Inland Waters & Catchment Ecology

Establishment success and benefits to the aquatic plant community of planting *Schoenoplectus tabernaemontani* around the shorelines of lakes Alexandrina and Albert 2013 – 2016

Jason Nicol, Susan Gehrig and Kate Frahn

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Cover Photo: Shoreline of Lake Alexandrina at Raukkan showing newly planted *Schoenoplectus tabernaemontani* (Josh Fredberg).

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EXECUTIVE SUMMARY

Since the completion of the barrages in 1940, the Lower Lakes have been subjected to relatively constant elevated water levels that has resulted in extensive shoreline erosion. *Schoenoplectus tabernaemontani* has been planted by community groups since 1996 to reduce shoreline erosion and under the vegetation program of the Coorong, Lower Lakes and Murray Mouth recovery project, planting has been expanded with an additional 30 km of shoreline being planted.

Schoenoplectus tabernaemontani 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 tabernaemontani* is a robust species; often growing on shorelines subjected to wave action, providing sheltered areas between the shoreline and planted stand where less robust species can persist. These characteristics have resulted in *S. tabernaemontani* being planted extensively around the edges of lakes Alexandrina and Albert to reduce shoreline erosion.

Prior to the establishment of this monitoring program, only limited data have been collected to evaluate the survivorship, density and extent of the planted stands. Furthermore, vegetation surveys were not undertaken at most planting sites prior to planting and there was limited information regarding the benefits of planting *S. tabernaemontani* on aquatic plant communities. This project was designed to address these data deficiencies and had four aims:

- To compare the survivorship, density, height and extent of existing *S. tabernaemontani* plantings in lakes Alexandrina and Albert between 2013, 2014, 2015 and 2016.
- To compare the density, height and extent of *S. tabernaemontani* between shorelines that were planted and areas where it occurs naturally.
- To investigate the effect of *S. tabernaemontani* planting on the aquatic plant community by comparing the plant community in planted and non-planted areas and where *S. tabernaemontani* is present naturally.

- Continue monitoring at sites planted in 2014 (Poltalloch, Hartnett's and Wellington Lodge).

The study was initially conducted at seven planted shorelines; four old plantings (planted between 2006 and 2007) and three new plantings (planted between 2012 and 2013) and surveyed every autumn between 2013 and 2016. Three shoreline sites where *S. tabernaemontani* is present naturally were added in autumn 2014 (age unknown, herein referred to as "natural shorelines") and three new planted sites (two of which were surveyed before they were planted) were established in 2014 and 2015 (planted between summer 2014 and summer 2015). Survivorship, stand width, stem density and maximum and mean stem height of *S. tabernaemontani* were compared between old plantings, new plantings and natural shorelines in autumn 2014, 2015 and 2016. The benefits of planting to the aquatic plant community were assessed by comparing the plant community at all planted, adjacent unplanted (control) shorelines (in 2013, 2014, 2015 and 2016), natural shorelines (in 2014, 2015 and 2016) and shorelines planted after 2014 (in 2015 and 2016).

Between autumn 2013 and 2015, there were increases in stand width, stem density and the calculated number of stems at most planted sites. However, there was a decrease in the number of stems between 2015 and 2016 at all sites planted before 2014, except at Lake Albert Road (where numbers were low). At the three sites planted after 2014 there was generally no significant change in stand width or density; however, there was an increase in the number of stems at all sites except Poltalloch. In autumn 2014, *S. tabernaemontani* 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. Stand width, stem density and the total number of stems changed at natural sites between 2014 and 2016 with increases in the number of stems at Hindmarsh Island Bridge, a general decrease at Loveday Bay, and an increase in 2015 at the Bremer River Mouth. Stem height was similar at natural and all planted shorelines and generally did not change through time.

The plant community at natural shorelines was distinct from the planted and control sites; however, planted shorelines became more similar to natural sites through time. A diverse aquatic plant community was generally present at shorelines planted prior to 2007, compared to the control sites, which were often devoid of aquatic vegetation. The aquatic plant community at shorelines planted after 2010 was similar to the control shorelines, with the exception of Meningie Foreshore (all years) and the newly planted site at Nurra Nurra Point in 2016, which were similar to sites planted before 2007. Vegetation at sites planted after 2014 was also similar to control shorelines.

Results showed that planted *S. tabernaemontani* survived at all sites and there was evidence that it was expanding between 2013 and 2015 at all but two sites due to the increase in the calculated number of stems recorded, even in areas where no statistically significant increases in stand width or stem density were detected. There was a decrease in stem number observed between 2015 and 2016 but numbers are comparable to those observed in 2014 and the reason for the decline is unknown. Future monitoring is recommended to determine whether the trend continues into the future. 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 2016 further supported the hypothesis that *S. tabernaemontani* 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 could be used as a target to evaluate the success of the planting program.

1. INTRODUCTION

1.1. Background

Schoenoplectus tabernaemontani is a large, native, perennial, rhizomatous sedge that grows 2–3 m in height (up to 5 m in favourable conditions) in water up to 1.5 m deep (Cunningham *et al.* 1992; Sainty and Jacobs 2003). Ecosystem services provided by *S. tabernaemontani* include erosion control, waterbird and 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; 2014). *Schoenoplectus tabernaemontani* usually grows in deeper water than *T. domingensis* and *P. 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; 2014; 2015).

Since the completion of the barrages in 1940, the Lower Lakes have been subjected to relatively constant elevated water levels that has resulted in extensive shoreline erosion. *Schoenoplectus tabernaemontani* has been planted by community groups since 1996 to reduce shoreline erosion and under the vegetation program of the Coorong, Lower Lakes and Murray Mouth (herein referred to as CLLMM) recovery project, planting has been expanded with an additional 30 km of shoreline being planted.

The ability of *S. tabernaemontani* to tolerate wave action has resulted in it being planted by community groups since 1996 around the edges of lakes Alexandrina and Albert in water depths up to 80 cm, primarily to control shoreline erosion (Goolwa to Wellington Local Action Planning Board *et al.,* no date). Since 2012, an additional 30 km of shoreline being planted has been planted by the vegetation program of the CLLMM recovery project. 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 planted stands 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). In autumn 2014, monitoring results showed that all planted stands had persisted for a further 12 months and the total number of stems had increased in each of the 100 m of shoreline that was surveyed (Nicol *et al.* 2014). Furthermore, there was evidence that plantings of *S. tabernaemontani* benefitted the aquatic plant community by providing a sheltered area where submergent and less robust emergent species could establish (Nicol *et al.* 2013). In 2014, the plant community in areas where *S. tabernaemontani* grows naturally was surveyed and the plant community in these areas was different to planted sites (Nicol *et al.* 2014); however, the change in the plant community composition at sites planted prior to 2007, between autumn 2013 and 2014, showed that the vegetation at planted sites was becoming more similar to areas where *S. tabernaemontani* occurs naturally (Nicol *et al.* 2014). In autumn 2015, similar trends were observed to 2014; stand widths, stem densities and total estimated number of stems increased at most planted sites and shoreline plant communities at planted sites becoming more similar to areas where *S. tabernaemontani* occurs naturally (Nicol *et al.* 2015).

1.2. Objectives

Despite *Schoenoplectus tabernaemontani* being planted extensively around the shorelines of lakes Alexandrina and Albert, there have been only three previous monitoring events (autumn 2013, 2014 and 2015) to evaluate the survivorship, density and extent of the planted stands. Furthermore, vegetation surveys were not undertaken prior to planting (except at the stands planted at Wellington Lodge in 2015 and Poltalloch in 2014), with data collected in autumn 2013 (at Wellington Lodge) and 2014 (at both sites) available to assess the impacts of planting *S. tabernaemontani* on the aquatic plant community. Finally, quantitative comparisons of the aquatic plant community between shorelines planted with *S. tabernaemontani* and shorelines where the species occurs naturally were undertaken in autumn 2014 and 2015. This project was designed to continue the monitoring program established in 2013 and had four aims:

- To compare the survivorship, density, height and extent of existing *S. tabernaemontani* plantings in lakes Alexandrina and Albert between 2013, 2014, 2015 and 2016.
- To compare the density, height and extent of *S. tabernaemontani* between shorelines that were planted and areas where it occurs naturally.
- To investigate the effect of *S. tabernaemontani* planting on the aquatic plant community by comparing the plant community in planted and non-planted areas and where *S. tabernaemontani* is present naturally.

- Continue monitoring at sites planted after 2014 (Poltalloch, Hartnett’s and Wellington Lodge).

2. METHODS

2.1. Study sites

A total of 11 locations, with 21 sites (each representing 100 m of shoreline) were surveyed in 2016 (Table 1, Figure 1). Seven locations were established in 2013 where *S. tabernaemontani* 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 (old and new) (Figure 1) and surveyed in autumn 2013, 2014, 2015 and 2016 (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 *S. tabernaemontani* grows naturally (Hindmarsh Island Bridge, Loveday Bay and Bremer Mouth) (Figure 1) were established and surveyed (Table 1). All sites where *S. tabernaemontani* grows naturally were also surveyed again in 2015 and 2016 (Table 1). Planting was undertaken at Wellington Lodge and Poltalloch and these shorelines were surveyed in 2015 and 2016 (Table 1). At Wellington Lodge *S. tabernaemontani* was planted at the 2013 and 2014 control site and the 2014 proposed planting site is now the control site. Whilst this was unfortunate in terms of data continuity at this site, it means that two years of vegetation data were collected prior to planting that we do not have for any other sites and will enable direct changes in the plant community before and after planting to be assessed. The proposed planting site at Point Sturt was abandoned in 2015 and replaced with a site nearby at Hartnett's, where planting occurred in 2014 (Table 1). GPS coordinates of sites, the year *S. tabernaemontani* was planted and the years monitoring was undertaken 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	Sites	Age	Year Planted	Years Surveyed
Dumandang	Planted (+Control)	Old	2003, 2004 and 2006	2013, 2014, 2015 and 2016
Raukkan	Planted (+Control)	Old	2006	2013, 2014, 2015 and 2016
Wellington Lodge	Old Planted, New Planted (+Control)	Old and New	2007 and 2015	2013, 2014, 2015 and 2016
Nurra Nurra Point	Old Planted, New Planted (+Control)	Old and New	2006, 2012 and 2013	2013, 2014, 2015 and 2016
Meningie Foreshore	Planted (+Control)	New	2012	2013, 2014, 2015 and 2016
Lake Albert Road	Planted (+Control)	New	2013	2013, 2014, 2015 and 2016
Poltalloch	Planted (+Control)	New	2014	2015 and 2016
Hartnett's	Planted (+Control)	New	2014	2015 and 2016
Loveday Bay	Natural	NA	NA	2014, 2015 and 2016
Bremer Mouth	Natural	NA	NA	2014, 2015 and 2016
Hindmarsh Island Bridge	Natural	NA	NA	2014, 2015 and 2016

Figure 1: Satellite image of lakes Alexandrina and Albert showing the survey locations.

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

At each site, a 100 m section of shoreline in the centre of the planted stand was selected where the survivorship, stand characteristics and the aquatic plant community were assessed. Stem density (no. stems m^{-2}), stem height (maximum and mean) and extent (stand width) of planted *S. tabernaemontani* stands was assessed at each of the planted/natural sites (n = 10) (Table 1). In autumn 2013, 2014, 2015 and 2016 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). Random numbers were generated for each survey to avoid repeated measures. The same measurements were undertaken on natural *S. tabernaemontani* (n = 3) stands in autumn 2014, 2015 and 2016.

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.

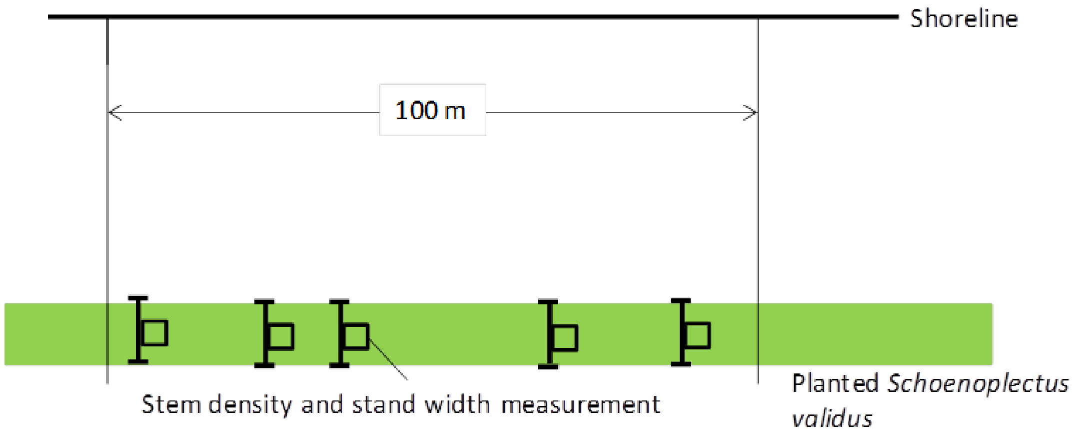

Figure 2: Plan view of a planted shoreline section showing the stand width measurement and quadrats within which stem density and height measurements were undertaken.

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

The vegetation monitoring protocol used the same methods as The Living Murray (TLM) lake shore vegetation condition monitoring for lakes Alexandrina and Albert (Frahn *et al.* 2014). This method was shown to be robust and sufficiently sensitive to detect changes in floristic composition in the Lower Lakes. Furthermore, it enables quantitative comparison of data collected as part of the TLM vegetation condition monitoring to be undertaken. At each location, 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 sites (Figure 3). Two sites were established at Poltalloch in autumn 2014 with one planted in spring 2014 and the other the control (Figure 1). One extra site was established at Wellington Lodge in autumn 2014, which became the new control as *S. tabernaemontani* was planted at the old control site established in autumn 2013. A planted and control site were established at Hartnett's in autumn 2015 (Figure 1). At locations where *S. tabernaemontani* occurs naturally one site was established as controls were not required (Figure 1).

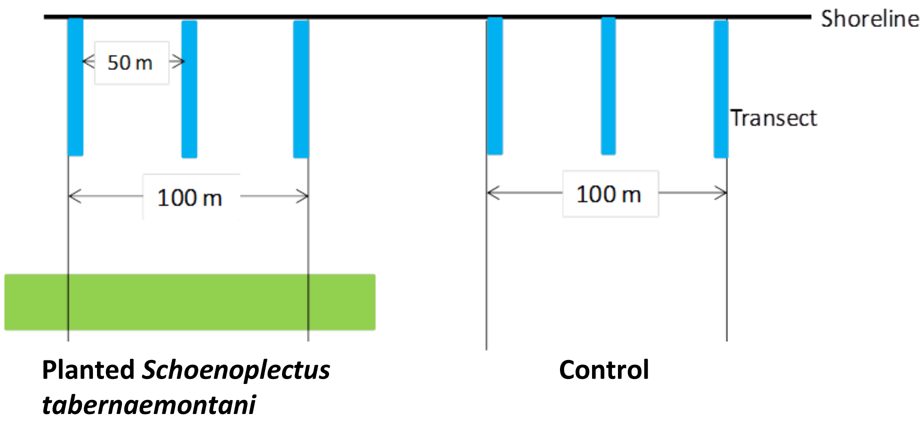

Figure 3: Plan view of planted and control shoreline sections showing the placement of vegetation monitoring transects.

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).

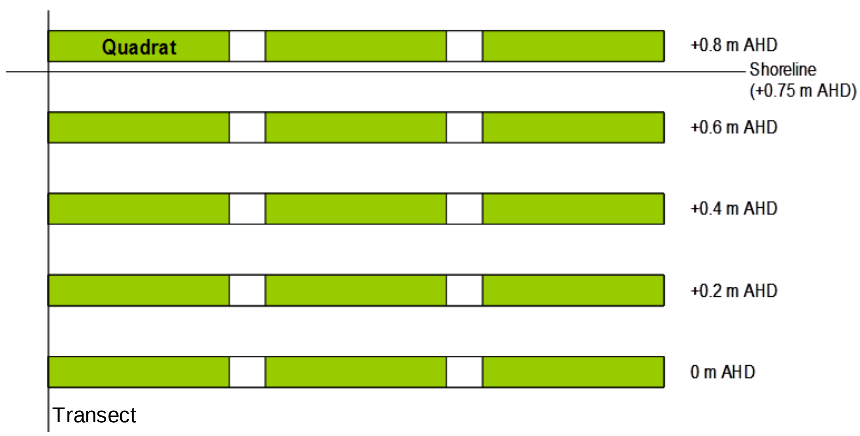

Figure 4: Vegetation surveying protocol for each transect: plan view showing placement of quadrats relative to the shoreline and transect.

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 *S. tabernaemontani* stems = (mean stand width x 100) x mean stem density

Equation 1: Formula used to calculate total number of *S. tabernaemontani* 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, 2014, 2015 and 2016 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 floristic composition in 2013, 2014, 2015 and 2016 at shorelines where *S. tabernaemontani* has been planted, control shorelines and natural shorelines were compared 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). Species were correlated with the similarity matrix and those with a Spearman Correlation Coefficient of greater than 0.5 were overlaid on the ordination plots as vectors. 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). 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 with the Bonferroni correction used for multiple comparisons (Quinn and Keogh 2002).

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 (2016).

3. RESULTS

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

Stand width

Live *S. tabernaemontani* was present and established at all planted sites indicating it survived the previous 12 months. The widest planted *S. tabernaemontani* stands were at Raukkan (where the stand width exceeded 10 m in places) and Wellington Lodge (shorelines planted prior to 2007) (Figure 5). The width of *S. tabernaemontani* stands at the Bremer River Mouth and Hindmarsh Island Bridge were greater than any of the planted stands; however, the stand at Loveday Bay was a similar width to the stands at Raukkan and Wellington Lodge (Figure 5).

There was no significant change in stand width at any of the naturally occurring stands between 2014 and 2016 (Table 3). There were significant changes in stand width at several planted sites between autumn 2013 and autumn 2016; the newly planted stand at Nurra Nurra Point (significant increase between 2013 and 2014, no significant change between 2014 and 2015 and an increase between 2015 and 2016), Raukkan (no significant change between 2013 and 2014, a significant increase between 2014 and 2015 but decreasing between 2015 and 2016 to the same widths recorded in 2013 and 2014), the old planted site at Wellington Lodge (no significant change between 2013 and 2015 but a significant increase between 2015 and 2016) and Hartnett's (a significant increase between 2015 and 2016) (Table 3, Figure 5). Whilst there were no significant increases in stand width at the other planted sites there were often increasing trends, particularly at the newly planted shorelines (Figure 5).

Furthermore, there was a significant positive relationship between stand age and width (R^2 = 0.3402; P = 0.003) (Figure 6). However, there was less variability in stand width at shorelines where the stands were less than five years old (Figure 6) and there was a stronger relationship between stand age and width (R^2 = 0.5220; P < 0.001).

Table 3: PERMANOVA results comparing the changes in stand width, stem density and mean stem height at the shorelines planted with *S. tabernaemontani* between 2013, 2014, 2015 and 2016 (2015 and 2016 for sites planted after 2014) and shorelines where *S. tabernaemontani* occurs naturally between 2014, 2015 and 2016 (significant values in bold).

Shoreline	Stand Measurements	*Pseudo-F*	*DF*	*P*	Annual comparisons
Meningie Foreshore (new)	Stand Width	1.876	3,19	0.152	NA
	Stem Density	5.009	3,19	**0.010**	2013<2014=2015=2016
	Mean Stem Height	1.851	3,199	0.142	NA
Nurra Nurra Point (new)	Stand Width	8.504	3,19	**0.003**	2013<2014=2015<2016
	Stem Density	12.395	3,19	**0.002**	2013<2014=2016<2015
	Mean Stem Height	1.954	3,199	0.121	NA
Lake Albert Rd (new)	Stand Width	1.736	3,19	0.174	NA
	Stem Density	9.681	3,19	**0.004**	2013=2014<2015=2016
	Mean Stem Height	20.097	3,199	**0.001**	2013=2015=2016<2014
Dumandang (old)	Stand Width	1.519	3,19	0.237	NA
	Stem Density	2.957	3,19	**0.017**	2013=2014=2015>2016
	Mean Stem Height	36.633	3,199	**0.001**	2013>2014=2015=2016
Nurra Nurra Point (old)	Stand Width	2.202	3,19	0.124	NA
	Stem Density	3.748	3,19	**0.032**	2013=2014=2015>2016
	Mean Stem Height	1.538	3,199	0.242	NA
Raukkan (old)	Stand Width	3.731	3,19	**0.033**	2013=2014=2016<2015
	Stem Density	0.974	3,19	0.413	NA
	Mean Stem Height	3.618	3,199	**0.019**	2013>2014=2015=2016
Wellington Lodge (old)	Stand Width	2.841	3,19	**0.020**	2013=2014=2015<2016
	Stem Density	2.952	3,19	**0.017**	2013=2014=2015>2016
	Mean Stem Height	1.436	3,199	0.291	NA
Poltalloch (new)	Stand Width	0.036	1,9	0.958	NA
	Stem Density	0.127	1,9	0.696	NA
	Mean Stem Height	0.120	1,99	0.744	NA
Wellington Lodge (new)	Stand Width	1.196	1,9	0.381	NA
	Stem Density	5.956	1,9	**0.033**	2015<2016
	Mean Stem Height	0.108	1,99	0.765	NA
Hartnett's (new)	Stand Width	6.019	1,9	**0.034**	2015>2016
	Stem Density	0.618	1,9	0.472	NA
	Mean Stem Height	0.011	1,99	0.916	NA
Bremer Mouth (natural)	Stand Width	2.081	2,14	0.176	NA
	Stem Density	1.051	2,14	0.394	NA
	Mean Stem Height	0.037	2,149	0.964	NA
Loveday Bay (natural)	Stand Width	2.614	2,14	0.136	NA
	Stem Density	2.080	2,14	0.192	NA
	Mean Stem Height	1.669	2,149	0.239	NA
Hindmarsh Island Bridge (natural)	Stand Width	2.675	2,14	0.108	NA
	Stem Density	7.280	2,14	**0.011**	2014<2015=2016
	Mean Stem Height	31.336	2,149	**0.001**	2014<2015<2016

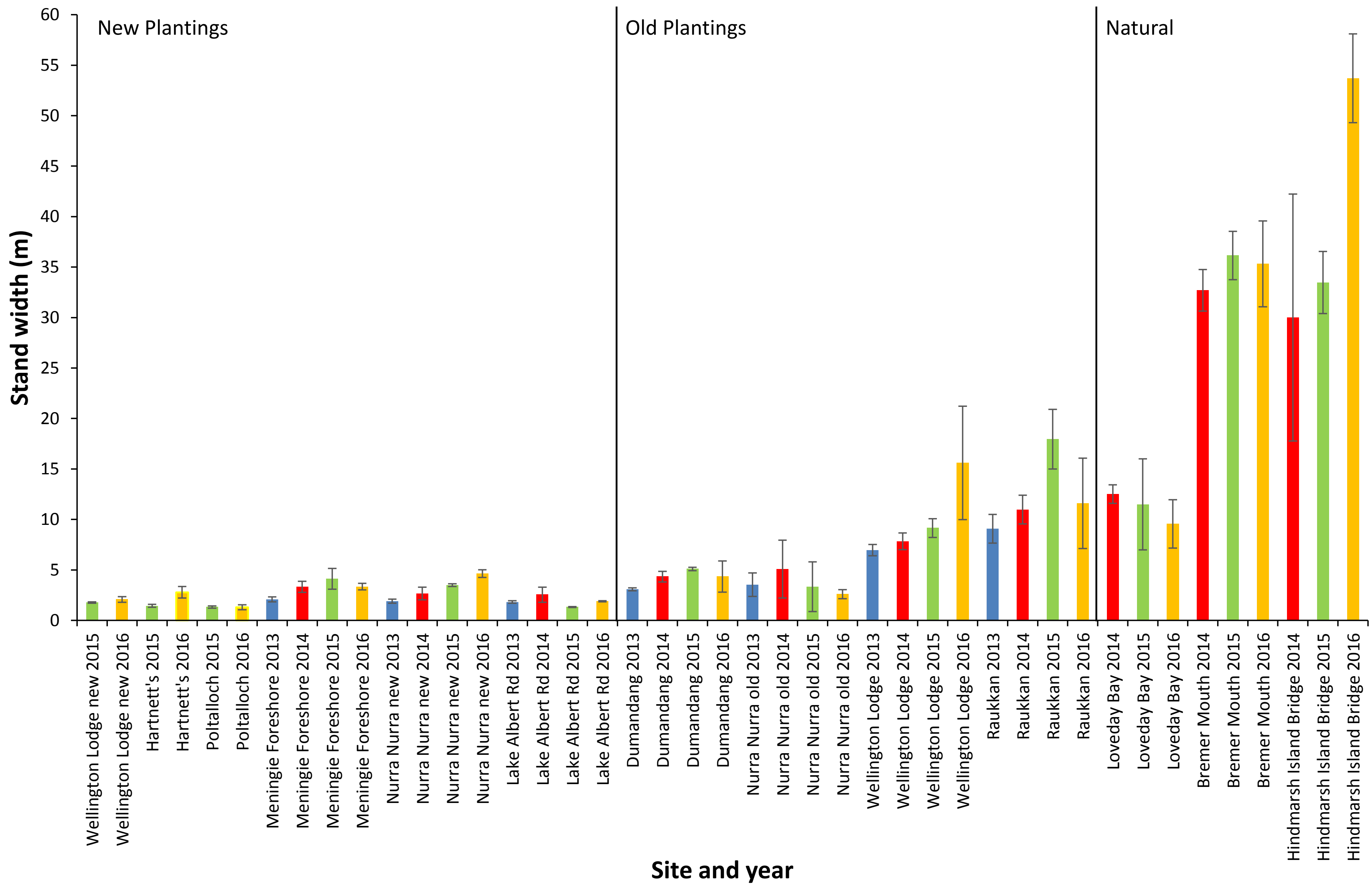

Figure 5: *Schoenoplectus tabernaemontani* stand width for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 (blue), 2014 (red), 2015 (green) and 2016 (yellow) (error bars=±1 SE).

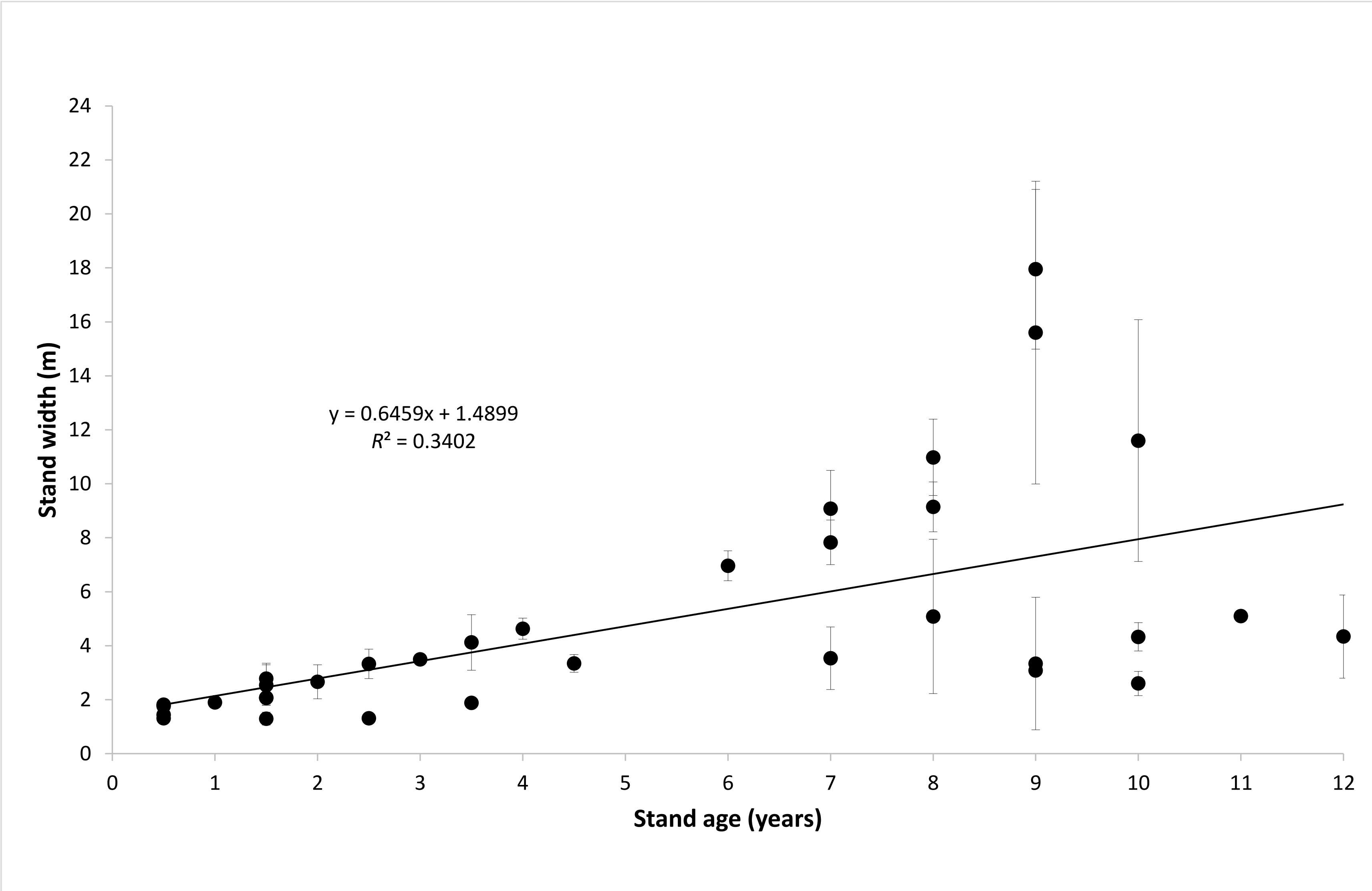

Figure 6: Relationship between *S. tabernaemontani* stand width and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013, 2014, 2016 and 2016 (error bars=±1 SE).

Stem density

Change in stem density through time was variable between sites (Figure 7). At sites planted between 2012 and 2013, there were significant increases between 2013 and 2016 but how stem density increased was different between sites. At Meningie Foreshore there was a significant increase between 2013 and 2014, but no significant change between 2014 and 2016 (Table 3, Figure 7). At the newly planted site at Nurra Nurra Point there was a significant increase each year from 2013 to 2015, but a decrease between 2015 and 2016 with densities that year equivalent to those recorded in 2014 (Table 3, Figure 7). At Lake Albert Road there was no significant change between 2013 and 2014, a significant increase between 2014 and 2015 and no change between 2015 and 2016 (Table 3, Figure 7). There was no change in stem density from 2013 to 2015, and a significant decrease, between 2015 and 2016 at all sites planted before 2007, except at Raukkan where there was no significant change between 2013 and 2016 (Table 3, Figure 7). At sites planted later than 2013 there was also a variable response in stem density between 2015 and 2016; there was no significant change at Poltalloch, a significant decrease at Harnett's and a significant increase at the newly planted site at Wellington Lodge (Table 3, Figure 7).

Stem density at the natural shorelines was variable within and between sites (Figure 7). The highest density was at Loveday Bay in 2014, which was comparable to the densities recorded at the shorelines planted prior to 2007 and at Meningie Foreshore, the new planting at Nurra Nurra Point and Lake Albert Road in 2015 and 2016 (Figure 7). There was no significant change in stem density at the Bremer River Mouth and Loveday Bay between 2014 and 2016 and a significant increase at the Hindmarsh Island Bridge between 2014 and 2015, but no significant change thereafter (Table 3, Figure 7).

Linear regression analysis showed no relationship between stand age and stem density (R^2=0.084; P=0.101) (Figure 8). However, if the data from the old planted site at Nurra Nurra Point are removed (outliers with much lower stem densities than the other sites planted prior to 2007) there was a significant, positive relationship between stand age and stem density (R^2 = 0.350; P < 0.001).

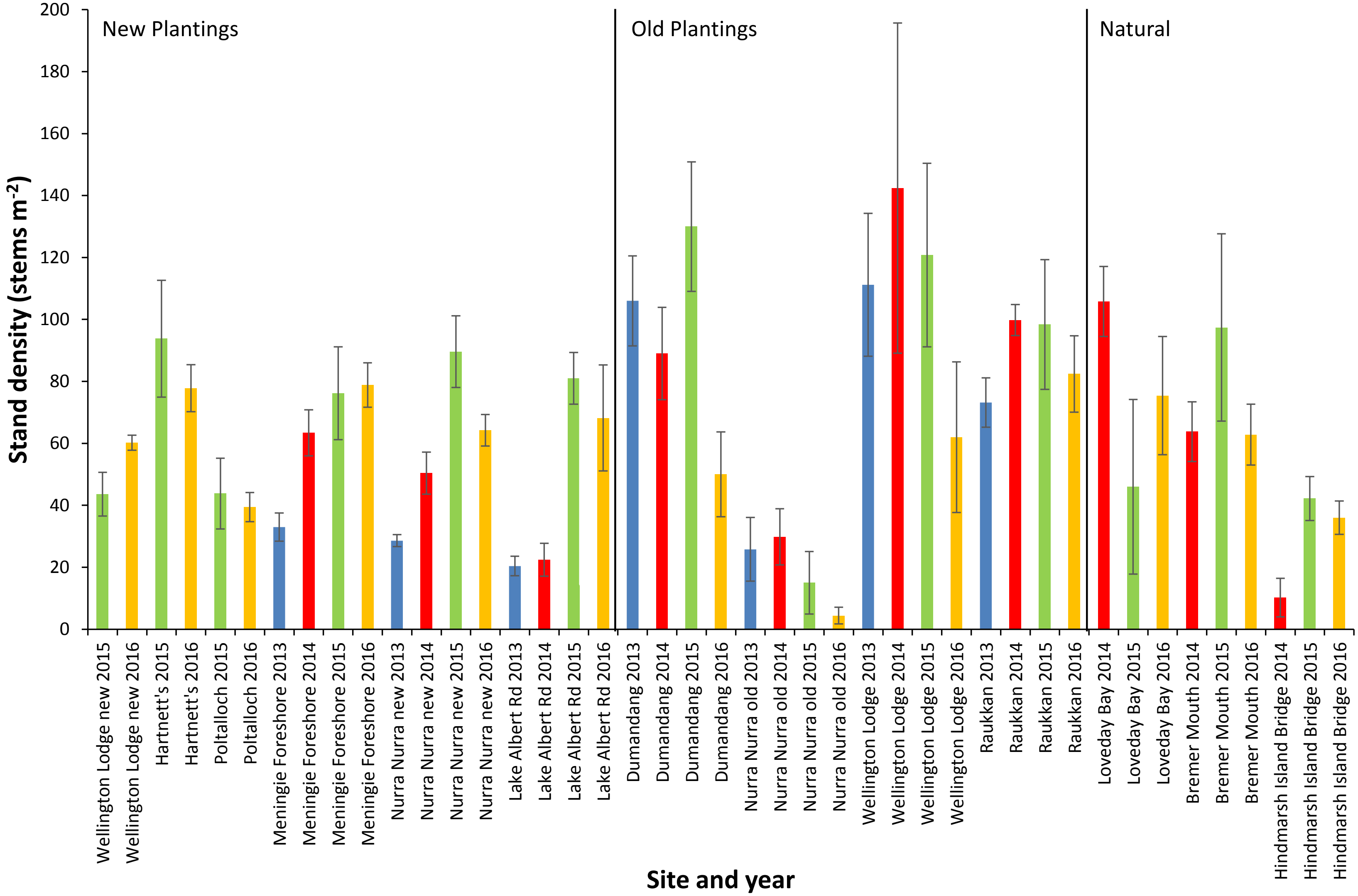

Figure 7: *Schoenoplectus tabernaemontani* stem density for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 (blue), 2014 (red), 2015 (green) and 2016 (yellow) (error bars=±1 SE).

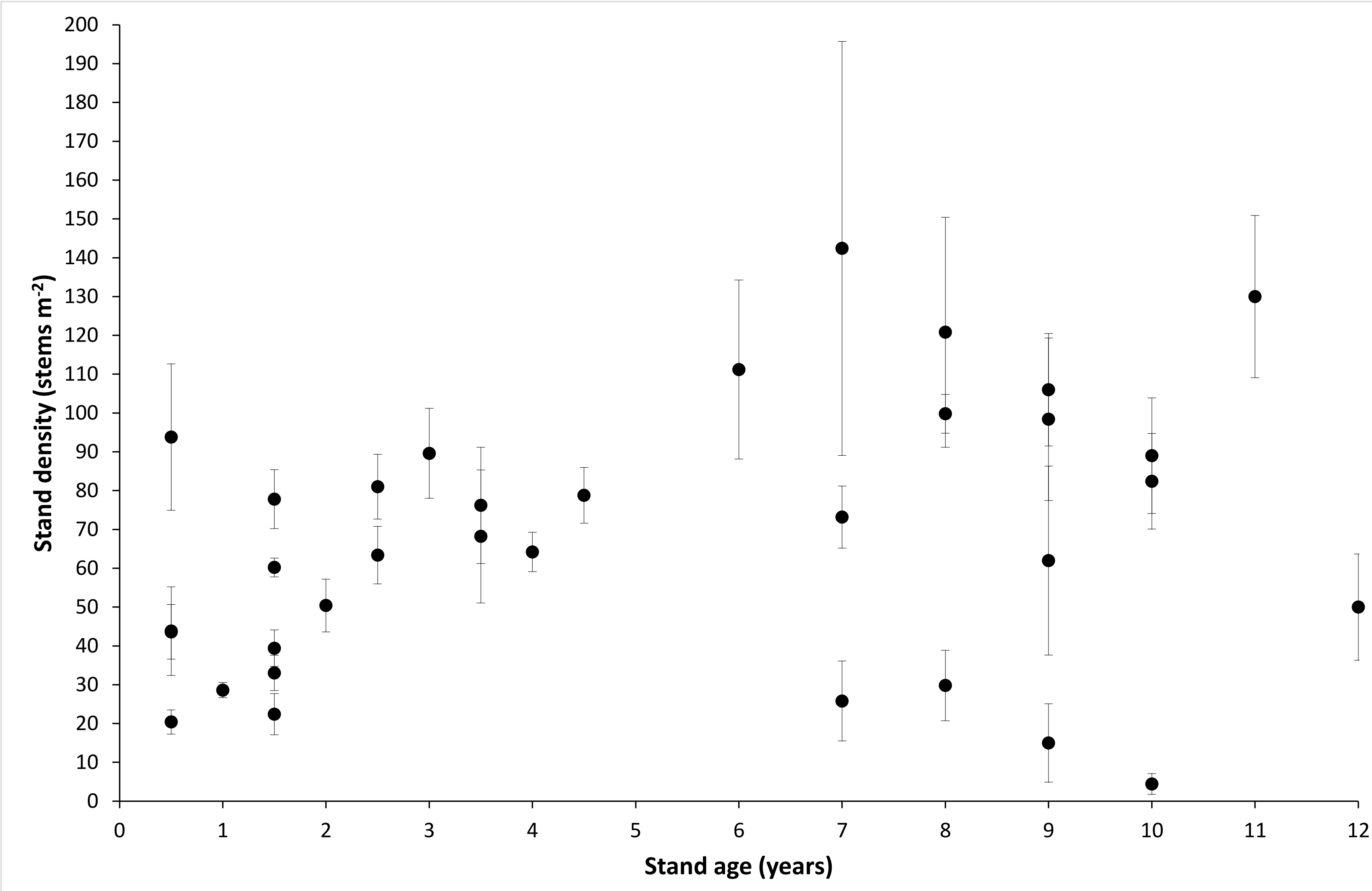

Figure 8: Relationship between *S. tabernaemontani* stem density and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013, 2014, 2015 and 2016 (error bars=±1 SE).

Maximum stem height

The height of the tallest stem present in each quadrat was relatively consistent between planted shorelines and surveys (autumn 2013, 2014, 2015 and 2016), although maximum heights ranged from 118 cm (at the newly planted site at Wellington Lodge) to 244 cm (at Raukkan) (Figure 9). At the old planting at Nurra Nurra Point the maximum height of stems was lower and more variable (Figure 9). Maximum stem height was also consistent for the natural stands, but stems were generally taller than the planted sites (Figure 9). Due to the consistent maximum height of stems there was no relationship between stand age and maximum stem height (R^2 = 0.006; P = 0.666) (Figure 10).

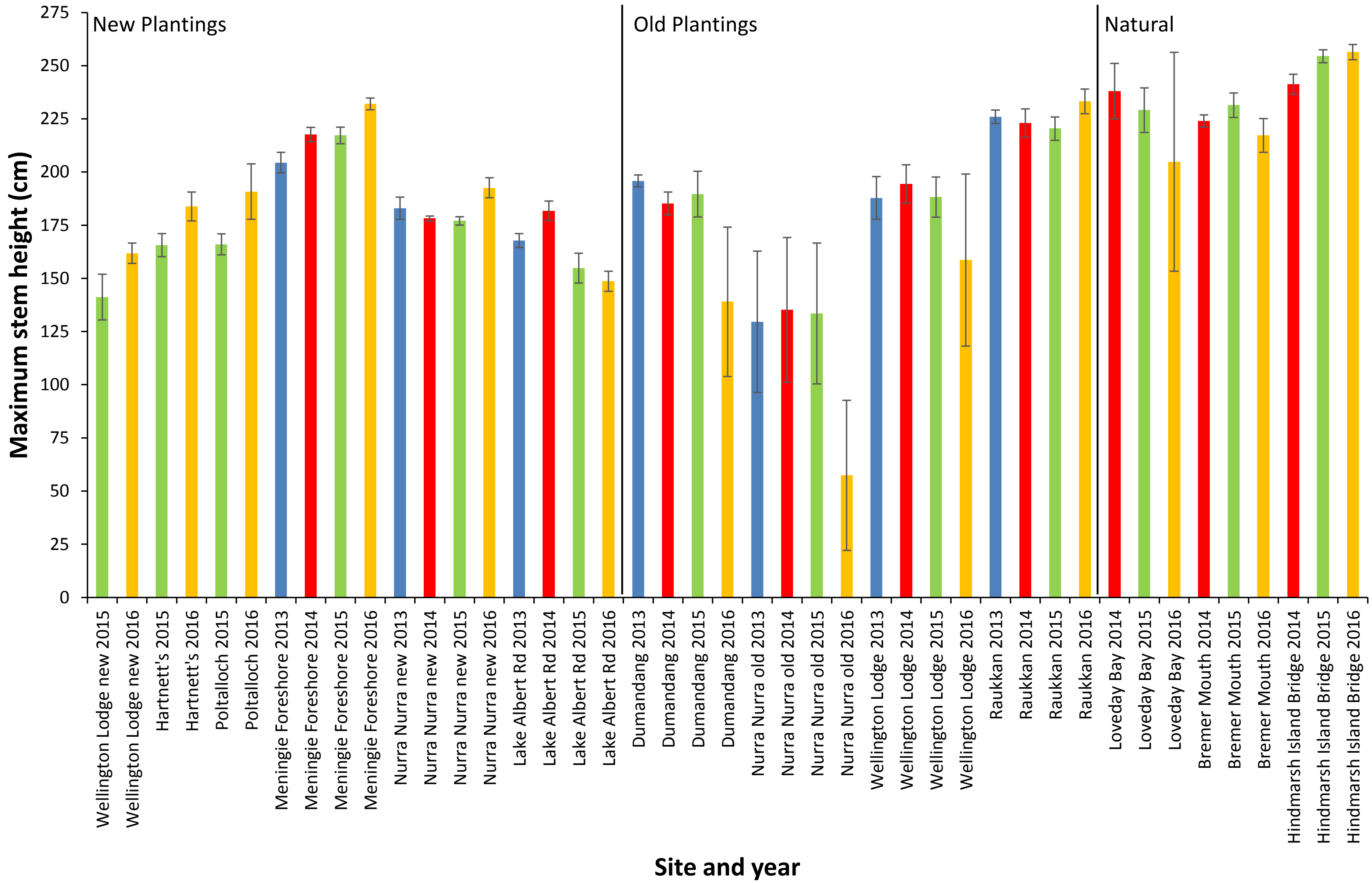

Figure 9: *Schoenoplectus tabernaemontani* maximum stem height for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 (blue), 2014 (red), 2015 (green) and 2016 (yellow) (error bars=±1 SE).

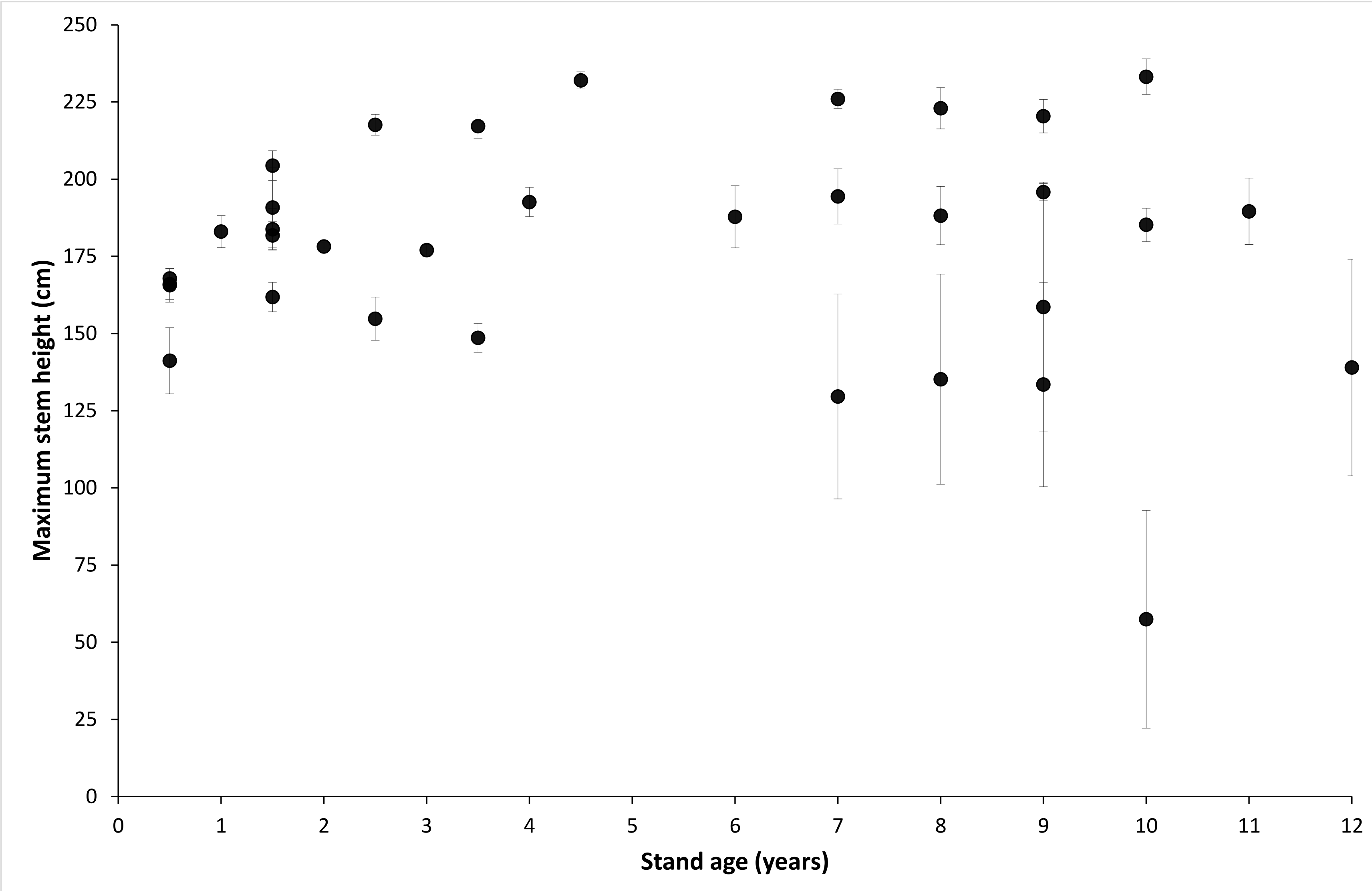

Figure 10: Relationship between *S. tabernaemontani* maximum stem height and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013, 2014, 2015 and 2016 (error bars=±1 SE).

Mean stem height

Mean stem height generally did not change significantly between 2013 and 2016 at planted sites except at Lake Albert Road (stems were significantly taller in 2014 but with no significant difference in height for the other years) and Dumandang and Raukkan (stems were significantly taller in 2013) (Table 3, Figure 11). At the natural sites, there was no significant change in height between 2014 and 2016, except at Hindmarsh Island Bridge where there was a significant increase each year (Table 3, Figure 11). Similar to maximum stem height, there was no relationship between stand age and mean stem height (R^2 = 0.055; P = 0.180) (Figure 12).

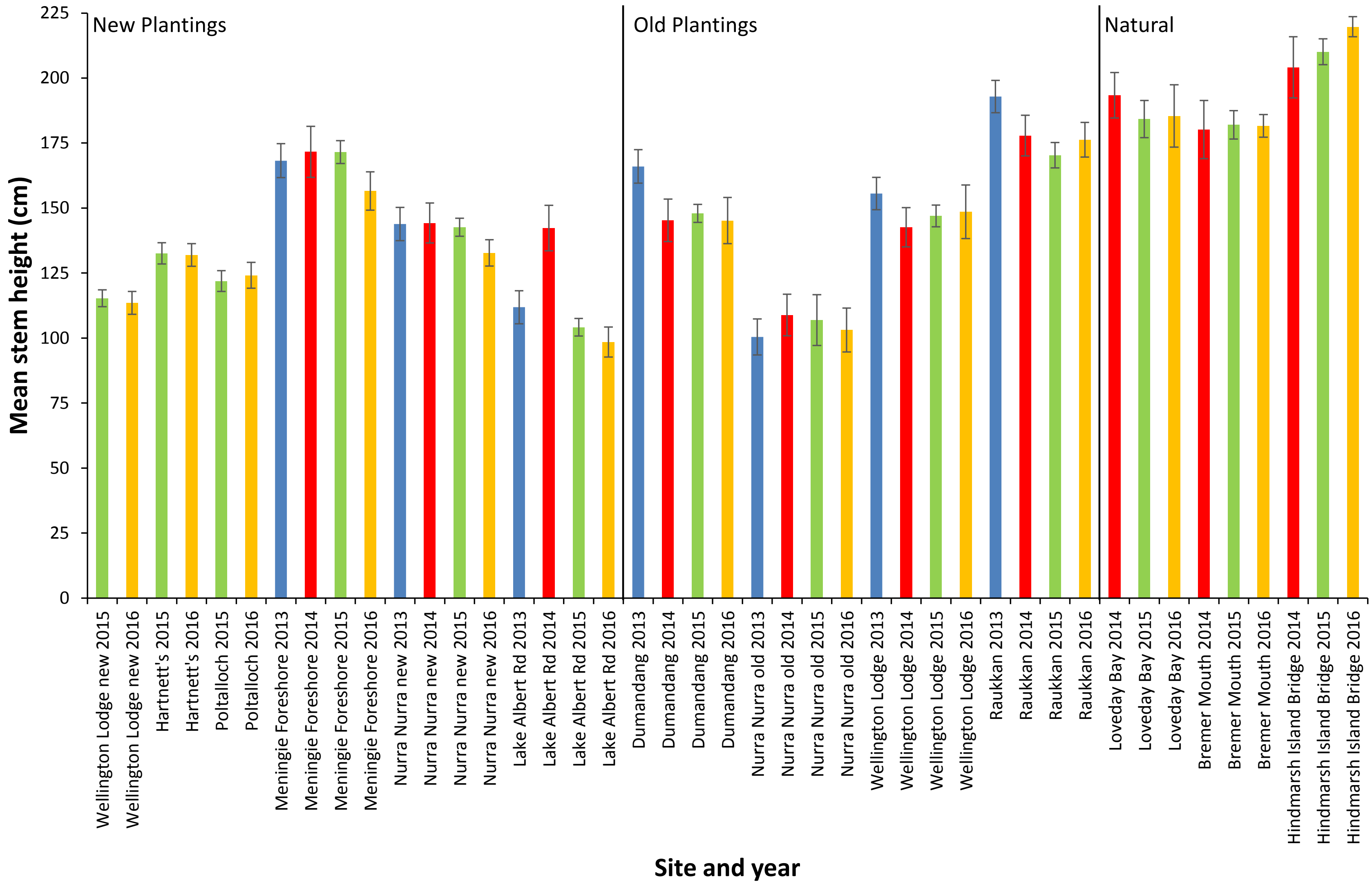

Figure 11: *Schoenoplectus tabernaemontani* mean stem height for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 (blue), 2014 (red), 2015 (green) and 2016 (yellow) (error bars=±1 SE).

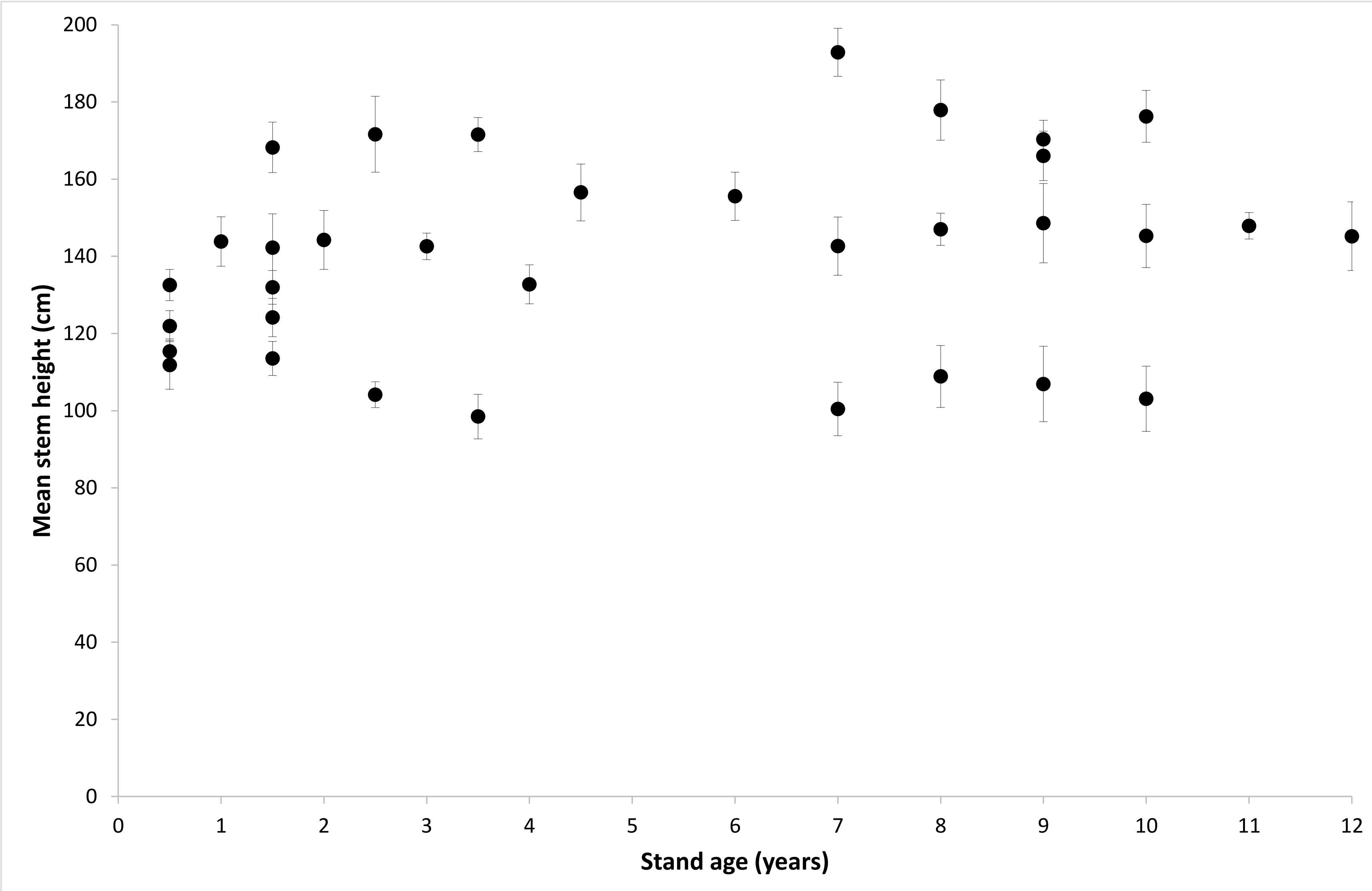

Figure 12: Relationship between *S. tabernaemontani* mean stem height and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013, 2014, 2015 and 2016 (error bars=±1 SE).

The trends over the study period of the estimated total number of *S. tabernaemontani* stems present at each shoreline were variable between sites (Figure 13). There were increases between 2015 and 2016 at the most recently planted sites, except Poltalloch where numbers were similar (Figure 13). At Lake Albert Road there were increases each year; however, at Meningie Foreshore and the newly plant site at Nurra Nurra Point numbers peaked in 2015 and then declined slightly (Figure 13). Similar patterns were observed at the older sites at Dumandang, Raukkan and Wellington Lodge, but the decline was greater (compared to the newly planted sites) and the number of stems has been declining at the old planted site at Nurra Nurra Point since 2014 (Figure 13).

The trends between 2014 and 2016 at shorelines where *S. tabernaemontani* occurs naturally was also variable between sites (Figure 13). There was a decrease in the total number of stems at Loveday Bay between 2014 and 2015, but an increase (albeit not to the same numbers as recorded in 2014) between 2015 and 2016 (Figure 13). At the Bremer Mouth there was a large increase between 2014 and 2015, but a decrease (to slightly higher numbers than recorded in 2014) between 2015 and 2016 (Figure 13). In contrast, at Hindmarsh Island Bridge there has been an increase each year (Figure 13).

Linear regression showed a significant positive relationship (R^2 = 0.280; P = 0.001) between stand age and total number of stems (Figure 14). However, if the data from the old planted site at Nurra Nurra Point are removed (outliers with lower stem numbers than sites of a similar age) there was a stronger positive relationship between stand age and stem density (R^2 = 0.472; $P <$ 0.001).

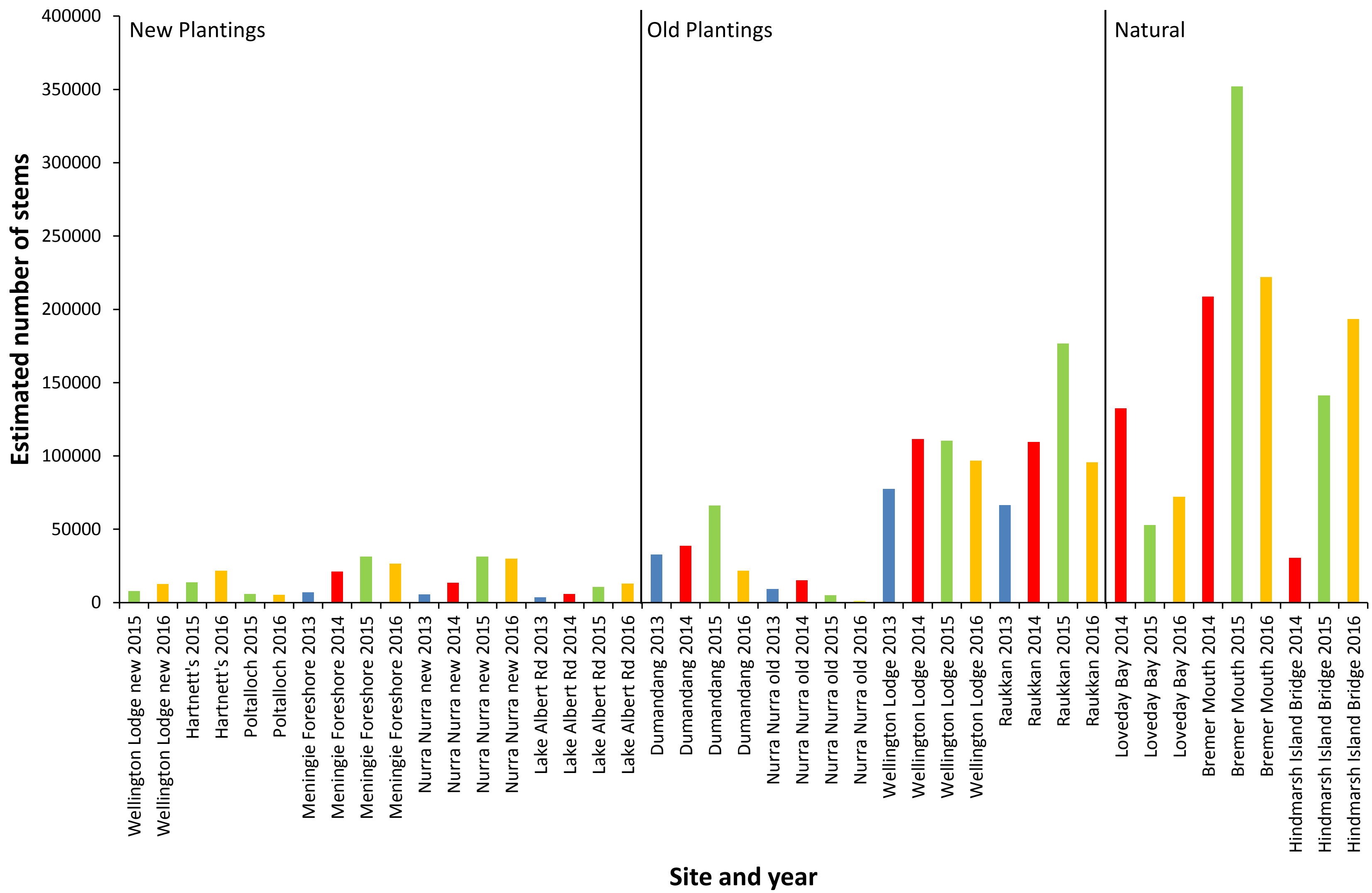

Figure 13: Estimated number of *S. tabernaemontani* stems for each planted and natural shoreline in lakes Alexandrina and Albert in autumn 2013 (blue), 2014 (red), 2015 (green) and 2016 (yellow).

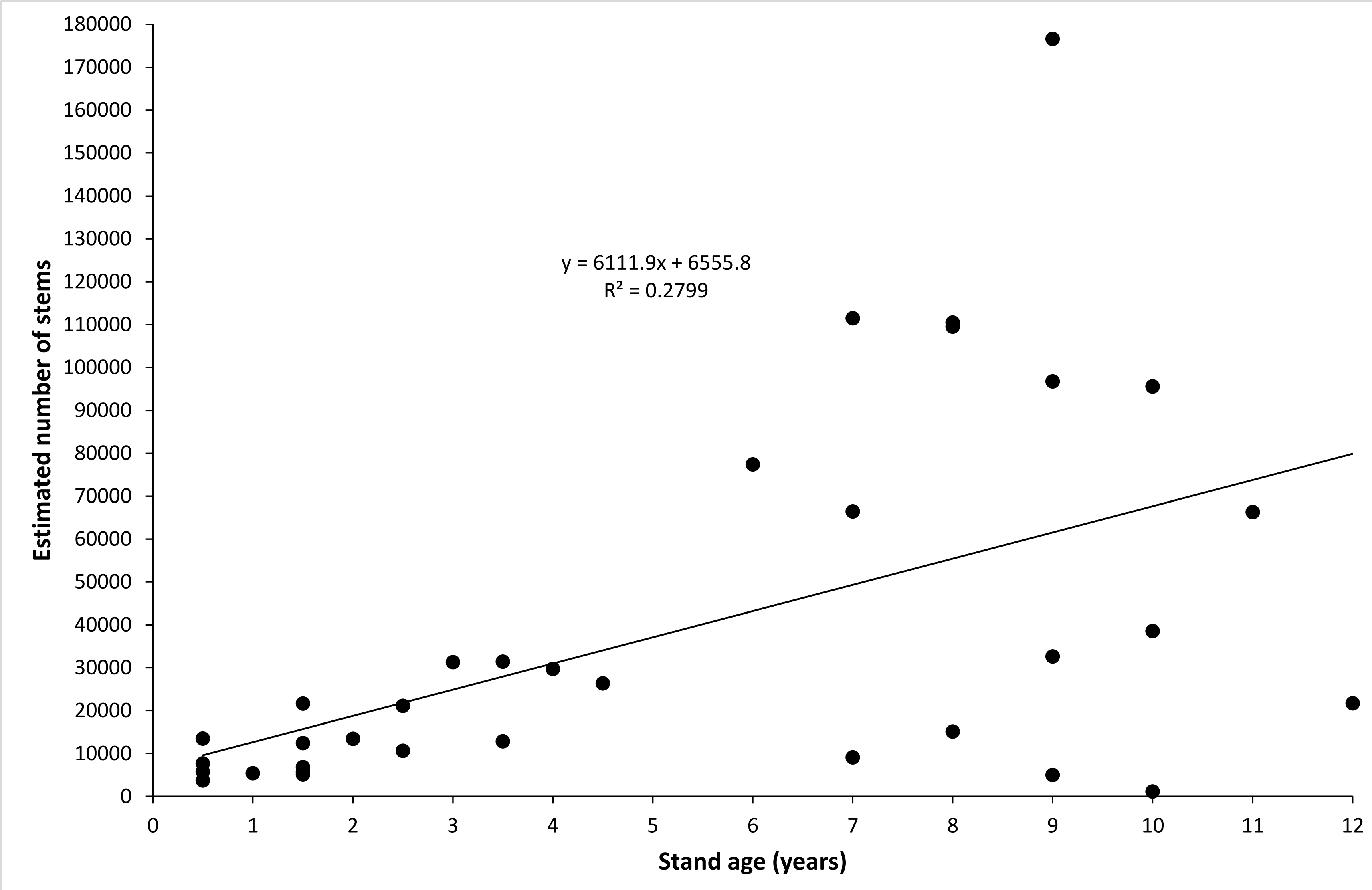

Figure 14: Relationship between the estimated number of *S. tabernaemontani* stems and stand age, for each planted site in lakes Alexandrina and Albert for autumn 2013, 2014, 2015 and 2016.

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

NMS ordination comparing the plant community at all shorelines across all elevations showed the plant community at planted shorelines was becoming more similar to shorelines where *S. tabernaemontani* grows naturally through time (Figure 15, Appendix 2). A diverse assemblage of emergent (e.g. *T. domingensis, P. australis, S. tabernaemontani*), amphibious (e.g. *Mentha* spp*., Calystegia sepium, Azolla filiculoides*) and submergent (*C. demersum*) taxa was present at shorelines where *S. tabernaemontani* grows naturally and some of the planted shorelines in 2015 and 2016 (Figure 15). Control and recently planted shorelines (e.g. Hartnett's, Poltalloch, the newly planted site at Wellington Lodge) were typically devoid of vegetation or dominated by low growing clonal species such as *Cenchrus clandestinus* and *Paspalum distichum* at high elevations (Appendix 2). The plant community at Lake Albert Road, despite being planted in 2013, was also similar to control and newly planted sites in 2016 (Figure 15). In contrast, Meningie Foreshore and the newly planted site at Nurra Nurra Point (planted in 2012 and 2013, respectively) developed plant communities similar to those at sites planted prior to 2007 (Figure 15).

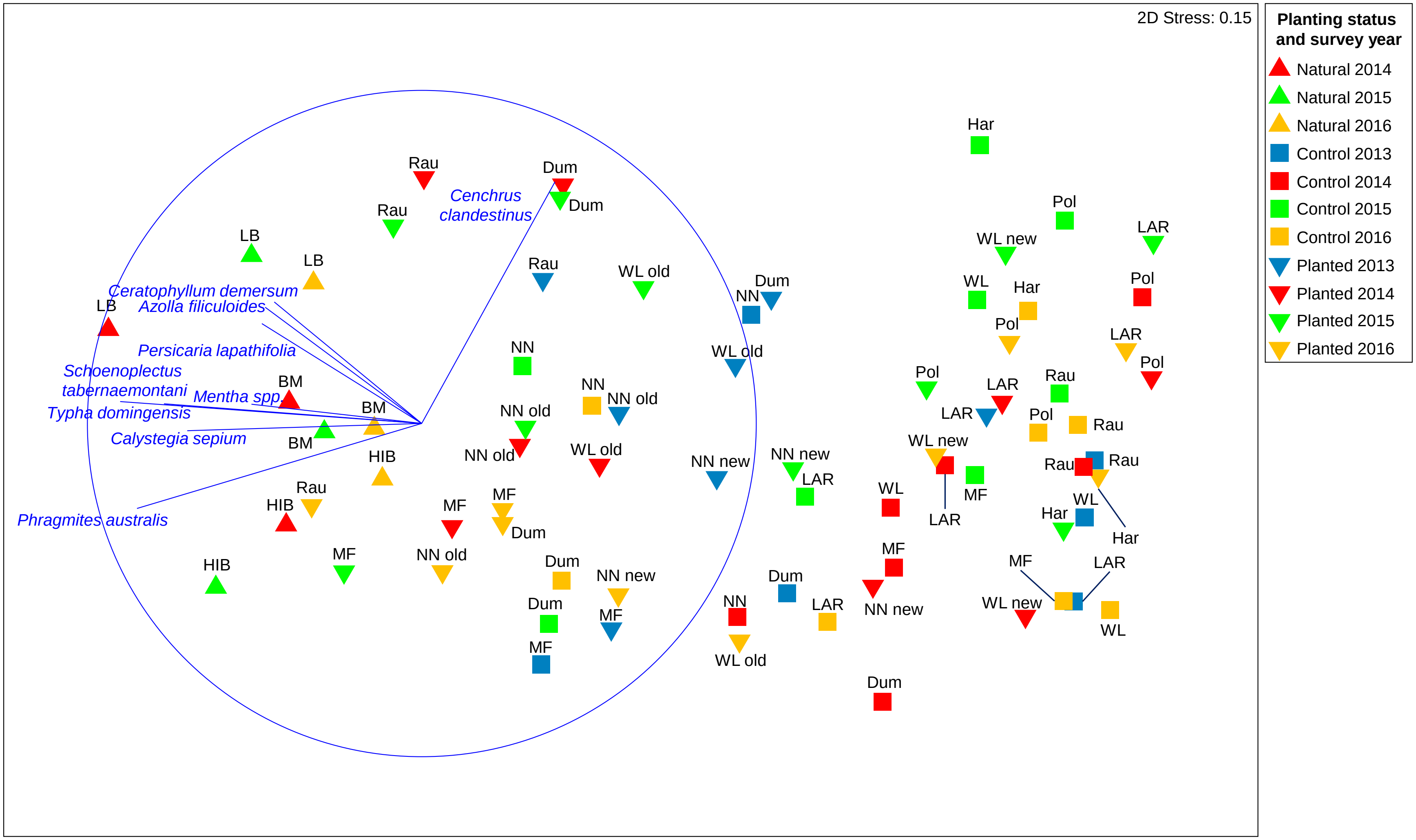

Figure 15: NMS ordination comparing the plant community (all elevations) at each shoreline in autumn 2013, 2014, 2015 and 2016 (LB=Loveday Bay, HIB=Hindmarsh Island Bridge, BM=Bremer River Mouth, Rau=Raukkan, MF=Meningie Foreshore, NN=Nurra Nurra Point, Dum=Dumandang, WL=Wellington Lodge, LAR=Lake Albert Road, Har=Hartnett's, Pol=Poltalloch).

There were fewer differences in vegetation between natural shorelines, planted shorelines and controls at high elevations (Figure 15, Figure 16). The exception was the plant community at high elevations at Loveday Bay, which was distinctive throughout the study period (Figure 16). This was due to species such as *C. clandestinus* and *P. distichum* (clonal low growing grasses) often being abundant at many shorelines (irrespective of planting status) at high elevations (Appendix 2). Shorelines planted after 2014 (Poltalloch, Hartnett's and the new planting at Wellington Lodge) had plant communities at high elevations similar to control shorelines, as did Lake Albert Road between 2013 and 2016 (Figure 16). Nevertheless, amphibious (*C. sepium* and *Mentha* spp.) and emergent (*T. domingensis* and *P. australis*) taxa were associated with planted and natural shorelines at high elevations (Figure 16).

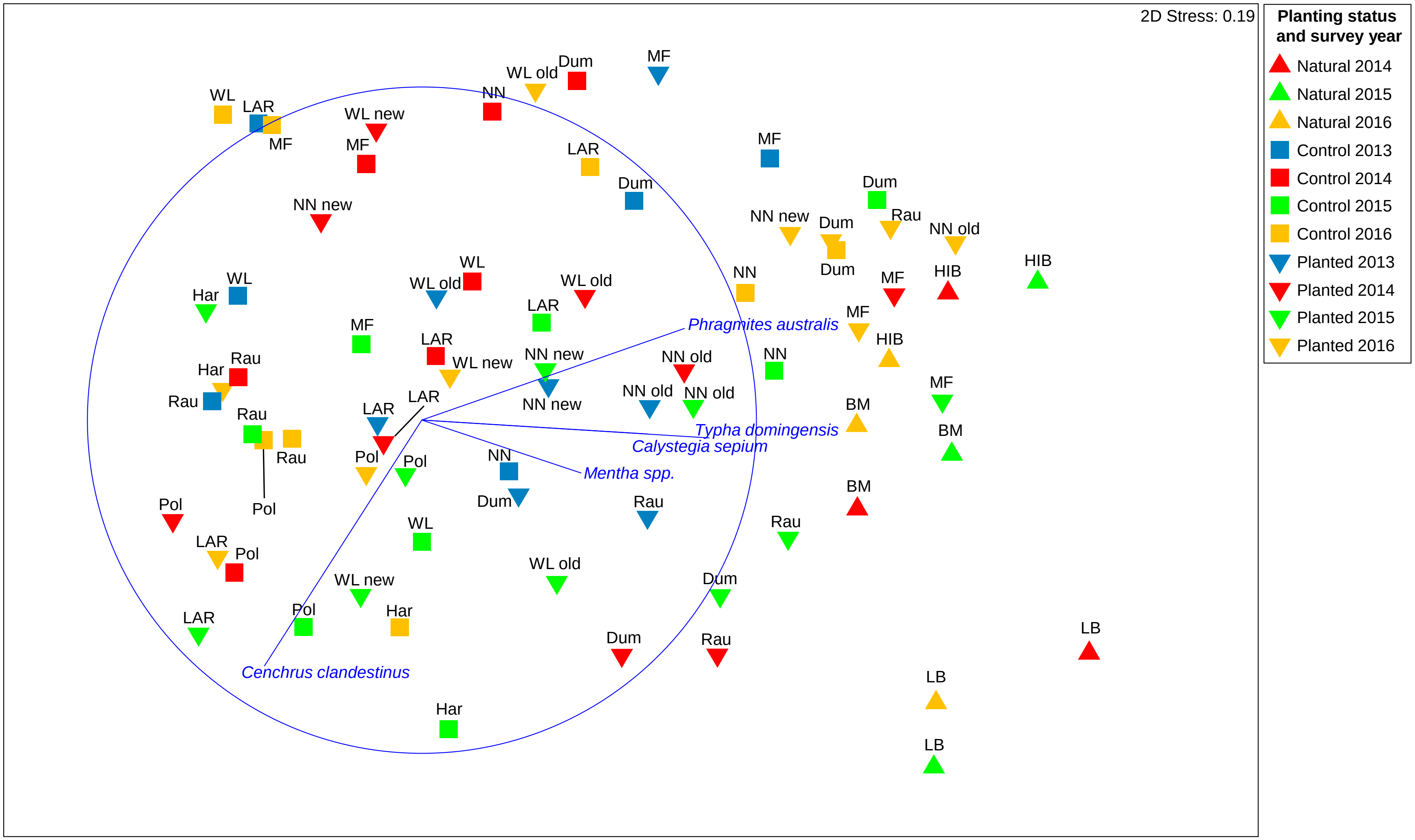

Figure 16: NMS ordination comparing the high elevation plant community (+0.8 and +0.6 m AHD) at each shoreline in autumn 2013, 2014, 2015 and 2016 (LB=Loveday Bay, HIB=Hindmarsh Island Bridge, BM=Bremer River Mouth, Rau=Raukkan, MF=Meningie Foreshore, NN=Nurra Nurra Point, Dum=Dumandang, WL=Wellington Lodge, LAR=Lake Albert Road, Har=Hartnett's, Pol=Poltalloch).

The plant community at low elevations at natural shorelines and the shorelines planted prior to 2007 were dominated by emergent species (*T. domingensis, S. tabernaemontani* and *P. australis*) and *A. filiculoides* (Figure 17). The group of points on the right of the ordination were shorelines dominated by open water with very few plants present (most points represent control shorelines); however, the planted shoreline at Lake Albert Road and shorelines planted after 2014 (Poltalloch, Hartnett's and the newly planted site at Wellington Lodge) are also present in this group (Figure 17). The plant community at low elevations at all shorelines planted before 2007 and Meningie Foreshore (and to a lesser extent the newly planted site at Nurra Nurra Point) became more similar to the plant community at natural shorelines between autumn 2013 and 2016 (Figure 17).

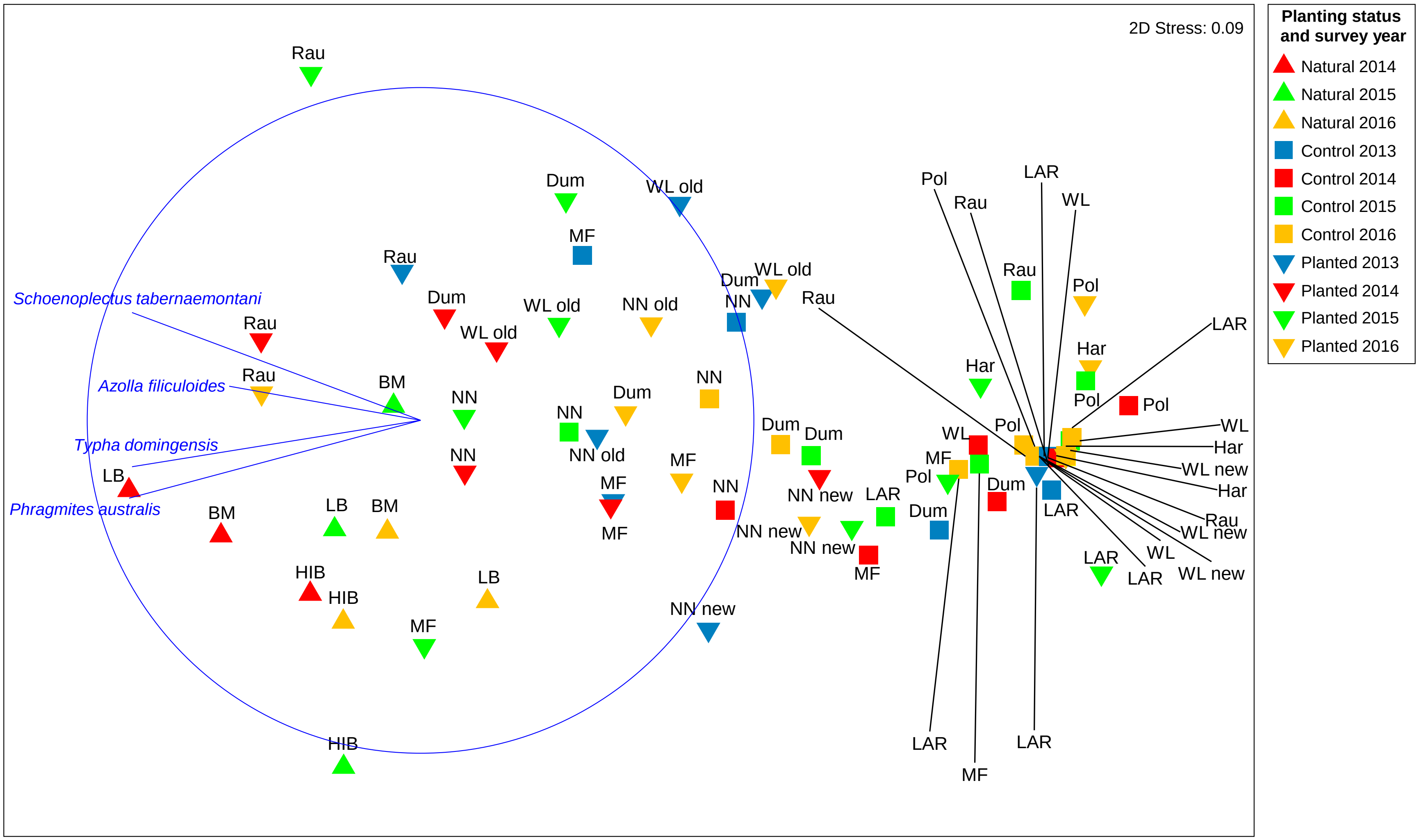

Figure 17: NMS ordination comparing the low elevation plant community (+0.4, +0.2 and 0 m AHD) at each shoreline in autumn 2013, 2014, 2015 and 2016 (LB=Loveday Bay, HIB=Hindmarsh Island Bridge, BM=Bremer River Mouth, Rau=Raukkan, MF=Meningie Foreshore, NN=Nurra Nurra Point, Dum=Dumandang, WL=Wellington Lodge, LAR=Lake Albert Road, Har=Hartnett's, Pol=Poltalloch).

4. DISCUSSION

Results from the autumn 2016 survey provided further evidence that *S. tabernaemontani* 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. The increases in stand extent and density that were observed at all but one planted shoreline between 2013 and 2015 (Nicol *et al.* 2015) did not continue at many sites in 2016. Furthermore, the plant communities associated with old planted stands (and some of the shorelines planted after 2010) are becoming more similar to the community present in naturally occurring stands.

Results from the first year of the monitoring program (2013) and TLM vegetation condition monitoring showed that *S. tabernaemontani* was resistant to drying because it survived through the height of the millennium drought and period of critical low water levels (2007–2010) and sprouted from rhizomes after water levels were reinstated (Frahn *et al.* 2013; Nicol *et al.* 2013). Results from 2013 to 2016, indicated that at most planted shorelines (even recently planted ones) *S. tabernaemontani* created a ‘breakwater’, providing a sheltered area between the planted stand and shoreline where less robust species could establish and persist (Nicol *et al.* 2014; 2015). 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 *P. australis* or *T. 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, third and fourth years of the monitoring program demonstrated that *S. tabernaemontani* persisted at all planted shorelines, which was expected due to the planted stands being inundated to depths of between 23 and 81 cm throughout the study period (*sensu* Sainty and Jacobs 2003). Furthermore, the current monitoring program allowed comparisons of stand characteristics between autumn 2013, 2014, 2015 and 2016 at planted shorelines, along with comparisons of planted and natural stands.

Data collected from autumn 2013 to autumn 2016 showed that there was expansion of planted *S. tabernaemontani* stands (at different rates) between 2013 and 2015 at Meningie Foreshore, the new planting at Nurra Nurra Point and Lake Albert Road, but between 2015 and 2016 there was no increase or indeed, reductions. It was expected that the stand extent (density, width and total number of stems) would increase into the future at the newly planted sites because there were large areas of suitable unoccupied habitat at these sites (Nicol *et al.* 2015). *Schoenoplectus tabernaemontani* was observed growing at depths of over 100 cm (-0.4 m AHD) at Hindmarsh Island Bridge in 2016 and there was generally no vegetation at the 0 m AHD elevation at all planted sites, which suggests that there are large areas at the planted sites that *S. tabernaemontani* stands could expand into. Furthermore, stem densities were typically lower at the aforementioned sites compared to sites planted prior to 2007 and sites where the species grows naturally, which suggests that a maximum stand density has not been reached. Therefore, stands are not constrained by lack of suitable habitat to expand into or by space in areas they currently occupy, and the reason behind the reduction in extent between 2015 and 2016 is unknown.

There was also decreased extent of *S. tabernaemontani* stands between 2015 and 2016 at all shorelines planted prior to 2007 and at the Bremer River Mouth. Stem density (which is higher at these sites, except at the old planted site at Nurra Nurra Point) and competition from *T. domingensis* and *P. australis* may be controlling the extent of *S. tabernaemontani* in areas already occupied at the old planted sites; however, water depth would not be limiting stand expansion into deeper areas of the lakes. Therefore, the cause in the reduction in extent is unknown and unexpected; however, plants appear healthy, show evidence of flowering and seed set and in the majority of cases extent is greater compared to 2013. Furthermore, there were increases in extent at the newly planted site a Wellington Lodge and Hartnett's and no change at Poltalloch. The Lower Lakes, similar to other freshwater wetland systems, is a dynamic system and inter-annual variability of plant communities is to be expected.

The number of *S. tabernaemontani* stems at Lake Albert Road continued to be lower than other sites planted at a similar time. This is probably due to the site being on a lee shore exposed to the prevailing southerly and south-westerly winds and subsequent wave action. Stand extent at Poltalloch is lower compared to Hartnett's and the newly planted site at Wellington Lodge and, similar to Lake Albert Road, this may be due to this site being exposed to prevailing winds. Nevertheless, plants persisted at these sites and in the future may form stands sufficiently dense to act as a breakwater, reduce erosion and facilitate the recruitment of other aquatic and amphibious species.

Lower stem density, stand width and subsequent lower total number of stems were also observed in 2016 at the old planting at Nurra Nurra Point compared to other sites planted prior to 2007. This stand is the same age as the old stand at Wellington Lodge and older than the stand at Raukkan, which both recovered well after water levels were reinstated after the drought in 2010. Therefore, it is probably not a case of the stand being less well established (and less able to recover when water levels were reinstated) when water levels declined in 2007. Nurra Nurra Point is also more protected from the prevailing winds than Raukkan and Wellington Lodge and the newly planted stand increased in width between 2013 and 2016, and density between 2013 and 2015 indicating that conditions at the site are favourable for *S. tabernaemontani*. One hypothesis for the poor performance of *S. tabernaemontani* at Nurra Nurra point is that rhizomes were not buried as deeply and were thus, subjected to greater desiccation compared to more exposed locations. Between 2007 and 2010, small dunes formed at Raukkan and Loveday Bay where *S. tabernaemontani* occurred (planted and natural respectively) (J. Nicol pers. obs.), which buried rhizomes, protecting them from desiccation and maintaining viability in the absence of favourable hydrological conditions. This did not occur at Nurra Nurra Point and the shallower burial depth of rhizomes may have resulted in reduced viability and slower recolonisation after water levels were reinstated.

Natural *S. tabernaemontani* stands were wider than planted stands, except at Loveday Bay where they were comparable to shorelines planted prior to 2007. Stem density was variable with the lowest density recorded at the Hindmarsh Island Bridge in 2014 and the highest at Loveday Bay in 2014, which was comparable to the highest densities recorded at shorelines planted prior to 2007. There was a large amount of variation in stem density and stand width (and subsequently the total numbers of stems) between 2014 and 2016 at sites where *S. tabernaemontani* naturally occurs. Hindmarsh Island Bridge increased (driven by increasing stand widths), Bremer Mouth increased between 2014 and 2015, but decreased between 2015 and 2016 to numbers similar to 2014, and Loveday Bay decreased between 2014 and 2015, but increased slightly between 2015 and 2016. These data indicated that inter-annual variability in stand extent and density of natural stands is a natural occurrence (driven by a combination of local and regional factors) in a dynamic ecosystem such as the Lower Lakes. This is in contrast to planted stands, most of which showed the same pattern of increases between 2013 and 2015 and a decrease between 2015 and 2016.

Maximum and mean stem height showed no relationship with stand age, which was expected because full grown plants were planted. There was generally no significant change in mean stem height over the study period except at Lake Albert Road, Dumandang, Raukkan and Hindmarsh Island Bridge. Stems were significantly taller at Lake Albert Road in 2014, there was a significant decrease between 2013 and 2014 with no further change after then at Raukkan and Dumandang. At Hindmarsh Island Bridge there was a significant increase each year. The reason for these changes is unclear and there are no clear patterns between changes in stem height and other stand characteristics except at Hindmarsh Island Bridge where the increase in stem height corresponds to an increase in stand width and density.

The aquatic and littoral plant community of planted shorelines where four years of data have been collected, except Lake Albert Road, were generally more similar to the natural shorelines rather than the controls. 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 controls was less clear. This was due to the planted and unplanted shorelines at high elevations both often being dominated by low growing clonal grasses such as *P. distichum* and *C. clandestinus*. Nevertheless, amphibious species such as *P. lapathifolia, B. erecta, Centella asiatica, Mentha* sp. and *Hydrocotyle verticillata* were present at planted shorelines and natural shorelines, whereas these species tended to be absent at control shorelines (Appendix 2).

Floating species such as *A. filiculoides* and *Lemna minor* were also present at high elevations at the planted and natural shorelines, which was probably due to the breakwater effect. *A. filiculoides* and *L. minor* 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 colonise and reproduce rapidly asexually.

Differences in plant communities between planted, natural and control shorelines were most evident at the low elevations. This was in part due to the presence of *S. tabernaemontani* 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 is evidence for the breakwater effect provided by *S. tabernaemontani,* 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).

At Lake Albert Road the *S. tabernaemontani* stand width and density has been lower compared to stands of a similar age; hence, the breakwater effect it provides is less effective at reducing wave action. Coupled with the fact that it is a high energy shoreline exposed to the prevailing southerly winds it was expected that the plant community was similar to control shorelines between 2013 and 2016 because of less conducive conditions for plant recruitment. How long it will take for the planted *S. tabernaemontani* stand to provide sufficient protection from waves at this site to promote plant recruitment is unknown. The plant community at shorelines planted after 2014 were also similar to control shorelines suggesting that the planted *S. tabernaemontani* stands do not yet provide sufficient protection from waves to facilitate recruitment of other species. This is not unexpected given that these stands are only 1–2 years old, but there have been increases in the total number of stems present at the newly planted site and Wellington Lodge and Hartnett's. An increase in the number of stems was not observed at Poltalloch between 2015 and 2016. The number of stems at the newly planted site at Wellington Lodge and Hartnett's in 2016 were greater than the number of stems at Meningie Foreshore in 2013 (1.5 years after the stand was planted). Therefore, it is possible that the planted *S. tabernaemontani* has started to provide a breakwater effect and recruitment of amphibious, emergent and submergent species will be observed in the next two years. In contrast, the number of stems at Poltalloch in 2016 was similar to the number of stems observed at Lake Albert Road in 2014 (1.5 years after the stand was planted) and probably not providing a breakwater. The length of time required for planted *S. tabernaemontani* stand density and width to provide a breakwater effect at Poltalloch is unknown, but if the trends observed at Lake Albert Road occur at Poltalloch it may be longer than three years before any recruitment of other species can be expected.

Surveys in 2014, 2015 and 2016 showed there was evidence to suggest that the plant communities (particularly at low elevations) at locations planted prior to 2007, Meningie Foreshore and the newly planted site at Nurra Nurra Point were becoming similar to natural locations. 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. However, the change in the plant community observed at Meningie Foreshore and the newly planted site at Nurra Nurra Point showed that this is already occurring with the vegetation resembling sites planted prior to

2007. If natural sites are 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.

We conclude that planting *S. tabernaemontani* 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, amphibious 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 remain adequately represented.

Future research and monitoring

The monitoring program over the past four years has provided strong evidence that planting *S. tabernaemontani* provides conditions conducive to the recruitment of amphibious and aquatic species on lakeshores. Future research and monitoring should focus on stand dynamics in areas where expansion has been slow to determine optimal planting densities for these areas and newly planted areas to evaluate planting success and determine whether follow up planting is required. In addition, complementary research to investigate the ecosystem services (e.g. fish, invertebrate and water bird habitat, erosion control, water quality improvement), improvements in habitat diversity, increases in ecosystem resilience and restoration of ecological character provided by planting *S. tabernaemontani*. Potential projects include:

- 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.
- Determine habitat provided by planted and natural stands of *S. tabernaemontani* and compare habitat provided by stands of different ages.
- Monitor stand dynamics of newly planted shorelines (e.g. north of Point Malcolm, Narrung, Raukkan, northern shoreline of Lake Alexandrina) to determine planting success, rate of stand expansion and the need for additional planting.
- Investigate different planting densities or additional planting along shorelines where density and extent have been slow to increase (e.g. Poltalloch and Lake Albert Road).
- 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, when *Schoenoplectus tabernaemontani* was planted and when each site was surveyed.

Site	Easting	Northing	Planting Status	Year Planted	Years Surveyed
Bremer Mouth	323061	6081991	Natural	NA	2014, 2015 and 2016
Dumandang	339058	6053687	Planted	2003, 2004 and 2006	2013, 2014, 2015 and 2016
Dumandang Control	340594	6054244	Control	NA	2013, 2014, 2015 and 2016
Hartnett's	319449	6081919	Planted	2014	2015 and 2016
Hartnett's Control	320978	6081950	Control	NA	2015 and 2016
Hindmarsh Island Bridge	299349	6081493	Natural	NA	2014, 2015 and 2016
Lake Albert Road	350743	6060734	Planted	2013	2013, 2014, 2015 and 2016
Lake Albert Road Control	350313	6054328	Control	NA	2013, 2014, 2015 and 2016
Loveday Bay	326167	6082052	Natural	NA	2014, 2015 and 2016
Meningie Foreshore	349673	6049720	Planted	2012	2013, 2014, 2015 and 2016
Meningie Foreshore Control	350237	6053018	Control	NA	2013, 2014, 2015 and 2016
Nurra Nurra Point Control	341547	6063414	Control	NA	2013, 2014, 2015 and 2016
Nurra Nurra Point Old	341723	6063637	Planted	2006	2013, 2014, 2015 and 2016
Nurra Nurra Point New	341808	6063808	Planted	2012 and 2013	2013, 2014, 2015 and 2016
Poltalloch	339761	6082305	Planted	2014	2014, 2015 and 2016
Poltalloch Control	342616	6082355	Control	NA	2014, 2015 and 2016
Raukkan	327643	6067143	Planted	2006	2013, 2014, 2015 and 2016
Raukkan Control	327414	6082076	Control	NA	2013, 2014, 2015 and 2016
Wellington Lodge	349440	6079043	Planted	2007	2013, 2014, 2015 and 2016
Wellington Lodge Control	349278	6082469	Control	NA	2013, 2014, 2015 and 2016
Wellington Lodge New	349469	6079117	Planted	2014	2014, 2015 and 2016

Appendix 2: Species list for: a. sites planted after 2013, b. sites planted after between 2010 and 2013, c. sites planted before 2007 and d. natural sites (*denotes exotic species, **denotes proclaimed pest plant in South Australia, # denotes listed as rare in South Australia).

a.

Site	**Hartnett's**				**Poltalloch**						**Wellington Lodge**		
Planting	**Control**		**Planted**		**Control**			**Planted**			**Planted**		
Year	**2015**	**2016**	**2015**	**2016**	**2014**	**2015**	**2016**	**2014**	**2015**	**2016**	**2014**	**2015**	**2016**
Taxon													
*Aster subulatus**	*	*			*								
Berula erecta							*						
Bolboschoenus caldwellii						*							
Calystegia sepium						*							
*Cenchrus clandestinus**	*	*	*	*	*	*	*	*	*	*		*	*
Centella asiatica		*											
Ceratophyllum demersum							*						
Chara sp.				*		*							
Cotula coronopifolia	*	*											
Crassula helmsii					*								
Cyperus gymnocaulos			*		*				*				
Distichlis distichophylla						*						*	
Duma florulenta					*	*			*				
Ficinia nodosa											*	*	
Isolepis producta	*	*											
Lilaeopsis polyantha					*								
Limosella australis	*	*											
Lobelia alata						*							
Ludwigia peploides		*											
*Lycium ferocissimum****						*							
Lythrum hyssopifolia		*											
Medicago spp.*		*			*								
Mimulus repens	*	*			*								
Myriophyllum salsugineum	*	*		*		*				*		*	
Myriophyllum verrucosum		*											
*Paspalum distichum**	*	*	*	*	*	*	*		*	*	*	*	*
Phragmites australis							*		*	*	*	*	*
*Polypogon monspeliensis**	*	*			*								
Potamogeton pectinatus			*										
*Ranunculus tribolus**		*											
*Riechardia tingitana**					*								
Rorippa nasturtium-aquaticum		*											
Rumex bidens	*	*							*			*	
Schoenoplectus pungens	*	*		*					*			*	
Schoenoplectus tabernaemontani			*										
Trifolium spp.*	*								*		*	*	
Triglochin procera	*	*											
Typha domingensis										*			
Total	**13**	**19**	**5**	**5**	**11**	**10**	**5**	**1**	**8**	**5**	**4**	**9**	**3**

b.

Site	**Lake Albert Road**								**Meningie Foreshore**								**Nurra Nurra Point**			
Planting	**Control**				**Planted**				**Control**				**Planted**				**Planted**			
Year	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**
Taxon																				
*Aster subulatus**				*				*					*	*	*	*				*
*Atriplex prostrata**											*									
Atriplex spp.													*				*			
Bolboschoenus caldwellii													*	*	*	*				
Brassica spp.*																	*			
Calystegia sepium													*	*	*	*	*		*	
*Cenchrus clandestinus**		*	*		*	*	*	*		*	*				*		*	*	*	*
*Centaurea calcitrapa**																	*			
Cotula coronopifolia													*			*	*			
Crassula helmsii						*														
Cyperus gymnocaulos			*	*									*	*	*					
Duma florulenta		*	*	*			*									*				
Eleocharis acuta													*		*	*				
*Festuca arundinacea**						*														
*Fumaria bastardii**													*							
Hydrocotyle verticillata															*					
*Hypochoeris glabra**					*															
Isolepis producta						*							*	*						
*Juncus acutus**						*								*	*					
Juncus kraussii					*		*	*							*	*				
Lachnagrostis filiformis							*								*	*				
Lilaeopsis polyantha						*														
Limosella australis																*				
Lobelia alata															*	*				
Medicago sp.*		*													*					
*Melilotus indicus**					*															
Mimulus repens		*	*	*	*								*	*	*	*			*	
Myriophyllum salsugineum					*															
Nitella spp.																			*	
*Oxalis pes-caprae***																	*			
*Paspalum distichum**	*	*	*	*	*	*			*	*	*	*	*	*	*	*	*		*	
Phragmites australis	*	*	*	*	*	*			*	*	*	*	*	*	*	*	*	*	*	*
*Plantago coronopus**					*								*							
*Polypogon monspeliensis**													*				*			
Potamogeton pectinatus					*														*	
*Ranunculus tribolus**													*		*	*				
Rumex bidens							*				*						*		*	
*Scaeveola atropuroura**													*							
Schoenoplectus pungens	*		*		*		*	*					*		*	*	*	*	*	*
Schoenoplectus tabernaemontani									*				*	*	*	*		*	*	*
*Silybum marianum***					*															
*Sonchus asper**																	*			
*Sonchus oleraceus**					*		*						*		*		*		*	
Trifolium spp.*					*								*	*	*		*		*	
Triglochin striatum																*				
Typha domingensis													*	*	*	*	*		*	*
Vallisneria australis					*															*
Total	**3**	**6**	**7**	**6**	**15**	**8**	**7**	**4**	**3**	**3**	**5**	**2**	**21**	**12**	**21**	**18**	**16**	**4**	**13**	**7**

c.

Site	**Dumandang**								**Nurra Nurra Point**								**Raukkan**								**Wellington Lodge**							
Planting	**Control**				**Planted**				**Control**				**Planted**				**Control**				**Planted**				**Control**				**Planted**			
Year	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	2015	2016
Taxon																																
_Apium graveolens_*			*				*					*																				
_Aster subulatus_*	*	*	*	*			*		*		*	*	*									*	*									
_Atriplex prostrata_*		*	*																						*							
Atriplex spp.													*																			
Azolla filiculoides							*	*													*	*	*	*	*					*	*	
Berula erecta																						*	*									
Bolboschoenus caldwellii						*							*								*	*	*									
Brassica spp.*																	*															
_Brassica tournifortii_*						*																										
Calystegia sepium			*	*							*				*	*							*	*						*	*	
_Cenchrus clandestinus_*					*	*	*		*	*	*	*	*	*	*		*	*	*	*	*	*	*		*	*	*		*	*	*	*
Centella asiatica			*				*					*									*	*										
_Centaurea calcitrapa_*	*	*							*																		*					
Ceratophyllum demersum#						*															*	*	*	*								
Chara sp.					*		*																									
_Conyza bonariensis_*							*																									
Cotula coronopifolia	*	*	*						*																							
Cyperus gymnocaulos		*					*											*			*		*		*				*		*	
Distichlis distichophylla																															*	
Duma florulenta					*	*	*																								*	
Epilobium pallidiflorum																					*											
Euphorbia terracina**											*																					
Ficinia nodosa																					*	*	*				*					
Helichrysum luteo-album									*																							
Hydrocotyle verticillata	*										*																					
_Hypochoeris radicata_*																					*	*										
Isolepis producta																									*							
_Juncus acutus_*	*					*	*																		*							
Juncus holoschoenus																									*							
Juncus kraussii					*			*														*										
Juncus subsecundus																									*							
Juncus usitatus																										*						
Lachnagrostis filiformis							*																									
_Lactuca serriola_*			*																													
_Lagurus ovatus_*																					*	*										
Lemna minor																					*	*		*								
Lilaeopsis polyantha																															*	
Limosella australis																									*							
Lobelia alata							*																									

Site	**Dumandang**								**Nurra Nurra Point**								**Raukkan**								**Wellington Lodge**							
Planting	**Control**				**Planted**				**Control**				**Planted**				**Control**				**Planted**				**Control**				**Planted**			
Year	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	**2015**	**2016**	**2013**	**2014**	2015	2016
Taxon																																
Lolium spp.*	*	*																														
Ludwigia peploides																							*									
*Lupinus cosentini**																															*	
Lycopus australis																														*		
Lythrum salicaria	*																															
*Malva parviflora**		*							*																							
Medicago spp.*		*																		*												
*Melilotus indicus**													*																			
Mimulus repens																															*	
Myriophyllum salsugineum							*	*	*										*		*				*	*			*	*	*	*
Nitella sp.							*																		*							
*Oxalis pes-caprae***									*				*																			
*Paspalum distichum**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*
Persicaria lapathifolia							*	*															*						*			
Phragmites australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
*Plantago coronopus**	*																								*							
*Polypogon monspeliensis**	*	*																														
Potamogeton crispus																														*	*	
*Ranunculus tribolus**							*																									
*Riechardia tingitana**		*									*																					
Runes bidens		*	*			*	*	*							*						*	*					*				*	
Ruppia tuberosa							*																									
Schoenoplectus pungens	*	*	*	*	*	*	*	*	*		*		*				*		*	*	*	*	*	*	*	*						
Schoenoplectus tabernaemontani	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*				*	*	*	*	*	*	*			*	*	*	*
*Senecio pterophorus**																					*											
*Solanum nigrum**			*																													
*Sonchus asper**	*		*				*				*																					
Sonchus oleraceus	*	*	*						*				*				*				*		*		*					*		
Tecticornia pergranulata	*																															
Trifolium spp.*	*		*			*	*		*		*		*								*	*	*				*				*	
Triglochin striatum							*																									
Typha domingensis	*		*	*		*	*	*	*	*	*	*	*	*	*	*					*	*	*	*					*	*	*	*
*Urtica urens**											*																					
Vallisneria australis																									*				*			
Wolffia sp.																							*									
Total	**18**	**16**	**17**	**7**	**8**	**13**	**26**	**10**	**15**	**5**	**14**	**8**	**13**	**5**	**7**	**5**	**5**	**4**	**4**	**6**	**21**	**19**	**19**	**9**	**18**	**7**	**7**	**1**	**9**	**11**	**17**	**6**

d.

Site	**Bremer Mouth**			**Hindmarsh Island Bridge**			**Loveday Bay**		
Year	**2014**	**2015**	**2016**	**2014**	**2015**	**2016**	**2014**	**2015**	**2016**
Taxon									
*Aster subulatus**		*					*	*	
Azolla filiculoides	*		*				*	*	*
Berula erecta	*						*	*	*
Bolboschoenus caldwellii								*	
*Brassica tournifortii**							*		
Calystegia sepium	*	*	*	*	*	*	*	*	*
Carex fascicularis									*
*Cenchrus clandestinus**	*	*	*			*		*	*
Centella asiatica	*		*						*
Ceratophyllum demersum#		*	*				*	*	*
Chara sp.								*	
Cyperus gymnocaulos	*								
Duma florulenta							*		
Eleocharis acuta	*		*						
Epilobium pallidiflorum	*							*	*
Ficinia nodosa		*				*		*	
Hydrocotyle verticillata	*						*		
Juncus holoschoenus			*				*		
Juncus kraussii			*						
Lachnagrostis filiformis		*							
*Lactuca serriola**	*								
*Lagurus ovatus**							*		
Lemna minor	*						*		*
Ludwigia peploides							*		
Lycopus australis	*	*	*					*	*
Lythrum hyssopifolia									*
Mentha australis							*		
Mentha sp.*	*	*	*	*	*	*		*	*
Myriophyllum salsugineum	*		*		*	*		*	*
*Paspalum distichum**	*	*	*	*	*	*	*	*	*
Persicaria lapathifolia	*	*	*				*	*	*
Phragmites australis	*	*	*	*	*	*	*	*	*
*Plantago lanceolata**						*			
Potamogeton crispus			*						
Potamogeton pectinatus							*		
*Ranunculus tribolus**		*					*	*	*
Rumex bidens	*							*	
*Scaevola atropurpurea**						*			
Schoenoplectus pungens	*	*	*				*		
Schoenoplectus tabernaemontani	*	*	*	*	*	*	*	*	*
*Senecio pterophorus**						*			
Trifolium spp.*			*				*	*	
Triglochin procera									*
Typha domingensis	*	*	*	*	*	*	*	*	*
*Urtica urens**		*						*	
Vallisneria australis	*	*	*						*
Wolffia sp.								*	
Total	**22**	**17**	**20**	**6**	**7**	**12**	**22**	**23**	**21**