CTENVIRONMENTAL

Horning Street Saltmarsh Revegetation Project 2013/14 Annual Report

Sutherland Shire COUNCIL

Local Land Services Greater Sydney

NSW GOVERNMENT

Prepared for

Sutherland Shire Council

August 2014

DOCUMENT TRACKING

Item	Detail
Project Name	Horning Street Saltmarsh Revegetation Project – 2013/14 Annual Report
Prepared by	Carl Tippler (CTENVIRONMENTAL)
Reviewed by	Brendon Graham (SSC) and Nerida Gill (GSLLS)
Approved by	Brendon Graham (SSC)
Status	Final
Cover photo	Nerida Gill

Citation: CTENVIRONMENTAL (2014) Horning Street Saltmarsh Revegetation Project – Annual Report 2013/14. Prepared for Sutherland Shire Council.

ACKNOWLEDGEMENTS

This document has been prepared by CTENVIRONMENTAL with support from Brendon Graham (Sutherland Shire Council) and Nerida Gill (Greater Sydney Local Land Service)

CTENVIRONMENTAL

Contents

Figures

Tables

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. As part of this offset strategy, 17,000 m^2 of coastal saltmarsh and mangroves was identified for protection and rehabilitation. The site also provided an opportunity to compare active revegetation with natural regeneration.

A revegetation plan was developed and baseline monitoring was undertaken in April 2013 to assess the condition of the ecological community prior to revegetation. A select range of ecological indicators were surveyed which included vegetation cover, dominant vegetation species, crab burrow abundance and abundance of two gastropods (snails), *Phallomedusa solida* and *Ophicardelus spp.*

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 2014.

Comparison between survey plot categories was undertaken with data collected throughout the 2013/14 monitoring period and comparison of baseline condition was made with data collected one year after revegetation of the Site.

Results from the 2013/14 monitoring period show:

- Variation in vegetation cover was evident between plot categories for high and low plot categories however comparison to baseline condition revealed no significant change had occurred since revegetation of the site.
- One year after revegetation of the Site, 68% of *Sporobolus virginicus* seedlings used to revegetate plots were found to have died.
- Crab burrow abundance did not vary between plot categories nor was significant change in abundance evident when compared to baseline condition.
- At low elevation plots gastropod abundance was found to vary between plot categories in both summer 2013 and winter 2014. At high elevation plots significant variation in abundance was evident in summer 2013 only. Comparison to baseline

condition revealed no significant change in gastropod abundance across all plot categories had occurred over time.

- Saltmarsh community structure was found to have significantly changed since revegetation of the Site at high treatment plots and to a lesser extent at low control plots. No other significant changes in community structure were evident.

The primary recommendations of this report are:

1. Continue with vegetation and invertebrate monitoring to assess the response of the saltmarsh community to revegetation and rehabilitation over the next 12 months. On completion, seasonal comparison of crab burrow and gastropod abundance should be conducted and results of analysis used to determine the frequency of future monitoring.
2. Survey plot markers are recoloured and co-ordinates are re-plotted and mapped for future ease of identification.

The purpose of this report is to detail the results of 2013/14 monitoring, and make comparison to baseline conditions to assess the scale of recovery of the saltmarsh community one year after revegetation of the Site.

Introduction

The assessment of the coastal saltmarsh community of Horning Street Saltmarsh (the Site), Kurnell, NSW, was conducted by CTENVIRONMENTAL between June 2013 and June 2014. 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).

It is expected that planting and 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).

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 (Figures 1 and 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 September 11, 2014. Location of Horning St. Saltmarsh circled in red. Source: Near Map 2014.

Figure 2..Aerial photo of Horning St. Saltmarsh taken June 30, 2014. Source: Nearmap 2014.

Prior to revegetation the Site had a history of neglect and was frequently 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*).

Patches of saltmarsh vegetation remain scattered throughout the Site, predominantly in the upper tidal limits. Saltmarsh species recorded include 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).

Site Revegetation

117 plots were identified in the site revegetation plan (CTENVIRONMENTAL 2013) and of these, 36 plots were allocated for revegetation and categorised as treatment plots, 39 plots were allocated as control plots and left to naturally regenerate and 44 plots were naturally vegetated and classified as reference plots. Plots located above 0.65 m AHD were then classified as high plots and plots below 0.65 m AHD classified as low plots.

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. Revegetation was completed in May/June 2013.

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

Following the revegetation plan (CTENVIRONMENTAL 2013) 27 low plots and 17 high plots were revegetated. Each revegetation plot was divided into four quadrants and each quadrant randomly planted with 22 seedlings of one species. Seedlings were planted in alternate quadrants in a pattern of 22 *Sarcocornia quinqueflora,* 22 *Sporobolus virginicus,* 22 *Sarcocornia quinqueflora* and 22 *Sporobolus virginicus* (Figure 3). Seedlings were planted at a density of 28 plants/m^2. A number of plots were surrounded by three steel fence posts to provide protection from illegal car or motorbike activity.

Figure 3. Revegetation plot with alternate planting pattern and protective steel posts. Red line delineates planting quadrants**.**

Baseline Survey

In 2013 CTENVIRONMENTAL conducted a baseline survey of the ecological community at the Site prior to the commencement of revegetation. This was carried out to establish baseline conditions for which future comparisons could be made to enable an understanding of how the plant and invertebrate communities at the Site respond to revegetation.

Saltmarsh cover, dominant saltmarsh species, crab burrow abundance and abundance of two common gastropods (*Ophicardelus spp.* and *Phallomedusa solida* (formerly *Salinator solida*) were surveyed (CTENVIRONMENTAL 2013).

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 Low control category survey plot with active crab holes circled in red

Gastropods (snails) *Phallomedusa solida* (formerly *Salinator solida*) and *Ophicardelus spp.* 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).

Results from baseline monitoring are found in "Horning Street Saltmarsh Revegetation Project: Baseline Survey, 2013" (CTENVIRONMENTAL 2013) and comparison with baseline results are made in the current study.

Annual Monitoring Program 2013/14

Survey Plot Locations

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

Following the completion of revegetation works, steel posts were erected around a number of control and treatment plots to protect from possible illegal vehicle activity. The presence/absence of posts is not considered in analysis of 2013/14 monitoring data as posts were not present when the baseline survey was undertaken.

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

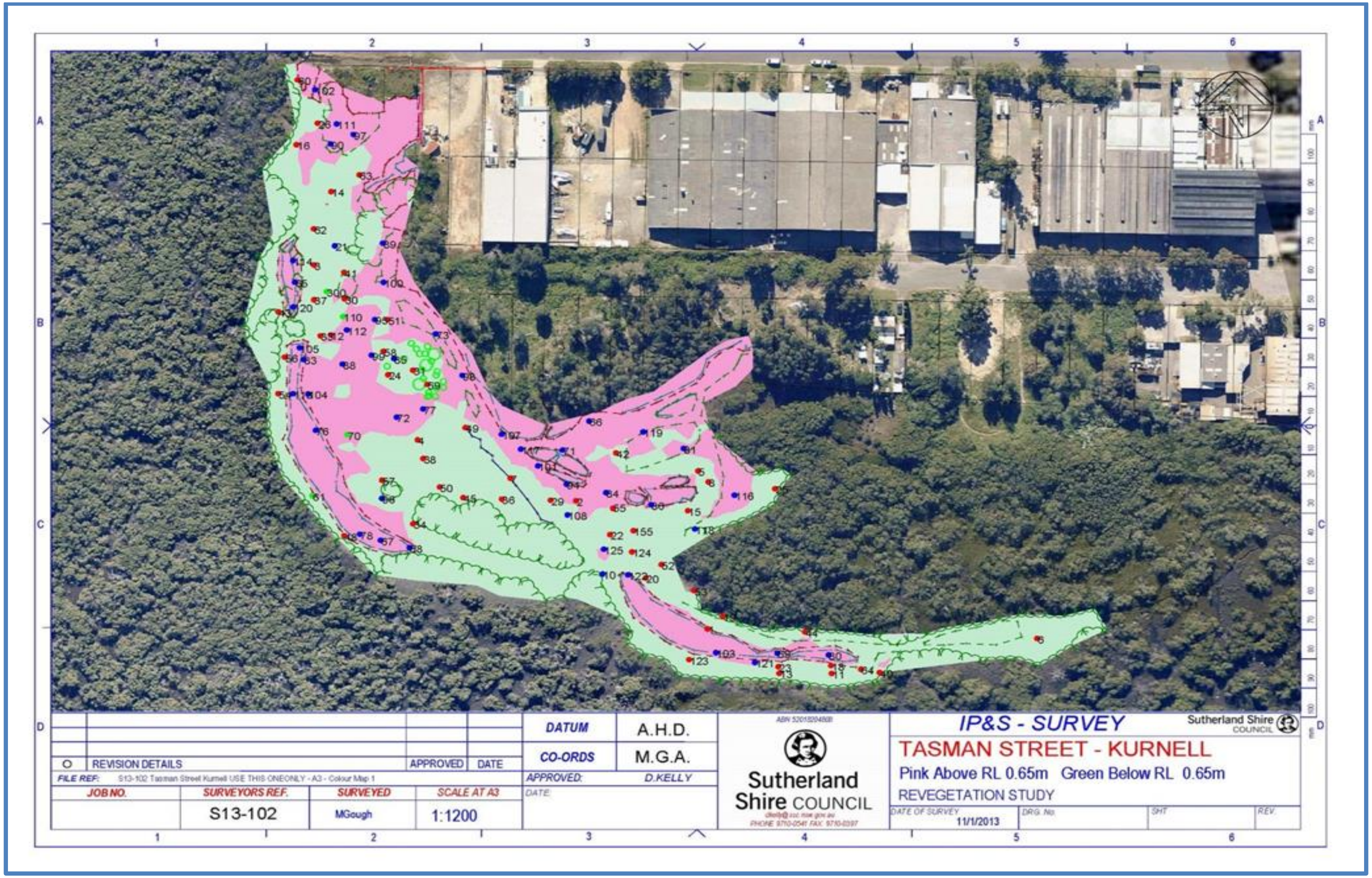

Figure 6 . Aerial photograph of the Site displaying locations of high (blue) and low (red) survey plots. (SSC 2013).

Saltmarsh vegetation and invertebrate survey

During the 2013/14 monitoring period the saltmarsh vegetation community was surveyed at three monthly intervals in September 2013 (spring), December 2013 (summer), March 2014 (autumn) and June 2014 (autumn). In addition crab burrow abundance and Gastropod abundance was surveyed in December 2013 (summer) and June 2014 (winter).

The following methods were applied to monitoring the saltmarsh community throughout the 2013/14 monitoring period.

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.

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 Points

To record changes in vegetation cover across the site over time, panoramic photographs were taken from a fixed point at the eastern edge of the Site in November 2012, March 2013, June 2013, December 2013 and June 2014. In addition aerial photographs provided by Nearmap were used for observation comparison.

Statistical Analysis

For univariate analysis the abundance of *Phallomedusa solida* and *Ophicardelus spp.* were combined for total gastropod abundance. Mean and standard error 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 2014) 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 2014). 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 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 2014) 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 2014, one year after revegetation of the Site.

Results

Observational Comparison

Observation comparison of panoramic photographs (Figures 8 – 12) show noticeable change in the visual condition of the Site occurred throughout the period November 2012 to June 2014.

In November 2012 (Figure 8) conditions typical of the Site prior to rehabilitation and revegetation can be seen with deep vehicle wheel ruts and scarce vegetation visible. Incremental change can be seen throughout the photograph series with reductions in vehicle wheel ruts evident in April and June 2013 (Figure 9 and 10), the establishment of an algae mat in July 2013 (Figure 11) and re-establishment of saltmarsh vegetation in June 2014 (Figure12).

Figure 8 . Panoramic photograph of Site. Taken November 2012 prior to the commencement of site rehabilitation works.

Figure 9. Panoramic photograph of Site. Taken April 2013 shortly after the Site was fenced to prohibit illegal vehicle access.

Figure 10. Panoramic photograph of Site. Taken June 2013 during revegetation works.

Figure 11. Panoramic photograph of Site. Taken July 2013 after the completion of revegetation works.

Figure 12. Panoramic photograph of Site. Taken June 2014 approximately one year after revegetation works.

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 vegetation plots were dominated by *Sarcocornia quinqueflora* and to a lesser extent *Sporobolus virginicus* and occasional *Samolus repens.* In contrast high vegetation 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* was observed across the site (Figure 13). Although not accounting for significant vegetation change, plots with natural regeneration were recorded. 17 high plots were found to have regenerating *Sarcocornia quinqueflora,* with the highest rate of regeneration recorded in winter 2014 (7 plots). In addition 16 low plots were found to have natural regeneration with the highest rate (5 plots) recorded in spring 2013 and autumn 2013 (Figure 14)

Figure 13. Natural regeneration of *Sarcocornia quinqueflora* in a low control plot 2013/14 monitoring period. (Photo: Nerida Gill).

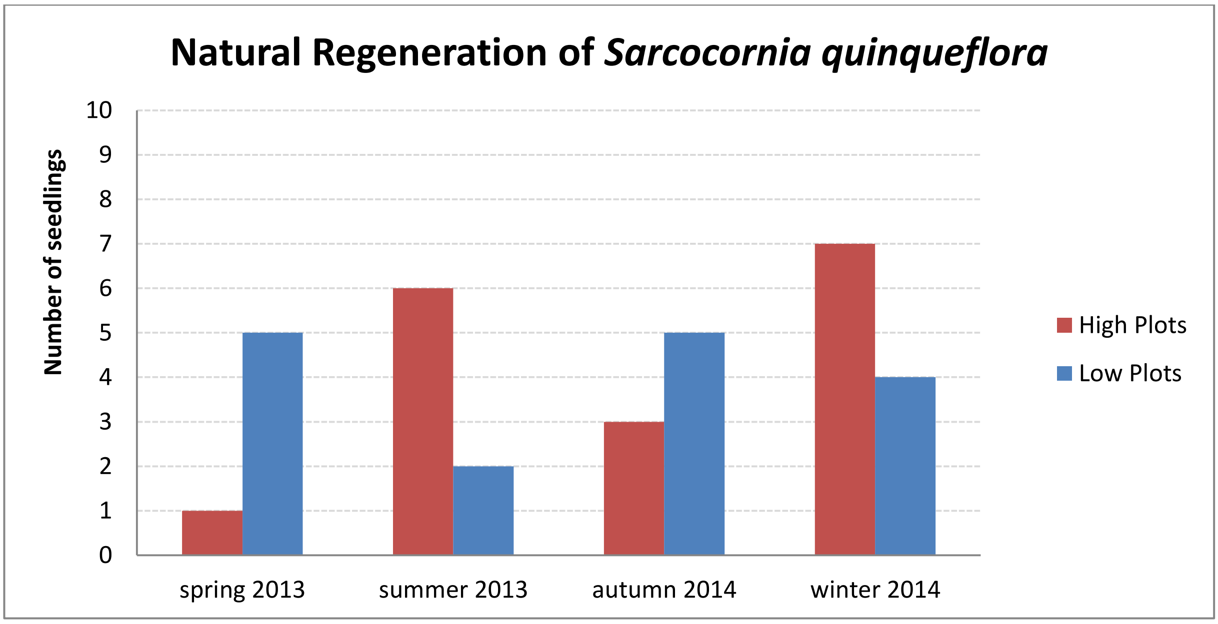

Figure 14. Natural regeneration of *Sarcocornia quinqueflora* recorded across high and low survey plots during the 2013/14 monitoring period.

In contrast to the natural regeneration of *Sarcocornia quinqueflora,* a significant die-off of *Sporobolus virginicus* seedlings that were used to regenerate the Site was recorded. In winter 2014, one year after revegetation, surviving *Sporobolus virginicus* seedlings were counted at 17 treatment plots (10 low and 7 high). Of the 765 seedlings planted only 244 survived the first year after revegetation which equates to 68% mortality of *Sporobolus virginicus* seedlings used to revegetate the site.

Seasonal vegetation monitoring of high survey plots throughout the 2013/2014 monitoring period showed mean percentage of vegetation cover at control and treatment plots remained constant. Comparison of control and treatment plots with baseline condition shows little change in mean vegetation cover occurred since revegetation of the Site (Figure 15).

Comparison of high reference plots in spring 2013 with baseline condition shows a decline in mean vegetation cover from 61% +/- 7% during the baseline survey to 43% +/- 20% in spring 2013. Subsequent sampling showed mean vegetation cover increased in summer 2013 to 58% +/- 30%, a result comparable to baseline condition, and remained constant for the remainder of the monitoring period (Figure 15).

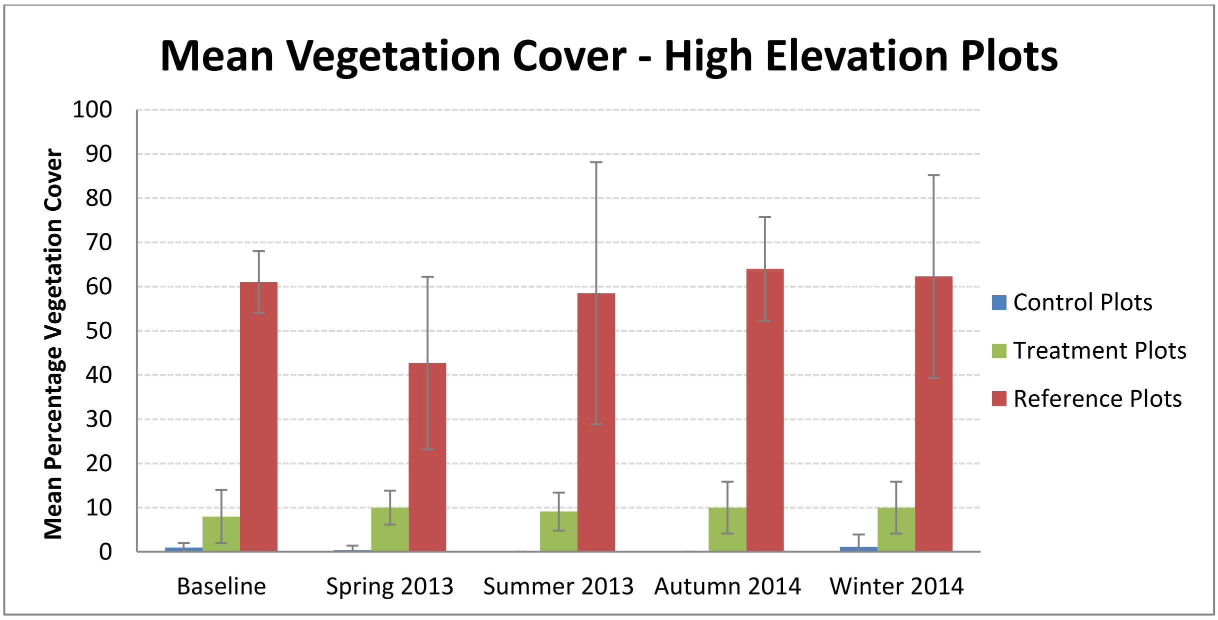

Figure 15. Mean vegetation cover (+/- SEM) of high survey plots recorded during 2013 baseline monitoring and 2013/14 monitoring period.

Statistical analysis by one way ANOVA of vegetation cover one year after the revegetation of the Site (winter 2014) shows significant difference (F (2, 15) = 45, p= <0.05) in cover was evident between high survey plot categories. This result is confirmed by pairwise comparisons which show significant differences in vegetation cover between high reference plots and high control plots (t(4)=6.79, p=<0.05), high control plots and high treatment plots (t(7)=4.47, p=<0.05) and high treatment plots and high references plots (t(5)=5.30, p=<0.05).

Pairwise comparison of baseline conditions with results from winter 2014 (one year after revegetation) showed no significant change in vegetation cover was evident at high control, high treatment and high reference plots.

Seasonal vegetation cover monitoring of low survey plots throughout the 2013/2014 monitoring period showed mean vegetation cover of treatment plots remained constant. Comparison of baseline condition with winter 2014 (one year after revegetation) showed mean vegetation cover of treatment plots marginally increased from 7% +/- 3% to 8% +/- 7% (Figure 16).

Mean vegetation cover of control plots showed slight variation throughout the 2013/14 monitoring period with highest mean cover (4% +/- 8%) recorded in autumn 2014 and lowest (0.25% +/- 0.6%) in summer 2013. Mean vegetation cover of control plots throughout 2013/14 was marginally lower than baseline condition (Figure 16).

A declining trend was recorded for reference plots with a maximum of 60% +/- 6% cover recorded during the baseline survey which gradually declined throughout the 2013/14 monitoring period to a minimum of 33% +/- 25% in winter 2014 (Figure 16). Statistical analysis by one way ANOVA of vegetation cover one year after the revegetation of the Site (winter 2014) shows significant difference (F (2, 20) = 6.8, p= <0.05) in cover was evident between low survey plot categories. This result is confirmed by pairwise comparisons which show significant differences in vegetation cover were evident in between low reference plots and low control plots (t(5)=4.31, p=<0.05), low control plots and low treatment plots (t(11)=3.51, p=<0.05) and low treatment plots and low references plots (t(5)=3.81, p=<0.05).

Pairwise comparison of baseline conditions with results from winter 2014 (one year after revegetation) showed no significant change in vegetation cover was evident at low control, low treatment and low reference plots.

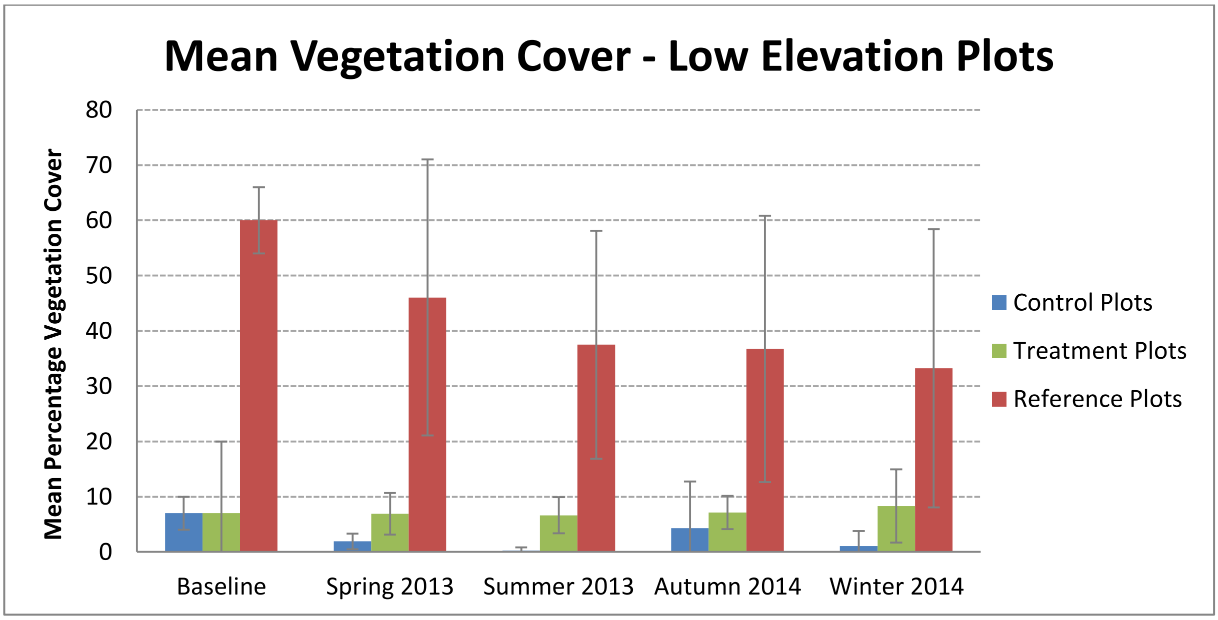

Figure 16. Mean vegetation cover (+/- SEM) of low survey plots recorded during 2013 baseline monitoring and 2013/14 monitoring period.

Crab burrow abundance

Results from summer 2013 show mean crab burrow abundance across all high plot categories declined when compared to baseline condition. This trend was reversed in winter 2014 with all plot categories recording greater mean crab burrow abundance when compared to summer 2013. Statistical analysis by one way ANOVA of mean crab abundance revealed differences in abundance was not significant across plot categories in both summer 2013 and winter 2014.

Comparison of reference condition to winter 2014 (one year after revegetation) showed an increase in mean crab burrow abundance was recorded for control and treatment plots however mean abundance declined at reference plots (Figure 17). Pairwise comparison of winter 2014 to baseline condition show no statistically significant differences were evident for all plot categories.

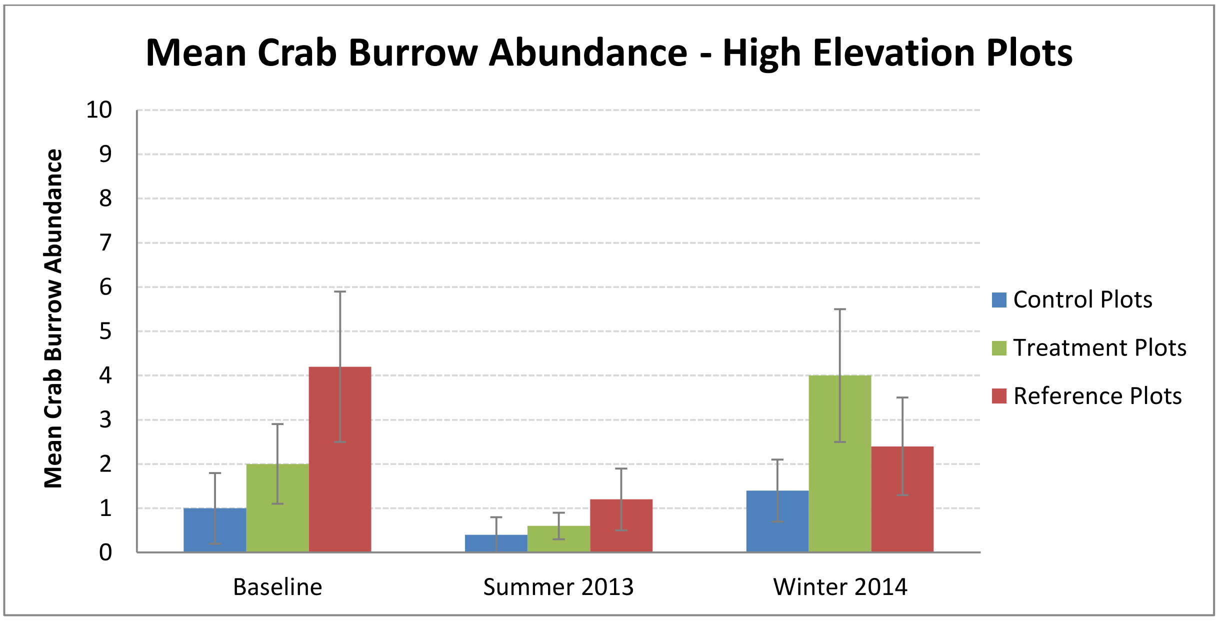

Figure 17. Mean crab burrow abundance (+/- SEM) of high survey plots recorded during 2013 baseline monitoring and 2013/14 monitoring period.

Comparison of results from 2013/2014 monitoring show mean crab burrow abundance at low plot categories slightly increased in winter 2014 at control and reference plots and did not change at treatment plots (Figure 18). Statistical analysis by one way ANOVA revealed no significant difference in abundance was evident between plot categories in both summer 2013 and winter 2014.

Comparison of results from winter 2014 (one year after revegetation) to baseline condition show slight increase in crab burrow abundance was recorded at treatment and control plots however abundance was found to have decreased at reference plots (Figure 18). Pairwise comparison of data from winter 2014 to baseline condition shows change in crab burrow abundance was not statistically significant for all low plot categories.

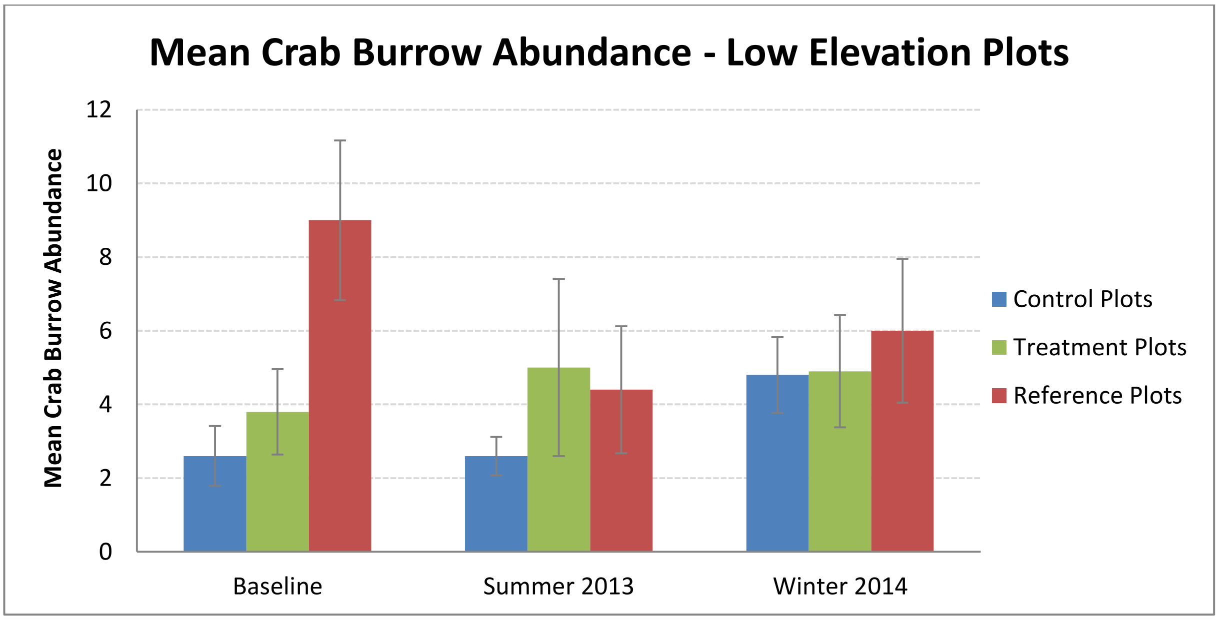

Figure 18. Mean crab burrow abundance (+/- SEM) of low survey plots recorded during 2013 baseline monitoring and 2013/14 monitoring period.

Gastropods

A total of 307 individual Gastropods were recorded throughout the 2013/2014 monitoring period with 181 individuals recorded in winter 2014 and 126 individuals recorded in summer 2013. *Ophicardelus spp.* was most abundant at high plots with 90 individuals recorded in summer 2013 and 85 individuals recorded in winter 2014. *Ophicardelus spp*. was less abundant at low plots with nine individuals recorded in summer 2013 and 38 in winter 2014.

Abundance of *Phallomedusa solida* was highest at low plots with 27 individuals recorded in summer 2013 and 49 individuals recorded in winter 2014. In high plots, 18 *Phallomedusa solida* were recorded in summer 2013 and nine individuals recorded in winter 2014.

Mean Gastropod abundance at high reference plots was shown to increase from 6+/-3 individuals (baseline survey) to 18+/-11 individuals (summer 2013) and remained steady with 18+/-8 individuals recorded in winter 2014 (Figure 19).

The presence of Gastropods in high control plots was undetected throughout the monitoring period, indicating no change when compared to baseline condition. A marginal increase at treatment plots was recorded with 0.4 +/- 0.4 individuals recorded in winter 2014 (Figure 19).

Statistical analysis by one way ANOVA revealed no significant variation in abundance was evident between high plot categories in summer 2013. In contrast variation in abundance between plot categories was found to be significant in winter 2013 (F (2, 15) = 5.7, p= <0.05).

Although increased abundance was recorded at high reference plots, pairwise comparison of baseline data with winter 2014 (one year after revegetation) indicates this change is not statistically significant.

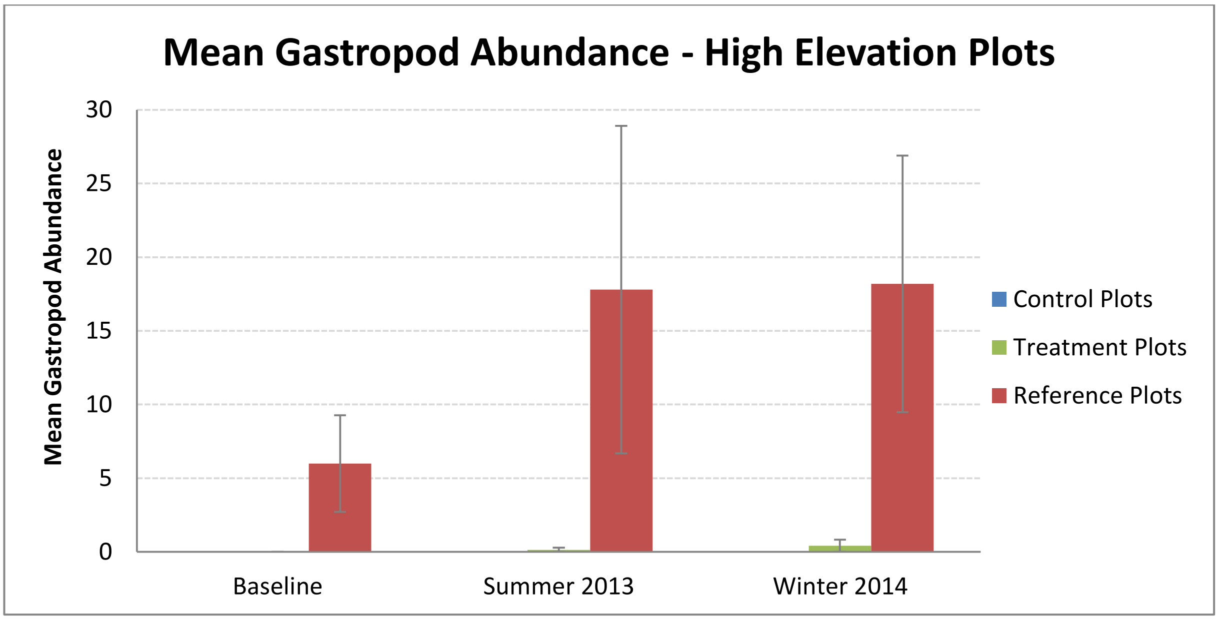

Figure 19. Mean Gastropod abundance (+/- SEM) of high survey plots recorded during 2013 baseline monitoring and 2013/14 monitoring period.

Mean Gastropod abundance at low reference plots decreased from 12+/-3 individuals (baseline survey) to 6+/-3 individuals in summer 2013 and increase to 14+/-8 individuals in winter 2014 (Figure 20).

When compared to baseline condition, mean abundance at control and treatment plots was found to have decreased throughout the monitoring period (Figure 19). Statistical analysis by one way ANOVA revealed significant variation in abundance was evident between low plot categories in both summer 2013 ($F(2,20) = 5.0$, $p= <0.05$) and winter 2014 ($F(2,22) = 5.5$, $p= <0.05$).

Pairwise comparison of baseline data with winter 2014 (one year after revegetation) indicate that although change in abundance was recorded, they were not statistically significance for all plot categories.

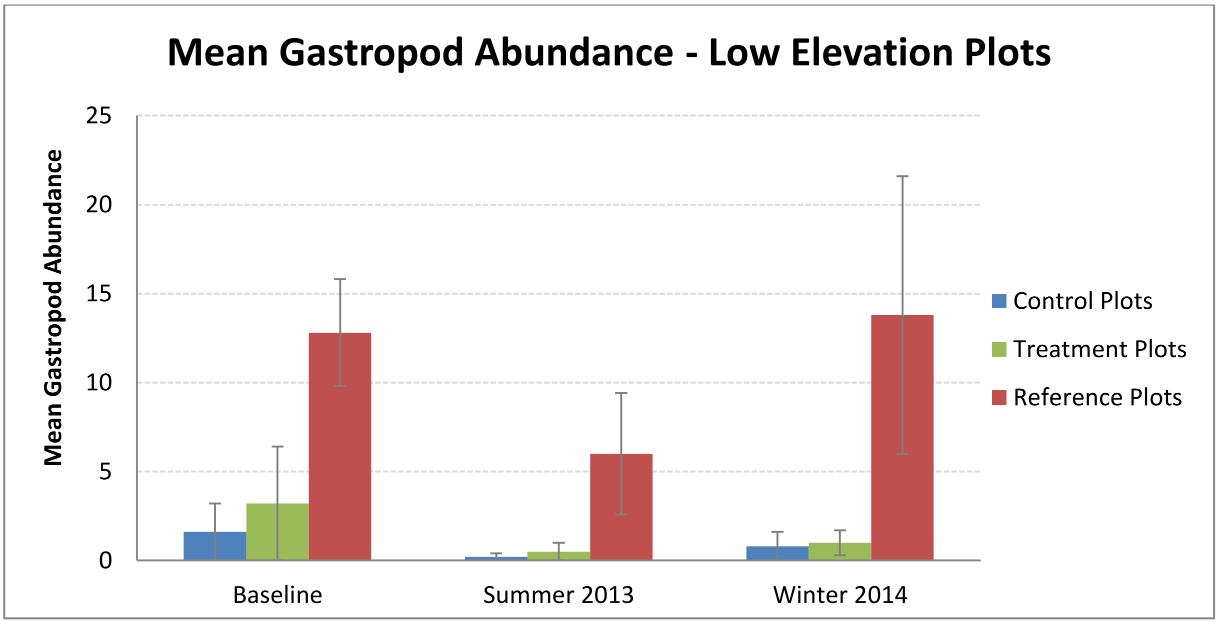

Figure 20. Mean Gastropod abundance (+/- SEM) of low survey plots recorded during 2013 baseline monitoring and 2013/14 monitoring period.

Multivariate analysis of the saltmarsh community structure (vegetation cover, crab burrow and gastropod abundance) in winter 2014 (one year after revegetation) revealed differences in high and low categories were variable. Lose clustering between high treatment and low control plots is evident however a dominant pattern of no distinct clustering can be seen in the nMDS plot (Figure 21) which indicates an overall dissimilarity in salt marsh community structure between and within plot categories. Analysis by one-factor ANOSIM confirms this pattern with highly significant differences in saltmarsh community structure evident between high control and reference plots (R=0.896, p=<0.05), high control and treatment plots (R=0.816, p=<0.05) and high reference and treatment plots (R=0.845, p=<0.05).

A similar pattern of dissimilarity was evident in low plots with results of ANOSIM showing highly significant difference in saltmarsh community structure between low control and reference plots (R=0.852, p=<0.05). Slightly less dissimilarity in community structure (indicated by lower R values) was evident in the comparison of control and treatment plots (R=0.407, p=<0.05) and low reference and treatment plots (R=0.492, p=<0.05).

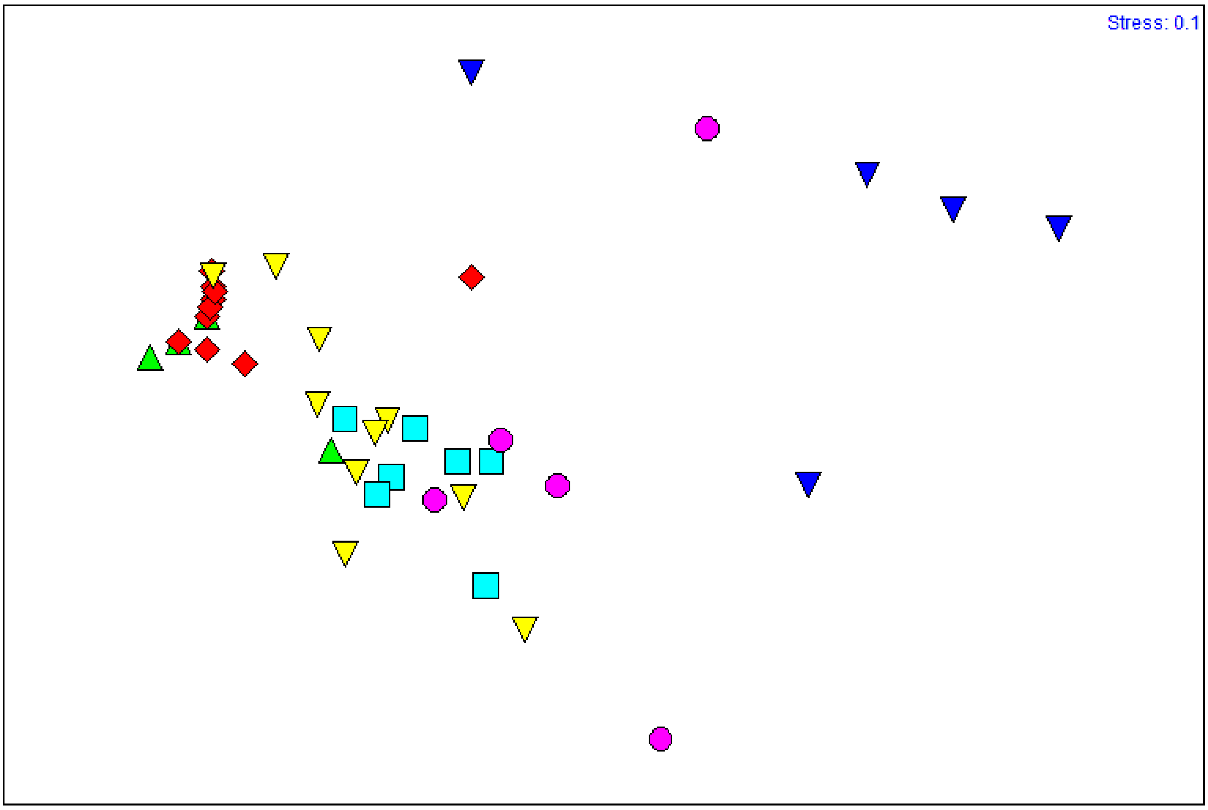

Figure 21. nMDS 2-D plot of saltmarsh community structure recorded in winter 2014, one year after revegetation of the Site. Green triangles = high control plots, blue triangles = high reference plots, light blue squares = high treatment plots, red diamonds = low control plots, pink circles = low reference plots, yellow triangles =low treatment plots.

Comparison of saltmarsh community structure between baseline condition and winter 2014 (one year after revegetation) revealed changes in community structure between plot categories were variable. An overall trend of dissimilarity between and within low plot categories is evident in the nMDS plot (Figure 22) which shows a lack of discreet clustering between and within baseline and winter 2014 plot categories.

Comparison of saltmarsh community structure from baseline survey and winter 2014 by one-factor ANOSIM revealed no significant difference in community structure was evident in the comparison of high control plots and high reference plots, a result which indicates community structure of these plots has not changed significantly since the revegetation of the Site. In contrast, high treatment plots were found to differ significantly between baseline and winter 2014 (R=0.683, p=<0.05) indicating significant change in community composition at high treatment plots has occurred since revegetation of the Site.

Comparison of saltmarsh community composition by one-factor ANOSIM at low plots revealed no significant difference was evident in the comparison of low treatment and low reference plots over time. This result indicates no significant change has occurred in saltmarsh community structure at these plots since the revegetation of the Site. In contrast, community structure of low control sites were found to significantly differ (*R*=0.351, *p*=<0.05) between baseline and winter 2014, a result that indicates a slight change in community composition at low control sites since revegetation of the site.

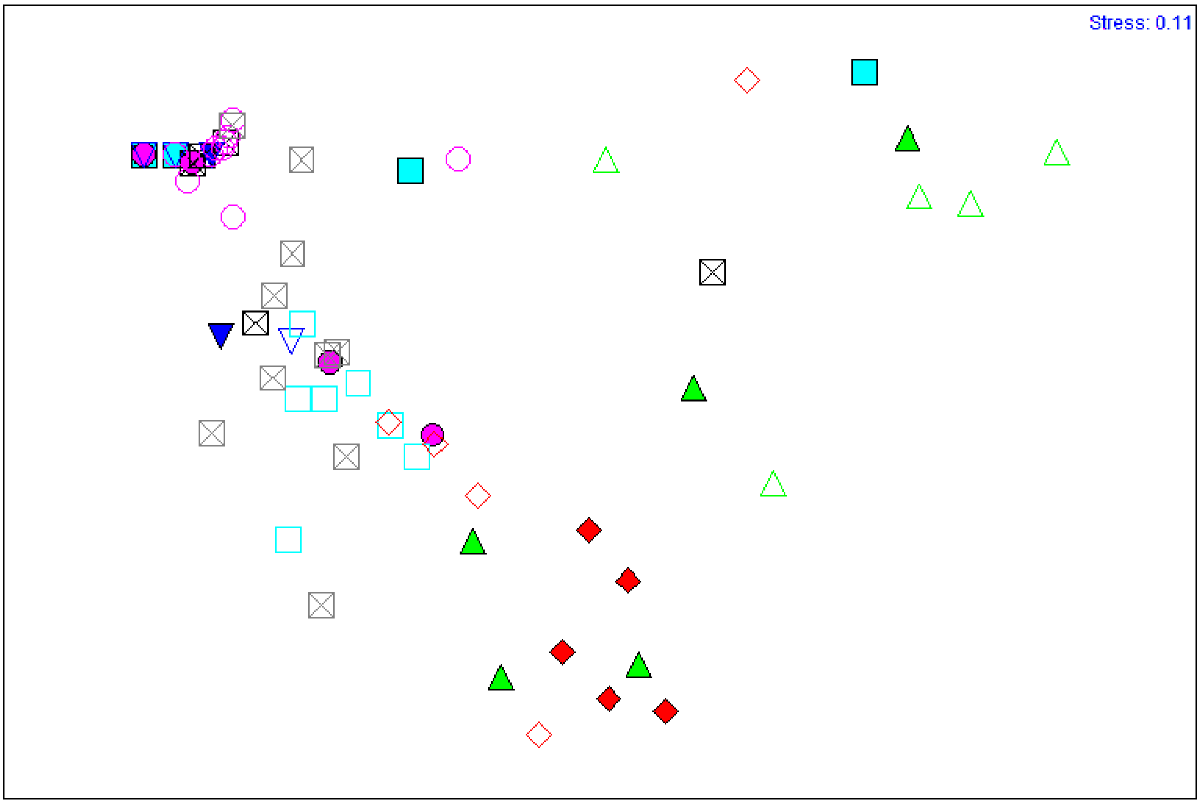

Figure 22. nMDS 2-D plot of baseline and winter 2014 (one year after revegetation of the Site) saltmarsh community structure. Green triangles = high control plots, blue triangles = high reference plots, light blue squares = high treatment plots, red diamonds = low control plots, pink circles = low reference plots, yellow triangles =low treatment plots.

Discussion

Results from vegetation monitoring show slight yet non-significant changes in vegetation cover were recorded across both high and low plot categories for the 2013/14 monitoring period. Vegetation cover at high plots was dominated by *Juncus krausii* with reference plots containing the highest mean vegetation cover. Statistical comparison revealed significant difference in vegetation cover was evident between all high plot categories. Comparison of baseline condition to winter 2014 (one year after revegetation) showed no significant change in vegetation cover over time was evident for all high plot categories.

Sarcocornia quinqueflora was found to be the dominant species in low plots with vegetation cover highest in low reference plots. Statistical comparison revealed significant difference in vegetation cover was evident between all low plot categories, a trend similar to results recorded for high plots. Although vegetation was found to have decreased over time at low reference plots, comparison of baseline condition to winter 2014 (one year after revegetation) showed this change was not significant. Similarly, vegetation cover at treatment and control plots did not show significant change over time.

Results of monitoring changes in vegetation cover across the Site are to be expected as the rate at which saltmarsh vegetation recovers after disturbance is slow. Studies have shown that it can take from 14 months to greater than 20 years for significant changes to occur in the vegetation community (Laegdsgaard 2002; Wolters et al 2005).

Although changes in vegetation cover were not found to be significant, a high degree of natural regeneration of *Sarcocornia quinqueflora* was observed and recorded throughout the 2013/14 monitoring period. Natural regeneration of *Sarcocornia quinqueflora* was first observed in April 2013, shortly after fencing the Site to exclude illegal vehicle use. Although two minor incidences of motorbike access were observed throughout 2013/14, fencing of the Site has had the desired outcome of vehicle exclusion. Fencing and the removal of vehicles from saltmarsh communities has been documented as a major factor in promoting the recovery of the saltmarsh vegetation community (Alletson *et al* date unknown; Laegdsgaard 2006). Therefore it is likely the natural regeneration of *Sarcocornia quinqueflora* is attributed to the exclusion of vehicles from the Site and it is expected that over time natural regeneration will continue to a point that future vegetation surveys will record significant changes in vegetation cover.

In contrast to the natural regeneration observed across the Site, a significant die-off of transplanted *Sporobolus virginicus* was recorded. One year after revegetation of the Site it was found that 68% or of *Sporobolus virginicus* seedlings had died. The direct cause of this die-off cannot be accounted for by this study however multiple factors to the success of transplanting *Sporobolus virginicus* have been identified such as constant inundation, ideal salinity levels during establishment and (Clarke and Hannam 1970), soil water concentration and elevation (Burchett et al 1998).

Crab burrow abundance was found to vary throughout the 2013/14 monitoring period and statistical comparison between plot categories at high and low elevations showed no statistical differences between plot categories were evident. Comparison to baseline conditions showed mean crab burrow abundance recorded in summer 2013 and winter 2014 was lower in high and low reference plots, however this result was not significant. Comparison of baseline condition with results from winter 2014 (one year after revegetation) show crab burrows were more abundant at treatment and control sites in both high and low plot categories.

Although not statistically significant this result is s a positive indication the crab community at the Site is showing signs of recovery. Burrowing crab communities of intertidal saltmarsh are known to be susceptible to degradation caused by vehicles (Kelleway 2006 and Laegdsgaard 2006) and it is highly likely restriction of vehicles to the Site is having a positive impact. By eliminating vehicles from the Site, the risk of crushing and soil compaction is ameliorated and habitat and algae food sources restored which encourages recolonisation of burrowing crabs (Roach 1998, Ross 2006, Kelleway 2006 and Green et al 2009).

Gastropod abundance at high plots was highest at reference plots in both summer 2013 and winter 2014 with *Ophicardelus spp*. the dominant taxa. Gastropods were absent in control plots and very few recorded in treatment plots in all surveys since the commencement of monitoring. Statistical comparison between revealed significant differences in abundance was evident between plot categories in summer 2013 and winter 2014. Comparison of baseline condition to winter 2014 (one year after revegetation) show no significant change in gastropod abundance was evident.

Gastropod abundance at low plots was higher for all plot categories in winter 2014 with greatest abundance recorded in reference plots with *Phallomedusa solida* being the dominant taxa. Statistical comparison revealed significant difference in gastropod abundance was evident between plot categories in summer 2013 and winter 2014. Comparison of baseline condition to winter 2014 (one year after revegetation) show no significant change in gastropod abundance was evident.

The distribution of *Ophicardelus spp*. at the Site was associated with the cover of *Juncus krausii.* In revegetation plots where *Ophicardelus spp.* was present, they were found clumping around the base or higher up the stems of *Juncus krausii.* Green et al (2009) and Ross et al (2009) recorded similar behaviour and Ross (2006) documented that *Ophicardelus spp.* was most affected by disturbance and populations took longer to recover than other species. The association with *Juncus krausii* and comparatively longer recovery time are likely to have influenced the absence or rarity of this species in high treatment and control plots.

Phallomedusa solida was the dominant gastropod taxa of low plots and during sampling *Phallomedusa solida* were observed as being partially buried in moist sediment mostly under *Sarcocornia quinqueflora* or taking refuge in the opening of crab burrows. This was also the case during the baseline survey (CTENVIRONMENTAL 2013). It has been documented that *Phallomedusa* utilises *Sarcocornia quinqueflora* as refuge from desiccation in hot or dry and windy conditions (Green et al 2009) and predation by fish during times of inundation (Roach 1998). However abundance of this species has been negatively correlated with increasing cover of *Sarcocornia quinqueflora* and a preference for patches of bare sediment has been shown (Wong 2002). These factors are likely to have influenced the distribution of *Phallomedusa solida* and may explain the variable abundance recorded within low plot categories.

Although slight changes in vegetation cover, crab burrow and gastropod abundance were recorded for the 2013/14 monitoring period, few are of statistical significance. The application of multivariate statistical analysis to compare structure of the saltmarsh community over time confirmed that the overall condition of plot categories had not significantly changed. However exceptions to this were evident for high treatment plots and to a lesser extent low control plots which both showed significant change in community structure over time.

This result provides an indication that after one year the ecological community at the Site is responding to rehabilitation and revegetation. 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 of the ecological community at the Site 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. This, in turn, will result in the increase of primary and secondary productivity which will provide benefits the wider Botany Bay ecosystem.

Future Direction of Monitoring

As a result of 2013/14 monitoring the following recommendations has been made to enhance both the site and monitoring program.

1. Future assessment of change to the ecological community of the Site is recommended. Monitoring should continue and apply the current methods for an additional 12 months after which time further historical comparison of the ecological community of the Site can be made. It is well documented saltmarsh rehabilitation is a relatively new concept in Australia and many projects go undocumented. Therefore little information exists to measure successes of such projects (Laegdsgaard 2006) and continued monitoring and reporting will contribute valuable information to land managers considering similar projects.
2. On completion of 2014/15 monitoring seasonal comparison of crab burrow and gastropod abundance should be conducted and results of analysis used to determine the frequency of future monitoring.
3. Prior to baseline monitoring, wooden survey posts were used to mark survey plot locations. Posts were painted blue to indicate high plots and yellow to indicate low plots. Tidal inundation and weathering have discoloured posts and identification of plot category had become difficult. It is recommended plots markers are recoloured and co-ordinates are re-plotted and mapped for future ease of identification.
4. Although vehicle access to the Site has been restricted, two minor incidences of motorbike entry were observed throughout the 2013/14 monitoring period with the likely entry point being the western edge of the Tasman Street perimeter fence. To ensure no future access and damage occurs at the Site it is recommended the fence be extended or strategic planting of *Juncus krausii* and/or *Casuarina spp.* is used to create a vegetative barrier to the site. This approach will further restrict access to the Site and enhance the habitat quality of the Site margin.

References

Adam P (1990) Saltmarsh Ecology, Cambridge University Press, Cambridge.

Adam, P (2002) Saltmarshes in a time of change, *Environmental Conservation,* 29, 39-61Australian Saltmarsh Ecology editor Neil Saintlan (2009) CSIRO publishing, Collingwood, Australia.

Alletson, T.,J Green and A. Reichelt-Brushett (unknown) Saltmarsh Restoration – Rebuilding habitat with a community partnership. Tweed Shire Council.

Blionis,G.J. and S.J. Woodin (1999) Vehicle rack damage to salt marsh soil and vegetation at Culbin Sands, NE Scotland. *Journal of Scotland* . Volume 51, Issue 2, 1999.

Buck Tracy L., Greg A. Breeda,Steven C. Penningsa,Margo E. Chaseb, Martin Zimmerc, Thomas H. Carefoot (2003) Diet choice in an omnivorous salt-marsh crab: different food types, body size, and habitat complexity. *Journal of Experimental Marine Biology and Ecology*. 292, 103– 116.

Burchett M. D., Allen C., Pulkownik A. and MacFarlane G. (1998) Rehabilitation of Saline Wetland, Olympics 2000 Site, Sydney (Australia) - II: Saltmarsh Transplantation Trials and Application. *Marine Pollution Bulletin Vol*. 37, 8-12, pp. 526-534,

Chapman, M. G. and Underwood, A. J. (2000). The need for a practical scientific protocol to measure successful restoration. *Wetland*s (Australia) 19, 28-48.

Chapman G (2012) Rehabilitation of estuarine habitats in *Estuary plants and what's happening to them in south east Australia.* Ed. Geoff Sainty, John Hosking, Geoff Carr and Paul Adam. Sainty and Associates 2012.

Clarke, K. R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, 18, 117–143.

Clarke L.D. and Hannon N.J. (1970). The mangrove swamp and salt marsh communities of the Sydney district III Plant growth in relation to salinity and waterlogging. *Journal of Ecology*. 56: 351_369.

Dalby-Ball, M. and A. Olsen (2012) Engaging the community and rehabilitating saltmarsh, mangroves and seagrasses in *Estuary plants and what's happening to them in south east*

Australia. Ed. Geoff Sainty, John Hosking, Geoff Carr and Paul Adam. Sainty and Associates 2012.

Department of Sustainability, Environment, Water, Population and Community (DSEWPC) 2013. www.environment.gov.au accessed Nov 2013.

Freewater, P (2004) Hydro-ecology: a framework for estuarine research and management In *science* University of Technology 271.

Freewater, P., Margaret Platell, William Galdstone, David Taylor, Sean Garber and Maarten van Ormondt (2007) Export and dispersal of crab zoeae from saltmarsh-mangrove complexes in Brisbane Water and their importance to fish. Gosford City Council.

Green J., A. Reichelt-Brushett and S.W.L Jacobs (2009) Investigating gastropod habitat association in saltmarsh*. WETLANDS (Australia)* 25(1).

Kaly U,L (1988) Distribution, abundance and size in mangrove and saltmarsh gastropods. PhD thesis, University of Sydney, Australia.

Kaly U.L., Eugelink G. and Robertson A.I. 1997. Soil conditions in damaged North Queensland mangroves. Estuaries 20: 291–300.

Katrak G., S. Dittman and L. Seuront (2008) Spatial variation in burrow morphology of the mud shore crab *Helograpsus heswellianus* (Brachyura, Grapsidae) in South Australian saltmarshes. *Marine and Freshwater Research,* 59, 902-911.

Kelleway,J (2006) Ecological impacts of recreational vehicle use on saltmarshes of the Georges River, Sydney. *WETLANDS (Australia),* 22(2).

Kneib, R.T (1984) Patterns of distribution and abundance in the intertidal saltmarsh: Causes and questions. *Estuaries*. Volume 7, Issue 4A, pp 392-412.

Marchant, R., Barmutta, L. A., & Chessman, B. C. (1994). Preliminary study of the ordination and classification of macroinvertebrate communities from running waters in Victoria, Australia. *Australian Journal of Marine & Freshwater Research*, 45, 945–962.

Laegdsgaard P. (2002). Recovery of small denuded patches of the dominant NSW coastal saltmarsh species (Sporobolus virginicus and Sarcocornia quinqueflora) and implications for restoration using donor sites. *Ecological Management and Restoration* 3(3): 202206.

Laegdsgaard Pia (2006) Ecology, disturbance and restoration of coastal saltmarsh in Australia: a review. *Wetlands Ecology and Management*. Volume 14, Issue 5, pp 379-399.

Mazumder, D., Saintlan, N. and Williams, R.J (2006) Trophic relationships between itinerant fish and crab larvae in a temperate Australian saltmarsh. *Marine and Freshwater Research*, 57, 193-199.

Mazumder D, Saintilan N. and Williams R. J. (2006) Trophic relationships between itinerantfish and crab larvae in a temperate Australian saltmarsh. *Marine and Freshwater Research* 57: 193-199.

Mazumder. D, Neil Saintilan and Robert J. Williams (2008)Zooplankton inputs and outputs in the saltmarsh at TowraPoint, Australia . Wetland Ecological Management.

Mazumder D (2009) Ecology of burrowing crabs in temperate saltmarsh of south –east Australia. In: Australian Saltmarsh Ecology (Ed. Neil Saintilan) pp. 75-114.

Mazumder D, Neil Saintilan, Robert J. Williams and Ron Szymczak (2011) Trophicimportance of a temperate intertidal wetland to resident and itinerant taxa: evidence from multiplestable isotope analyses. Marine and Freshwater Research, 62, 11–19.

McFarlane G (2010) Non- destructive sampling techniques for the rapid assessment of population parameters in estuarine shore crabs. Wetlands (Australia) 20(2).

Rader D. N. (1984) Salt-marsh benthic invertebrates: Small-scale patterns of distribution and abundance. Estuaries. Volume 7, Issue 4, pp 413-420.

Roach A.C. 1998. Effects of predation on the size structure of the gastropod Salinator solida (Martens) populations at Towra Point, NSW, Australia. *Marine and Freshwater Reseacrh*. 49: 779–784.

Ross P (2006) Macrofaunal Loss and Microhabitat Destruction: The Impact of Trampling in a Temperate Mangrove Forest, NSW Australia. *Wetlands Ecology and Management*, Volume 14, Issue 2, pp 167-184.

Ross P.M., Minchinton, T.E. and Ponder, W. (2009) The ecology of molluscs in Australian saltmarshes. In: *Australian Saltmarsh Ecology* (Ed. Neil Saintilan) pp. 75-114.

Sutherland Shire Council (2012) Environmental Strategy for Captain Cook Drive. Prepared by B. Graham, Parks and Waterways Branch.

Vanderzee, M.P (1988) Changes in saltmarsh vegetation as an early indicator of sea level rise. In *Estuary plants and what's happening to them in south east Australia.* Ed. Geoff Sainty, John Hosking, Geoff Carr and Paul Adam. Sainty and Associates 2012.

WARREN J. H (2006) The use of open burrows to estimate abundances of intertidal estuarine crabs. *Australian Journal of Ecology.*Volume 15, Issue 3, pages 277–280, September 1990.

Warwick, R. M. (1993). Environmental impact studies on marine communities: pragmatical considerations. *Australian Journal of Ecology*, 18, 63–80.

Wright, I. A., Chessman, B. C., Fairweather, P. G., & Benson, L. J. (1995). Measuring the impact of sewage effluent of an upland stream: the effect of different levels of taxonomic resolution and quantification. *Australian Journal of Ecology*, 20, 142–149.

Wolters M, Garbutt A. and Bakker J.P. (2005) Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe. *Biological Conservation,* 123,249–268.

Wong P (2002) Distribution and abundance of *Salinator solida*. Honours Thesis, University of Sydney, NSW, Australia.

Appendix

Raw data for 2013/14 monitoring period of the saltmarsh ecological community at Horning Street Saltmarsh, Kurnell.

HCP = High Control Pole, HR = High Reference, HTP = High Treatment Pole, HT = High Treatment, LC = Low Control, LCP = Low Control Pole, LR = Low Reference, LT = Low Treatment, LTP = low Treatment Poles.

Sq = Sarcocornia Quinqueflora, s = Sporobolus virginicus, j = Juncus krausii, sr = Samolus repens, su = Suaeda australensis, buf = Buffalo grass, man = mangrove, O.spp = Ophicardelus spp., P. spp = Phallomedusa solida

Appendix 1A. Raw data for spring 2013 monitoring.

Date - Sept 8 2013	Conditions - Cold Southerly Wind, Tidal inundation									
	Percentage Vegetation Cover									
Plot Category	Quadrant 1	Species	Quadrant 2	Species	Quadrant 3	Species	Quadrant 4	Species	Average Cover	Regen.
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HCP	5	sq	0	nil	5	sq	0	nil	2.5	n
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HCP	0	regen sq	0	nil	nil	nil	0	nil	0	y
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HR	30	SQ	40	sq	40	sq	20	sq	32.5	n
HR	90	s,sq	80	sq	70	sq	10	sq	62.5	n
HR	50	sq	40	sq	80	jk	70	j,sq	60	n
HR	5	sq	70	sq	40	sq	5	sq	30	n
HR	80	s	70	sq	50	s	25	s, sa,j	56.25	n
HR	20	sq	15	sq	15	sq	10	sq	15	n
HT	5	s	5	s	10	sq	10	sq	7.5	n
HTP	5	s	5	sq	5	s	5	sq	5	n
HTP	15	sa	15	sq	15	sa	15	sq	15	n
HTP	5	sq	15	sq	15	sq	10	sq	11.25	n
HTP	15	s	10	sq	5	s	15	sq	11.25	n
LC	0	nil	0	nil	0	nil	5	sq	1	n
LC	0	nil	0	nil	0	nil	5	sq	1.25	n
LC	0	nil	2.5	regen sq	0	nil	0	nil	2.5	y
LC	0	nil	0	nil	0	nil	15	sq	3.75	n
LC	0	nil	10	sq	0	nil	5	sq	3.75	n
LCP	0	nil	0	nil	0	nil	0	nil	0	n

LCP	2.5	regen sq	2.5	regen sq	2.5	regen sq	2.5	regen sq	2.5	y
LCP	2.5	regen sq	0	nil	0	nil	0	nil	nil	y
LCP	0	nil	0	nil	0	nil	0	nil	0	n
LCP	2.5	regen sq	0	nil	0	nil	0	nil	2.5	y
LR	90	sq	80	sq	40	sq	60	sq, Regen sq	67.5	y
LR	10	sq	10	sq	10	sq	30	sq	15	n
LR	60	sq,sr	80	sq,s	50	sq,s,sr	60	sq,s,sr	50	n
LR	80	sq	60	sq	90	sq	10	sq	60	n
LR	75	sq	60	sq	60	sq	80	sq	68.75	n
LR	0	nil	10	sq	50	sq	0	nil	15	n
LT	5	sq	5	sq	5	sq	5	s	5	n
LT	10	sq,s	10	sq,s	20	sq	10	sq,s	12.5	n
LT	10	sq	0	nil	5	sq	5	sq	5	n
LT	10	sq,s	5	sq	10	s,sq	15	s,sq	10	n
LTP	15	sq,s	15	s,sq	10	sq,s	10	sq,s	12.5	n
LTP	5	sq,s	0	nil	5	sq	0	nil	2.5	n
LTP	5	s	5	sq	0	nil	10	sq	4	n
LTP	0	nil	15	sq	0	nil	10	sq	6.25	n
LTP	5	sq	5	sq	2.5	regen sq	5	sq	4.375	y

Appendix 1B. Raw data for summer 2013 monitoring.

Date - Dec 17 2013	Conditions - Sunny. Rain 16th Dec												
Percentage Vegetation Cover											Macroinvertebrate Abundance		
Plot Category	Quadrant 1	Species	Quadrant 2	Species	Quadrant 3	Species	Quadrant 4	Species	Average Cover	Regen.	Crab	O. spp.	P. spp.
HCP	0	nil	0	nil	0	nil	0	nil	0	y	0	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	n	0	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	y	0	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	n	2	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	n	0	0	0
HR	90	buf,s	100	buf,s	100	j,s,buf	100	buf.s	97.5	n	0	0	0
HR	30	sq	20	sq	15	sq	5	sq	17.5	n	0	0	0
HR	0	nil	90	j	70	j	20	j	45	n	0	38	17
HR	80	sq	10	sq,j	90	j,sq,s	90	j	67.5	y	3	31	1
HR	80	sq	70	sq	60	sq	50	S,sq	65	n	3	2	0
HV	10	s	5	sq	5	s,sq	10	s	7.5	y	1	0	0
HV	15	sq	5	s	15	sq	5	s	10	n	2	0	0
HVP	5	s	10	sq	10	s	10	sq	8.75	n	0	0	0
HVP	5	s	10	sq	5	s	5	s,sq	6.25	y	1	0	0
HVP	15	sq	15	s	5	sq	5	s	10	n	0	0	0
HVP	10	s,sq	5	s	15	sq	40	s	17.5	y	0	1	0

HVP	2.5	s	5	sq	2.5	s	5	sq	3.75	n	0	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	n	4	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	n	1	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	n	3	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	n	0	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	n	4	0	2
LCP	0	nil	0	nil	0	nil	0	nil	0	y	4	0	0
LCP	0	nil	0	nil	0	nil	0	nil	0	n	1	0	0
LCP	0	nil	0	nil	0	nil	0	nil	0	n	4	0	0
LCP	2.5	sq	2.5	sq	0	nil	2.5	sq	1.875	n	4	0	0
LCP	0	nil	0	nil	0	nil	2.5	sq	0.625	y	1	0	0
LR	40	sq	20	sq	15	sq	15	sq	22.5	n	2	0	0
LR	50	sq	70	sq	80	sq	40	sq	60	n	10	2	1
LR	5	sq	20	sq	15	sq	60	sq	25	n	4	0	0
LR	0	nil	10	sq	60	sq	10	sq	20	n	6	6	3
LR	50	sq	80	sq	70	sq	40	sq	60	n	0	1	17
LV	2.5	s	5	sq	2.5	s	10	sq	5	n	1	0	0
LV	15	sq	5	s	10	sq	5	s	8.75	n	5	0	0
LV	20	sq	0	nil	20	sq	2.5	s	10.625	n	0	0	4
LVP	15	sq	5	s	10	sq	10	s	10	n	1	0	0
LVP	2.5	sq	2.5	s	0	nil	2.5	sq	1.875	n	20	0	0
LVP	5	sq	5	s	5	sq	2.5	s	4.375	n	9	0	0
LVP	15	sq	0	nil	20	sq	0	nil	8.75	n	4	0	0
LVP	10	sq	0	nil	5	sq	0	nil	3.75	n	0	0	0

Appendix 1C. Raw data for autumn 2014 monitoring.

Date - Feb 28 2014	Conditions - Raining, Falling Tide									
Percentage Vegetation Cover										
Category	Quadrant 1	Species	Quadrant 2	Species	Quadrant 3	Species	Quadrant 4	Species	Average Cover	Regen
HCP	0	nil	0	nil	0	nil	0	nil	0	y
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HCP	0	nil	0	nil	0	nil	0	nil	0	n
HR	0	nil	80	j	70	j	70	j	44	n
HR	100	j	80	j,sq	60	sq	100	j,sq,su	68	n
HR	90	j,s	70	j	70	j,s	90	j,sq,su	64	n
HR	90	j	80	j	80	j	100	j	70	n
HR	100	j,s	100	j,s	80	j,s	90	j,sq,su	74	n
HV	30	sq	25	s	20	sq	15	s	18	n
HV	20	sq	20	s	20	sq	15	s	15	y

HV	30	sq	10	s	15	sq	5	sq,s	12	n
HVP	10	sq	0	nil	10	sq	5	s	5	n
HVP	30	sq	15	s	20	sq	10	s	15	n
HVP	20	sq	0	nil	10	sq	5	s	7	n
HVP	15	sq	5	sq,s	10	sq	5	sq	7	n
HVP	5	sq	0	nil	0	nil	0	nil	1	y
LC	60	man	20	man	0	nil	50	man	26	n
LC	0	nil	0	nil	0	nil	0	nil	0	n
LC	0	nil	0	nil	0	nil	10	sq	2	n
LC	0	nil	0	nil	0	nil	10	sq	2	y
LC	0	nil	0	nil	20	sq	40	sq	12	y
LC	0	nil	0	nil	0	nil	0	nil	0	n
LCP	0	nil	0	nil	0	nil	0	nil	0	y
LCP	0	nil	0	nil	0	nil	0	nil	0	n
LCP	5	sq	0	nil	0	nil	0	nil	1	y
LCP	0	nil	0	nil	0	nil	0	nil	0	y
LR	70	sq	20	sq	0	nil	0	nil	18	n
LR	80	sq	90	sq	80	sq	70	sq	64	n
LR	20	sq	10	sq	15	sq	30	sq	15	n
LR	10	sq	70	sq	80	sq	90	sq	50	n
LV	15	sq	5	s	10	sq	5	s	7	n
LV	30	sq	0	nil	15	sq	5	s	10	n
LV	20	sq	5	s	20	sq	5	s	10	n
LVP	0	nil	10	sq	0	nil	15	sq	5	n
LVP	15	sq	0	nil	20	sq	5	sq	8	n
LVP	20	sq	5	s	15	sq	5	s	9	n
LVP	0	nil	0	nil	5	sq	0	nil	1	n
LVP	15	sq	5	s	10	sq	5	nil	7	n

Appendix 1D. Raw data for winter 2014 monitoring.

Date - June 1 2014	Conditions - Overcast Falling tide												
Percentage Vegetation Cover											Macroinvertebrate Abundance		
Category	Quadrant 1	Species	Quadrant 2	Species	Quadrant 3	Species	Quadrant 4	Species	Average Cover	Regeneration	Crab	O. spp.	P. spp.
HC	0	nil	0	nil	0	nil	0	nil	0	0	0	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	0	1	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	0	4	0	0
HCP	5	sq	15	sq	5	sq	2.5	sq	6.875	1	2	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	1	0	0	0
HCP	0	nil	0	nil	0	nil	0	nil	0	0	1	0	0
HR	20	sr,s	90	j,s,sr	90	j,s,sr	20	sr,s	55	1	1	20	1
HR	60	j,sq	90	j	60	sq,su	50	sq	65	0	2	0	1
HR	100	s,j	100	j,s	100	j,s	80	j,s	95	0	1	46	3

HR	90	j	80	j	70	j	21	j,s	65.25	1	7	17	1
HR	20	su	20	su	70	su	15	su	31.25	0	12	2	0
HV	40	sq	5	s	30	sq	10	sq	21.25	1	4	0	0
HV	20	sq	20	s	15	sq	15	s	17.5	1	0	0	3
HVP	5	s	15	sq	10	s	15	sq	11.25	0	2	0	0
HVP	30	sq	0	nil	10	sq	10	sq	12.5	1	1	0	0
HVP	15	sq	2.5	sq	5	sq	2.5	s	6.25	0	4	0	0
HVP	60	sq	2.5	s	40	sq	2.5	s	26.25	0	7	0	0
HVP	2.5	s	15	sq	5	s	25	sq	11.875	0	6	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	0	11	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	0	4	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	0	8	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	0	6	0	0
LC	0	nil	0	nil	0	nil	0	nil	0	0	5	0	0
LCP	0	nil	0	nil	0	nil	0	nil	0	0	7	0	0
LCP	0	nil	0	nil	0	nil	2.5	sq	0.625	1	1	0	0
LCP	5	sq	0	nil	0	nil	0	nil	1.25	0	3	0	0
LCP	0	nil	0	nil	0	nil	0	nil	0	0	1	0	0
LCP	0	nil	0	nil	5	s	30	s	8.75	1	2	0	8
LR	0	nil	0	nil	80	j	0	nil	20	0	7	38	3
LR	50	sq	60	sq	0	nil	10	sq	30	1	11	0	3
LR	0	nil	0	nil	0	nil	70	sq	17.5	0	9	0	3
LR	80	sq	80	sq	70	sq	80	sq	77.5	0	1	0	22
LR	20	sq	50	sq	10	sq	5	sq	21.25	0	2	0	0
LV	30	s	20	sq	25	sq	15	s	22.5	0	0	0	7
LV	2.5	s	20	sq	15	s	25	sq	15.625	0	3	0	1
LV	0	nil	2.5	s	5	sq	5	sq	3.125	0	8	0	0
LV	0	nil	15	sq	2.5	s	15	sq	8.125	1	1	0	0
LV	5	s	10	sq	10	s	5	sq	7.5	0	0	0	2
LVP	2.5	2	10	sq	0	nil	5	sq	4.375	0	3	0	0
LVP	2.5	s	20	sq	0	nil	15	sq	9.375	0	5	0	0
LVP	20	sq	5	s	10	sq	2.5	s	9.375	0	4	0	0
LVP	0	nil	0	nil	0	nil	0	nil	0	0	10	0	0
LVP	2.5	s	5	sq	2.5	sq	2.5	s	3.125	0	15	0	0

CTENVIRONMENTAL

www.ctenvironmental.com.au

L209/8 Loveridge St. Alexandria, NSW. 2015