CTENVIRONMENTAL

Horning Street Saltmarsh Revegetation Project 2014/15 Annual Report

Prepared for Sutherland Shire Council

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Item	Detail
Project Name	Horning Street Saltmarsh Revegetation Project – 2014/15 Annual Report
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Executive summary

In 2012 Horning Street saltmarsh (the Site) was selected for revegetation as part of the environmental offset required by the Captain Cook Drive widening project at Woolooware Bay. A revegetation plan was developed and baseline monitoring was undertaken in April 2013 to assess the condition of the ecological community prior to revegetation.

Following recommendations outlined by the baseline study, monitoring of the saltmarsh community was undertaken at three month intervals commencing in September 2013 and continuing through to June 2015.

Comparison between survey plot categories was undertaken with data collected throughout the 2014/15 monitoring period and comparison of baseline condition was made with data collected in winter 2015 (2.5 years after revegetation).

Results from the 2014/15 monitoring period show:

- Natural regeneration of *Sarcocornia quinqueflora* within survey plots was the highest recorded since monitoring commenced in 2013.
- Comparison of high reference plots to high control and high treatment plots showed significance differences in vegetation cover was evident. No difference was evident in the comparison of high treatment and high control plots.
- Due to the high degree of variation of vegetation cover within low survey plots no significant differences were evident.
- Historical comparison showed significant change in vegetation cover had occurred at high treatment and high control plots. Change across all other plot categories was not significant.
- The comparison of summer 2014 crab burrow abundance showed significant differences were evident between high reference plots and high control and high treatment plots. Crab burrow abundance did not vary significantly for all other plot categories nor was variation evident with the comparison to baseline data.
- Gastropod abundance was variable over time and a declining trend can be seen at low reference plots. Results from winter 2015 show significant difference in abundance between high reference plots and high control and treatment plots however abundance did not vary significantly for all other plot categories nor was variation evident with comparison to baseline data.
- The comparison of ecological community structure between the baseline survey and winter 2015 survey (2.5 years after revegetation) found community structure had not changed at high reference plots however change was evident for high treatment plots and high control plots. This trend was reversed for low plots with change occurring to community structure of low reference plots and no significant change evident for low control and low treatment plots.

Primary recommendations of this report are:

1. Scale back seasonal monitoring of the vegetation community to winter and summer only and continue with the monitoring of crab burrow and gastropod abundance. It is well documented saltmarsh rehabilitation is a relatively new concept in Australia and many projects go undocumented. Most restoration projects monitor for the short term, with

many projects recording success in the short term only to fail some years after the restoration works. Continued monitoring and reporting will contribute valuable information to land managers considering similar projects.

2. In consultation with Nerida Gill (GSLLS) it is recommended that future monitoring includes measuring gastropod shell length. Collection of this data will enable an investigation of the distribution of adult and juvenile snails and will provide evidence that the site is capable of supporting breeding populations of gastropods.
3. It is recommended steel posts erected around survey plots to deter motorbikes be removed. Only one incident of bicycle riding through the site was recorded for the 2014/15 monitoring period and therefore these posts are no longer required to protect plots.
4. It is recommended the makeshift fence erected at the end of the Tasman St. fence line be maintained to further deter motorbikes and bicycles from entering the site.

The purpose of this report is to detail the results of 2014/15 monitoring, and make comparison to baseline conditions to assess the scale of recovery of the saltmarsh community 2.5 years after revegetation of the Site.

1. Introduction

The assessment of the coastal saltmarsh community of Horning Street Saltmarsh (the Site), Kurnell, NSW, was conducted by CTENVIRONMENTAL between June 2014 and June 2015. This assessment was undertaken as part of an ongoing program to monitor change in the saltmarsh community after the Site was revegetated as part of a NSW Fisheries offset strategy associated with the widening of Captain Cook Drive on the Woolooware Bay (Sutherland Shire Council 2012).

Due to past degradation and the potential for rehabilitation, the Site was selected to offset vegetation removed by road widening activities along Captain Cook Drive. As a result, 17,000 m^2 of coastal saltmarsh and mangroves at the Site were designated for protection and revegetation. Additional on-ground works were outlined in the offset strategy which included the removal of rubbish and asbestos, fencing off entry points to restrict illegal vehicle entry and weed removal.

Central to the offset strategy was the revegetation of the Site with locally indigenous saltmarsh species. In 2012 a revegetation plan was developed by Associate Professor Paul Adam and Jacinta Green of University of New South Wales and CTENVIRONMENTAL (CTENVIRONMENTAL 2013). Revegetation of the site commenced in early 2013 and was completed in May/June 2013 (see CTENVIRONMENTAL (2013) for detailed methodology).

Ongoing seasonal monitoring has shown slight increases in vegetation cover across the site, however to date this has not been significant. The majority of revegetation recorded and observed was attributed to *Sarcocornia quinqueflora*, which appears as the species most successful at revegetating and recolonising the site. Results of monitoring over the 2013/14 period showed the *Sporobolis virginicus* used to revegetate the site suffered significant mortality.

It is expected that the planting and continued protection of the Site will enhance the biodiversity of the coastal saltmarsh and promote re-colonisation of intertidal invertebrates such as burrowing crabs and gastropods which will have the likely outcome of increasing productivity of the Site. The productivity of saltmarsh has been highlighted by a number of studies in the Kurnell area which intrinsically link crab and gastropod larvae with commercially important fish species (Mazumder et al, 2006, 2008 and 2011).

1.1 Study Area

Horning Street Saltmarsh is located within the north western tip of the Kurnell Peninsular, NSW, and covers an area of 2.9 hectares (Figure 1 and Figure 2). Surrounding landuse includes light industrial and residential and a large expanse of mangroves connects the Site to the 600 hectare RAMSAR listed Towra Point Nature Reserve (DSEWPC, 2012).

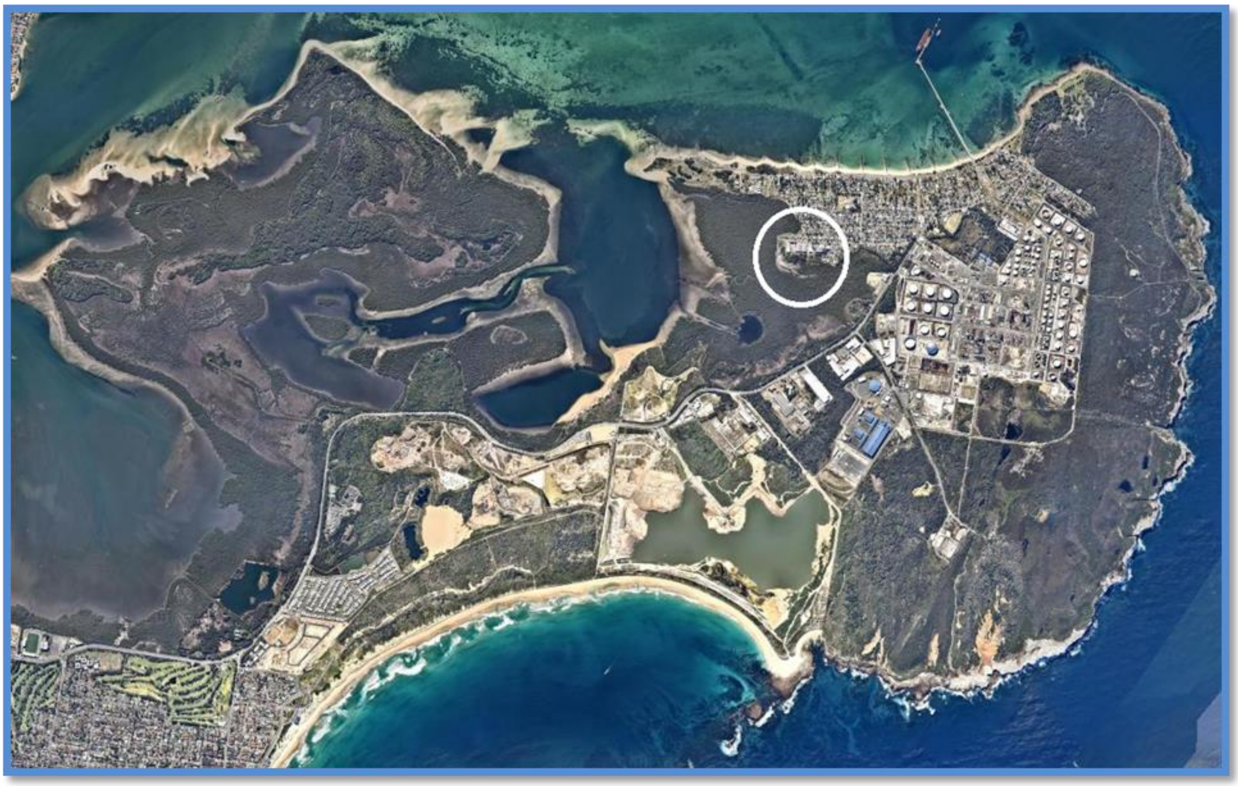

Figure 1. Aerial photo of Kurnell Peninsular taken August 11, 2015. Location of Horning St. Saltmarsh circled in white. Source: Near Map 2015.

Figure 2. Aerial photo of Horning St. Saltmarsh taken August 11, 2015. Source: Nearmap 2015.

Prior to revegetation the Site had a history of neglect and was frequently used to dump vehicles, rubbish and building materials. In addition illegal vehicle use had resulted in significant damage to the saltmarsh community and adjoining remnant bushland patches were dominated by invasive weed species (SSC, 2012, personal observation 2013).

A mosaic of vegetation communities are found at the Site with the most dominant being mangroves characterised by Grey Mangrove (*Avicennia marina var. australasica*) with the occasional River Mangrove (*Aegieceras corniculatum*) occurring in lower lying patches of open mudflats (SSC 2012 and personal observation). Remnant patches of swamp oak floodplain forest dominated by Swamp Oak (*Casuarina glauca*) are established on the landward side of mangroves. The Swamp Oak Floodplain Forest community merges into areas of Littoral Rainforest at slightly higher elevations. The Littoral Rainforest community includes less common species such as Tuckeroo (*Cupaniopsis anacardioides*), Guioa (*Guioa semiglauca*) and Cockspur Thorn (*Maclura cochinchinensis*).

Since 2012 contract bush regeneration teams have worked to clear invasive species from remnant swamp oak flood plain forest and littoral rainforest communities. It has been observed since 2012 the condition of these remnant patches have improved and in many places natural regeneration of understory and canopy species has occurred. Most noticeable is the regrowth of *Causarina glauca* at the Horning Street entrance of the site which now presents as a thick barrier of fringing vegetation to the saltmarsh.

1.2 Site Revegetation

Revegetation of the saltmarsh community commenced at the Site in late 2012. Prior to revegetation, isolated patches of saltmarsh remained scattered throughout the site however these were disconnected from other patches and were predominantly restricted to fringes of the upper tidal limit. Saltmarsh species recorded at the Site prior to revegetation included Sea Rush (*Juncus krausii*), Austral Seablite (*Suaeda australis*), Samphire (*Sarcocornia quinqueflora*), Creeping Brookweed (*Samolus repens*), Knobby Club Rush (*Ficinia nodosa*) and Salt Couch (*Sprorobolus virginicus*) (SSC 2012).

In 2012 a revegetation plan was developed by Associate Professor Paul Adam and Jacinta Green of University of New South Wales and CTENVIRONMENTAL (CTENVIRONMENTAL 2013). Revegetation of the site commenced in early 2013 and was completed in May/June 2013 (see CTENVIRONMENTAL (2013) for detailed methodology).

14,000 seedlings of a variety of species were provided for revegetation of the Site (Table 1). Seedlings were of local providence and salt hardened by receiving 600mg/L salt solution for two weeks followed by 1250mg/L salt solution for one week in a nursery prior to planting. *Sarcocornia quinqueflora* and *Sporobolus virginicus* were used to revegetate survey plots with remaining species planted in larger patches across the Site.

Table 1. Saltmarsh plant species and number of seedlings supplied for revegetation of the Site.

Species	Number of seedlings
Baumea juncea	200
Ficinia nodosa	3,500
Juncus krausii	3,500
Samolus repens	300
Sarcocornia quinqueflora	2,500
Suaeda australis	1,500
Sporobolus virginicus	2,500
Total	14,000

Results of monitoring across the 2012 – 2014 period has shown slight increases in vegetation cover across the site, however to date this has not been significant. The majority of revegetation seen across the Site has been attributed to *Sarcocornia quinqueflora*, which appears as the species most successful at revegetating and recolonising the site. *Sporobolis virginicus* used to revegetate the site has suffered significant mortality (CTENVIRONMENTAL 2014) (Figure 3).

Figure 3. Low revegetation plot showing alternate planting pattern. Bare patches indicate failure of *S. virginicus* to survive revegetation. Photo taken June 2015.

1.3 Baseline and Seasonal Surveys

A baseline survey of the ecological community at the Site prior to the commencement of revegetation was undertaken by CTENVIRONMENTAL in 2013. This was followed up by seasonal monitoring of vegetation cover (i.e. spring, summer, autumn, winter) and twice yearly (summer and winter) monitoring of crab burrow and Gastropod abundance.

Crab burrow abundance is a reliable surrogate of crab numbers and is commonly used in studies of saltmarsh crab populations. Survey of crab burrow abundance offers a non-destructive sampling technique which minimises site disturbance during sampling (Kelleway, 2006, Mazumder et al 2006, McFarlane 2010 and Warren 1990). The link between crab abundance and the function of the saltmarsh ecosystem is important as there is a direct trophic link between crab zoeae and itinerant fish species that feed in saltmarsh in periods of inundation (Mazumder et al, 2006).

Figure 4. Active crab holes found across the Site. Photo taken June 2015.

Gastropods (snails) *Phallomedusa solida* (formerly *Salinator solida*) and *Ophicardelus spp*. (Figure 5) are common taxa which have been previously studied in saltmarsh communities of the Georges River and Towra Point (Green et al 2009, Kelleway 2006). Gastropods have also been shown to be an important food source for fish and wading birds (Freewater et al 2007) and sampling of gastropods in saltmarsh communities is commonly used to understand trophic relationships and habitat associations (Kaly 1988, Buck et al 2003, Green, J et al 2009).

Figure 5. Gastropods (snails) *Phallomedusa solida* (formerly *Salinator solida*) (left) and *Ophicardelus spp*. (right).

The monitoring program was established to document baseline conditions for which future comparisons could be made and to enable a long term understanding of how the plant and invertebrate communities at the Site respond to revegetation.

Results from baseline monitoring and 2013/14 annual monitoring are found in "Horning Street Saltmarsh Revegetation Project: Baseline Survey, 2013" (CTENVIRONMENTAL 2013) and

"Horning Street Saltmarsh Revegetation Project – Annual Report 2013/14" (CTENVIRONMENTAL 2014). Comparison with historical data is made in the current study.

2. Method

2.1 Annual Monitoring Program

2.1.1 Survey Plot Locations

117 survey plot locations were identified by the revegetation plan (CTENVIRONMENTAL 2013). Plots were categorised by height (high >0.65 m AHD or low <0.65 m AHD) (Figure 6) and as Reference (> 10% existing vegetation), Control (< 10% existing condition and not revegetated) and Treatment (revegetated) (Table 2).

Table 2. Number of survey plots allocated to plot categories across the Site.

Plot Category	High	Low
Reference	17	27
Control	14	25
Treatment	25	9

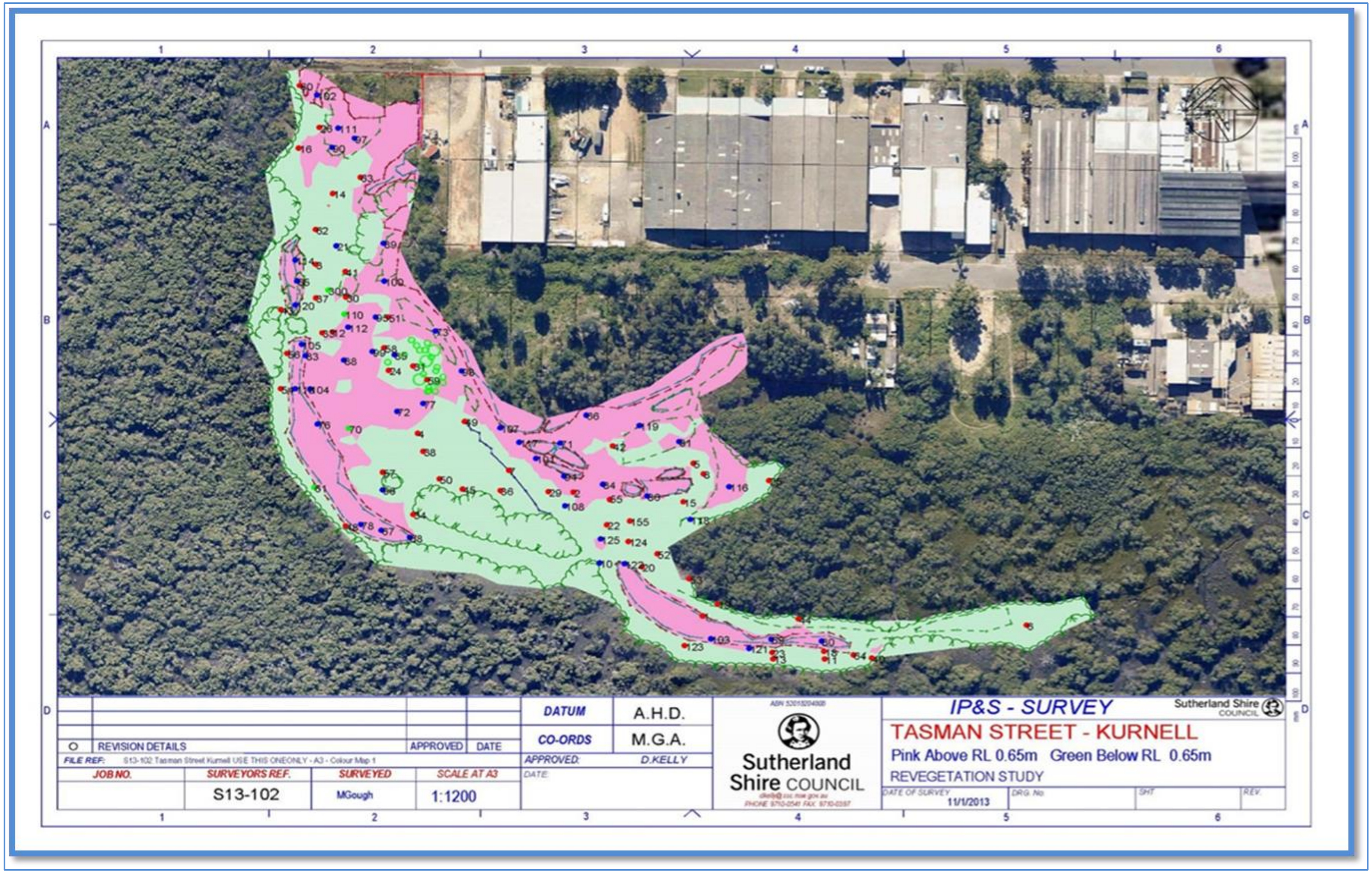

Figure 6. Aerial photograph of the Site displaying locations of high (blue) and low (red) survey plots. (SSC 2013)

2.2 Saltmarsh Vegetation and Invertebrate Survey

During the 2014/15 monitoring period the saltmarsh vegetation community was surveyed at three monthly intervals in September 2014 (spring), January 2015 (summer), April 2015 (autumn) and June 2015 (winter). In addition crab burrow abundance and Gastropod abundance was surveyed in January 2015 (summer) and June 2015 (winter).

The following methods were applied to monitoring the saltmarsh community throughout the 2014/15 monitoring period.

2.2.1 Vegetation

To survey saltmarsh vegetation cover and dominant species, a minimum of five plots from each plot category were randomly selected and surveyed. Percentage vegetation cover and dominant saltmarsh species were recorded along four transects at 90° intervals around each circular plot and mean vegetation cover for each plot calculated. In addition the presence of naturally germinated seedlings and dominant species was noted.

2.2.2 Invertebrates

To survey macroinvertebrate abundance, a 50 cm x 50 cm quadrat was randomly placed in each survey plot (Figure 7) and the number of crab burrows and abundance of Gastropods *Ophicardelus spp*. and *Phallomedusa solida* recorded. No specimens were removed from survey plots.

The field guide Seashells of South East Australia (Jansen 2000) was used for field identification of Gastropods, however due to the difficulty of absolute species determination of *Ophicardelus ornatus* and *Ophicardelus sulcatus* in the field (Green et al 2009), *Ophicardelus spp*. is used to describe the abundance of these species.

Figure 7. High reference category survey plot with 600 mm survey stake as centre point and 50 cm x 50 cm invertebrate survey quadrant. Photo taken June 2015.

2.2.3 Photo Points

To record changes in vegetation cover across the site over time, aerial photos taken from Near map and panoramic photographs taken from a fixed point at the eastern edge of the Site since prior to revegetation until June 2015 were used.

2.3 Statistical Analysis

For univariate analysis the abundance of *Phallomedusa solida* and *Ophicardelus spp*. were combined for total gastropod abundance. Mean and standard deviation was calculated for percentage vegetation cover, dominant saltmarsh species cover and crab burrow and gastropod abundance.

A one-factor analysis of variance (ANOVA) and pairwise *t*-tests assuming unequal variance was used to investigate whether saltmarsh biotic indices (percentage cover, crab burrow abundance and gastropod abundance) varied according to plot categories (reference, treatment and control) and over time (baseline and winter 2015) for high and low elevation plots.

The software package PRIMER5 (Clarke and Warwick 2001) was used to perform multivariate analysis to assess and compare saltmarsh community structure between the three plot categories (reference, treatment and control) for high and low elevation plots and over time (reference and winter 2015).

Multivariate analysis has been demonstrated to be a powerful and useful approach to evaluate the condition of a wide variety of ecological communities (e.g. Marchant et al. 1994; Wright et al. 1995). To assess dissimilarity between sampling plots, Bray–Curtis dissimilarity procedure was performed on fourth root transformed saltmarsh community data. Clarke and Warwick (2001) recommend using Bray–Curtis dissimilarity in ecological studies, as this is not affected by absences and gives more weight to abundance in comparing communities.

Non-metric multidimensional scaling (NMDS) was performed on the similarity matrix. Data were grouped by plot categories (high reference, treatment and control and low reference, treatment and control and baseline and winter 2015) and two-dimensional NMDS ordination plots were generated to give a representation of the dissimilarity among survey plots.

ANOSIM analysis (Clarke 1993) was used to test for significance between saltmarsh community structure across survey plot categories and between the baseline survey and winter 2015, 2.5 years after revegetation of the Site.

3. Results

3.1 Observational Comparison

Observation comparison of Nearmap aerial images (Figure 8 and Figure 9) and panoramic photographs (Figures 10 – 13) show noticeable change in the visual condition of the Site throughout the period November 2012 to June 2015.

Figure 8 shows an aerial image of the site taken in October 24 2012, prior to the commencement of revegetation. Deep vehicle wheel ruts and scattered hard rubbish are visible and saltmarsh vegetation across the open mudflat area appears patchy and fragmented. Figure 9, taken on August 11 2015, shows significant increase in the coverage of saltmarsh vegetation across the once bare mudflat area. Additionally wheel ruts are no longer visible and vegetation canopy cover within the northern extent of the Site appears thicker.

Figure 8. Aerial image of the Site taken 24 October 2012, prior to revegetation of the Site. Source: Nearmap

Figure 9. Aerial image of the Site taken 11 August 2015, approximately 2.5 years after revegetation of the Site. Source: Nearmap

Panoramic photographs taken from a fixed location on the western edge of the Site show incremental change over the period November 2012 to June 2015. Deep scarring caused by wheel ruts has disappeared and saltmarsh planted in survey plots and randomly across the Site has spread and formed larger patches (Figures 10-13).

Figure 10. Panoramic photograph of Site. Taken November 2012 prior to the commencement of site revegetation works.

Figure 11. Panoramic photograph of Site. Taken June 2014 approximately one year after revegetation works.

Figure 12. Panoramic photograph of Site. Taken January 2015 approximately two years after revegetation works.

Figure 13. Panoramic photograph of Site. Taken June 2015 approximately 2.5 years after revegetation works.

3.2 Vegetation cover

Results of seasonal monitoring of the vegetation community across the Site show dominant vegetation species and the matrix of species composition varied according to the category of elevation. Low survey plots were dominated by *Sarcocornia quinqueflora* and due to the high mortality of *Sporobolis virginicus* seedlings recorded during the 2013/14 survey period (CTENVIRONMENTAL 2014) few low survey plots were observed as containing a thriving population of this species.

In contrast high survey plots were found to contain a more complex vegetation matrix with plots dominated by *Juncus krausii* and *Sarcocornia quinqueflora* and interspersed with *Sporobolus virginicus* and *Suaeda australensis*.

Throughout the monitoring period natural regeneration of Sarcocornia quinqueflora has continued to increase across the Site. At the time of the most recent survey (winter 2015) natural regeneration of this species was observed across most of the Site with prolific regrowth in areas adjacent to moisture retaining channels (Figure 14).

Figure 14. Natural regeneration of Sarcocornia quinqueflora observed across lower lying areas of the Site. Photo taken June 2015.

Seasonal fluctuation in the regeneration of *Sarcocornia quinqueflora* since the baseline survey in spring 2013 through to spring 2014 (Figure 15). After this time an increasing trend in natural regeneration across both high and low survey plots has been recorded. The maximum total number of plots with natural regeneration was recorded during the most recent survey (winter 2015) with 16 of 30 survey plots having naturally occurring regeneration of *Sarcocornia quinqueflora*. Eleven of these were in high survey plots and five were in low plots (Figure 15).

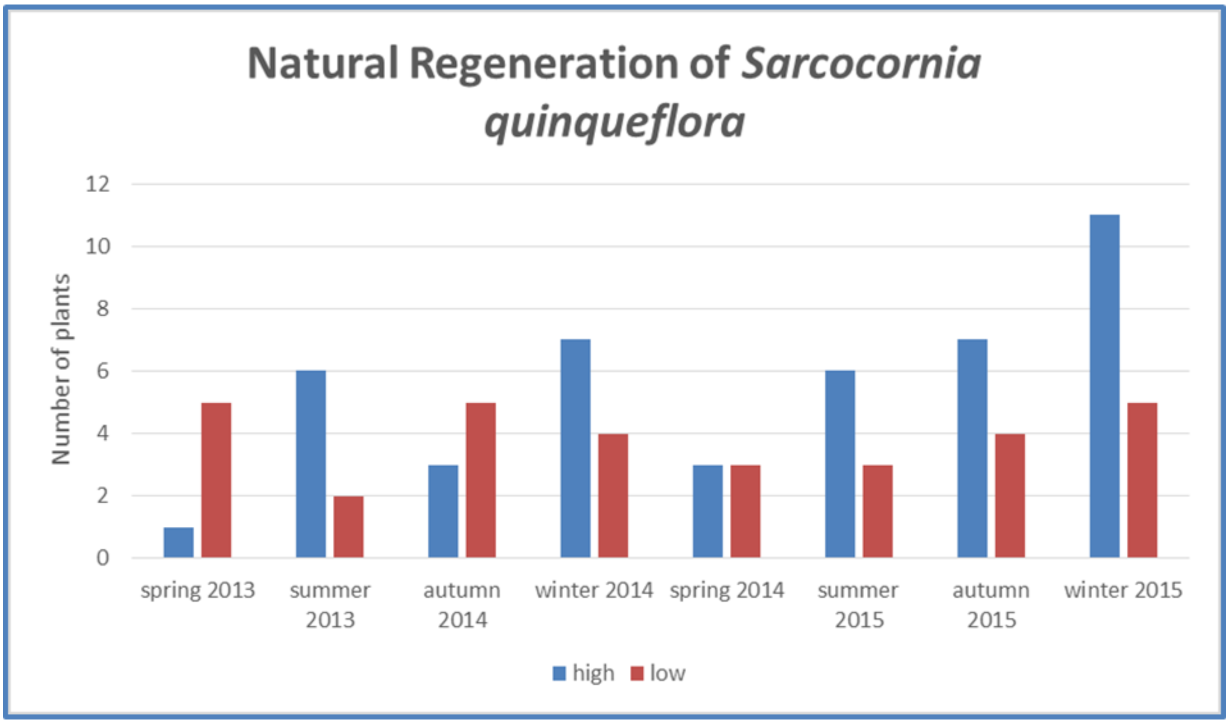

Figure 15. Natural regeneration of Sarcocornia quinqueflora recorded across high and low survey plots since commencement of seasonal monitoring in spring 2013.

Seasonal vegetation monitoring of high survey plots throughout the 2014/2015 monitoring period showed mean percentage of vegetation cover at high reference plots remained relatively constant since baseline monitoring. However the comparison of mean vegetation cover at high control and treatment plots show an increase when compared to baseline (Figure 16).

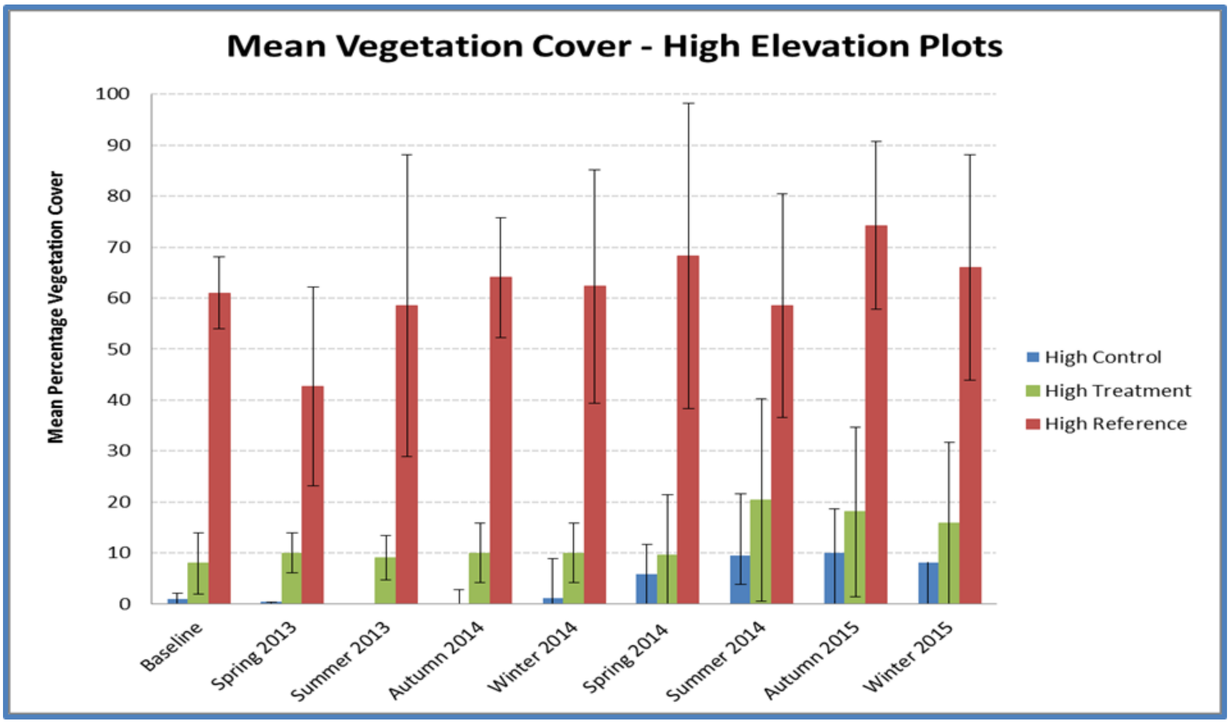

Figure 16. Mean vegetation cover (+/- 1 S.D) of high survey plots recorded during 2013 baseline monitoring and 2013/14 and 2014/15 monitoring periods.

Statistical analysis by one way ANOVA of vegetation cover in winter 2015 (2.5 years after the revegetation of the Site) shows significant difference (F (2, 12) = 17, p= <0.05) in cover was evident between high survey plot categories. Pairwise comparison show significant differences in vegetation cover between high reference plots and high control plots (t(8)=5.29, p=<0.05) and high treatment plots and high references plots (t(8)=3.7, p=<0.05). However difference in vegetation cover between high control plots and high treatment plots was not significant.

Pairwise comparison of baseline conditions with results from winter 2015 showed no significant change in vegetation cover at high treatment at high reference plots (t(8)=0.69, p=0.69). In contrast change in vegetation cover at high treatment plots was significant (t(8)=2.10, p=<0.05) as was change at control plots (t(8)=2.30, p=0.06) (p values of <0.05 are statistically significant however a p value of 0.06 may be considered as significant as it is marginally outside 0.05)).

Seasonal monitoring of low survey plots throughout the 2014/2015 monitoring period show a slight increase in vegetation cover of reference and control plots and fluctuation in the cover of treatment plots (Figure 16). Comparison of baseline condition with winter 2015 (2.5 years after revegetation) shows mean vegetation cover of treatment and control plots increased and mean cover of reference plots remained lower than baseline (Figure 17)

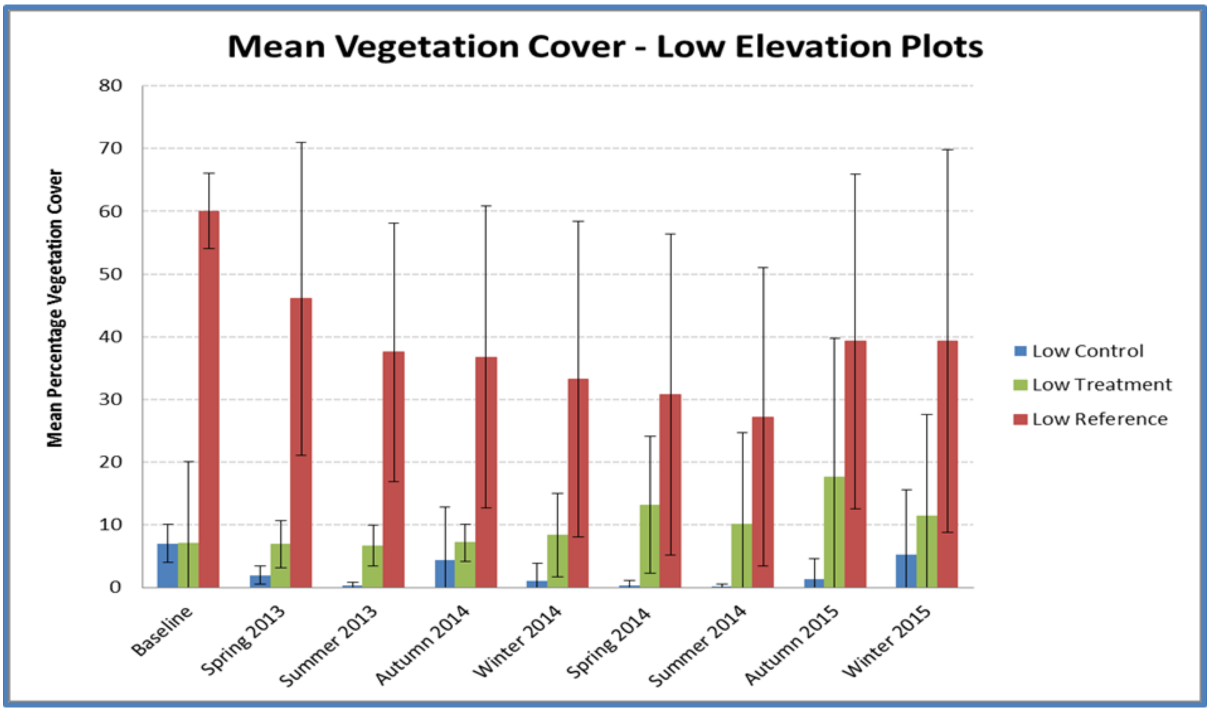

Figure 17. Mean vegetation cover (+/- 1 S.D) of low survey plots recorded during 2013 baseline monitoring and 2013/14 and 2014/15 monitoring periods.

Statistical analysis by one way ANOVA of vegetation cover 2.5 years after the revegetation of the Site (winter 2015) shows no significant difference in cover was evident between low survey plot categories. This result is confirmed by the high degree of error across plot categories as indicated by the large error bars shown in Figure 17.

Pairwise comparison of baseline conditions with results from winter 2015 (2.5 years after revegetation) showed no significant change in vegetation cover was evident at low control, low treatment and low reference plots.

3.3 Crab Burrow Abundance

Results from winter 2015 show marginal changes in mean crab burrow abundance across all high plot categories when compared to baseline condition. High reference plots were found to have the highest mean abundance in both summer 2014 and winter 2015 survey periods (Figure 18). Mean abundance at high reference and treatment plots were slightly lower than baseline condition while mean abundance at control plots was slightly higher than baseline. The highest mean abundance since monitoring commenced of 5.8 +/- 3/1 burrows was recorded in summer 2014 (Figure 18).

Statistical comparison by one-way ANOVA showed no difference in abundance was evident between plot categories in winter 2015 (2.5 years after revegetation). In addition pairwise comparison of results from winter 2015 (2.5 years after revegetation) and baseline showed no significant difference for all high plot categories.

In contrast, statistical analysis by one way ANOVA showed differences in abundance was significant across plot categories surveyed in summer 2014 ($F(2, 12) = 14.5$, $p = <0.05$). Pair wise comparison of these results showed this difference was evident between high control and high reference plots ($t(8)=3.4$, $p=<0.05$) and high treatment and high reference plots ($t(8)=3.5$, $p=<0.05$). Difference in abundance between high control and high treatment plots was not significant.

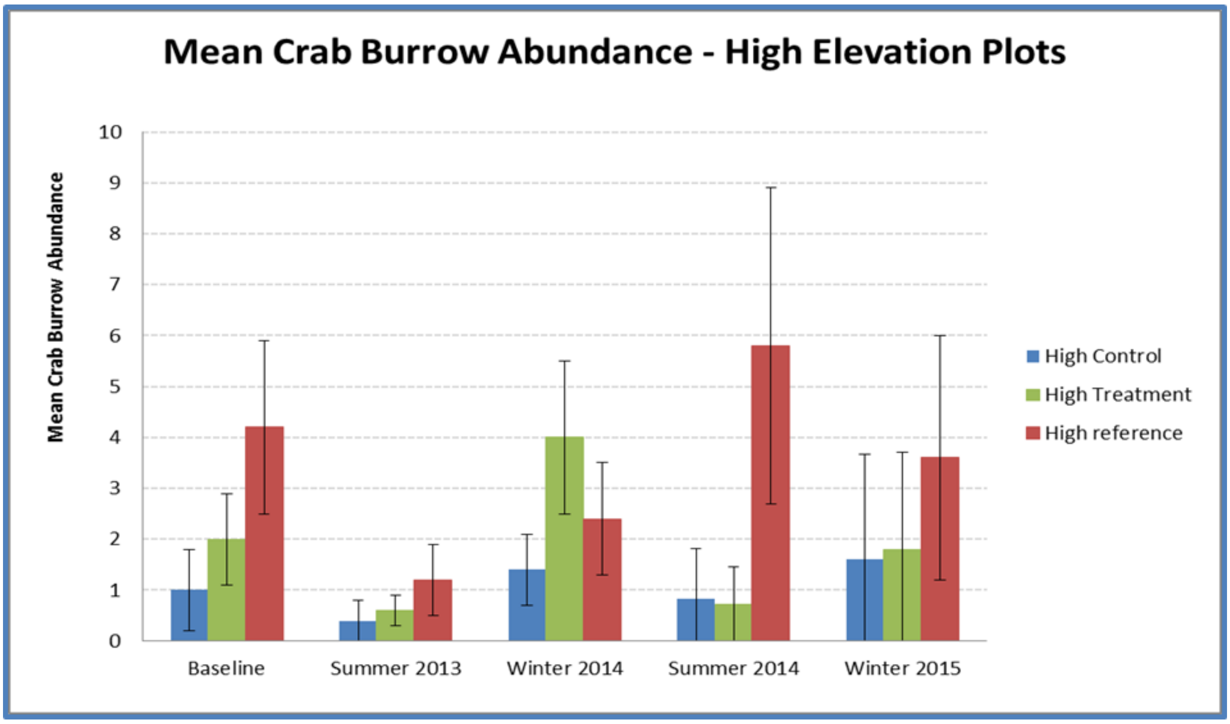

Figure 18. Mean crab burrow abundance (+/- 1 S.D) of high survey plots recorded during 2013 baseline monitoring and 2013/14 and 2014/15 monitoring periods.

Results of monitoring mean crab burrow abundance at low plot categories shows marginal change in abundance recorded at low reference plots since the baseline survey. However a decline in abundance has been recorded at low treatment and low control sites since winter 2014 (Figure 19).

Although declines are evident, statistical analysis by one way ANOVA revealed no significant difference in abundance was between plot categories in both summer 2013 and winter 2014.

Comparison of results from winter 2015 (2.5 years after revegetation) to baseline condition show very similar mean abundance for all plot categories (Figure 19) and pairwise comparison shows change in crab burrow abundance was not statistically significant for all low plot categories. A result which is confirmed by the high degree of error across plot categories as indicated by the large error bars shown in Figure 19.

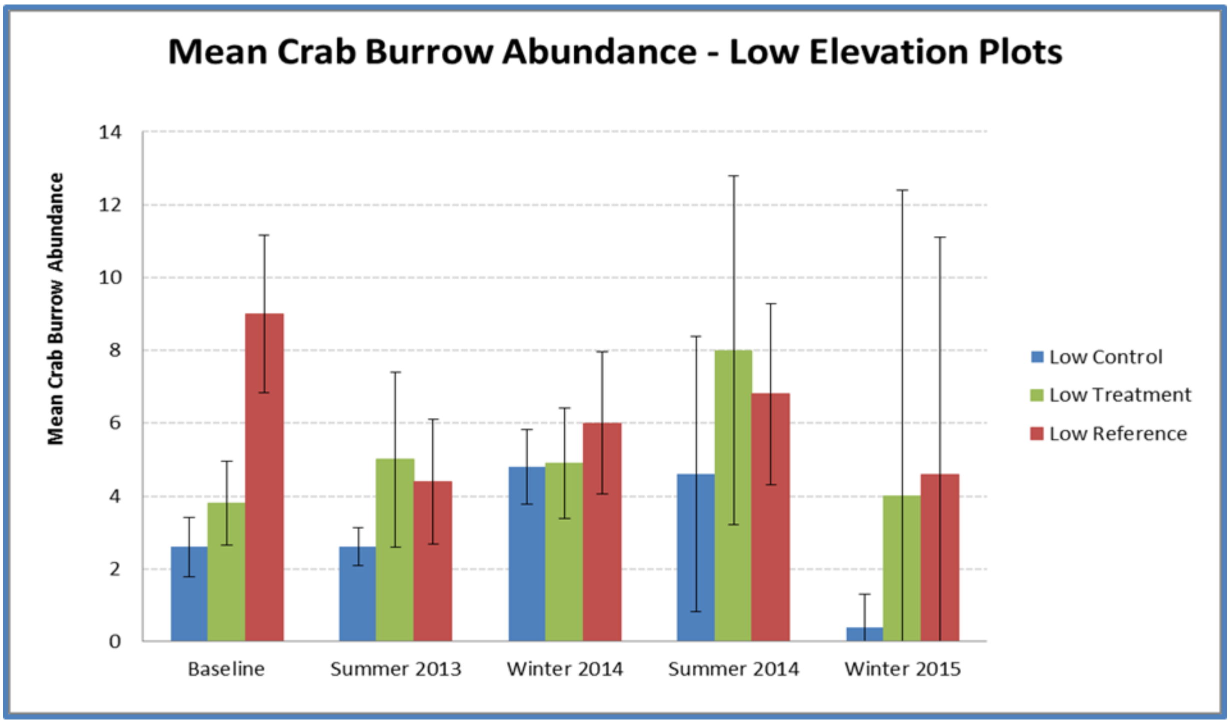

Figure 19. Mean crab burrow abundance (+/- 1 S.D) of low survey plots recorded during 2013 baseline monitoring and 2013/14 and 2014/15 monitoring periods.

3.4 **Gastropod Abundance**

A total of 255 gastropods were recorded throughout the 2014/2015 monitoring period with 205 recorded in summer 2014 and 150 in winter 2015. Of these *Ophicardelus spp*. was most abundant with 150 recorded in summer 2014 and 102 recorded in winter 2015. *Ophicardelus spp*. was found to favour high survey plots with only six individuals recorded in low plots in summer 2014 and 25 in winter 2015.

Fifty *Phallomedusa solida* were recorded in summer 2014 and 48 in winter 2015. This species was found to favour low plots with only six recorded in high plots in summer 2014 and 15 in winter 2015.

Results from summer 2014 and winter 2015 monitoring show the highest mean Gastropod abundance recorded since monitoring commenced. 31 +/- 26 specimens were recorded in summer 2014 and 19+/-25 during winter 2015. In contrast Gastropods were recorded as being absent from high treatment plots and control plots in both summer 2014 and winter 2015 (Figure 20)

Statistical analysis by one way ANOVA showed significant variation in abundance was evident between high plot categories in summer 2014 ($F (2,9) = 4.5$, $p= <0.05$) however variation in abundance was not significant in winter 2015. This result is reflected by the large standard deviation indicated by error bars seen in Figure 20.

Pairwise comparison of results from summer 2014 show a marginal significant difference in mean abundance between reference plots and both treatment plots ($t(4)=2.6$, $p=<0.06$) and control plots ($t(4)=2.6$, $p=<0.06$) (p values of <0.05 are statistically significant however a p value of 0.06 may be considered as significant as it is marginally outside 0.05)).

Pairwise comparison of baseline and winter 2015 (2.5 years after revegetation) surveys show no significant change in Gastropod abundance for all high plot categories.

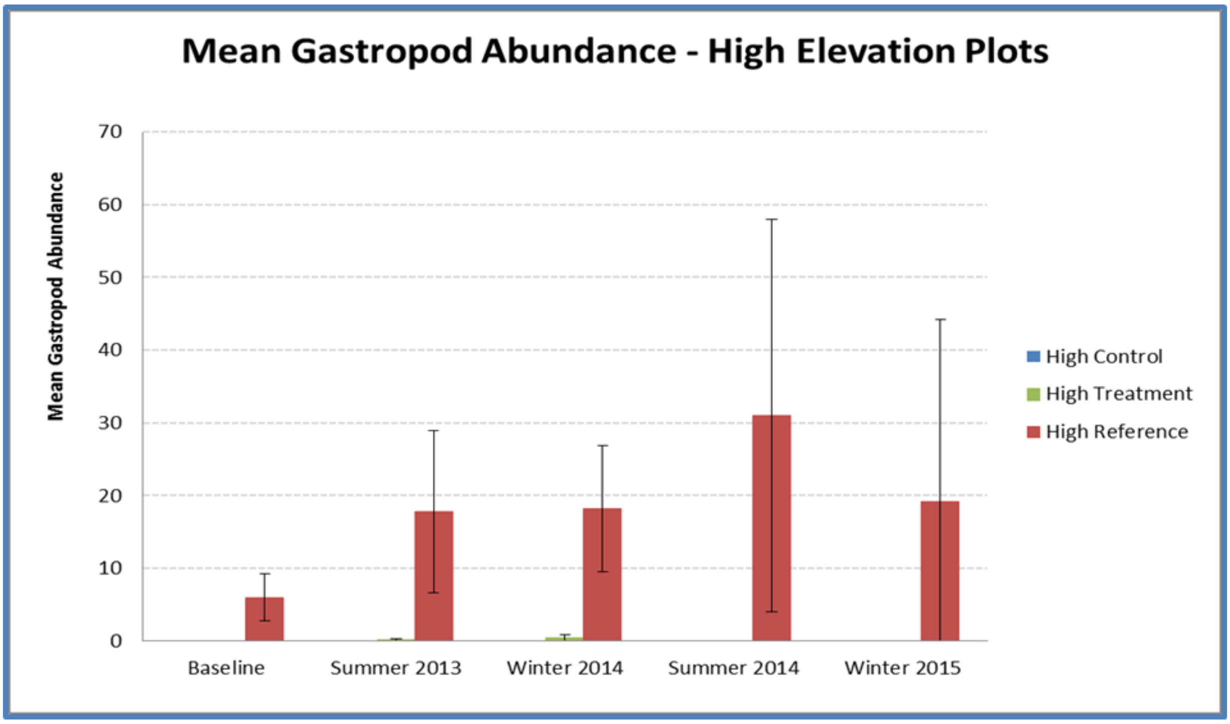

Figure 20. Mean Gastropod abundance (+/- 1 S.D) of high survey plots recorded during 2013 baseline monitoring, 2013/14 and 2014/15 monitoring periods.

Mean Gastropod abundance recorded during summer 2014 and winter 2015 at low reference plots were found to be the lowest since monitoring commenced with 4+/-10 specimens recorded during summer 2014 and 3+/-4 in winter 2015. In contrast the highest mean abundance for low control plots of 7+/-6 specimens was recorded in summer 2014 (Figure 21).

Statistical analysis by one way ANOVA revealed no significant variation in abundance was evident between low plot categories in both summer 2014 and winter 2015. In addition pairwise comparison of baseline results to winter 2015 (2.5 years after revegetation) show no significant change in abundance has occurred over time.

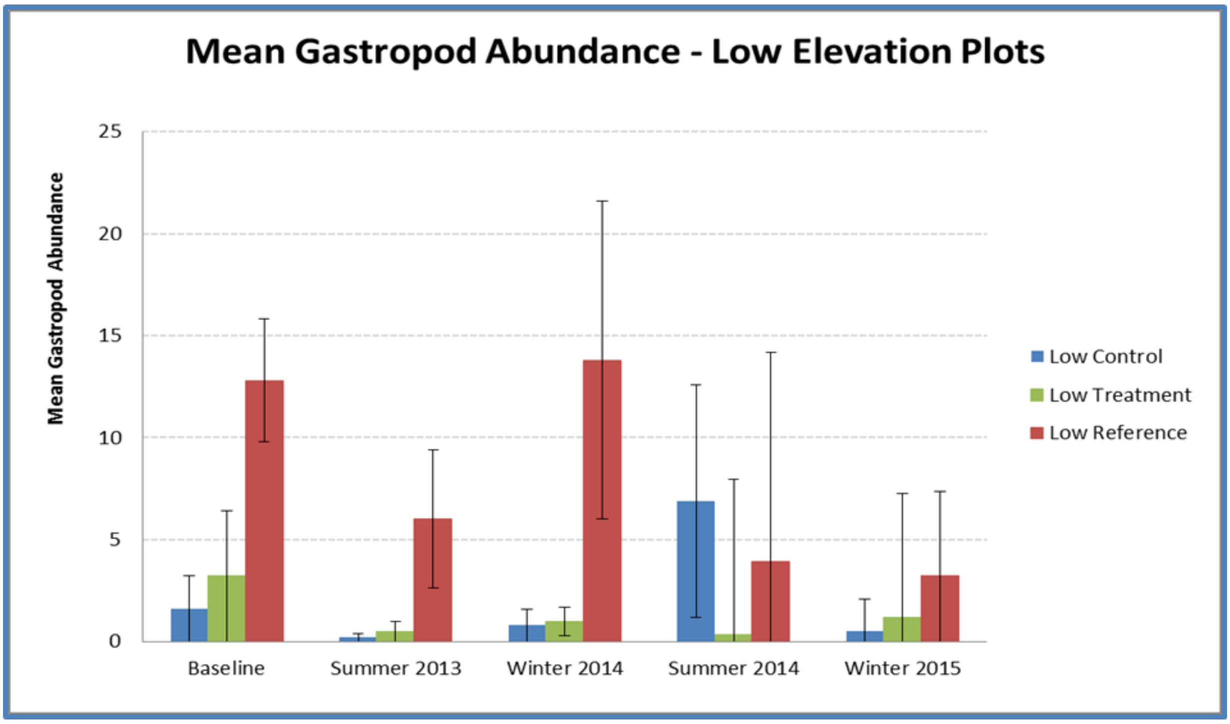

Figure 21. Mean Gastropod abundance (+/- 1 S.D) of low survey plots recorded during 2013 baseline monitoring, 2013/14 and 2014/15 monitoring periods.

3.5 Ecological Community Structure

Multivariate analysis of the saltmarsh community structure at high plots (vegetation cover, crab burrow and gastropod abundance) in winter 2015 (2.5 years after revegetation) revealed differences in community structure were evident. The nMDS plot in Figure 22 shows high reference plots (blue stars) clustering separate from high treatment (yellow triangles) and control plots (green crosses), however high treatment and high control plots share some degree of overlap.

Analysis by one-factor ANOSIM confirms these results with highly significant differences in saltmarsh community structure between high control and high reference plots ($R=0.989$, $p=<0.05$) and high reference and high treatment plots ($R=0.968$, $p=<0.05$). However no difference was evident between high control and high treatment plots.

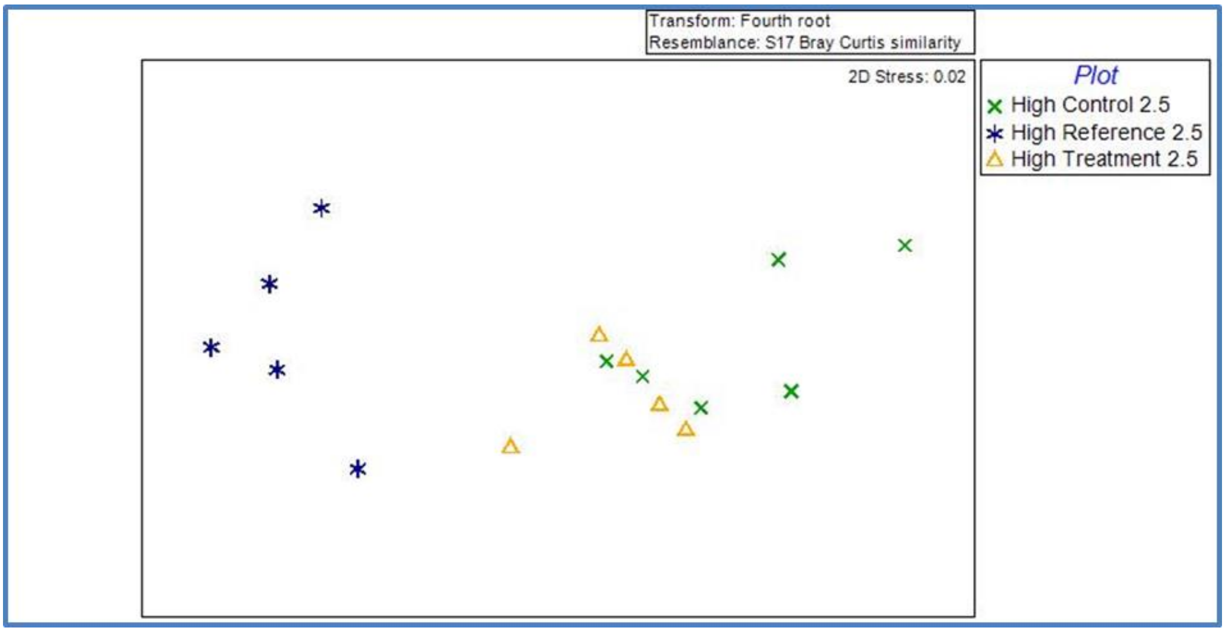

Figure 22. nMDS plot representing difference in structure of the saltmarsh community recorded across high survey plots during winter 2015 (approx. 2.5 years after revegetation).

Comparison of community structure of high plots between baseline and winter 2015 (2.5 years after revegetation) surveys shows baseline reference plots (green triangle) loosely cluster with reference plots from winter 2015 (blue star) (Figure 23), a result indicative that no significant change in community structure has occurred over time.

In contrast high treatment plots from the baseline survey (blue square) are scattered and separate from winter 2015 high treatment plots (orange triangle) which can be seen forming a tight cluster. This result indicates community structure within high treatment plots has changed over time and is becoming more uniform across high treatment plots (Figure 23).

High control plots from the baseline survey (blue triangle) show mild overlap with control plots from winter 2015 (green cross) indicative of mild differences in community structure. Winter 2015 plots can be seen to forming a cluster indicating community structure within these plots is becoming similar and this cluster is merging with high treatment plots from winter 2015 indicating community structure within these plots are becoming similar (Figure 23).

Analysis by one-factor ANOSIM confirms the results displayed in Figure 24 with no significant difference in saltmarsh community structure evident at high reference plots between baseline and winter 2015 survey results. In contrast moderate difference in structure was evident for the comparison of high control plots ($R=0.347$, $p=<0.05$) and for comparison of high treatment plots ($R=0.388$, $p=<0.05$).

These results indicate no change in community structure is evident for high reference plots however significant change has occurred at high treatment and high control plots.

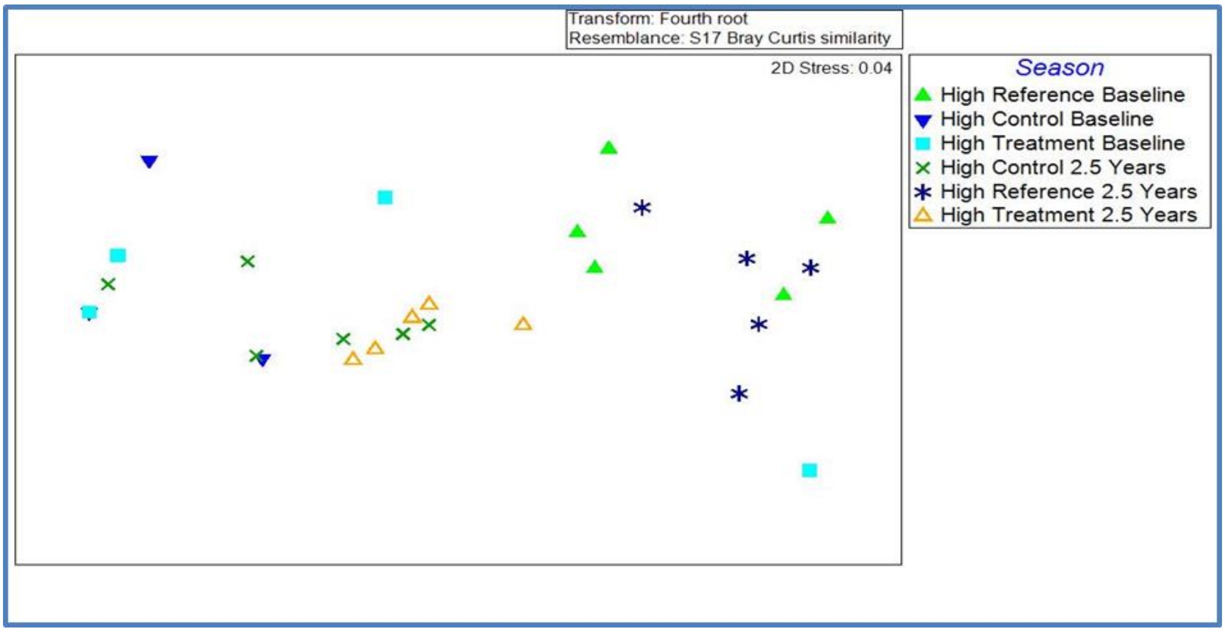

Figure 23. nMDS plot representing difference in structure of the saltmarsh community recorded across high survey plots in the baseline survey and during winter 2015 (approx. 2.5 years after revegetation).

Multivariate analysis of saltmarsh community structure at low plots (vegetation cover, crab burrow and gastropod abundance) in winter 2015 (2.5 years after revegetation) revealed differences in community structure.

The nMDS plot in Figure 24 shows low control plots (yellow triangle) clustering separate from low reference plots (turquoise square) indicating difference in community structure between these plot categories. However, overlap can be seen in clusters between low control (yellow triangle) and low treatment plots (pink diamond) and with low treatment plots and low reference plots, indicating similarities in community structure.

Analysis by one-factor ANOSIM confirms these results with a moderately significant difference in saltmarsh community structure evident between low control and low reference plots ($R=0.304$, $p=<0.05$). However no significant differences were evident between low control and low treatment plots or low reference and low treatment plots.

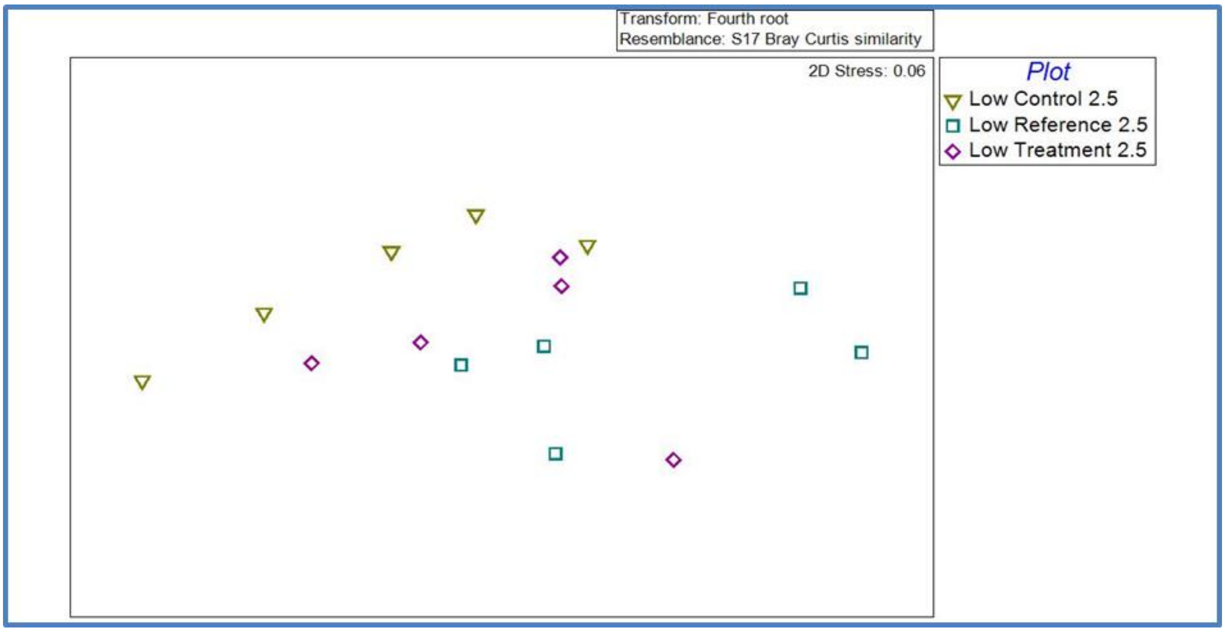

Figure 24. nMDS plot representing difference in structure of the saltmarsh community recorded across low survey plots during winter 2015 (approx. 2.5 years after revegetation).

Comparison of community structure of low plots between baseline and winter 2015 (2.5 years after revegetation) surveys shows baseline reference plots (red circles) cluster separate from with reference plots from winter 2015 (turquoise square) which appear loosely scattered in Figure 25. This result indicatives change in community has occurred over time and community structure of reference plots in winter 2015 was more variable than those surveyed in the baseline study.

Low treatment plots from both the baseline survey (black cross) and winter 2015 survey (purple diamond) appear scattered across the plot and no discreet clustering is evident (Figure 25). A similar pattern for low control plots is evident with baseline survey plots (pink circle) scattered across the plot and showing slight overlap with control plots from winter 2015 (yellow triangle) (Figure 25). These results are indicative of non-significant change over time and variation both within and between plot categories.

Analysis by one-factor ANOSIM confirms the results displayed in Figure 25 with significant difference in saltmarsh community structure evident at low reference plots between baseline and winter 2015 survey results ($R=0.404$, $p=<0.05$). In contrast no difference in structure was evident for the comparison of low control plots or for comparison of low treatment plots over time.

These results indicate change in community structure is evident for low reference plots however no significant change has occurred at low treatment and low control plots since the baseline survey.

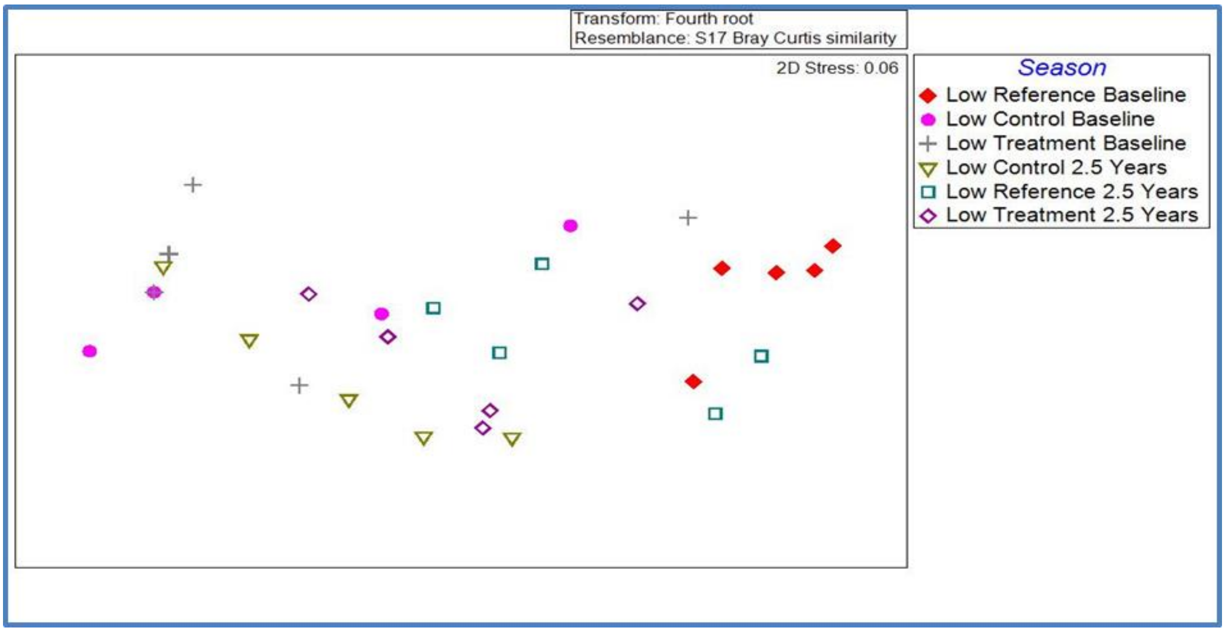

Figure 25. nMDS plot representing difference in structure of the saltmarsh community recorded across low survey plots during winter 2015 (approx. 2.5 years after revegetation).

4. Discussion

Results of seasonal monitoring of the vegetation community across the Site show dominant vegetation species and the matrix of species composition varied according to the category of elevation. Low survey plots were dominated by *Sarcocornia quinqueflora* and due to the high mortality of *Sporobolis virginicus* seedlings recorded during the 2013/14 survey period few low survey plots were observed as containing a thriving population of this species.

In contrast high survey plots were found to contain a more complex vegetation matrix with plots dominated by *Juncus krausii* and *Sarcocornia quinqueflora* and interspersed with *Sporobolus virginicus* and *Suaeda australis.*

Natural regeneration of *Sarcocornia quinqueflora* continued to increase across the Site with the maximum total number of plots with natural regeneration recorded during the winter 2015 survey. Only one minor incidence of bicycle access was observed throughout 2014/15 monitoring period and it is clearly evident that fencing of the Site has had the desired outcome of excluding vehicles and bicycles. Fencing of the Site has been the most significant contributor to natural regeneration of the saltmarsh vegetation community and reflect findings of studies by Alletson et al (date unknown) and Laegdsgaard (2006).

Statistical analysis of vegetation cover from the 2014/15 period show cover between high reference plots was significantly different when compared to high treatment and high control plots. Comparison of baseline and 2014/15 data shows no significant change in vegetation cover was evident for reference and treatment plots however cover in control plots was found to have significantly changed.

Slight increases in vegetation cover was evident across all low plot categories during the 2014/15 period however these were not significant. No significant change was evident in the comparison of cover recorded during the baseline survey and 2014/15.

Although some improvement in vegetation cover was evident across the site, statistically the results of the survey are not significant. Statistically significant change in vegetation cover may take many years to occur as recovery of the saltmarsh vegetation is slow. Laegdsgaard (2002) and Wolters et al (2005) report periods of greater than 20 years may be required before significant changes to the vegetation community occur.

Crab burrow abundance varied throughout the 2014/15 monitoring period. Statistical comparison between high plot categories shows significant difference in abundance between high reference plots and both high treatment and control plots. Comparison of crab burrow abundance across high plots during winter 2014 and all low plot categories shows no significant differences to the baseline survey.

Although the majority of results were not statistically significant, observational comparison of photographs taken during baseline surveys and throughout the 2014/15 monitoring period indicate crab burrow abundance is increasing with the majority of burrows located across sparsely vegetated mud flats. Burrowing crab communities of intertidal saltmarsh are known to be susceptible to degradation caused by vehicles (Kelleway 2006 and Laegdsgaard 2006) and it is evident the restriction of vehicle aces to the site continues to have a positive outcomes.

Gastropod abundance at high plots was highest at reference plots in both summer 2014 and winter 2015 with *Ophicardelus spp*. the dominant taxa. The highest abundance recorded since the commencement of monitoring was recorded at high reference plots during summer 2014. In contrast gastropods were absent in high control plots and treatment plots during the 2014/15 survey period.

Statistical comparison between high plot categories revealed significant differences in abundance were evident between reference plots and both control and treatment plots. However comparison of baseline condition to winter 2015 showed no significant change.

The distribution of *Ophicardelus spp*. across the Site was associated with the cover of Juncus krausii. In survey plots where *Ophicardelus spp*. was present, they were found clumping around the base or higher up the stems of *Juncus krausii*. This observation follows those made by Green et al (2009) and Ross et al (2009) who recorded similar behaviour in the species.

In addition Ross (2006) documented that *Ophicardelus spp*. was most affected by disturbance and populations took longer to recover than other species. This association with Juncus krausii and its absence in high control and treatment plots combined with the long recovery time of *Ophicardelus spp.* populations are likely to influence the distribution of the species across the Site and confine it to patches where Juncus krausii is present.

Gastropod abundance at low plots was variable for all plot categories. When compared to results from previous surveys, abundance was the lowest recorded for reference plots and second lowest for control plots. In contrast to high plots *Phallomedusa solida* was the dominant taxa recorded across low plots.

Statistical comparison revealed no significant difference in gastropod abundance between low plot categories in summer 2014 and winter 2015, nor was the comparison of abundance recorded during baseline survey with results from winter 2015.

Throughout this study *Phallomedusa solida* were observed as being partially buried in moist sediment mostly under *Sarcocornia quinqueflora* or taking refuge in the opening of crab burrows. Green et al (2009) and Roach (1998) observed that the species utilises *Sarcocornia quinqueflora* as refuge from desiccation in hot or dry and windy conditions and from predation by fish during times of inundation. Factors such as these are likely to have influenced the distribution of *Phallomedusa solida* and may explain the variable abundance recorded within low plot categories.

Analysis of the structure of the ecological community recorded across the Site during the 2014/15 monitoring period show highly significant differences were evident in the comparison of high control and high reference plots and high reference and high treatment plots. However no difference was evident between high control and high treatment plots. This result indicates the ecological communities found within high control and high treatment plots are very similar to one another however these communities have not regenerated to a state comparable to those found in high reference plots.

Comparison of results from the baseline survey with those from 2014/15 indicate no change in the community structure recorded within reference plots. However moderate change in structure was evident for high control plots and high treatment plots. These results indicate the ecological community found within high reference plots has remained stable however change has occurred within control, and treatment plots over time.

Analysis of results from the 2014/15 monitoring period show differences in community structure were evident between low control and low reference plots, however community structure in low control and low treatment plots were similar as were low reference and low treatment plots. These results indicate that community structure recorded in low control plots has not regenerated to a state comparable with that of reference plots and community structure of low control and low treatment has developed at a similar rate.

Of significance is the comparison of low reference and low treatment plots with results indicating similarity between these categories which is likely due to the high degree of variation observed in vegetation cover and crab burrow and gastropod abundance across each plot categories which is reflected by the overlap of error bars found in Figures 14, 16 and 18.

Comparison of results from the baseline survey with those from 2014/15 indicate change in community structure was evident for low reference plots, a result reflected by less vegetation cover and lower gastropod abundance recorded during the winter 2015 survey. In contrast no changes were evident for low treatment and low control plots indicating community structure has not changed significantly over time.

Since the baseline survey, a high degree of variation in vegetation cover, crab burrow and gastropod abundance have been recorded both within plot categories and across plot categories. This trend has continued throughout the 2014/15 monitoring period resulting in few statistically significant comparisons between plot categories and throughout time.

The application of multivariate statistical analysis to compare structure of the saltmarsh community over time showed that community structure of many plot categories have undergone change. Examples of this can be seen in high control and high treatment plots which have recorded results that indicate positive change has occurred over time.

In contrast, negative change in community structure was evident for low reference plots, a result reflective of the variability within the saltmarsh community. Temporal variation in vegetation cover and invertebrate abundance within saltmarsh communities both in undisturbed states and in those undergoing regeneration have been observed (EPBC 1999 and Mackenzie 2013).

The results from 2014/15 monitoring show that after 2.5 years the ecological community at the Site is responding to rehabilitation and revegetation across some plot categories and observation comparison shows many areas of the Site have responded positively to revegetation and natural regeneration. It is anticipated re-colonisation of invertebrate taxa and natural regeneration of plant species will continue which will be enhanced by further establishment of re-vegetated plots. Ongoing improvement over time is expected and will continue to enhance and provide additional habitat and food resources for species, both invertebrate and vertebrae, that rely on this ecosystem for survival saltmarsh.

5. Recommendations

As a result of 2014/15 monitoring the following recommendations has been made to enhance both the site and monitoring program.

1. The primary recommendation of this study is to continue the assessment of change in the ecological community. It has been established that the vegetation community across the Site is responding positively to unground works and natural revegetation however the response of the crab and gastropod communities is inconclusive. It is recommended seasonal monitoring of the vegetation community be scaled back to winter and summer only and monitoring of crab burrows and gastropod abundance continue with surveys conducted during winter and summer.

   It is well documented saltmarsh rehabilitation is a relatively new concept in Australia and many projects go undocumented. In cases where monitoring is conducted it is for a short term only. A number of projects with short term monitoring have recorded success over an initial two year period however these project have gone on to fail several years after restoration works. Continued monitoring and reporting will contribute valuable information to land managers considering similar projects.

2. In consultation with Nerida Gill (GSLLS) it is recommended that future monitoring includes measuring gastropod shell length. Collection of this data will enable an investigation of the distribution of adult and juvenile snails and will provide evidence that the site is capable of supporting breeding populations of gastropods.

3. It is recommended steel posts erected around survey plots to deter motorbikes be removed. Only one incident of bicycle riding through the site was recorded for the 2014/15 monitoring period and therefore these posts are no longer required to protect plots.

4. It is recommended the makeshift fence erected at the end of the Tasman St. fenceline be maintained to further deter motorbikes and bicycles from entering the site.

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Appendix A: Survey Data – 2014/15

Season: Spring 2014	Date: October 28, 2014	Conditions: 21 Degrees, overcast	
Plot Type	**Mean %Total Vegetation Cover**	***Mean % Cover of S.quinqueflora.***	***Mean % Cover of J. Krausii.***
HR1	80	27	27
HR2	53	0	53
HR3	88	0	88
HR4	98	0	98
HR5	24	24	0
HC1	19	19	0
HC2	0	0	0
HC3	11	11	0
HC4	5	5	0
HC5	0	0	0
HT1	10	10	0
HT2	0	0	0
HT3	33	33	0
HT4	14	14	0
HT5	11	11	0
LR1	58	58	0
LR2	58	58	0
LR3	25	25	0
LR4	10	10	0
LR5	4	4	0
LC2	0	0	0
LC3	0	0	0
LC4	3	3	0
LC5	0	0	0
LC6	0	0	0
LT1	9	9	0
LT2	34	34	0
LT3	10	10	0
LT4	26	26	0
LT5	8	8	0

Season: Summer 2015		Date: February 24, 2015		Conditions: 22 Degrees, clear		
Plot Type	Mean %Total Vegetation Cover	*Mean % Cover of S.quinqueflora.*	*Mean % Cover of J. Krausii.*	*Crab Burrows*	*Phallomedusa sp.*	*Ophicardelus spp.*
HR1	40	0	40	2	3	63
HR2	70	25	45	7	1	34
HR3	78	0	78	3	2	43
HR4	30	26	4	9	0	4
HR5	75	46	24	8	0	5
HC1	6.25	6	0	1	0	0
HC2	15	15	0	0	0	0
HC3	1	1	0	2	0	0
HC4	15	15	0	2	0	0
HC5	14	14	0	0	0	0
HT1	53	53	0	0	0	0
HT2	41.25	41.25	0	0	0	0
HT3	18.75	18.75	0	2	0	0
HT4	12.5	12.5	0	1	0	0
HT5	0	0	0	1	0	0
LR1	10	10	0	9	0	1
LR2	16.25	16.25	0	9	1	2
LR3	30	30	0	6	1	1
LR4	67.5	67.5	0	7	35	2
LR5	12.25	12.25	0	3	0	0
LC1	0	0	0	1	0	0
LC2	1.25	1.25	0	7	0	0
LC3	0	0	0	10	0	0
LC4	0	0	0	2	0	0
LC5	0	0	0	3	0	0
LT1	27.5	27.5	0	3	0	0
LT2	36.25	36.25	0	13	5	0
LT3	5	5	0	9	0	0
LT4	3.75	3.75	0	12	0	0
LT5	28.75	28.75	0	3	2	0

Season: Spring 2015	Date: April 13, 2015	Conditions: 18 Degrees, clear	
Plot Type	**Mean %Total Vegetation Cover**	***Mean % Cover of S.quinqueflora.***	***Mean % Cover of J. Krausii.***
HR1	93	43	50
HR2	76	38	38
HR3	80	0	80
HR4	75	37	37
HR5	48	25	23
HC1	0	0	0
HC2	26	0	0
HC3	23	0	0
HC4	11	0	0
HC5	0	0	0
HT1	48	48	0
HT2	11	11	0
HT3	24	24	0
HT4	26	26	0
HT5	18	18	0
LR1	28	28	0
LR2	75	75	0
LR3	16	16	0
LR4	60	60	0
LR5	18	18	0
LC2	1	1	0
LC3	0	0	0
LC4	3	3	0
LC5	0	0	0
LC6	10	10	0
LT1	40	40	0
LT2	51	51	0
LT3	35	35	0
LT4	5	5	0
LT5	45	45	0

Season: Winter 2015		Date: June 23, 2015	Conditions: 12 Degrees, clear			
Plot Type	**Mean %Total Vegetation Cover**	***Mean % Cover of S.quinqueflora.***	***Mean % Cover of J. Krausi i.***	***Crab Burrows***	***Phallomedusa sp.***	***Ophicardelus spp.***
HR1	54	54	0	7	2	0
HR2	73	53	20	1	0	0
HR3	36	0	36	3	9	38
HR4	73	64	9	5	0	0
HR5	95	48	48	2	5	42
HC1	10	10	0	2	0	0
HC2	16	16	0	0	0	0
HC3	0	0	0	1	0	0
HC4	20	20	0	5	0	0
HC5	3	3	0	0	0	0
HT1	48	48	0	5	0	0
HT2	13	13	0	1	0	0
HT3	19	19	0	1	0	0
HT4	14	14	0	0	0	0
HT5	17	0	0	2	0	0
LR1	19	19	0	16	10	0
LR2	13	13	0	4	0	0
LR3	20	20	0	1	0	4
LR4	70	70	0	1	12	0
LR5	75	75	0	1	10	9
LC1	11	11	0	0	0	6
LC2	3	3	0	0	0	0
LC3	0	0	0	0	0	0
LC4	6	6	0	2	0	3
LC5	33	33	0	0	0	0
LT1	26	26	0	0	0	0
LT2	48	48	0	19	0	0
LT3	11	11	0	0	0	0
LT4	4	4	0	1	0	0
LT5	24	24	0	0	0	0