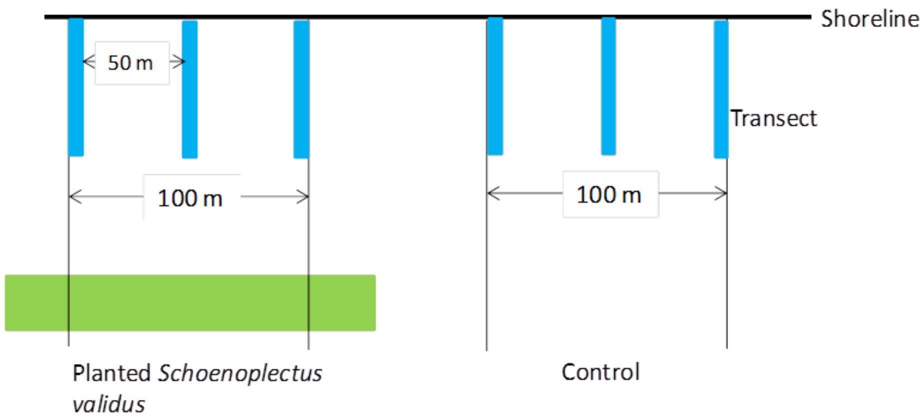

Figure 3: Plan view of planted and control shoreline sections showing the placement of vegetation monitoring transects. Potential future planting sites were also established following the same design.

Along each transect three 1 x 3 m quadrats separated by 1 m were established at +0.8, +0.6, +0.4, +0.2, and 0 AHD (Figure 4). Quadrats at lower elevations were not surveyed due to the absence of vegetation at all sites. Cover and abundance of each species present in the quadrat were estimated using the method outlined in Heard and Channon (1997), except that N and T were replaced by 0.1 and 0.5 to enable statistical analyses (Table 2).

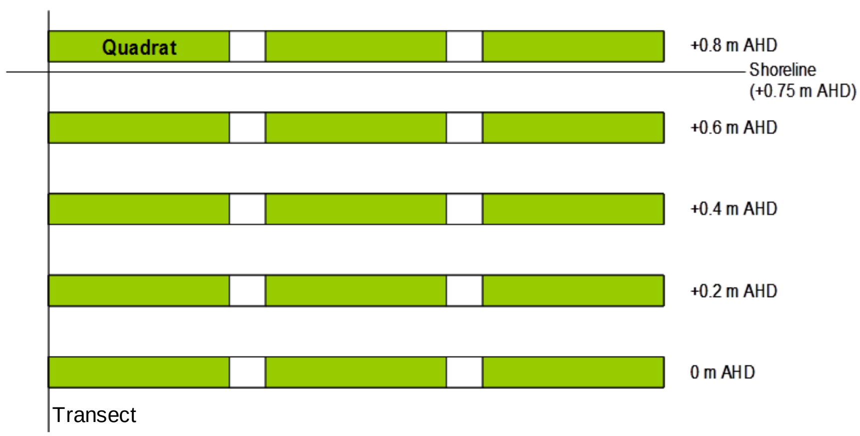

Figure 4: Vegetation surveying protocol for each transect: plan view showing placement of quadrats relative to the shoreline and transect.

Table 2: Modified Braun-Blanquet (1932) scale estimating cover/abundance as per Heard and Channon (1997).

Score	Modified Score	Description
N	0.1	Not many, 1-10 individuals
T	0.5	Sparsely or very sparsely present; cover very small (less than 5%)
1	1	Plentiful but of small cover (less than 5%)
2	2	Any number of individuals covering 5-25% of the area
3	3	Any number of individuals covering 25-50% of the area
4	4	Any number of individuals covering 50-75% of the area
5	5	Covering more than 75% of the area

2.4. Data Analysis

An estimate of the total number of stems (over the 100 m of shoreline where measurements were taken) at the planted and natural shorelines was calculated using the following equation (Equation 1):

Total number of *Schoenoplectus validus* stems = (mean stand width x 100) x mean stem density

Equation 1: Formula used to calculate total number of *Schoenoplectus validus* stems at the planted shorelines and natural shorelines.

Stand width, stem density, mean and maximum height and calculated stem number data were presented graphically and the relationship between stand age (time since planting) and stem density, stand width and calculated stem number analysed with regression analysis using Microsoft Excel. Stand width, stem density and mean stem height at each planted shoreline were compared between 2013 and 2014 with univariate PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) using the package PRIMER 6.1.15 (Clarke and Gorley 2006). Euclidean distances were used to calculate the similarity matrices for all univariate PERMANOVA tests.

Plant community data (all species present) collected at the different elevations at each site were pooled and the difference in floristic composition in 2013 and 2014 between shorelines where *Schoenoplectus validus* has been planted, control shorelines, natural shorelines and potential future sites were assessed with non-metric scaling (NMS) ordination (McCune *et al.* 2002). A dummy variable (equal to 1) was added to enable quadrats with no plants present to be included in the analysis (*sensu* McCune *et al.* 2002). In addition, the same analyses were performed separately on plant community data from high (+0.8 and +0.6 m AHD) and low elevations (+0.4, +0.2 and 0 m AHD) (McCune *et al.* 2002). Species with a Pearson Correlation Coefficient of greater than 0.5 were overlaid on the ordination plots as vectors. All ordinations were undertaken using the package PRIMER version 6.1.15 (Clarke and Gorley 2006). Bray-Curtis (1957) similarities were used to calculate the similarity matrices for all ordinations and α=0.05 for all statistical analyses.

2.5. Plant identification and nomenclature

Plants present were identified to species where possible using keys in Sainty and Jacobs (1981), Jessop and Tolken (1986), Prescott (1988), Dashorst and Jessop (1998), Romanowski (1998), Sainty and Jacobs (2003) and Jessop *et al.* (2006). In some cases due to immature individuals or lack of floral structures, plants were identified to genus only. Nomenclature follows the Centre for Australian National Biodiversity Research and Council of Heads of Australasian Herbaria (2014).

3. RESULTS

3.1. Survivorship, density, height and extent of *Schoenoplectus validus* stands

Live *Schoenoplectus validus* was present and established at all planted sites indicating it survived the previous 12 months. The widest stands of planted *Schoenoplectus validus* were at old planted sites (i.e. Raukkan and Wellington Lodge) in autumn 2013 and 2014, where stands were in excess of 6 m wide in places (Figure 5). There was no significant change in width over this time at Wellington Lodge but at Raukkan and Dumandang, stand width increased significantly (Table 3). The newly planted sites (Meningie Foreshore, Lake Albert Road and the newly planted shoreline at Nurra Nurra Point) were generally 2 m wide in autumn 2013 (Figure 5), but exhibited significant increases in width in autumn 2014 (except Lake Albert Road) (Table 3). There was a weak (albeit significant) positive relationship between stand age and width (R^2=0.3605; P=0.023) (Figure 6). At natural shorelines, stands were generally much wider (> 20 m), except at Loveday Bay where the width was comparable to the planted stand at Raukkan (Figure 5).

Table 3: PERMANOVA results comparing the changes in stand width, stem density and mean stem height at the shorelines planted with *Schoenoplectus validus* between 2013 and 2014.

Shoreline	Stand Measurements	*Pseudo-F*	*DF*	*P*
Meningie Foreshore (new)	Stand Width	4.41	1,9	0.014
	Stem Density	12.15	1,9	0.008
	Mean Stem Height	0.32	1,9	0.659
Nurra Nurra Point (new)	Stand Width	7.15	1,9	0.03
	Stem Density	9.5	1,9	0.02
	Mean Stem Height	0.08	1,9	0.931
Lake Albert Rd (new)	Stand Width	0.894	1,9	0.36
	Stem Density	0.11	1,9	0.75
	Mean Stem Height	29.95	1,9	0.001
Dumandang (old)	Stand Width	16.93	1,9	0.012
	Stem Density	0.67	1,9	0.456
	Mean Stem Height	21.81	1,9	0.001
Nurra Nurra Point (old)	Stand Width	3.22	1,9	0.123
	Stem Density	0.84	1,9	0.775
	Mean Stem Height	0.52	1,9	0.465
Raukkan (old)	Stand Width	5.94	1,9	0.032
	Stem Density	7.95	1,9	0.022
	Mean Stem Height	6.87	1,9	0.012
Wellington Lodge (old)	Stand Width	0.76	1,9	0.419
	Stem Density	0.29	1,9	0.688
	Mean Stem Height	4.17	1,9	0.047

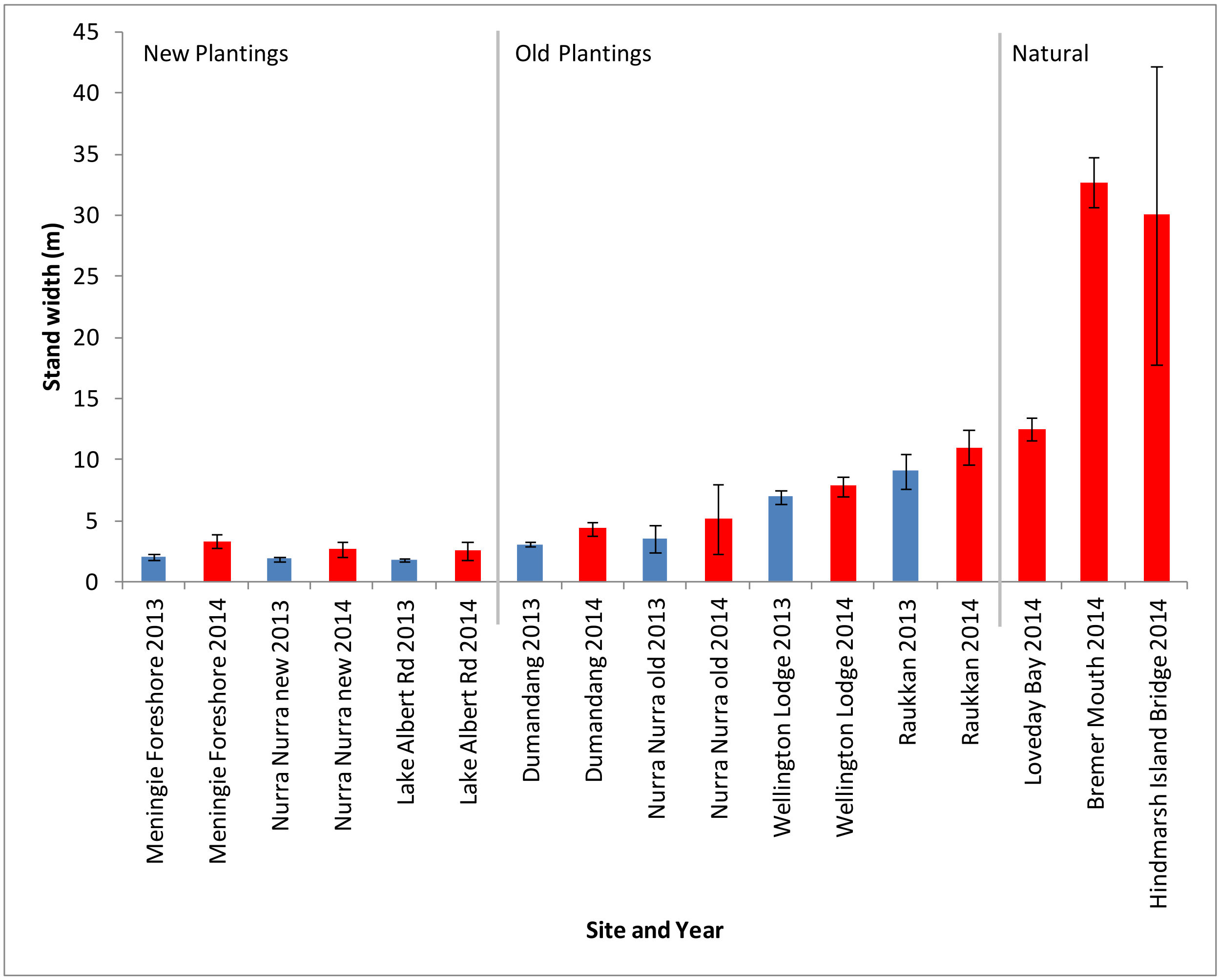

Figure 5: *Schoenoplectus validus* stand width for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 and 2014 (blue columns denote 2013 survey; red columns denote 2014 survey; error bars=±1 SE).

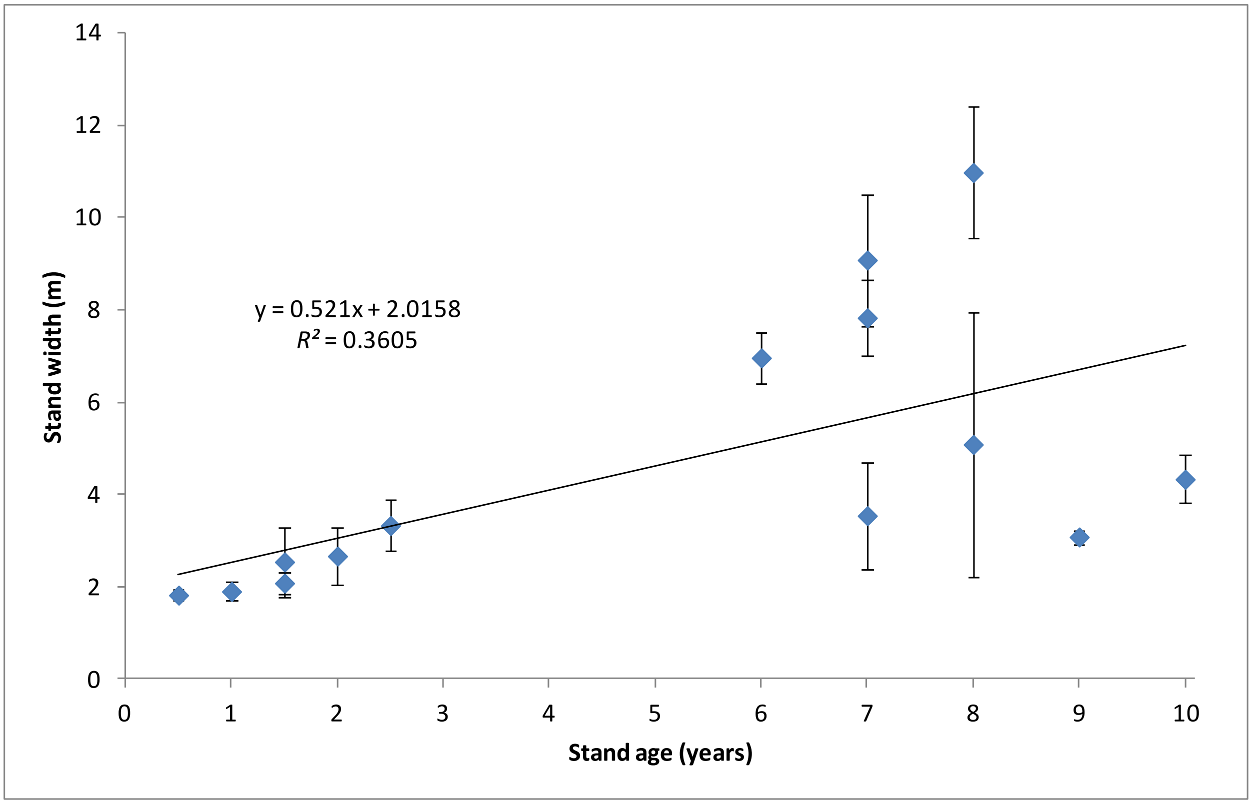

Figure 6: Relationship between *Schoenoplectus validus* stand width and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013 and 2014 (error bars=±1 SE).

In autumn 2013, stem density was typically higher at sites planted prior to 2007 than sites planted since 2010 (except the old planting at Nurra Nurra Point) (Figure 7). There was a significant increase in stem density between autumn 2013 and 2014 at Meningie Foreshore and the new planting at Nurra Nurra Point, but no significant change at Lake Albert Rd (Table 3). There was no significant change in stem density between autumn 2013 and 2014 at the sites planted prior to 2007, except at Raukkan where there was a significant increase (Table 3). Linear regression analysis showed a weak (albeit significant) positive relationship (R^2=0.38; P=0.019) between stand age and stem density (Figure 8). However, if the data from the old planted site at Nurra Nurra Point are removed there is a very strong positive, significant relationship (R^2=0.69; P<0.001).

Stem density at the natural shorelines was variable with the highest density at Loveday Bay, which was comparable to the densities recorded at the shorelines planted prior to 2007 (except the old planting at Nurra Nurra) (Figure 7). Stem density at the Bremer River Mouth was comparable to densities recorded in autumn 2014 at Meningie Foreshore and the new planting at Nurra Nurra Point and at Raukkan in autumn 2013 (Figure 7). The lowest stem density at all shorelines (planted and natural) in autumn 2013 and 2014 was recorded at the Hindmarsh Island Bridge (Figure 7).

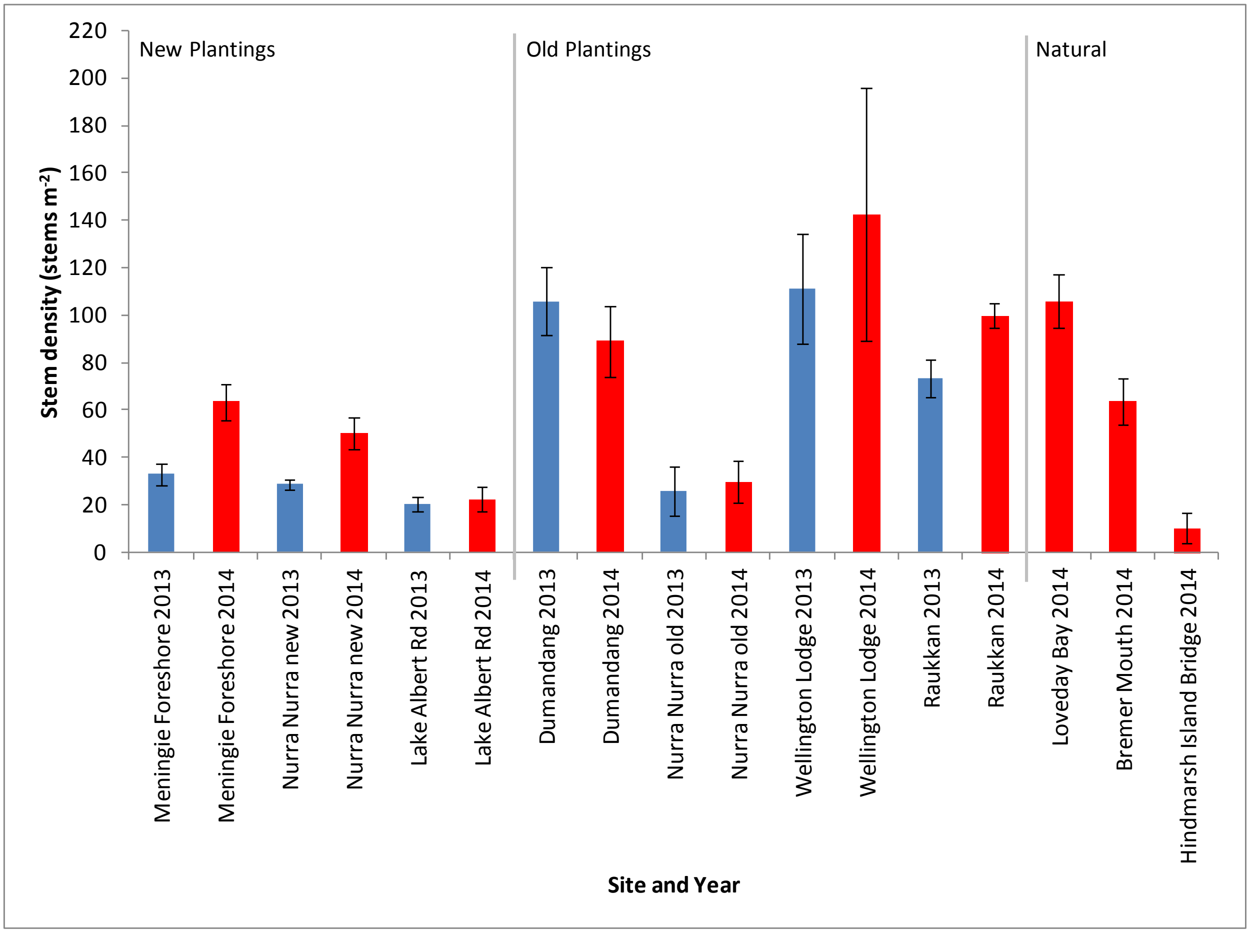

Figure 7: *Schoenoplectus validus* stem density for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 and 2014 (blue columns denote 2013 survey; red columns denote 2014 survey; error bars=±1 SE).

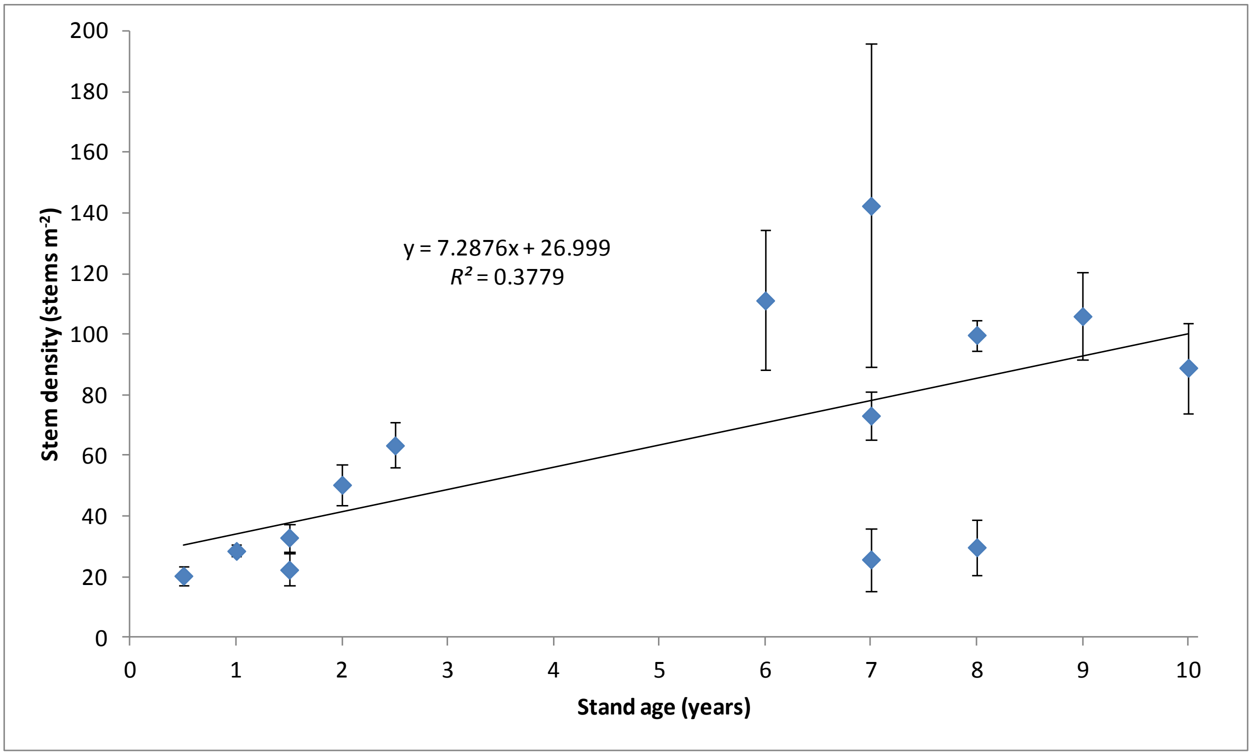

Figure 8: Relationship between *Schoenoplectus validus* stem density and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013 and 2014 (error bars=±1 SE).

The height of the tallest stems was relatively consistent between planted shorelines and surveys (autumn 2013 and 2014) with heights ranging from 168 to 226 cm, except at the old planting at Nurra Nurra Point where the maximum height of stems was lower and more variable (Figure 9). Maximum stem height was also consistent for Loveday Bay and the Bremer River Mouth but was lower and more variable for the Hindmarsh Island Bridge stand. Due to the consistent maximum height of stems there was no relationship between stand age and maximum stem height (Figure 10).

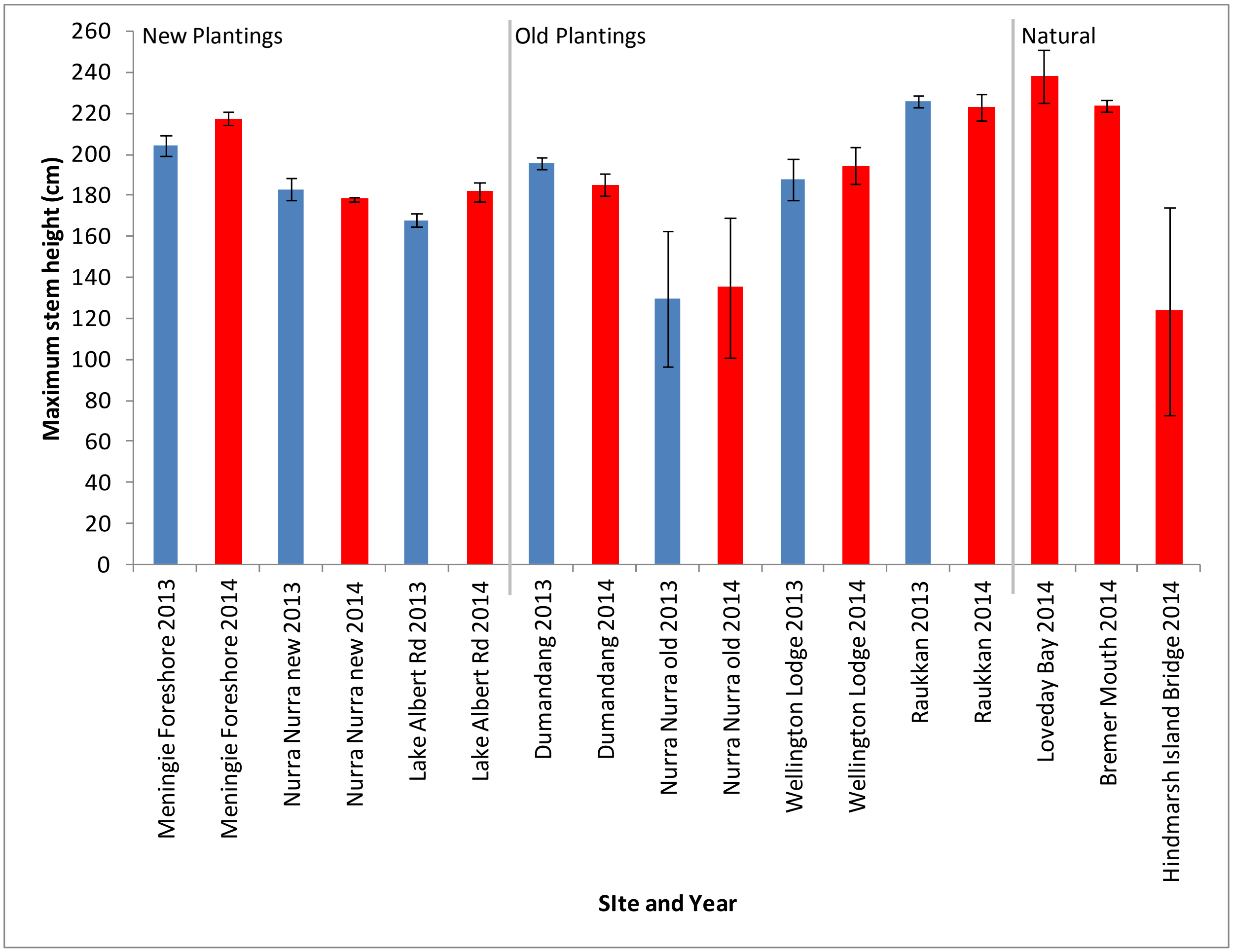

Figure 9: *Schoenoplectus validus* maximum stem height for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 and 2014 (blue columns denote 2013 survey; red columns denote 2014 survey; error bars=±1 SE).

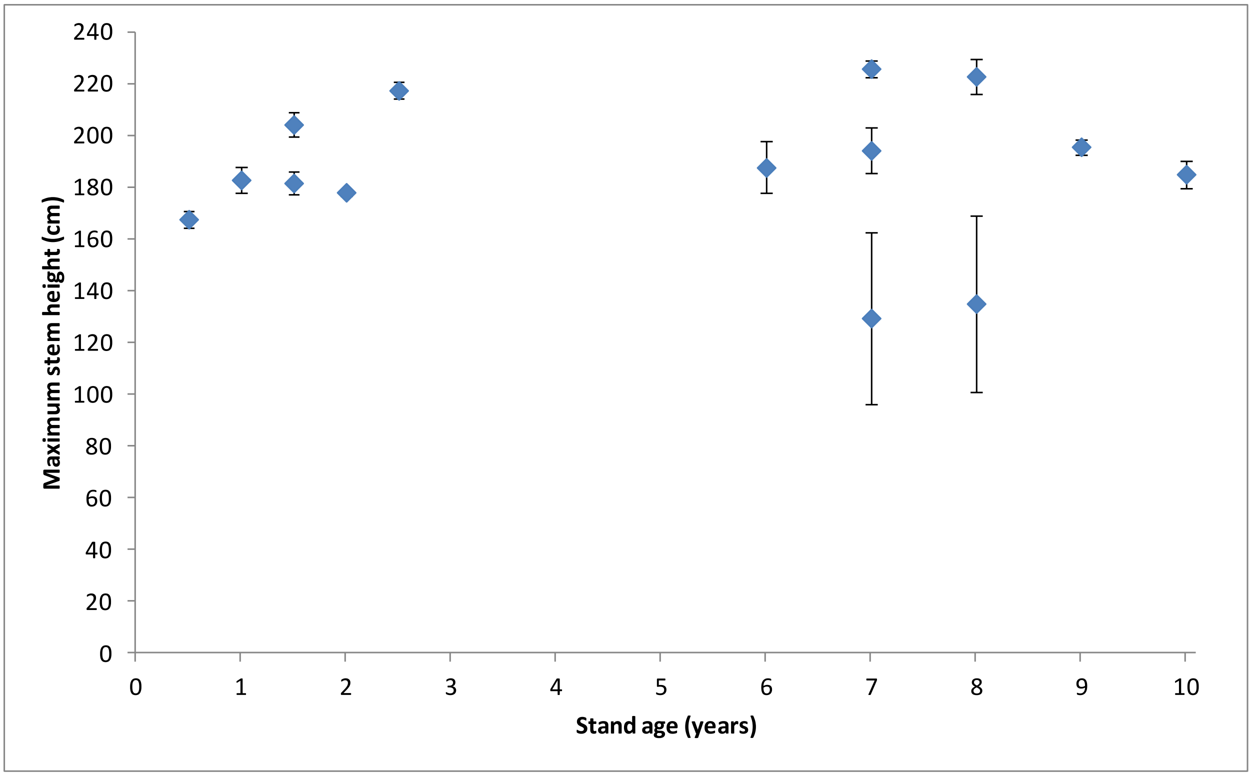

Figure 10: Relationship between *Schoenoplectus validus* maximum stem height and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013 and 2014 (error bars=±1 SE).

There was no significant difference in mean stem height at shorelines planted after 2010 between autumn 2013 and 2014, except at Lake Albert Road where there was a significant increase (Table 3, Figure 11). At shorelines planted before 2007 there was a significant decrease in mean stem height between autumn 2013 and 2014 at all shorelines, except the old planting at Nurra Nurra Point where there was no significant difference (Table 3, Figure 11). Similar to maximum stem height, there was no relationship between stand age and mean stem height (Figure 12).

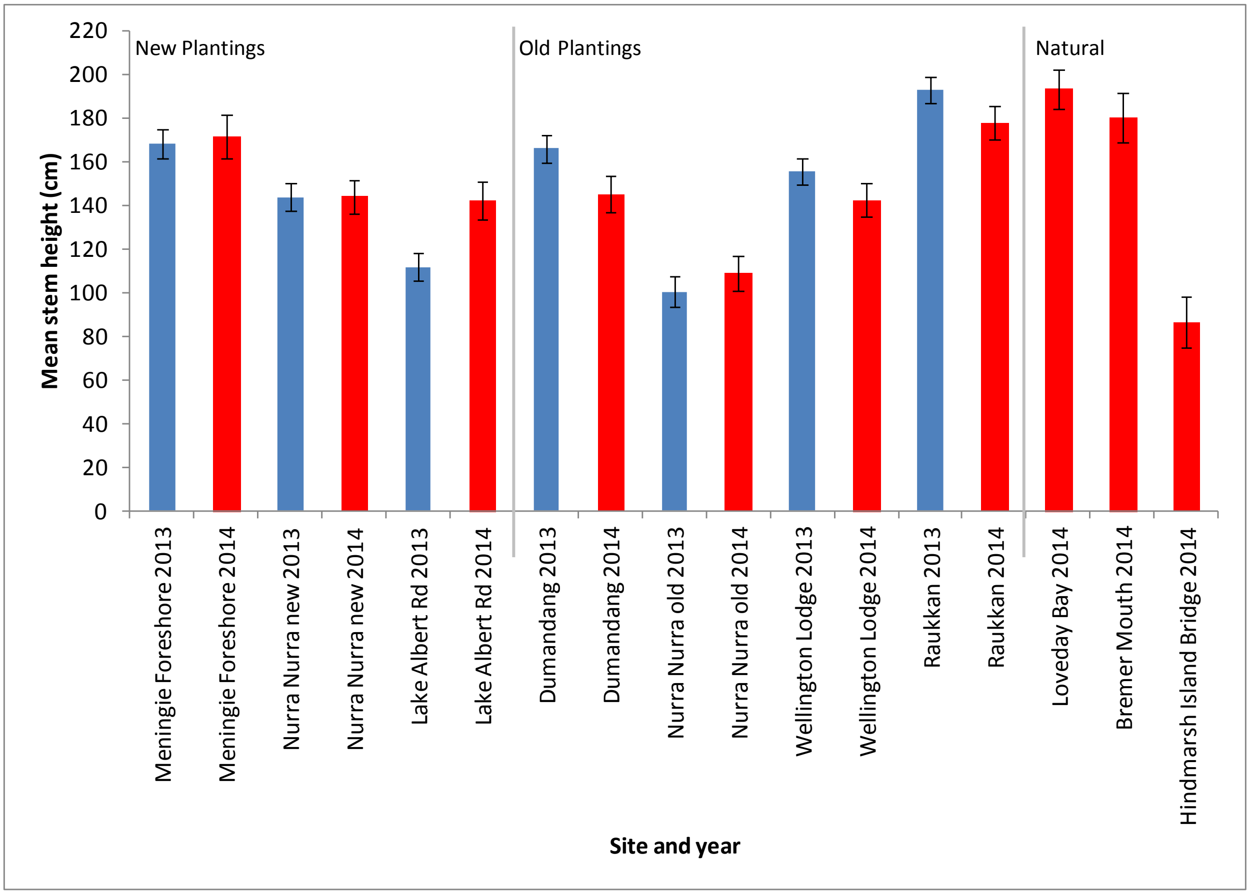

Figure 11: *Schoenoplectus validus* mean stem height for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 and 2014 (blue columns denote 2013 survey; red columns denote 2014 survey; error bars=±1 SE).

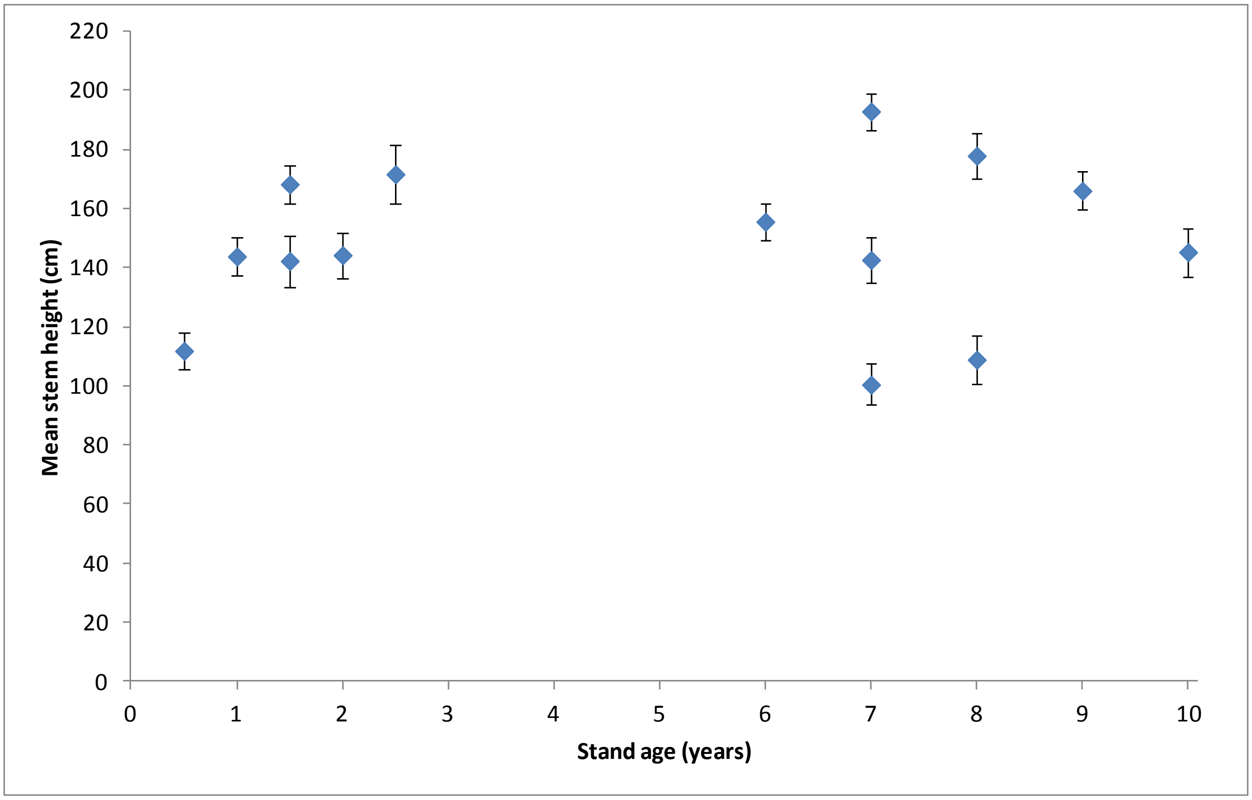

Figure 12: Relationship between *Schoenoplectus validus* mean stem height and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013 and 2014 (error bars=±1 SE).

At all planted sites there was an increase in the total number of *Schoenoplectus validus* stems present at each shoreline (Figure 13). Wellington Lodge and Raukkan had the highest number of stems present at planted shorelines; however, this was less than the number present naturally at Loveday Bay and the Bremer River Mouth (Figure 13). Linear regression analysis showed a weak (albeit significant) positive relationship (R^2=0.31; P=0.04) between stand age and total number of stems (Figure 14).

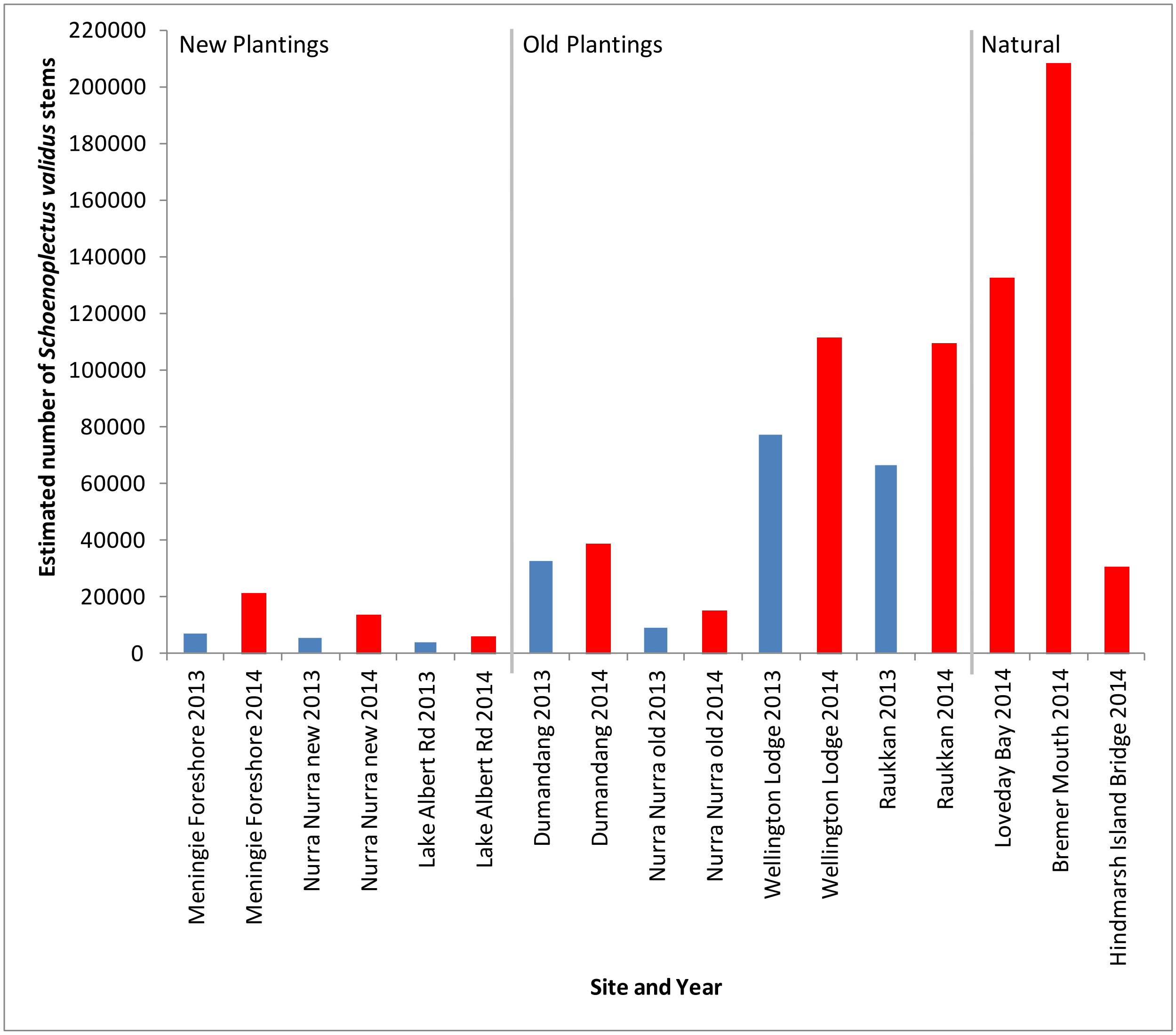

Figure 13: Estimated number of *Schoenoplectus validus* stems for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 and 2014 (blue columns denote 2013 survey; red columns denote 2014 survey).

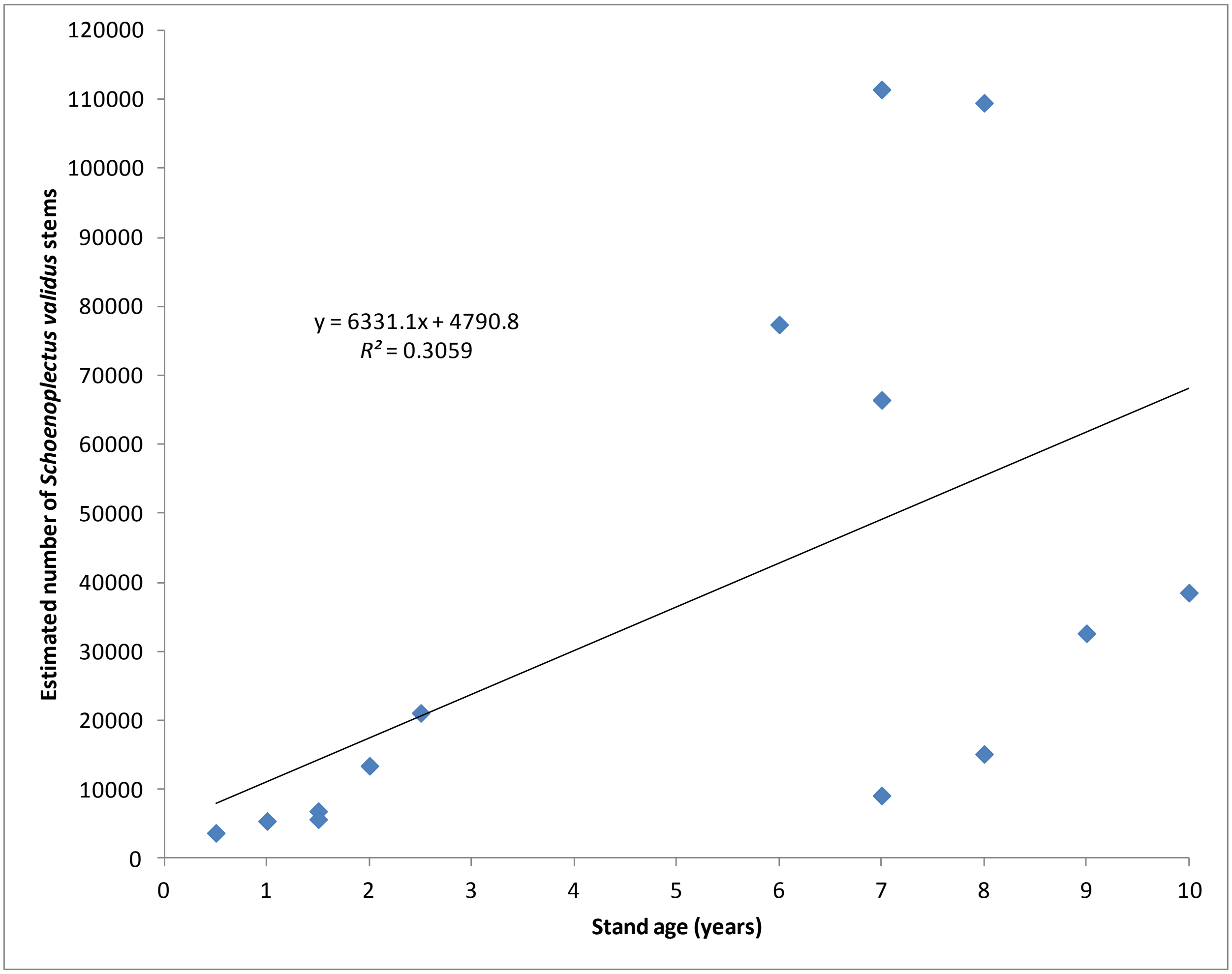

Figure 14: Relationship between the estimated number of *Schoenoplectus validus* stems and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013 and 2014.

3.2. Benefit of *Schoenoplectus validus* plantings for the aquatic plant community

NMS ordination comparing the plant community at all shorelines across all elevations showed that the natural shorelines were distinct from all other shorelines (Figure 15). A diverse assemblage of emergent (e.g. *Typha domingensis, Phragmites australis, Schoenoplectus validus*), floating (*Azolla filiculoides, Lemna* sp.) and amphibious (e.g. *Persicaria lapathifolia, Calystegia sepium*) taxa was present at these shorelines (Figure 15). The plant community was highly variable in autumn 2013 and 2014 at shorelines where *Schoenoplectus validus* was planted, control shorelines and potential future planting sites, but shorelines where *Schoenoplectus validus* was planted were generally more similar to the natural shorelines than the controls and potential new sites (Figure 15). However, Lake Albert Road (in 2013 and 2014) and the newly planted site at Nurra Nurra Point in 2014 were more similar to the controls than natural shorelines (Figure 15). The plant community at one of the potential future sites at Point Sturt was similar to shorelines where *Schoenoplectus validus* has been planted, which was due to the relatively high abundances of several submergent (*Vallisneria australis, Myriophyllum salsugineum* and *Potamogeton pectinatus*) emergent (*Typha domingensis, Schoenoplectus validus* and *Phragmites australis*) and amphibious (*Berula erecta* and *Calystegia sepium*) species (Appendix 2).

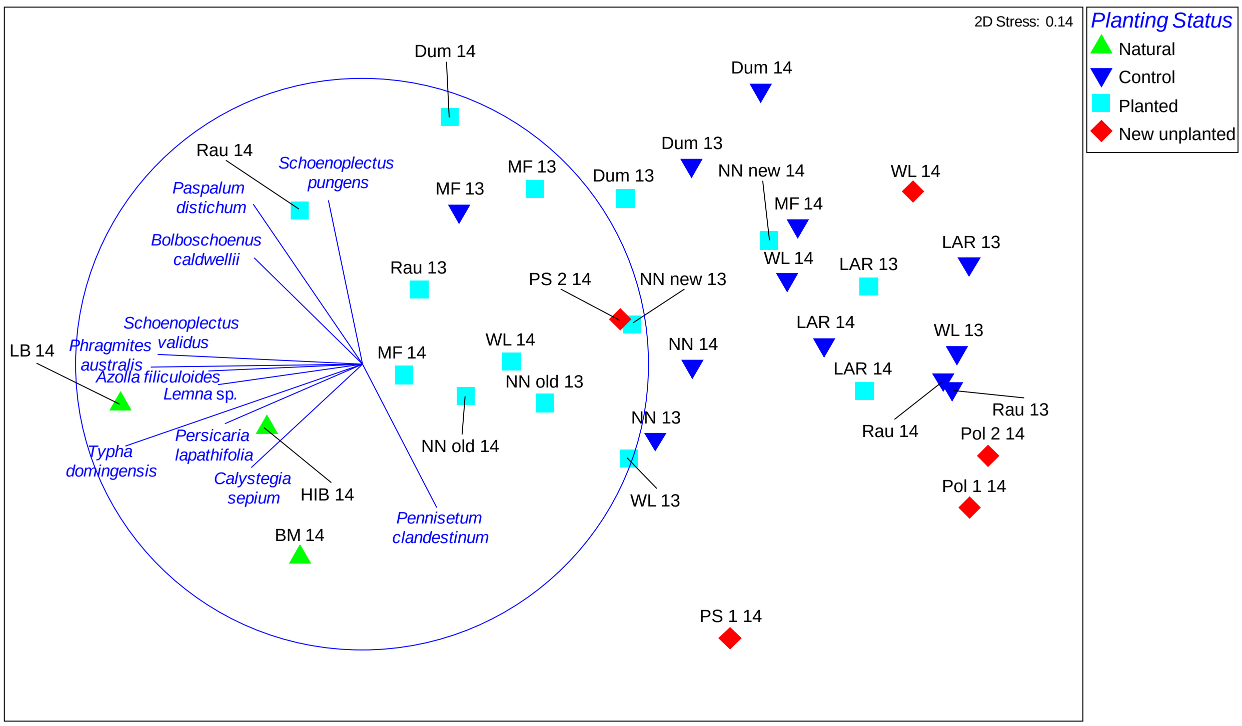

Figure 15: NMS ordination comparing the plant community (all elevations) at each shoreline in autumn 2013 and 2014 (LB=Loveday Bay, HIB=Hindmarsh Island Bridge, BM=Bremer River Mouth, Rau=Raukkan, MF=Meningie Foreshore, NN=Nurra Nurra Point, Dum=Dumandang, WL=Wellington Lodge, LAR=Lake Albert Road, PS=Point Sturt, Pol=Poltalloch).

The plant community at high elevations was highly variable (compared to the community present across all elevations) and there were less differences between the natural shorelines, the planted shorelines, controls and potential future sites (Figure 15, Figure 16). This was due to species such as *Cenchrus clandestinus* and *Paspalum distichum* (clonal low growing grasses) often being abundant at all shorelines (irrespective of planting status) at high elevations (Appendix 2). Nevertheless, amphibious (*Berula erecta, Hydrocotyle verticillata* and *Persicaria lapathifolia*), floating (*Lemna* sp.) and emergent (*Typha domingensis* and *Phragmites* *australis*) taxa were associated with planted and natural shorelines at high elevations (Figure 16).

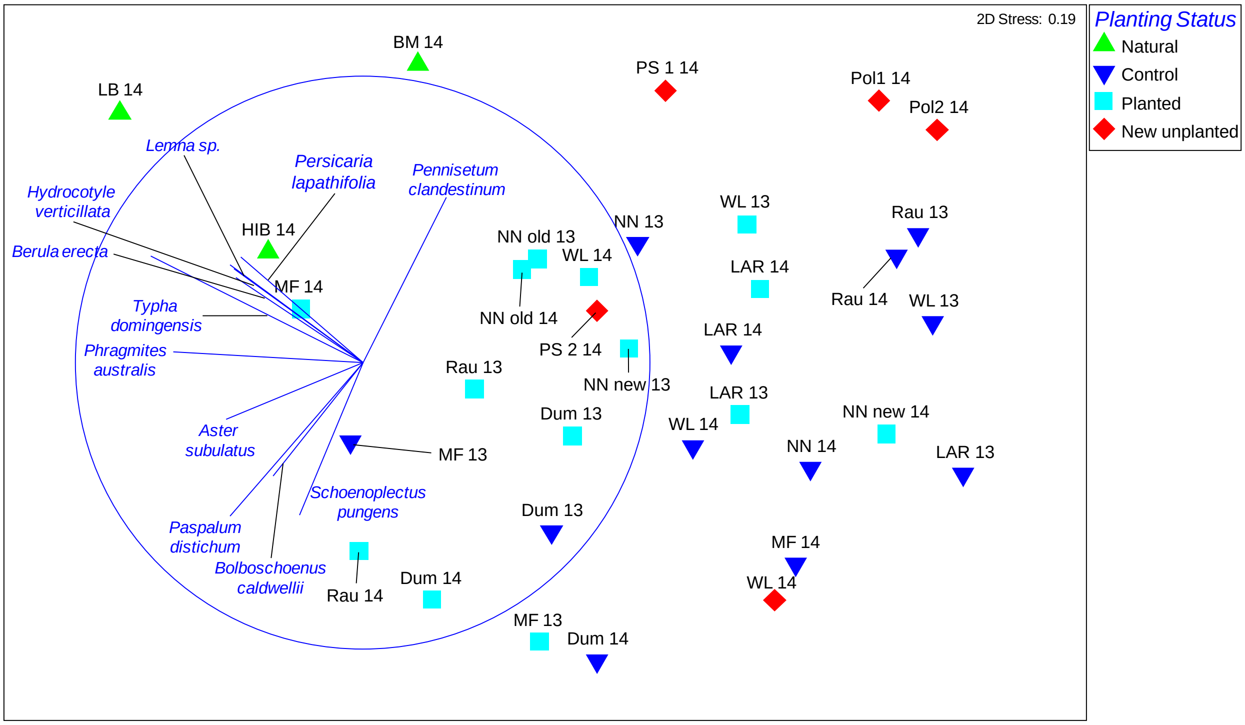

Figure 16: NMS ordination comparing the high elevation plant community (+0.8 and +0.6 m AHD) at each shoreline in autumn 2013 and 2014 (LB=Loveday Bay, HIB=Hindmarsh Island Bridge, BM=Bremer River Mouth, Rau=Raukkan, MF=Meningie Foreshore, NN=Nurra Nurra Point, Dum=Dumandang, WL=Wellington Lodge, LAR=Lake Albert Road, PS=Point Sturt, Pol=Poltalloch).

In contrast, the plant community at low elevations showed the greatest distinction between natural shorelines, planted shorelines and unplanted shorelines (Figure 17). The natural shorelines and shorelines planted prior to 2007 were dominated by emergent species (*Typha domingensis, Schoenoplectus validus* and *Phragmites australis*) and *Azolla filiculoides* (Figure 17). The group of points in the bottom left of the ordination were dominated by open water with very few plants present and are generally controls and potential new sites; however, the planted shoreline at Lake Albert Road (in autumn 2013 and 2014) is also present in this group (Figure 17). The low elevation plant community at all shorelines planted before 2007 became more similar to the plant community at natural shorelines between autumn 2013 and 2014 (Figure 17). The change in the plant community between autumn 2013 and 2014 at shorelines planted after 2010 was variable; there was little change at Lake Albert Road and Meningie Foreshore and the newly planted site at Nurra Nurra Point became more similar to the control shorelines (Figure 17).

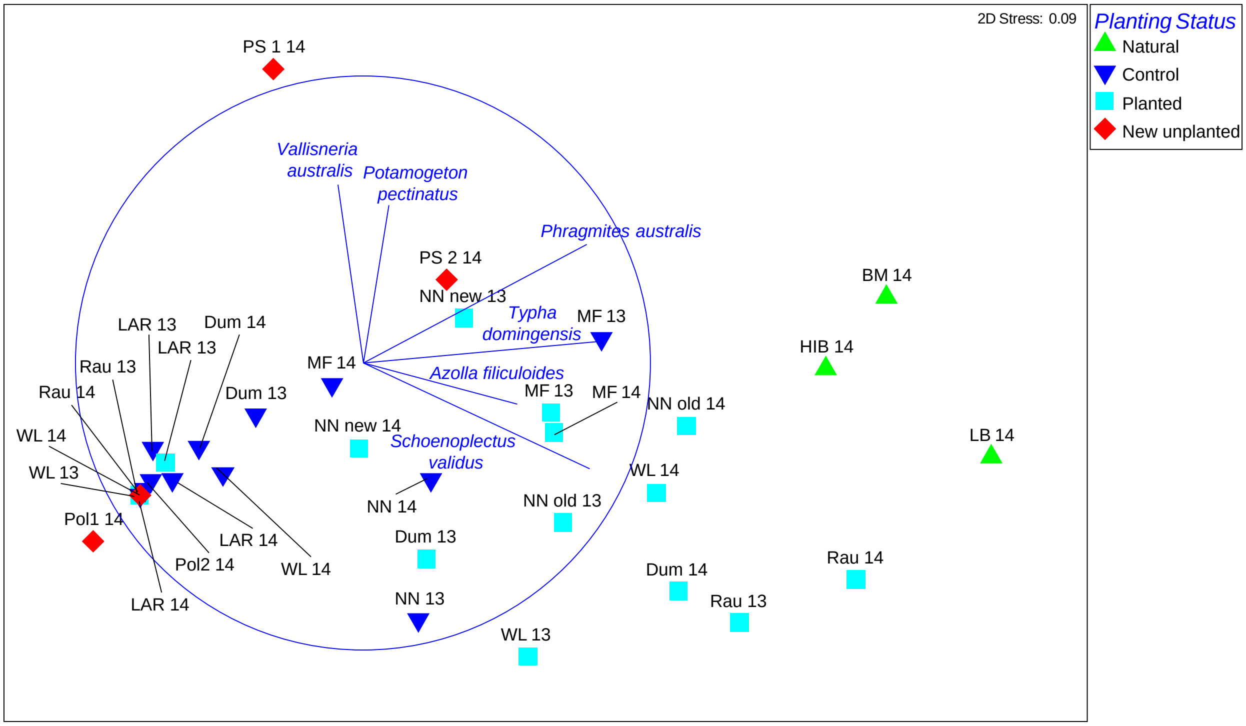

Figure 17: NMS ordination comparing the low elevation plant community (+0.4, +0.2 and 0 m AHD) at each shoreline in autumn 2013 and 2014 (LB=Loveday Bay, HIB=Hindmarsh Island Bridge, BM=Bremer River Mouth, Rau=Raukkan, MF=Meningie Foreshore, NN=Nurra Nurra Point, Dum=Dumandang, WL=Wellington Lodge, LAR=Lake Albert Road, PS=Point Sturt, Pol=Poltalloch).

4. DISCUSSION

Results from the autumn 2014 surveys provided further evidence that *Schoenoplectus validus* is an appropriate species for planting around the edges of the Lower Lakes, not only to control erosion but to provide greater lakeshore habitat diversity. Planted stands are increasing in extent and density and the plant community associated with old planted stands is becoming more similar to the community present in areas where the species occurs naturally.

Results from the first year of the monitoring program and TLM vegetation condition monitoring showed that *Schoenoplectus validus* was resistant because it survived through the drought and subsequent low water levels and sprouted from rhizomes after water levels were reinstated (Frahn *et al.* 2013; Nicol *et al.* 2013). Results from 2013 and 2014 indicate that at most planted shorelines (even recently planted ones) *Schoenoplectus validus* created a ‘breakwater’ providing a sheltered area where less robust species could establish and persist. This generally resulted in planted shorelines having a larger number of native emergent, submergent, floating and amphibious species compared to unplanted shorelines, which tended to be sparsely vegetated or dominated by *Phragmites australis* or *Typha domingensis* monocultures. Furthermore, Fairweather *et al.* (2013) reported higher diversity and abundance of macroinvertebrates and finer, more organic rich sediments at shorelines planted prior to 2007.

The second year of the monitoring program demonstrated that *Schoenoplectus validus* persisted at all planted shorelines, which was expected due to permanent inundation between 40 and 80 cm of planted stands (*sensu* Sainty and Jacobs 2003). Furthermore, the current monitoring program allowed comparisons of stand characteristics between autumn 2013 and 2014 at planted shorelines, along with comparisons of planted and natural stands.

The data collected in autumn 2013 and 2014 provided evidence that all of the stands planted after 2010 are expanding, albeit at different rates. The significant increases in stand width and stem density at Meningie Foreshore and the new planting at Nurra Nurra Point indicated that these stands have established well and are expanding and will probably continue to expand for several years. There was no significant increase in stand width or stem density at Lake Albert Road, which is less than two years old but is also a lee shore exposed to the prevailing south-westerly winds and subsequent wave action. Nevertheless, there was no decrease in the aforementioned stand parameters and the calculated total number of stems over the 100 m stretch of shoreline increased between autumn 2013 and 2014. Despite the slowest rate of expansion, at Lake Albert Road there was a significant increase in stem height. This result is unexplained because emergent macrophytes, when subjected to wave action, generally produce a larger number of shorter stems (e.g. Coops and Van der Velde 1996).

Whilst not statistically significant in all cases, there was an increase in stand width, stem density and total number of stems present along the 100 m of surveyed shoreline at all shorelines planted prior to 2007 (with the exception of Dumandang) providing evidence that these stands are also expanding. How long stands will continue to expand is unknown; however, natural stands were generally much wider than the planted shorelines and extended into deeper water (the maximum depth at natural stands was 95 cm compared to 70 cm for planted stands). These data suggest that the planted stands could expand a considerable distance into lakes Alexandrina and Albert; however, *Schoenoplectus validus* may be occupying deeper water at the natural sites due to being outcompeted by *Typha domingensis* and *Phragmites australis* in shallow water. *Typha domingensis* and *Phragmites australis* were not generally present at shorelines planted after 2010 and were probably not present when the shorelines planted before 2007 were established, which gave the planted *Schoenoplectus validus* an opportunity to establish in shallow water in the absence of competition from other large emergent species.

Natural *Schoenoplectus validus* stands were wider than planted stands, stem density was variable with the lowest density recorded at the Hindmarsh Island Bridge and the reason for this is unknown. The highest natural stem density was at Loveday Bay, which was comparable to the highest densities recorded at all shorelines planted prior to 2007. Only one year of stand density data has been collected for natural shorelines; therefore, it is unknown whether stem density has reached a maximum and whether these data can be used as restoration targets for planted stands. Similarly, only two years of data have been collected at planted shorelines and it is unknown whether the shorelines planted prior to 2007 have reached maximum stem densities; nevertheless, the decrease at Dumandang and high (albeit variable) density recorded at Wellington Lodge suggest that this may be the case for these shorelines. The significant increases in stem density at Raukkan, Meningie Foreshore and the newly planted site at Nurra Nurra Point showed that maximum stem density was not reached in autumn 2013 and it is unlikely that it has been reached in 2014 at Meningie Foreshore and the newly planted shoreline at Nurra Nurra Point. However, stem density at Raukkan in 2014 was similar to Loveday Bay and increases at this shoreline in the future may not be observed or be reduced. Whilst significant increases in stem density were not observed at Lake Albert Road and the old planted shoreline at Nurra Nurra Point, it is unlikely maximum stem density has been reached due to the low values recorded at these shorelines.

Maximum and mean stem height showed no relationship with stand age, which was due to full grown ramets being transplanted. However, at all shorelines planted prior to 2007 (except Nurra Nurra Point) there was a significant decrease in mean stem height between autumn 2013 and 2014 but the reason for this pattern is unclear.

The aquatic and littoral plant community of planted shorelines (except the newly planted site at Nurra Nurra Point and Lake Albert Road) were generally more similar to the natural shorelines rather than the controls and potential future planting sites. When only the high elevation (+0.8 and +0.6 m AHD) plant community was compared there was a similar pattern; however, the distinction of planted and natural shorelines from control and future planting shorelines was less clear. This was due to the planted and unplanted shorelines at high elevations both being dominated by low growing clonal grasses such as *Paspalum distichum* and *Pennisetum clandestinum*. Nevertheless, amphibious species such as *Persicaria lapathifolia, Berula erecta, Centella asiatica* and *Hydrocotyle verticillata* were present at planted shorelines and natural shorelines whereas, these species tended to be absent both at unplanted shorelines (Appendix 2).

Floating species were also present at high elevations at the planted and natural shorelines, which was probably due to the breakwater effect. *Azolla filiculoides* and *Lemna* spp. are able to reproduce asexually and their expansion rates under favorable conditions are exponential (Cheng *et al.* 2010; Fernandez-Zamudio *et al.* 2010) and can rapidly colonise large areas (Sainty and Jacobs 1981; 2003). At high energy shorelines floating species will probably be dispersed but when a plant fragment arrives into a localised area of calm water it is able to remain in the area and reproduce rapidly asexually.

Differences in plant communities between planted and natural shorelines and unplanted shorelines were most evident at the low elevations. This was in part due to the presence of *Schoenoplectus validus* at the planted and natural shorelines; however, submergent and emergent species were usually present at the low elevations at the aforementioned shorelines whereas the unplanted shorelines were generally devoid of vegetation. This provides further evidence for the breakwater effect provided by *Schoenoplectus validus* because submergent species are not generally found at high energy shorelines in the Lower Lakes and are restricted to wetlands (e.g. Dunn's Lagoon and Clayton Bay), the lower reaches of the Finniss River and

Currency Creek, Goolwa Channel and narrow channels (e.g. Hunters Creek) (Gehrig *et al.* 2011; 2012; Frahn *et al.* 2013).

There was also evidence to suggest that the plant communities at low elevations at shorelines planted prior to 2007 were becoming similar to the natural shorelines. Whether the plant community at planted shorelines actually became more similar to the natural shorelines is not known because there is no directly comparable information from natural shorelines from 2013 and a similar change in the plant community that occurred at the planted shorelines between autumn 2013 and 2014 may have also occurred at the natural shorelines. Nevertheless, the aquatic plant community at the natural shorelines could be used as a target for the aquatic plant community at planted sites to evaluate the success of the planting program. Shorelines planted after 2010 probably require several years for the stands to become sufficiently wide and dense to provide a breakwater effect that will facilitate the development of a diverse aquatic plant community similar to a natural shoreline. If natural sites were to be used as targets for planted shorelines it will likely require a long-term (e.g. 10 years) monitoring program to assess whether targets are being attained, especially for shorelines planted after 2010.

Undertaking vegetation surveys at three shorelines where *Schoenoplectus validus* may be planted in the future provided baseline information regarding the plant community prior to planting, which was unavailable at other sites. This will enable a BACI design (*sensu* Underwood 1992) to evaluate the benefit of planting to the aquatic plant community in the future and to gain information regarding the time taken for plant communities to develop at these sites. The three surveyed shorelines had similar plant communities to the control sites except for one site at Point Sturt where *Berula erecta, Schoenoplectus validus, Myriophyllum salsugineum, Potamogeton pectinatus* and *Vallisneria australis* were present in low abundances (Appendix 2). The aforementioned species were not usually present at shorelines where *Schoenoplectus validus* is absent; hence, the similarity of the plant community at this site, with planted shorelines and natural shorelines. It is unclear why these species were present at this site because most were absent at the other shoreline surveyed at Point Sturt (Appendix 2) which was less than 100 m away and both have an easterly aspect. This site has been surveyed as part of The Living Murray condition monitoring since spring 2008 and is generally devoid of submergent species and only sparsely vegetated with emergents (Frahn *et al.* 2013).

We conclude that planting *Schoenoplectus validus* around the shorelines of lakes Alexandrina and Albert has benefits for the aquatic plant community and provides greater regional aquatic habitat diversity. Future planting should target shorelines where erosion is occurring to slow or stop erosion and provide suitable conditions for submergent and emergent plant recruitment. However, planning for future planting needs to consider the ecosystem services provided by sparsely vegetated shorelines (e.g. mudflats that are water bird foraging habitat) and ensure that these habitats are not planted.

Future research and monitoring

- Continue the monitoring program to gain further information regarding planted *Schoenoplectus validus* stand dynamics and the benefit to shoreline plant communities.
- Assess seed banks in planted and control areas and in areas where species rich wetland plant communities are present to determine if there is local capacity for a species rich wetland plant community to develop or whether sediment transplant is an option to accelerate the establishment of an aquatic plant community
- Further expand the monitoring program to include other planted shorelines (e.g. Point Sturt and north of Point Malcolm) and additional potential planting sites.
- Compare planted shorelines with additional natural shorelines. The mapping of emergent plant communities undertaken in autumn 2014 identified numerous shorelines where *Schoenoplectus validus* occurs naturally and some of these sites could be included in future monitoring to give a better indication of the medium to long-term “target” aquatic plant community and stand condition at planted shorelines.
- Investigate tolerances of common macrophytes in the Lower Lakes to wave action.

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APPENDICES

Appendix 1: GPS coordinates (UTM format; map datum WGS 84) of survey sites, planting status and when *Schoenoplectus validus* was planted at each site.

Site	Easting	Northing	Planting Status	Year Planted
Bremer Mouth	323061	6081991	Natural	NA
Dumandang	339058	6053687	Planted	2003, 2004 and 2006
Dumandang Control	340594	6054244	Control	NA
Hindmarsh Island Bridge	299349	6081493	Natural	NA
Lake Albert Road	350743	6060734	Planted	2013
Lake Albert Road Control	350313	6054328	Control	NA
Loveday Bay	326167	6082052	Natural	NA
Meningie Foreshore	349673	6049720	Planted	2012
Meningie Foreshore Control	350237	6053018	Control	NA
Nurra Nurra Point Control	341547	6063414	Control	NA
Nurra Nurra Point Old	341723	6063637	Planted	2006
Nurra Nurra Point New	341808	6063808	Planted	2012 and 2013
Point Sturt 1	322567	6081981	Unplanted (potential future site)	NA
Point Sturt 2	322582	6081982	Unplanted (potential future site)	NA
Poltalloch 1	339761	6082305	Unplanted (potential future site)	NA
Poltalloch 2	342616	6082355	Unplanted (potential future site)	NA
Raukkan	327643	6067143	Planted	2006
Raukkan Control	327414	6082076	Control	NA
Wellington Lodge	349440	6079043	Planted	2007
Wellington Lodge Control	349469	6079117	Control	NA
Wellington Lodge New	349278	6082469	Unplanted (potential future site)	NA

Appendix 2: Species list and functional group classification (*sensu* Casanova 2011) at all shorelines in autumn 2013 and 2014 (green shading denotes taxon present, P=planted, C=control, Na=natural, Ne=potential future site, *denotes exotic species, **denotes proclaimed pest plant in South Australia, # denotes listed as rare in South Australia).

	Shoreline	Lake Albert Rd				Meningie Foreshore				Nurra Nurra						Dumandang				Raukkan				Wellington Lodge					Poltalloch		Point Sturt		Loveday Bay	Hindmarsh Island Bridge	Bremer Mouth
	Planting Status	P	P	C	C	P	P	C	C	P-old	P-old	P-new	P-new	C	C	P	P	C	C	P	P	C	C	P	P	C	C	Ne	Ne-1	Ne-2	Ne-1	Ne-2	Na	Na	Na
	Year	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	14	14	14	14	14	14	14
Species	**Functional Group**																																		
*Apium graveolens**	Terrestrial																														*	*			
*Aster subulatus**	Amphibious					*	*				*				*			*	*	*									*			*	*		
*Atriplex prostrata**	Terrestrial																	*									*								
Atriplex sp.	Terrestrial						*				*		*																						
Azolla filiculoides	Amphibious																			*	*			*			*						*		*
Berula erecta	Amphibious																			*												*	*		*
Bolboschoenus caldwellii	Emergent					*	*				*					*				*	*														
Brassica sp.*	Terrestrial												*			*							*										*		
Calystegia sepium	Amphibious					*	*						*											*									*	*	*
*Cenchrus clandestinus**	Terrestrial	*	*	*				*		*	*	*	*	*	*	*	*			*	*	*	*	*	*	*	*		*	*	*	*			*
*Centaurea calcitrapa**	Terrestrial												*		*			*	*																
Centella asiatica	Amphibious																			*	*														*
Ceratophyllum demersum#	Submergent															*				*	*												*		
Chara sp.	Submergent																*																		
*Cotula coronopifolia**	Amphibious						*						*		*			*	*																
Crassula helmsii	Amphibious	*																											*						
Cyperus gymnocaulos	Amphibious					*	*											*			*	*			*		*		*						*
Duma florulenta	Amphibious			*												*	*												*				*		
Eleocharis acuta	Amphibious						*																												*
Epilobium pallidiflorum	Amphibious																				*														*
*Festuca arundinacea**	Terrestrial	*																																	
Ficinia nodosa	Amphibious																			*	*							*							
*Fumaria bastardii**	Terrestrial						*																												
Helichrysum luteoalbum	Terrestrial														*																				
Hydrocotyle verticillata	Amphibious																		*													*	*		*
*Hypochaeris glabra**	Terrestrial		*																																
*Hypochaeris radicata**	Terrestrial																			*	*														
Isolepis producta	Amphibious	*				*	*																				*								
*Juncus acutus**	Amphibious	*				*										*			*								*								
Juncus holoschoenus	Amphibious																										*						*		
Juncus kraussii	Amphibious		*														*			*											*				
Juncus subsecundus	Amphibious																										*								
Juncus usitatus	Amphibious																									*									
Lachnagrostis filiformis	Amphibious																															*			
Lactuca serriola	Terrestrial																														*				*
*Lagurus ovatus**	Terrestrial																			*	*												*		
Lemna sp.	Amphibious																			*	*												*		*
Lilaeopsis polyantha	Amphibious	*																											*						
Limosella australis	Amphibious																										*								
Lolium spp.*	Terrestrial																	*	*													*			
Ludwigia peploides	Amphibious																																*		
Lycopus australis	Amphibious																							*											*
Lythrum salicaria	Amphibious																		*																
*Malva parviflora**	Terrestrial														*			*																	
Medicago spp.*	Terrestrial			*														*											*			*			
*Melilotus indicus**	Terrestrial		*								*																								
Mentha australis	Amphibious																																*		
Mentha spp.*	Amphibious																																	*	*
Mimulus repens	Amphibious		*	*		*	*																						*						
Myoporum insulare	Terrestrial																															*			
Myriophyllum salsugineum	Submergent		*												*						*			*	*	*	*					*			*
Nitella sp.	Submergent																										*								
*Oxalis pes-caprae***	Terrestrial										*		*		*																				
*Paspalum distichum**	Amphibious	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*		*	*	*	*	*
Persicaria lapathifolia	Amphibious																								*								*		*

	Shoreline	Lake Albert Rd				Meningie Foreshore				Nurra Nurra						Dumandang				Raukkan				Wellington Lodge					Poltalloch		Point Sturt		Loveday Bay	Hindmarsh Island Bridge	Bremer Mouth
	Planting Status	P	P	C	C	P	P	C	C	P-old	P-old	P-new	P-new	C	C	P	P	C	C	P	P	C	C	P	P	C	C	Ne	Ne-1	Ne-2	Ne-1	Ne-2	Na	Na	Na
	Year	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	14	14	14	14	14	14	14
Species	**Functional Group**																																		
Phragmites australis	Emergent	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*	*	*	*	*
*Plantago coronopus**	Terrestrial		*				*												*								*								
*Polypogon monspeliensis**	Amphibious						*						*					*	*										*						
Potamogeton crispus	Submergent																							*											
Potamogeton pectinatus	Submergent		*																												*	*	*		
*Ranunculus trilobus**	Amphibious						*																										*		
*Riechardia tingitana**	Terrestrial																	*											*						
Rumex bidens	Amphibious												*			*		*		*	*											*			*
Scaevola sp.	Terrestrial						*																												
Schoenoplectus pungens	Amphibious		*		*		*				*	*	*		*	*	*	*	*	*	*		*			*	*				*	*	*		*
Schoenoplectus validus	Emergent					*	*		*	*	*	*		*	*	*	*	*	*	*	*			*	*	*	*					*	*	*	*
*Senecio pterophorus**	Terrestrial																				*											*			
*Silybum marianum***	Terrestrial		*																																
*Sonchus asper**	Terrestrial												*						*																
*Sonchus oleraceus**	Terrestrial		*				*				*		*		*			*	*		*		*	*			*				*				
Tecticornia pergranulata	Amphibious																		*																
Trifolium spp.*	Terrestrial		*			*	*				*		*		*	*			*	*	*							*			*	*	*		
Typha domingensis	Emergent					*	*			*	*		*	*	*	*			*	*	*			*	*						*	*	*	*	*
Vallisneria australis	Submergent		*																						*		*					*			*