Port Botany Post Construction Environmental Monitoring

Port Botany Post Construction Monitoring Annual Report 2013

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Shaping the Future

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Executive Summary

This Port Botany Post Construction Monitoring Annual Report 2013 summarises the findings of the first year post-construction monitoring for five components of Penrhyn Estuary Habitat Enhancement Plan (PEHEP) implemented by Sydney Ports in association with the expansion of berthing facilities at Port Botany.

The primary objectives of the environmental enhancement works within Penrhyn Estuary are to:

> Expand the existing shorebird habitat, to continue to attract migratory shorebirds and potentially attract more shorebirds;

> Create seagrass habitat;

> Expand the area of saltmarsh habitat; and

> Provide controlled public access and minimise disturbance within the Estuary.

The Post Construction Environmental Monitoring program began in 2012 and extends until 2017 with the overall aim to verify the success of habitat enhancement and to identify corrective actions required to ensure long-term success of habitat enhancement. Monitoring has been done in accordance with an approved Monitoring Services Management Plan (MSMP) that describes the management and quality assurance/quality control (QA/QC) procedures that have been followed during implementation of the monitoring program.

Environmental Monitoring for the first year post-enhancement works has been completed for the following components:

1. Shorebirds, including monitoring the numbers and species composition of shorebirds, assessing feeding behaviour of shorebirds and monitoring the existing and future effects of disturbance in Penrhyn Estuary on shorebird behaviour;
2. Benthos, including monitoring changes in benthic invertebrate communities in existing and new intertidal/shallow subtidal habitats in terms of their impacts on food items for shorebirds, assessing changes in benthic communities in different feeding sub-habitats and assessing the sustainability of created habitats with respect to their provision of food items for shorebirds;
3. Saltmarsh; including monitoring changes in existing saltmarsh habitats that were retained in terms of the impacts of port construction and operation and assessing the success of created saltmarsh habitat, including its ecological function;
4. Seagrass, including mapping the distribution and measuring ecological characteristics of seagrasses in existing (Foreshore Beach to the mouth of the Mill Stream) and newly created habitat (the flushing Channel and intertidal areas of Penrhyn Estuary) and comparing these with information collected for seagrasses prior to and/or during construction works, and measuring the success of transplanting Posidonia from the dredged area to Quibray Bay.
5. Water Quality, including verifying that post-construction flushing of the estuary is sufficient to prevent eutrophic conditions from forming as a result of processes occurring within Penrhyn Estuary or its catchment, involving monitoring of key indicators such as turbidity, nutrient concentrations and flushing times.

The following table summarises key findings in each of the five monitoring programs.

Monitoring Program	Indicator	Result	Comment
Shorebirds	Peak Counts of Bar-tailed Godwits	Target not met, but average count increasing post-construction. Numbers consistent throughout the season Higher abundance nocturnally.	Positive trend
	Peak Counts of Red Knot	Absent from the estuary	No reference site available to compare populations.
	Peak Counts of Pacific Golden Plover	Target exceeded for three consecutive seasons.	Positive result. Variable numbers at low tide but gradual increase apparent post-construction.
	Peak Counts of Curlew Sandpiper	Target not met. Remained absent throughout construction and post-construction phases. .	Declining across SE Australia so likely to be caused by events at a greater scale
	Peak Counts of Red-necked Stint	Target exceeded	Positive result. Numbers consistent throughout season, higher average since construction phase.
	Peak Counts of Double-banded Plover	Target not met	Extremely variable within and among seasons at both Penrhyn and the reference site. No distinct pattern of population change
Benthos	Abundance of invertebrates (#/sample)	Target not met	Positive trend, increasing in third post-construction survey
	Biomass (wet weight g/sample)	Target exceeded	Positive result, increase significantly greater than at Reference locations
	Mean Grain Size (mm)	Target exceeded: Decrease compared to pre-enhancement	Positive result: soil amendments successful in increasing fine particles
	Fine sediment fraction (%)	Target exceeded: Increase compared to pre-enhancement	Positive result: soil amendments successful in increasing fine particles and organic material
	Link to shorebird abundance	No clear correlation	Insufficient data for trend analysis
Saltmarsh	Area of cover	Target met: Four fold increase in saltmarsh area	Positive result: habitat creation and planting successful
	Growth (assemblage along transects)	Target met: Better than baseline in all areas except altered areas	Positive result: indicates healthy habitat
	Species diversity in quadrats	Target met: Equivalent to or increased compared to baseline in all areas except those that received transplants	Positive result
	Sarcocornia quinqueflora (% cover)	Equivalent to or increased compared to baseline in all areas except those that were altered or received transplants	Positive result, but lower cover than at references in all but new habitat
	Sporobolus virginicus (% cover)	Equivalent to or increased compared to baseline except undisturbed areas or those	Positive result but lower than references

Monitoring Program	Indicator	Result	Comment
		that received transplants	
	Suaeda australis (% cover)	Increase in undisturbed areas, but not in areas that were altered or received transplants	Positive result but new areas lower than references
	Juncus kraussii (% cover)	Increase in areas that received transplants	Positive result compared to reference areas
	Plant health conditions	Target met: Better than baseline and references	Positive result
	Max height	Target met: Better than baseline and references	Positive result
	Ecological function (epifaunal assemblage)	Target met: Equivalent to assemblages in references	Positive result
	Mangrove Invasion Trees	Target met: Decreased compared to baseline and similar to references	Positive result
	Mangrove Invasion Seedlings	Target met: Decreased compared to baseline and similar to references	Positive result
	Mangrove Invasion Pneumatophores	Target met: Decreased compared to baseline and similar to references	Positive result
Seagrass	Distribution along Foreshore Beach	Decreased significantly prior to habitat enhancement	Negative but not associated with Port Expansion project
	Distribution in Rehabilitation Area (Channel)	Early signs of recovery for *Halophila* and *Zostera*, but not *Posidonia*	Positive trend
	Condition along Foreshore Beach	*Halophila* with short sparse leaves with medium load of epiphytes	Positive trend
	Distribution in intertidal areas within Penrhyn Estuary	Target met: Observation of sparse, ephemeral patches of *Zostera*	Positive result, similar to pre-enhancement
	Condition of *Posidonia* transplanted to Quibray Bay	Target met: Successful, generally not distinguishable from surrounding seagrass	Positive result
Water Quality	pH	Target met: No difference post-construction, no exceedances of guidelines	Positive result
	Dissolved Oxygen (DO)	Target met: No difference post-construction, very few exceedances of guidelines	Positive result
	Electrical Conductivity (EC)	Lower post-construction, no guideline value	Could be attributable to data quality in pre-construction phase
	Total Nitrogen (TN)	Target met: No change post-construction, few exceedances of guidelines	Positive result
	Total Phosphorous	Target met: No change post-construction, but some exceedances of guidelines	Positive result
	Total Suspended Solids (TSS)	Target met: Higher during high tide, but no difference post-construction, frequent	Positive result, exceedances typical of estuarine environment

Monitoring Program	Indicator	Result	Comment
		exceedances of guidelines	
	Chlorophyll a (Chl-a)	Target met: No change post-construction, few exceedances of guidelines	Positive result

No recommendations for change to any monitoring program are made at this stage.

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Appendices

1 Introduction

1.1 Background

As part of the Port Botany Expansion Project, Sydney Ports undertook one of the largest habitat rehabilitation projects in Australia. Penrhyn Estuary, located adjacent to the port expansion is a small waterway of approximately 80 ha located to the north of Brotherson Dock which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978. The estuary's underlying substratum was formed by placement of coastal sand and accumulated mud through time, with sediments in the inner estuary overlain by a mud veneer of varying thicknesses. Estuarine sediments have accumulated contaminants via Springdale and Floodvale creeks that drain the industrial and urbanised catchment. Long-lived compounds present in sediment include mercury, chromium, Hexachlorobenzene (HCB), organotins and pesticides DDT and DDE and groundwater contaminated with volatile halogenated compounds has been intercepted upstream of Penrhyn Estuary since late 2004. Despite the decades-long presence of contaminants, the inner estuary supports benthic fauna with abundance and diversity indices comparable to estuarine habitats with similar sediment characteristics; seagrass grows in sparse and ephemeral patches and the estuary supports migratory shorebird populations. The estuary opens adjacent to a much-altered foreshore which has seen significant decline in the extent of seagrasses which are now protected under state legislation.

Since its creation, Penrhyn Estuary has been utilised by a diverse group of migratory birds. The main purpose of the rehabilitation works was to enhance the existing intertidal habitat, to expand the estuary as a long term habitat for migratory shorebirds, and to create habitat where seagrass could recolonise naturally. Enhancement tasks included the removal of mangroves, weeds and introduced species, the enhancement of existing intertidal sand flat habitat and the creation of new saltmarsh habitat and roosting habitat for migratory shorebirds. An extensive area of fore dune was levelled to create an intertidal feeding and roosting habitat for key species of migratory shorebirds, and to potentially attract a greater number of shorebirds upon completion (**Table 1Figure 1**). The channel leading to the estuary was designed to ensure adequate flushing and water quality and to support the growth of seagrass. The design, methodology and ongoing maintenance for the estuary are outlined within the Penrhyn Estuary Habitat Enhancement Plan (PEHEP).

Cardno Ecology Lab was commissioned by Sydney Ports Corporation (SPC) to undertake the Port Botany Post Construction Environmental Monitoring program over the period 2012 to 2017. The man aims of the monitoring program are to verify the success of habitat enhancement and to identify corrective actions required to ensure long-term success of habitat enhancement. Monitoring has been done in accordance with an approved Monitoring Services Management Plan (MSMP) that describes the management and quality assurance/quality control (QA/QC) procedures that have been followed during implementation of the monitoring program.

This document summarises the trends in key indicators within the five components of the monitoring program at the end of the first year of monitoring, corresponding to 27 months after the completion of enhancement works within and adjacent to the estuary. A timeline for relevant enhancement activities, summary of data, analyses and results for each monitoring component are presented in appendices to this document.

1.2 Aims

The primary objectives of the environmental enhancement works (within Penrhyn Estuary) as outlined in the PEHEP are to:

> Expand the existing shorebird habitat, to continue to attract migratory shorebirds and potentially attract more shorebirds;

> Create seagrass habitat;

> Expand the area of saltmarsh habitat; and

> Provide controlled public access and minimise disturbance within the Estuary.

Key components of the five-year post-construction monitoring program and their specific aims are:

6. Shorebirds (Appendix A)

   a. To monitor the numbers and species composition of shorebirds found in Penrhyn Estuary following the habitat enhancement works and assess changes;

   b. To assess the feeding behaviour of shorebirds in Penrhyn Estuary following habitat enhancement to determine habitat usage patterns;

   c. To monitor the existing and future effects of disturbance in Penrhyn Estuary on the behaviour of shorebirds; and

   d. To monitor the disturbance and predation in the Estuary and assess the effectiveness of security access restriction measures.

7. Benthos (Appendix B)

   a. To monitor changes in benthic invertebrate communities in existing and new intertidal/shallow subtidal habitats in terms of their impacts on food items for shorebirds;

   b. To assess changes in benthic communities in different feeding sub-habitats used by shorebirds; and

   c. To assess the sustainability of created habitats with respect to their provision of food items for shorebirds.

8. Saltmarsh (Appendix C)

   a. To monitor changes in existing saltmarsh habitats that were retained in terms of the impacts of port construction and operation; and

   b. To assess the success of created saltmarsh habitat, including its ecological function.

   The saltmarsh monitoring plan aims to verify that the goal of creating appropriate, ecologically functional saltmarsh habitat has been achieved and that the habitat is sustainable under the conditions of port operation. The plan is linked to the goal of improving numbers of migratory shorebirds by providing quality saltmarsh habitat used by the shorebirds for roosting and (to a lesser extent) feeding.

9. Seagrass (Appendix D)

   a. To map the distribution and measure ecological characteristics of seagrasses in existing (Foreshore Beach to the mouth of the Mill Stream) and newly created habitat (the flushing Channel and intertidal areas of Penrhyn Estuary) and compare these with information collected for seagrasses prior to and/or during construction works; and

   b. To measure the success of transplanting Posidonia from the dredged area to Quibray Bay.

10. Water Quality (Appendix E)

    The primary objective of the water quality monitoring program is to verify that post construction flushing of the estuary is sufficient to prevent eutrophic conditions from forming as a result of processes occurring within Penrhyn Estuary or its catchment. If eutrophic conditions developed within Penrhyn Estuary a range of potential adverse impacts could arise and the most significant of these could be a deficiency in dissolved oxygen leading to mortality of fish and invertebrates which are key components of the Penrhyn Estuary ecosystem. The key indicators for potential eutrophic conditions in the estuary are nutrient concentrations and prolonged flushing times.

Figure 1 Penrhyn Estuary (top) in August 2008 before habitat enhancement and (bottom) after habitat enhancement in November 2012

2 Summary of Results

2.1 Shorebirds

The Annual Report for Shorebird Monitoring Program is presented in **Appendix A**.

Surveys of shorebirds were done during low and high tide at Penrhyn Estuary and at selected reference sites from the start of April 2012 to the end of March 2013. During the off-peak season (April 2012 – August 2012), surveys were conducted fortnightly, increasing to weekly during the peak season (September 2012 – March 2013). Six key species were selected as indicators of the success of the Penrhyn Estuary Habitat Enhancement Plan (PEHEP): Bar-tailed Godwit, Red-necked Stint, Double-banded Plover, Curlew Sandpiper, Red Knot and Pacific Golden Plover. The abundance of key species was compared with counts at reference sites to measure the success of the works.

The first complete year of nocturnal monitoring revealed that some species were using the site more frequently as a nocturnal roost and feeding site, with higher numbers present nocturnally, for example, the peak count of Bar-tailed Godwit was higher during nocturnal feeding and roosting compared to diurnal counts. Bar-tailed Godwit peak counts remain below the target during both high and low tides.

Two key species reached target peak counts in the first year of post-construction monitoring: the Red-necked Stint at high tide (peak count of 25 birds) and the Pacific Golden Plover (16 birds at both high and low tide). Average numbers of Red-necked Stint have increased since the first year (pre-construction) average, while no significant change was found at the reference location. This indicates a positive result of the PEHE works.

Bar-tailed Godwit showed a significant decline during the construction phase. Numbers have since been increasing, coinciding with the post-construction phase of the PEHE. This indicates a positive result of the PEHE, with numbers increasing, approaching those at reference locations.

Numbers of Double-banded Plover were extremely variable within and among seasons, with no significant change over time in relation to the reference site. The Curlew Sandpiper followed a declining trend detected since pre-construction at Penrhyn Estuary and at the reference site. A similar pattern is apparent within populations across southeast Australia.

The PEHE works have expanded both feeding and roosting habitat for shorebirds, and has eliminated much disturbance in the estuary.

No changes to the Shorebird Monitoring Program are recommended at this time.

Table 1 summarises trends in abundance of six key shorebird species.

Table 1 Peak Abundance Trends of Key Shorebird Species

Species	Tidal State: High Tide –Roosting Low Tide - Feeding	Pre-construction	Construction			Post- construction			Comments
		Target	2008/09	2009/10	2010/11	2011/12	2012/13 Diurnal	2012/13 Nocturnal	
Bar-tailed Godwit	High	**95**	58	48	31	42	30	56	Average count increasing post-construction. Higher abundance nocturnally. Positive result.
	Low	**58**	40	36	13	31	17	24	Numbers consistent throughout the season. Average count increased post-construction. Positive result.
Red Knot	High	**3**	2	2	0	1	0	0	Absent from the estuary. . No reference site available to compare populations.
	Low	**3**	**5**	2	0	1	0	0	
Pacific Golden Plover	High	**9**	**9**	6	**13**	**16**	**16**	**11**	Target exceeded for three consecutive seasons. Positive result.
	Low	**9**	**9**	6	**13**	**16**	**16**	**14**	Target exceeded. Variable numbers but gradual increase apparent post-construction. Positive result.
Curlew Sandpiper	High	**2**	0	0	0	0	0	0	Remained absent throughout construction and post-construction phases. Declining across SE Australia so likely to be caused by events at a greater scale.
	Low	**2**	0	1	0	0	0	0	
Red-necked Stint	High	**25**	5	0	6	14	**25**	5	Target met. Numbers consistent throughout season, higher average since construction phase. Positive result.
	Low	**29**	5	5	6	24	20	4	Greater abundance post-construction, consistent numbers throughout the season. Positive result.
Double-banded Plover	High	**37**	29	31	19	20	4	3	Extremely variable within and among seasons at both Penrhyn and the reference site. No distinct pattern of population change.
	Low	**33**	**33**	31	22	20	23	3	

2.2 Benthos

The Annual Report for the Benthos Monitoring Program is presented in **Appendix B.**

The Benthos Monitoring Program has completed three sampling events post-construction and tracked the following indicators:

> Sediment parameters: Median Grain Size (MGS) (mm) and % Fines (silt +clay fractions, <0.074 mm)

> Biotic indicators: Biomass: g /sample (10 x 20 cm core) and Abundance (individuals /sample, 10 x 20 cm core)

Table 2 summarises trends in the indicators with respect to targets set in the PEHEP.

Table 2 Summary of tends for indicators in benthos monitoring program in comparison to targets set in the PEHEP

Habitat	Sediment Parameters		Biological Indicators		
Created Sand flats	**MGS (mm)**	**% Fine sediments (< 0.074 mm)**	**Macrobenthos biomass (g/sample)**	**Macrobenthos biomass (g/m²)**	**Abundance (individuals/ sample)**
Target	0.31 - 0.33	2 to 4 %	≥ 0.7	89.1	Average ≥ 39
Values for three surveys after enhancement	Av: 0.24 Min: 0.18 Max: 0.34	Av: 5.2 % Min: 0.7 % Max: 14.3 %	Av: 1.08 Min: 0.11 Max: 6.56	Av: 137.9 Min: 13.6 Max: 834.8	Av: 22.5 Min: 1.3 Max: 70.7
Change in comparison to pre-enhancement levels	↓	↑	↑	↑	↓
Outcome in relation to target levels					
Target met?	**YES**	**YES**	**YES**	**YES**	**NO**

The addition of organic material in the form of mud and seagrass wrack to imported sand has resulted in an increase in the proportion of fine sediments to which organic material readily binds. While the overall abundance of invertebrates did not achieve target values, biomass exceeded targets, and the changing composition of the macroinvertebrate assemblage suggests that the sedimentary system has not yet reached equilibrium.

Preliminary comparisons were made between abundance of benthic invertebrates and peak counts for three key shorebird species which have met or are trending towards meeting population targets (**Figure 2**). Data for shorebirds observed at Penrhyn Estuary were selected to correspond to the month prior to undertaking surveys of benthic invertebrates. Peak counts of Red-necked Stint roughly mirrored changes in invertebrate abundance reasonably well both before and after enhancement. Bar-tailed Godwit and Pacific Golden Plover counts showed similar patterns to invertebrate abundance before enhancement, but did not correspond after enhancement.

This preliminary comparison is simplistic in that it does not take into account factors other than food supply at Penrhyn Estuary that may influence peak shorebird counts. The relatively low abundance of invertebrates in November 2007 and March 2012 coupled with relatively high abundances of Bar-tailed Godwit suggest that abundance of food at Penrhyn Estuary does not necessarily restrict shorebird numbers and provides no insight as to minimum levels of prey items required to support shorebird populations before habitat enhancement.

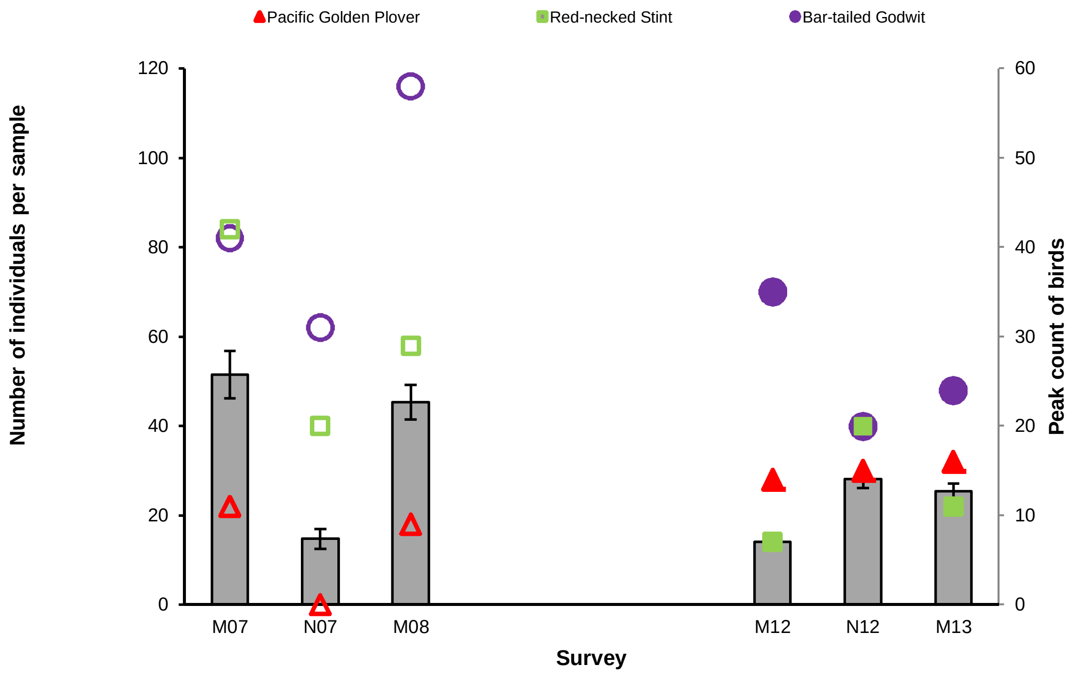

Figure 2 Comparison of peak counts for three shorebird species and invertebrate abundance at Penrhyn Estuary

Due to the inherently variable nature of shorebird and intertidal invertebrate populations, further surveys will be required to demonstrate long-term capacity of the created habitat to sustain sufficient productivity to supply adequate food for shorebirds.

No changes to the Benthos Monitoring Program are recommended at this time.

2.3 Saltmarsh

The Annual Report for the Saltmarsh Monitoring Program is presented in **Appendix C**.

The Saltmarsh Monitoring Program tracked various indicators of vegetative growth and health condition, as well as saltmarsh ecological function (via epifaunal assemblages) and mangrove management using a BACI (Before-After Control-Impact) approach. Key saltmarsh indicators included:

1. Saltmarsh Area
2. Growth (plant assemblage)
3. Species diversity in quadrats
4. Species abundance of:
   - *Sarcocornia quinqueflora*
   - *Sporobolus virginicus*
   - *Suaeda australis*
   - *Juncus kraussii*
5. Plant health conditions
6. Maximum plant height
7. Ecological function (abundance and diversity of epifauna)
8. Mangroves:
   - Trees
   - Seedlings
   - Pneumatophores.

Results indicated that saltmarsh species diversity and abundance generally increased following the rehabilitation works within Penrhyn Estuary and saltmarsh vegetation was in better condition compared to that present prior to the works. Importantly, the distribution and abundance of newly planted saltmarsh vegetation along the northern and southern shorelines successively grew during post-rehabilitation surveys. It appeared that areas that were recipient of transplanted saltmarsh did not increase in cover or diversity, although these areas have appeared to maintain these vegetative indictors since baseline data was collected. The ecological functioning of many of the saltmarsh areas within the estuary have decreased slightly from baseline conditions following the rehabilitation works, with epifaunal assemblages generally slightly lower in diversity and abundance, although a successive increase was observed throughout the two post-rehabilitation surveys done to date. This suggests that epifaunal assemblages are recolonising areas that have been disturbed during the rehabilitation works and are also recruiting into newly planted areas of saltmarsh vegetation. Importantly, monitoring has shown that mangroves were not present within the estuary following the rehabilitation works, verifying the success of mangrove management implemented within the estuary.

In general, the majority of ecological targets set with respect to the saltmarsh vegetation with Penrhyn Estuary were met, although a number of areas did not respond as expected. These included areas that were transplanted with saltmarsh vegetation and areas that were cleared of mangroves and weeds. Notwithstanding this, both of these treatments generally maintained values similar to baseline values.

No changes to the Saltmarsh Monitoring Program are recommended as this time.

Table 3 below summarises outcomes of the various indicators of saltmarsh extent and health in comparison to target values.

Table 3 Summary of the results for each ecological indicator at the four saltmarsh treatments and comparisons with targets. *After habitat rehabilitation. N = new saltmarsh habitat, TR = existing saltmarsh that received transplants, RET = retained, undisturbed habitat, ALT= altered saltmarsh habitat where weeds, mangroves were removed. NA = not applicable, ↑ = observed improvement, ↓ = observed decline, ≠ indicates variable results, = indicates no significant difference.

Indicator	Results								Conclusion in comparison to target							
	Compared to baseline				Compared to Reference*				Compared to baseline				Compared to Reference*			
Saltmarsh vegetation	N	TR	RET	ALT	N	TR	RET	ALT	N	TR	RET	ALT	N	TR	RET	ALT
Area	↑				NA				Y				NA			
Growth (assemblage along transects)	NA	≠	=	=	=	=	=	≠	NA	Y	Y	No	Y	Y	Y	No
Species diversity in quadrats	NA	=	↑	↑	=	=	=	=	NA	No	Y	Y	Y	Y	Y	Y
Sarcocornia quinqueflora (% cover)	NA	=	=	=	=	↓	↓	↓	NA	No	Y	No	Y	No	No	No
Sporobolus virginicus (% cover)	NA	=	↑	↑	=	↑	=	=	NA	No	No	Y	Y	No	Y	Y
Suaeda australis (% cover)	NA	=	=	=	↓	=	=	↑	NA	No	Y	No	No	Y	Y	No
Juncus kraussii (% cover)	NA	↑	↑	=	=	=	=	=	NA	Y	No	No	Y	Y	Y	Y
Plant health conditions	NA	↑	↑	↑	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Max height	NA	↑	=	↑	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Ecological function (epifaunal assemblage)	NA	=	=	=	=	=	=	=	NA	No	Y	No	Y	Y	Y	Y
Mangroves																
Tree	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Seedlings	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Pneumatophores	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y

2.4 Seagrass

The Annual Report for the Seagrass Monitoring Program is presented in **Appendix D**.

Several different sampling methods and indicators were used to capture the distribution, composition and condition of seagrasses at Foreshore Beach, the rehabilitated section of Penrhyn Estuary (the Rehabilitation Area), inner Penrhyn Estuary and at Planting Areas and Experimental Sites within Quibray Bay where seagrass from Foreshore Beach was transplanted.

Results of pre- and post-construction monitoring over the past 11 years has identified that seagrass distribution and species composition within Foreshore Beach, the Penrhyn Estuary Rehabilitation Area and within Penrhyn Estuary is highly variable. This is evident from a major decline in seagrass area from approximately 65,821 sq. m in 2002 to 698 sq. m in February 2007, prior to construction works commencing. Impacts to seagrasses as a result of the Port Botany Expansion are therefore relatively minor in relation to the variability (natural or otherwise) observed over the six year period prior to any construction works taking place. Monitoring carried out during the construction works indicated that seagrass condition and distribution remained relatively stable during this period.

Initial findings of the post–construction monitoring (March 2012 to March 2013) at Foreshore Beach and the Rehabilitation Area are positive and suggest early signs of recovery for *Halophila* spp. and *Z. capricorni* following the pre-construction decline, but not for *P. australis*. The majority of seagrass present within these areas was, however, sparse and patchily distributed. These initial findings are consistent with results of water quality monitoring, which suggest that water quality parameter are within the requirements for seagrass growth.

Within Penrhyn Estuary, no intertidal seagrasses were observed in searches in March 2012, but sparse patches of Z. capricorni and Halophila spp. were observed in November 2012 near the enhanced saltmarsh habitat on the northern side of the estuary and along the western boundary adjacent to the new terminal structure. Sparse patches of *Halophila* spp. were observed in the inner estuary near the confluence of Floodvale and Springdale creeks in March 2013. The observations of sparse, ephemeral seagrass since late 2012 indicates that inner estuary habitats have stabilised to the stage where they support seasonal patches of sparse seagrass in a manner similar to that observed prior to habitat enhancement.

Indicators of seagrass condition at Foreshore Beach showed significant improvements in post-construction surveys carried out from March 2012 to March 2013. The condition of the small areas of *Halophila* spp. sampled within the Rehabilitation Area was variable in terms of shoot densities and had relatively short leaves indicating that it was either newly established or may be a response to environmental stress.

The level of epiphytic growth observed on seagrasses ranged from none to high, but was generally recorded within the light to medium range which would be expected for a developed urban estuary within a major population centre. The invasive alga *Caulerpa taxifolia* was not observed at any location the March 2012 and March 2013 surveys.

Overall, water quality data (PAR and TSS) indicated that seagrass growth within the estuary is unlikely to be limited by light attenuation in the long term and should therefore be conducive to growth and recovery. TSS levels recorded within Penrhyn Estuary and at reference sites before and after construction did not appear to be significantly different. No clear spatial relationship between mean TSS and PAR levels with the distribution of seagrasses was evident. While some water quality indicators have varied from pre-construction averages, overall water quality outcomes in Penrhyn Estuary are suitable to support the habitats enhanced by the PEHEP, with no indication of potential for the formation of eutrophic conditions to date.

The transplantation of *P. australis* from Foreshore Beach to Quibray Bay appears to have been highly successful and will have helped offset direct losses of seagrass as a result of dredging and reclamation at Foreshore Beach.

Investigations into the various methods of transplantation treatments against control treatments have shown that all methods (whole, trimmed and rhizomes) showed positive results. As the growth and establishment of *P. australis* can be slow, continued monitoring of these treatments over the course of the project will be important in determining whether one or more methods were more successful than others.

No changes to the Seagrass Monitoring Program are recommended at this time.

A summary of key results is provided in **Table 4**.

Table 4 Summary of Seagrass Results

Seagrass Indicator	Result	Comment
Distribution along Foreshore Beach	Decreased significantly prior to habitat enhancement	Negative but not associated with Port Expansion project
Distribution in Rehabilitation Area (Channel and outer estuary)	Early signs of recovery for *Halophila* and *Zostera*, but not *Posidonia*	Positive trend
Condition along Foreshore Beach	*Halophila* with short sparse leaves with medium load of epiphytes	Positive trend
Distribution on intertidal/subtidal areas within Penrhyn Estuary	Observation of sparse, ephemeral patches of *Zostera*	Positive result, similar to pre-enhancement
Condition of *Posidonia* transplanted to Quibray Bay	Successful, generally not distinguishable from surrounding seagrass but variable among sites	Positive result

2.5 Water Quality

The Annual report for Water Quality is presented in **Appendix E**.

Water quality indicators monitored monthly included:

Physicochemical:

- Conductivity (salinity)
- pH
- Total Suspended Solids (TSS)
- Biological Oxygen Demand (BOD)
- Dissolved Oxygen (DO)
- Temperature
- Photosynthetically Active Radiation (PAR)

Nutrients:

- Total Nitrogen (TN)
- Total Phosphorous (TP)
- Chlorophyll a (chl-a).

Results of monitoring up to 36 months post-construction indicate that water quality outcomes in Penrhyn Estuary are suitable to support the habitats enhanced by the PEHEP. No indication of a potential for the formation of eutrophic conditions has been observed. The analysis of variance between pre and post-construction water quality has not identified any negative change in the post-construction water quality, although some parameters show some variance from pre-construction measurements. Trigger levels adopted from ANZECC (2000) guidelines have in some cases been exceeded, particularly for Total Suspended Sediments, although these exceedances have generally been associated with similar water quality conditions at control monitoring locations in Botany Bay outside Penrhyn Estuary. In general, ambient nutrient concentrations in Penrhyn Estuary have not exceeded predicted nutrient concentrations derived from numerical modelling of post-construction estuary conditions.

With due consideration of expected background variability of the monitored water quality parameters and the early stage of this monitoring program, water quality in Penrhyn Estuary is currently meeting the targets of the PEHEP.

No changes to the Water Quality Monitoring Program are recommended at this time.

Table 5 summarises the outcomes of the Water Quality Monitoring Program in comparison to pre enhancement conditions and to ANZECC guidelines.

Table 5 Summary of Water Quality Outcomes

Parameter	Post-Construction Data Quality	Pre vs Post Construction Results	ANZECC Exceedances	Modelled Nutrient Comparison
Physicochemical				
Temperature	✓	NA	No guideline	NA
pH	✓	↑ Within reasonable limits	none	NA
DO	✓	=	few	NA
EC	✓	↓ Within reasonable limits	No guideline	NA
PAR	✓ Limited analysis	NA	No guideline	NA
TSS	✓ Possible outliers	=	↑ Frequent exceedance	NA
Nutrients				
TN	✓ Possible outliers	=	few	✓
TP	✓ Possible outliers	=	↑ Occasional Exceedance	✓
Chl-a	✓	=	few	NA

3 Conclusions

Monitoring at the end of the first year post-enhancement has demonstrated that the physical conditions necessary for providing roosting and feeding habitat for shorebirds and potential habitat for seagrass have been successfully created, with indications that some processes have yet to reach equilibrium post-construction. Importantly, predictions of adequate flushing and water quality, particularly with respect to acceptable levels of nutrients have been verified, and further development in the estuary is expected to continue along a positive path.

Indicators such as biomass of invertebrates in created sand flats, and cover and health of created saltmarsh habitat have met or exceeded targets for rehabilitation, or are on positive trajectories to do so. Several key shorebird species have recovered to pre-enhancement levels and others shows positive trends. Further surveys will be required to identify relationships between shorebird populations and abundance of their invertebrate prey items, and factors beyond the scope of the enhancement project are likely to constrain such direct links.

The protected seagrass *Posidonia australis* has been successfully transplanted to Quibray Bay and varies in condition, but transplanted patches are largely undistinguishable from resident plants. There are early signs of seagrass colonisation in the channel designed for their growth, and sparse, ephemeral *Zostera capricorni* has reappeared in the inner estuary, as it did prior to enhancement works.

While no changes to any component of the monitoring program are recommended, works to repair erosion of roosting habitat is planned for August or early September, and management of further erosion, weed invasion and port lighting as well as campaigns to reduce predators require ongoing effort to maximise the environmental outcomes of the project.

The first year of post-construction monitoring involved over 3,930 person-hours on site and in the laboratory and was completed with no safety incidents.

4 Acknowledgements

This report was written by Dr Peggy O'Donnell and reviewed by Dr Craig Blount. Contributing authors include: Dr Phil Straw and Chelsea Hankin (Shorebirds), Dr Peggy O'Donnell and Dr Andrea Nicastro (Benthos), Dr Brendan Alderson and Dr Andrea Nicastro (Saltmarsh), Kate Reeds and Dr Craig Blount (Seagrass), Andrew Bradford and Matt Smith (Water Quality).

5 References

Cardno Ecology Lab 2012. Port Botany Expansion Environmental Enhancement Works – Post Construction Environmental Monitoring Services Management Plan. Final, June 2012.

Sydney Ports Corporation (2007). Port Botany Expansion Penrhyn Estuary Habitat Enhancement Plan. March 2007.

Port Botany Post Construction Monitoring
Annual Report 2013

APPENDIX A
SHOREBIRD ANNUAL MONITORING REPORT 2013

Cardno
Shaping the Future

Port Botany Post Construction Environmental Monitoring

Shorebird Monitoring Annual Report 2013

EL1112046

Bar-tailed Godwit flagged in Victoria passing through the Hunter Estuary on migration. Flagged birds observed in Botany Bay and the Hunter Estuary clearly show a turnover of birds moving through. This also means peak numbers counted during the study are only a proportion of the number of birds relying on habitat at Penrhyn Estuary and reference sites.

Photo by Chris Herbert

Avifauna Research & Services Pty. Ltd.

Cardno Shaping the Future

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Executive Summary

This annual report examines the findings of the Shorebird Monitoring program for the post-construction period from 1 April 2012 to 31 March 2013. Changes to shorebird populations at Penrhyn Estuary were analysed by comparing counts with previous peak seasons to determine correlations with the pre-construction and construction phases of the Penrhyn Estuary Habitat Enhancement Plan (Sydney Ports Corporation 2007).

Surveys of shorebirds were done during low and high tide at Penrhyn Estuary and at selected reference sites from the start of April 2012 to the end of March 2013. During the off-peak season (April 2012 – August 2012), surveys were conducted fortnightly, increasing to weekly during the peak season (September 2012 – March 2013). Six key species were selected as indicators of the success of the Penrhyn Estuary Habitat Enhancement Plan (PEHEP): Bar-tailed Godwit, Red-necked Stint, Double-banded Plover, Curlew Sandpiper, Red Knot and Pacific Golden Plover. The abundance of key species was compared with counts at reference sites to measure the success of the works.

The first complete year of nocturnal monitoring revealed that some species were using the site more frequently as a nocturnal roost and feeding site, with higher numbers present nocturnally, for example, the peak count of Bar-tailed Godwit was higher during nocturnal feeding and roosting compared to diurnal counts. Bar-tailed Godwit peak counts remain below the target during both high and low tides.

Two key species reached target peak counts this period (post-construction phase): the Red-necked Stint at high tide (peak count of 25 birds) and the Pacific Golden Plover (16 birds at both high and low tide). Average numbers of Red-necked Stint have increased since the first year (pre-construction) average, while no significant change was found at the reference location. This indicates a positive result of the PEHE works.

Bar-tailed Godwit showed a significant decline during the construction phase. Numbers have since been increasing, coinciding with the post-construction phase of the PEHE. This indicates a positive result of the PEHE, with numbers increasing, approaching those at reference locations.

Numbers of Double-banded Plover were extremely variable within and among seasons, with no significant change over time in relation to the reference site. The Curlew Sandpiper followed a declining trend detected since pre-construction at Penrhyn Estuary and at the reference site. A similar pattern is apparent within populations across southeast Australia.

The PEHE works have expanded both feeding and roosting habitat for shorebirds, and has eliminated much disturbance in the estuary. Ongoing management is needed, however, with two main issues including a) wind erosion of Big Island roosting site, and b) management of fox predation.

The following table summarises trends in abundance of six key shorebird species.

Species	Tidal State: High Tide – Roosting Low Tide - Feeding	Pre-construction Target	Construction			Post- construction			Comments
			2008/09	2009/10	2010/11	2011/12	2012/13 Diurnal	2012/13 Nocturnal	
Bar-tailed Godwit	High	**95**	58	48	31	42	30	56	Average count increasing post-construction. Higher abundance nocturnally. Positive result.
	Low	**58**	40	36	13	31	17	24	Numbers consistent throughout the season. Average count increased post-construction. Positive result.
Red Knot	High	**3**	2	2	0	1	0	0	Absent from the estuary. . No reference site available to compare populations.
	Low	**3**	**5**	2	0	1	0	0	
Pacific Golden Plover	High	**9**	**9**	6	**13**	**16**	**16**	**11**	Target exceeded for three consecutive seasons. Positive result.
	Low	**9**	**9**	6	**13**	**16**	**16**	**14**	Target exceeded. Variable numbers but gradual increase apparent post-construction. Positive result.
Curlew Sandpiper	High	**2**	0	0	0	0	0	0	Remained absent throughout construction and post-construction phases. Declining across SE Australia so likely to be caused by events at a greater scale.
	Low	**2**	0	1	0	0	0	0	
Red-necked Stint	High	**25**	5	0	6	14	**25**	5	Target met. Numbers consistent throughout season, higher average since construction phase. Positive result.
	Low	**29**	5	5	6	24	20	4	Greater abundance post-construction, consistent numbers throughout the season. Positive result.
Double-banded Plover	High	**37**	29	31	19	20	4	3	Extremely variable within and among seasons at both Penrhyn and the reference site. No distinct pattern of population change.
	Low	**33**	**33**	31	22	20	23	3	

Glossary

Term or Acronym	Definition
ANOVA	Analysis of Variance
Benthic	Living on or in the seabed
Peak count	The maximum count of birds on any one occasion during a survey period (e.g. April 2012-March 2013). Peak counts were recorded separately for low and high tide surveys as well as for diurnal and nocturnal surveys.
PEHEP	Penrhyn Estuary Habitat Enhancement Plan
Target / baseline	Pre-construction maximum count of each key species at Penrhyn Estuary (2006-2008 data). These are the minimum targets set for the PEHEP.
Intertidal	The portion of shoreline between low and high tide marks, that is intermittently submerged
SE	Standard Error

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Appendix

1 Introduction

1.1 Background

As part of the Port Botany Expansion Project, Sydney Ports has rehabilitated Penrhyn Estuary, located adjacent to the port expansion. Penrhyn Estuary is a small waterway of approximately 80 ha located to the north of Brotherson Dock, which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978. Since its creation, it has been utilised by a diverse group of migratory birds (Avifauna Research & Services 2003).

The purpose of the rehabilitation works was to enhance the existing intertidal habitat and to expand the estuary as a long-term habitat for migratory shorebirds. Key enhancement activities included the removal of mangroves and other tall vegetation as well as numerous introduced weeds and the enhancement of existing saltmarsh as well as the creation of a large area of new saltmarsh habitat. An extensive area of foredune was levelled to create an intertidal feeding and roosting habitat for key species of migratory shorebirds that currently use the estuary, and to potentially attract a greater number of shorebirds upon completion. The design, methodology and ongoing maintenance for the estuary are outlined within the Penrhyn Estuary Habitat Enhancement Plan (PEHEP).

The key objectives of the PEHEP were to expand the intertidal feeding habitat, provide secure roosting habitat in the form of three 'high tide' islands and restore saltmarsh habitat for shorebird roosting and feeding habitat. Penrhyn Estuary is considered a significant feeding and roosting site in Botany Bay for seven 'key' species (NSW Wader Study Group Data). Six of these species were selected to measure the success of the PEHEP project throughout the pre-construction, construction and post-construction phases. These are: Bar-tailed Godwit, Red-necked Stint, Double-banded Plover, Curlew Sandpiper, Red Knot and Pacific Golden Plover. The seventh key species, the Sharp-tailed Sandpiper, was unsuitable to include for monitoring because of its irregularity in numbers at coastal sites due to the variability of flooding of inland wetlands. The abundance of key species, compared with counts at reference sites, will indicate the success of PEHE works. No decline in numbers of any of the key species compared with baseline data would indicate that the habitat enhancement has had no negative impacts. Any increase in the numbers of each of these species would be evidence of habitat enhancement success.

The end of the peak season, March 2013, completes the end of the second year of post-construction phase monitoring. It is expected that after two years of post-construction monitoring there will be some indication of the success of the PEHE works, with comparison of shorebird counts to the construction and pre-construction phases.

1.2 Aims

The purpose of the shorebird monitoring plan is to verify that the stated aims of the PEHEP works are achieved. The specific aims of the Shorebird Monitoring Plan are:

> To monitor the numbers and species composition of shorebirds found in Penrhyn Estuary following the habitat enhancement works and assess changes;

> To assess the feeding behaviour of shorebirds in Penrhyn Estuary following habitat enhancement to determine habitat usage patterns;

> To monitor the existing and future effects of disturbance in Penrhyn Estuary on the behaviour of shorebirds; and

> To monitor the disturbance and predation in the Estuary and assess the effectiveness of security access restriction measures.

The shorebird monitoring plan outlines the monitoring procedure for the sustainable development of intertidal mudflats and saltmarsh habitat to provide secure feeding and roosting sites in association with monitoring of benthos. Potential disturbances and predation are to be monitored and recommendations are to be made to rectify the disturbance or habitat deterioration.

1.3 Review of Existing Information

Penrhyn Estuary is the most important feeding and roosting area for migratory and non-migratory shorebirds on the northern side of Botany Bay. Silts and nutrients enter Penrhyn estuary via two stormwater channels, Springdale and Floodvale drains, providing suitable substrate for a range of benthic organisms, in turn attracting a variety of shorebirds. The reconfiguration of the estuary including the PEHEP works resulted in enlarged intertidal feeding habitat, three high tide islands which provide secure roosting and nesting sites, as well as the enhancement of saltmarsh areas for shorebird roosting and feeding habitat. A summary of key activities in the PEHEP and timing of shorebird surveys are given in **Table 1** below.

Table 1 Timeline of construction works and shorebird surveys

Activity	Date	Comments
Before Construction Survey 1	December 2006 – March 2007	Weekly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2007)
Before Construction Survey 2 (Off-peak fortnightly surveys)	April 2007 – August 2007	Fortnightly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2008)
Before Construction Survey 3 (Peak weekly surveys)	September 2007 – March 2008	Weekly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2008)
Construction	January 2008 - July 2008	Removal and relocation of sand dunes Construction of temporary roosting island Saltmarsh seed collection, transplanting, commence propagation in nurseries
During Construction Survey 1 (Off-peak fortnightly surveys)	April 2008 – August 2008	Fortnightly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2009)
During Construction Survey 2 (Peak weekly surveys)	September 2008 – March 2009	Weekly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2009)
Construction	August 2008 – end March 2009 (*1st exclusion period - Shorebirds*)	Excavation, transfer and re-contouring of estuary (including formation of main roosting island) from sand dune behind Shorebird Exclusion Zone Mangrove removal by hand, weed clearing Saltmarsh transplantation No machine work in estuary exclusion zones (peak bird season) CSD dredging in Botany Bay from September
Construction	End March - July 2009	Central estuary filled, sand augmented with mud and seagrass wrack Filamentous algal bloom (until September 2009) Sand stockpiled for later filling outer estuary (80,000 m^3) Dredging in Botany Bay complete April
Construction	August 2009 – March 2010 *(2nd exclusion period – Shorebirds)*	Saltmarsh area augmentation (Nov) and mass planting (NE side of estuary and 2 roosting islands) (Dec) New boat ramp opened (Nov) Filling of outer estuary begins, less seagrass wrack than in inner estuary Tidal flow maintained throughout filling/contouring Shorebird exclusion zone to the back of the island No work in exclusion zones (peak bird season) except saltmarsh transplantation and mangrove removal

Activity	Date	Comments
During Construction Survey 3 (Off-peak fortnightly surveys)	April 2009 – August 2009	Fortnightly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2010)
During Construction Survey 4 (Peak weekly surveys)	September 2009 – March 2010	Weekly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2010)
Construction	April 2010 – July 2011	Further saltmarsh planting (southern corner of estuary and at the third roosting island) Filling outer estuary complete by end Dec 2010 Flushing channel contoured using small dredger
During Construction Survey 5 (Off-peak fortnightly surveys)	April 2010 – August 2010	Fortnightly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2011)
During Construction Survey 6 (Peak weekly surveys)	September 2010 – March 2011	Weekly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2011)
After Construction Survey 1	April 2011 – August 2011	Fortnightly surveys for abundance, diversity and behaviour Monthly survey for Shorebird health (Avifauna Research & Services 2012a)
After Construction Survey 2	September 2011 – March 2012	Weekly surveys for abundance, diversity, behaviour, disturbance and predation Monthly survey for disturbance Monthly survey for Shorebird health Nocturnal fortnightly survey for abundance, diversity and behaviour (from 02/2012) (Avifauna Research & Services 2012a)
After Construction Survey 3	April – August 2012	Fortnightly survey for abundance, diversity and behaviour Nocturnal fortnightly survey for abundance, diversity, behaviour, disturbance and predation (Avifauna Research & Services 2012b)
After Construction Survey 4	September 2012 - March 2013	Weekly surveys for abundance, diversity, behaviour, disturbance and predation Monthly survey for disturbance Monthly survey for Shorebird health Nocturnal fortnightly survey for abundance, diversity and behaviour (Avifauna Research & Services 2013)

Key species for this study include five northern hemisphere migrants: Bar-tailed Godwit, Red-necked Stint, Curlew Sandpiper, Red Knot and Pacific Golden Plover. These species depend on a network of sites, moving between non-breeding grounds in the southern hemisphere to staging areas across Asia, breeding as far north as the Arctic tundra in Siberia and Alaska. These migratory shorebirds spend up to seven months in Australia, from September- March, and two months in their breeding grounds in the far northern hemisphere. The rest of the year is spent on migration and at staging areas to feed and 'refuel' to continue migration (Sydney Olympic Park 2003). Migratory species feed on molluscs, worms and aquatic insects, maintaining a slim body weight for the majority of their non-breeding season from arrival (September), before fattening up in the weeks prior to their northern migration (March-April).

The sixth key species, Double-banded Plover, is a migrant of the southern hemisphere, breeding in New Zealand and migrating to Australia during the non-breeding season, spending five months in Australia from April to August.

2 Methods

2.1 Sampling Design

Fortnightly surveys of shorebirds were carried out at low and high tide during the off peak season (April-August 2012) at the study site, Penrhyn Estuary, and at selected reference sites in accordance with Monitoring Services Management Plan (Cardno Ecology Lab 2012). Surveys were increased to weekly for the duration of the peak season (September 2012- March 2013). In addition, one low and high tide nocturnal survey were conducted monthly at Penrhyn Estuary to determine any differences in use of the site between diurnal and nocturnal periods. Where possible, local reference sites were chosen to ensure accuracy of data collection, with sites being surveyed on the same day by the same team of shorebird experts. However, as sites around Botany Bay did not support sufficient numbers of some species for analysis, some regional sites were selected outside of the Bay for these species (**Table 2** and **Figures 1 - 4**).

Table 2 Key species monitored and associated reference sites

Area	Sites	Habitats	Key species
Penrhyn Estuary	Penrhyn transects	Tidal estuarine mudflats Tidal sand flats Sand spits Sandy beaches Stony substrate Sandy islands	Bar-tailed Godwit Red-necked Stint Pacific Golden Plover Red Knot Curlew Sandpiper Double-banded Plover
Southern Botany Bay	Quibray Bay	Tidal sand flats Sandy beaches Oyster lease structures	Bar-tailed Godwit
	Riverside Drive	Tidal estuarine mudflats Tidal sand flats Sand spit Sandy beaches	
	Woodlands Road	Tidal estuary mudflats Tidal sand flats Sandy beaches	
Parramatta Estuary	Hen and Chicken Bay	Tidal estuarine mudflats Tidal sand flats Sandy beaches Sand/rock spits Concrete jetty	Curlew Sandpiper
	Mason Park & Waterbird Refuge	Saltmarsh and lagoons	
Boat Harbour		Tidal rock platform Tidal sand flats Sandy beaches	Red-necked Stint Double-banded Plover
Hunter River Estuary[1]		Tidal estuarine mudflats Tidal sand flats Sandy beaches Rocky shores	Pacific Golden Plover

[1]Reference site monitored only during peak season (September-March)

2.2 Target for Shorebird Populations

Six key species are considered to be key indicators for measuring the success of the PEHE works, the Bar-tailed Godwit, Red-necked Stint, Curlew Sandpiper, Red Knot, Double-banded Plover and Pacific Golden Plover. The abundance of key species was measured before, during and after construction of the Port Botany Expansion. The baseline for measuring success is the annual counts of the six key species recorded in Penrhyn Estuary from September 2005 up to the commencement of construction (early 2008). Assessment of population change with comparison to reference sites (Before-After Control-Impact BACI design) will indicate the success of the PEHE works. No decline in numbers of any of the key species compared with baseline data would indicate that the habitat enhancement has had no negative impacts. Any increase in the numbers of each of these species would be evidence of habitat enhancement success. Target values for the success of the PEHE works are listed in **Table 3**.

Table 3 Target values for key species based on baseline data

Key species	Target peak count – High Tide (Roosting)	Target peak count – Low Tide (Feeding)
Bar-tailed Godwit	95	58
Red Knot	3	3
Pacific Golden Plover	9	9
Curlew Sandpiper	2	2
Red-necked Stint	25	29
Double-banded Plover	37	33

2.3 Summary of Survey Procedures

2.3.1 Study site

Shorebirds were observed for two hours at low and high tide recording their behaviour, habitat usage, abundance and species present. All shorebirds using the site were counted and recorded, giving a maximum count of each species per survey.

At low tide, surveys were conducted either by one or two observers on foot, with vehicular access via Foreshore Road. Two transects were established across the estuary, enabling a clear line of view of shorebird feeding areas (**Figure 1**). Conducting the surveys via marked transects ensured consistency of data among surveyors. At high tide, two observers conduct the surveys by boat, with transects varying depending on the height of the tide. The boat launching site was moved from the maintenance gate near the Bird Hide to the new boat ramp on Foreshore Road, accessing the estuary via the gate within the floating boom. Nocturnal surveys are carried out by two observers, with access via the same transects used diurnally.

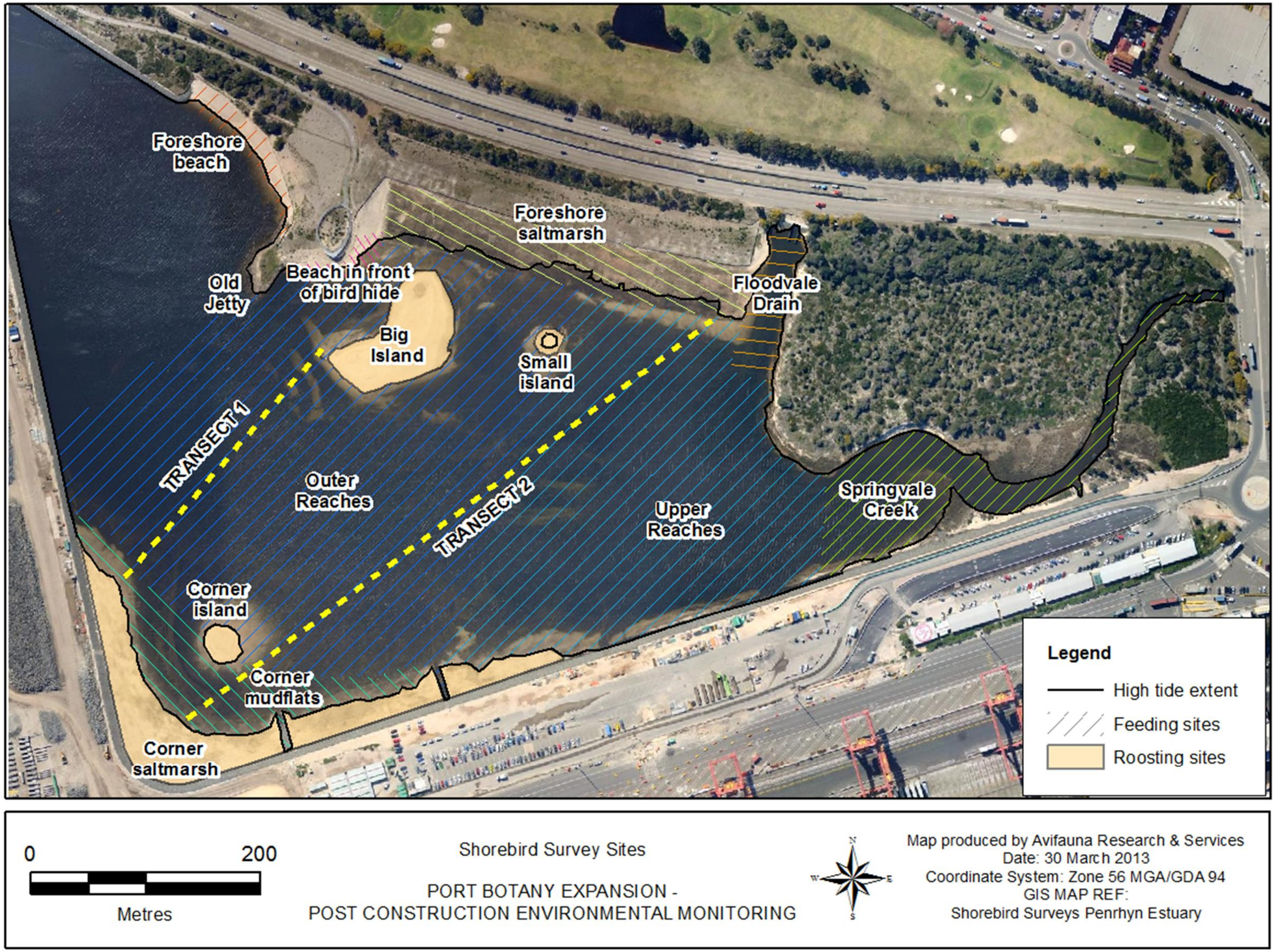

Figure 1 **Penrhyn Estuary Shorebird Feeding and Roosting Sites**

2.3.2 Reference sites

2.3.2.1 Parramatta Estuary

Sites around Parramatta River Estuary were used as reference locations for the Curlew Sandpiper (**Figure 2**). The area also provides habitat for large numbers of Bar-tailed Godwit. Hen and Chicken Bay provides feeding and roosting sites with several small beaches, rocky outcrops and jetties. Alternative habitat for Curlew Sandpiper and other shorebirds is available in tidal saltmarsh wetlands at Mason Park and the Waterbird Refuge at Homebush. Reference sites are accessed by road, then by foot via paved walkways.

2.3.2.2 Southern Botany Bay

Three reference sites are monitored by boat at high tide and on foot at low tide to measure relative abundance compared with Penrhyn Estuary while additional high tide roost sites were counted in order to estimate the total population of Bar-tailed Godwits in the Bay.

Riverside Drive provides approximately 6ha of tidal flats, with roosting areas confined to a beach and small sand spit at the outlet of a small creek at Scott Park. Bar-tailed Godwit regularly used the site however numbers have declined at high tide, probably due to wind and water erosion of the sand spit. Woodlands Road Reserve provides approximately 5ha of mudflats, providing feeding habitat for the Bar-tailed Godwit. Quibray Bay supports a steady population of Bar-tailed Godwits, with roosting sites including small beaches and nearby oyster lease posts. Gaps in data show that shorebirds move to other locations in Botany Bay depending on weather conditions, for example, in adverse conditions birds will avoid the exposed oyster leases. Because of this, additional roost sites at Sandringham, Spit Island and Carters Shoals were also monitored (**Figure 3**).

2.3.2.3 Boat Harbour

Boat Harbour is a medium-sized sandstone reef (approximately 3ha) located on the northeast of Bate Bay (**Figure 3**). The survey area selected as a reference site provides valuable shelter for migratory shorebirds, such as Red-necked Stint, Double-banded Plover, Pacific Golden Plover and Ruddy Turnstone, which use the area for feeding at low tide and as a roost site at high tide. The site is accessed on foot by entering either by Boat Harbour Park parking area or via Sir Joseph Banks Drive to Potter Point by car then on foot along the Cape Baily Track.

2.3.2.4 Hunter River Estuary

The Hunter River Estuary supports a stable population of Pacific Golden Plover, with most found foraging in the North Arm of the Hunter River upstream of Stockton Bridge and into Fullerton Cove (**Figure 4**). It is important to note that this is a much larger site than Penrhyn Estuary. Counts would be expected to be of very different orders of magnitude when comparing areas of such different size. Where comparisons were made between Penrhyn Estuary and the Hunter Estuary the means of each sample were adjusted to make them equal before regression analysis. Counts were carried out at the main roost site by boat on a weekly basis from September to March each year to coincide with the presence of the birds in the estuary. No significant numbers of birds remain over the winter period; therefore no surveys were carried out between April and August.

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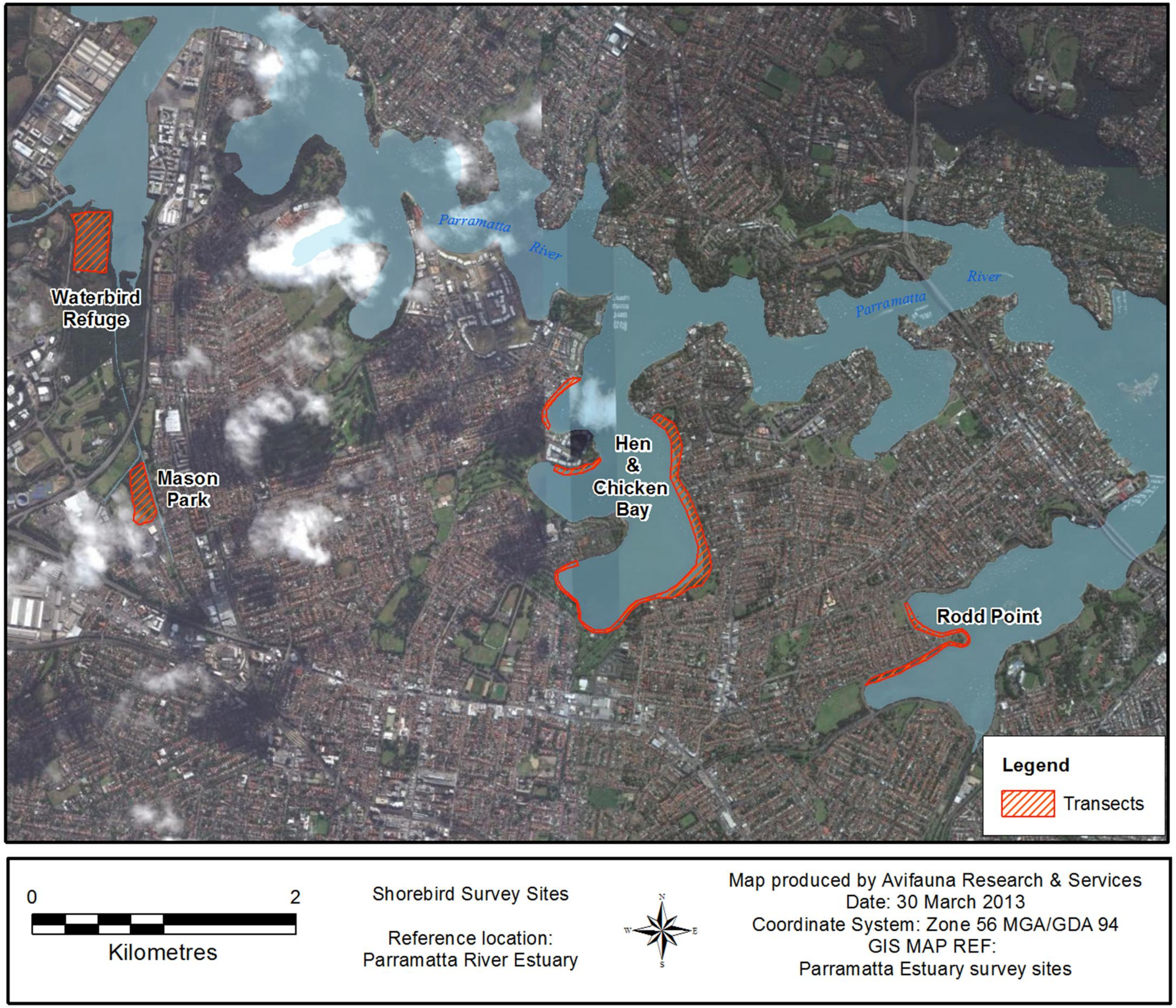

Figure 2 **Shorebird Reference Site Monitoring: Parramatta River Estuary transects**

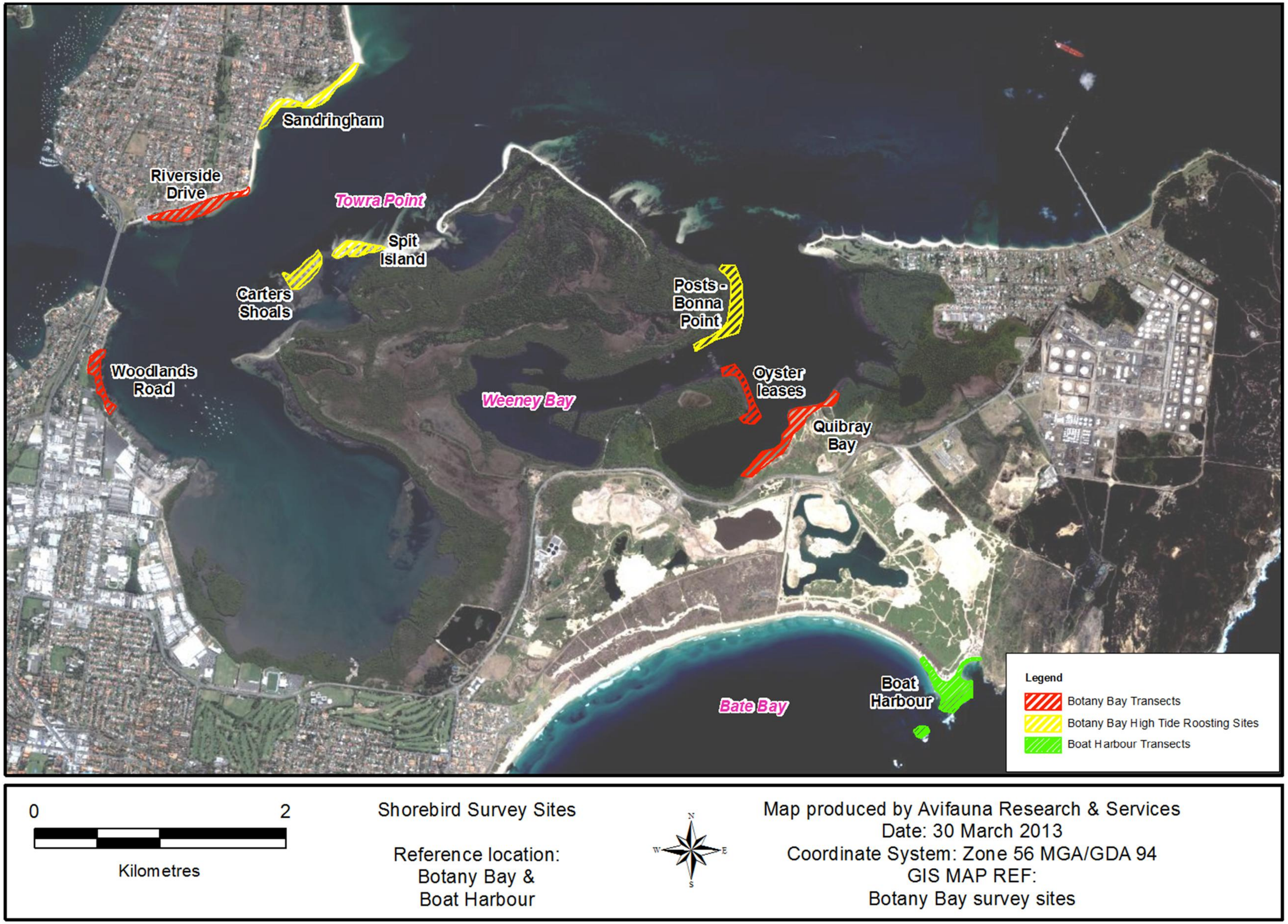

Figure 3 **Shorebird Reference Site Monitoring: Botany Bay and Boat Harbour transects**

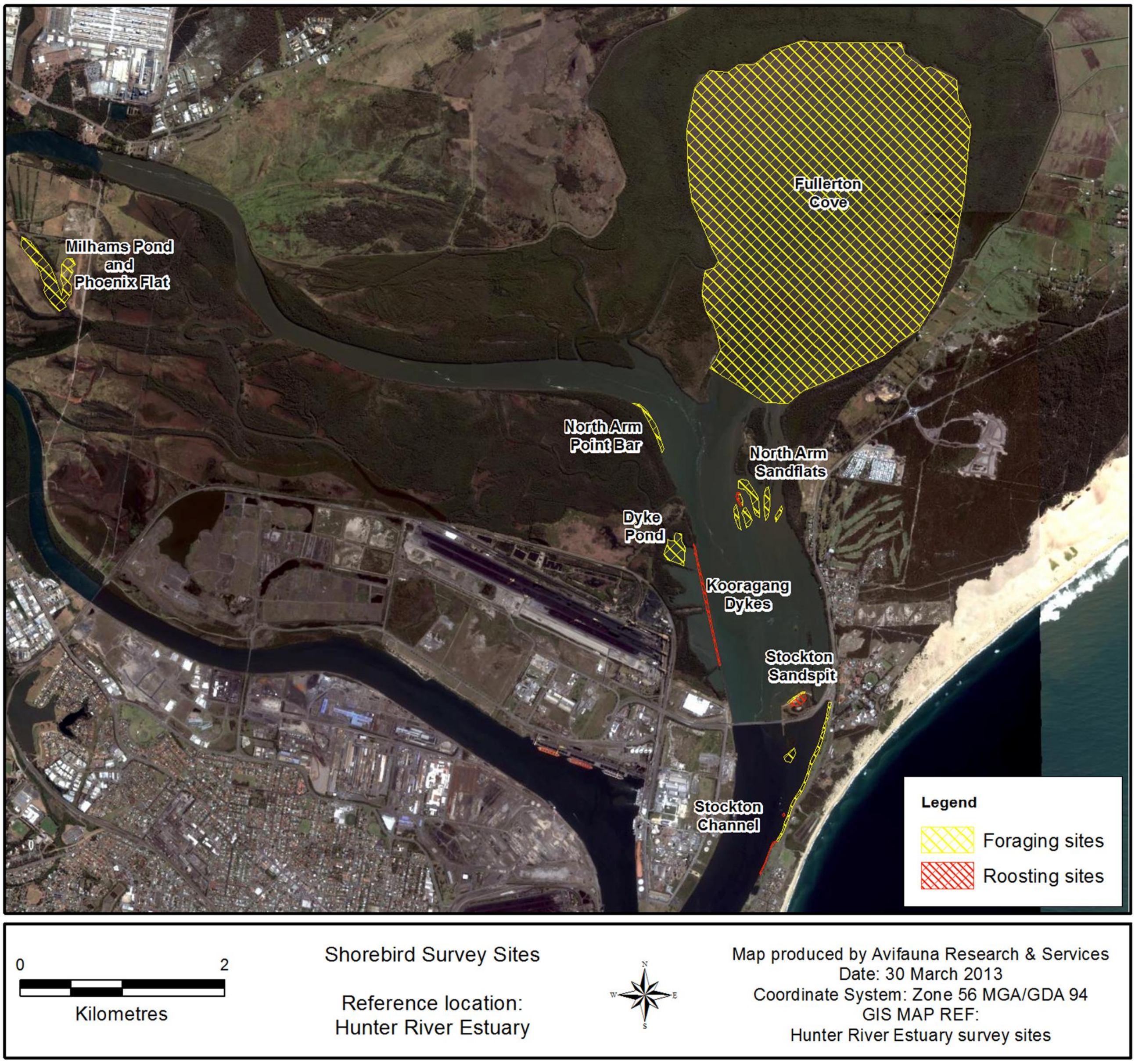

Figure 4 Shorebird Reference Site Monitoring: Hunter River Estuary transects

2.4 Sampling Dates

Shorebird surveys were conducted at the study site and associated reference sites as outlined in **Table 4**.

Table 4 Timing, location and frequency of shorebird monitoring

Survey Location	Project Phase			Indicators Monitored
	Pre- Construction	Construction	Post- Construction	
Penrhyn Estuary	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	> Shorebird abundance, diversity and behaviour > Disturbance and predation
			Nocturnal: Fortnightly year-round*	> Shorebird abundance, diversity and behaviour
			Once per month during peak period	> Disturbance (weekend survey) > Shorebird health
Reference sites				
Botany Bay	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	> Shorebird abundance, diversity and behaviour
Parramatta Estuary	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	> Shorebird abundance, diversity and behaviour
Boat Harbour	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	Off-peak period: Fortnightly, April- August Peak period: Weekly, September- March	> Shorebird abundance, diversity and behaviour
Hunter River Estuary	Peak period: Weekly, September- March	Peak period: Weekly, September- March	Peak period: Weekly, September- March	> Shorebird abundance, diversity and behaviour

*Reduced to fortnightly during peak season only from 2013.

2.5 Indicators Monitored

2.5.1 Abundance

Shorebird abundance was recorded as the maximum count of birds on any one occasion during a survey period (e.g. April 2012- March 2013). Peak counts were recorded separately for low and high tide surveys as well as for diurnal and nocturnal surveys.

2.5.2 Diversity

Shorebird diversity was recorded as the number of species present on any one occasion during a survey.

2.5.3 Behaviour

Shorebird behaviour was recorded at the same time as maximum counts of birds were recorded.

2.5.4 Disturbance and Predation

During nocturnal surveys observations of bird disturbance were recorded, and scans of the area made to attempt to identify the source of disturbances.

2.5.5 Health

Three species of shorebirds at Penrhyn Estuary were monitored to assess their health through body mass: the Bar-tailed Godwit, Pacific Golden Plover and the Red Knot. Birds were visually assessed using high-definition spotting scopes and digital photography and rated on a scale of 1-5 (5 being the fattest). Scale 1 would be below normal minimum and would be of concern if the bird also showed other signs of illness such as inactivity. Scale 2 to 3 is the expected level for birds not preparing to migrate, increasing to 4 to 5 prior to departure to the northern hemisphere.

3 Summary of Results

3.1 Abundance

Four of six key species were observed at Penrhyn Estuary in the 2013/2013 study period and targets for three species were met (**Table 5**). Neither the Red Knot or Curlew Sandpiper were observed at the study site during this period, however, the Curlew Sandpiper was observed on three occasions at the reference site, Parramatta Estuary, with a maximum of two birds in August 2012.

There was successful nesting of shorebirds in Penrhyn Estuary in this study period, including the Little Tern, an endangered migratory species, as well as for resident shorebirds in Penrhyn Estuary, with the successful breeding of the endangered Pied Oystercatcher and Red-capped Plover.

Table 5 Peak Abundance Trends of Key Species

Species	Tidal State: High Tide – Roosting Low Tide - Feeding	Pre-construction	Construction			Post- construction			Comments
		Target	2008 /09	2009 /10	2010 /11	2011 /12	2012/13 Diurnal	2012/13 Nocturnal	
Bar-tailed Godwit	High	**95**	58	48	31	42	30	56	Average count increasing post-construction. Higher abundance nocturnally. Positive result.
	Low	**58**	40	36	13	31	17	24	Numbers consistent throughout the season. Average count increased post-construction. Positive result.
Red Knot	High	**3**	2	2	0	1	0	0	Absent from the estuary. . No reference site available to compare populations.
	Low	**3**	**5**	2	0	1	0	0	
Pacific Golden Plover	High	**9**	**9**	6	**13**	**16**	**16**	**11**	Target exceeded for three consecutive seasons. Positive result.
	Low	**9**	**9**	6	**13**	**16**	**16**	**14**	Target exceeded. Variable numbers but gradual increase apparent post-construction. Positive result.
Curlew Sandpiper	High	**2**	0	0	0	0	0	0	Remained absent throughout construction and post-construction phases. Declining across SE Australia so likely to be caused by events at a greater scale.
	Low	**2**	0	1	0	0	0	0	
Red-necked Stint	High	**25**	5	0	6	14	**25**	5	Target met. Numbers consistent throughout season, higher average since construction phase. Positive result.
	Low	**29**	5	5	6	24	20	4	Greater abundance post-construction, consistent numbers throughout the season. Positive result.
Double-banded Plover	High	**37**	29	31	19	20	4	3	Extremely variable within and among seasons at both Penrhyn and the reference site. No distinct pattern of population change.
	Low	**33**	**33**	31	22	20	23	3	

3.2 Diversity

The diversity of migratory species at Penrhyn Estuary increased and approached pre-construction conditions (fourteen species present when the studies began in December 2006) (**Table 6**).

There was a greater number of migratory species in the 201/2103 survey period compared with the construction phase, with twelve species observed in both post-construction years, an increase from the previous nine migratory species observed during the second and third year of the construction phase (**Table 6**).

Table 6 Species observed before, during and post-construction phases

	EPBC	TSC	Pre-construction	Construction			Post-construction	
			Dec 2006-Mar 2008	2008/09	2009/10	2010/11	2011/12	2012/13
Migratory species								
Bar-tailed Godwit*	M		✓	✓	✓	✓	✓	✓
Eastern Curlew	M		✓				✓	
Common Greenshank	M		✓	✓				
Common Sandpiper	M		✓					
Grey-tailed Tattler	M		✓	✓	✓	✓	✓	✓
Ruddy Turnstone	M		✓					
Great Knot	M		✓	✓				
Red Knot*	M		✓	✓			✓	
Sanderling	M	V	✓			✓	✓	✓
Pacific Golden Plover*	M		✓	✓	✓	✓	✓	✓
Double-banded Plover*	M		✓	✓	✓	✓	✓	✓
Lesser Sand Plover	M	V				✓		✓
Curlew Sandpiper*	M		✓		✓			
Red-necked Stint*	M		✓	✓	✓	✓	✓	✓
Sharp-tailed Sandpiper	M		✓	✓	✓	✓	✓	✓
Terek Sandpiper	M	V	✓					✓
Little Tern	M	E	✓	✓	✓	✓	✓	✓
Caspian Tern	M		✓	✓	✓	✓	✓	✓
Common Tern	M		✓	✓			✓	✓
Non-migratory species								
Pied Oystercatcher		E	✓	✓	✓	✓	✓	✓
Black-winged Stilt			✓	✓	✓		✓	✓
Red-capped Plover			✓	✓	✓	✓	✓	✓
Black-fronted Dotterel			✓					
Masked Lapwing			✓	✓	✓	✓	✓	✓

* Key species for Penrhyn Estuary
EPBC Species protected under the Environment Protection and Biodiversity Conservation Act 1999 (Migratory species)
TSC Species protected under the Threatened Species Conservation Act 1995 (Vulnerable, Endangered)

3.3 Health

There were no sightings of the Red Knot in the 2012/2013 survey period, however the body mass of the Bar-tailed Godwit and Pacific Golden Plover were consistent with a natural transition through post-migration, resting period and pre-migration condition.

The highest count of Bar-tailed Godwit in Penrhyn Estuary occurred early in the peak season (September-November 2012), with 56 birds using the site as a nocturnal roost and 30 as a diurnal roost. Of these, 90% were juveniles. Later in the year numbers dropped off with most juveniles moving on to other areas as they are yet to establish site preference. Remaining birds showed no sign of fattening up for migration, maintaining a fat level of between 2 to 3. Juvenile birds do not return to breeding grounds in their first year, remaining in non-breeding range all year (Hayman *et al.* 1986). In comparison, in other sites in Botany Bay and Parramatta Estuary reference sites, many birds fattened up, approaching a fat level of 5 prior to departure (C. Hankin, pers. obs.).

Similar to previous years, a small number of Pacific Golden Plover arrived at Penrhyn Estuary early in the peak season (September 2012), with a larger flock (peak count of 16 birds) arriving in November 2012. These birds maintained a fat scale of 2 to 3 until March 2013, when birds fattened up to a level 4 approaching 5, along with 50% of breeding plumage (**Figure 5**) prior to departure in April.

Figure 5 **Pacific Golden Plover starting to show breeding plumage and fattening up prior to migration. Flushing channel, Penrhyn Estuary, 19/03/2013. Photo by Chelsea Hankin**

3.4 Mitigation Works in Penrhyn Estuary

In February 2013 sandbags were placed on end of Big Island to prevent further loss of sand from the roosting island. Works are planned to begin in August or early September to rebuild the island and prevent further erosion. The proposed mitigation measures on the roosting islands include remedial treatments such as placement of coarse materials, for example shell grit or gravel, to reduce or prevent further loss of sand material.

4 Data Analysis

4.1 Analytical Methods

Shorebird surveys have been carried out on a number of occasions every month at low and high tide in Penrhyn Estuary and selected reference locations since December 2006. Data collected within the first summer season were excluded from analysis because surveys were only conducted over 3 months (i.e. December 2006 to March 2007) compared to seven months (i.e. September to March) within subsequent 'summer' seasons. Because only one set of data was available to be used for the pre-construction phase compared to three sets of data collected within the during-construction phase, the framework for analysing the different sets of data had to be simplified. A minimum of two sets of sampling prior to construction and two sets during the construction phase are required to ensure that the monitoring programme is not temporally confounded (Underwood 1992, Underwood 1993).

Instead, analyses were done to compare differences in numbers of the key species surveyed at each of low- and high-tide within summer and winter seasons at Penrhyn compared to selected reference sites. The mean count for each species of bird was calculated for each month at low- and high-tide and used as replicates within each season (Summer: September to March, n = 7 replicate months; Winter: April to August, n = 5 replicate months).

It should be noted that only one reference location was available to be assessed for each of the Curlew Sandpiper, Red-necked Stint, Pacific Golden Plover and Double-banded Plover. Ideally, a minimum of two reference locations should be chosen to ensure that the monitoring programme is not spatially confounded.

No reference location was available to be sampled for Red Knot. For this reason and because numbers were extremely low throughout the study period it was not considered appropriate to statistically analyse the available data.

Nocturnal counts are only indicative of a minimum count of the birds present, as some birds could be missed in the dark, and identification is more difficult. Without pre-construction and during-construction phase nocturnal monitoring, these data were not statistically analysed.

Average counts of key species throughout the pre-, during and post-construction phases were analysed to examine changes in abundance over time at Penrhyn Estuary and associated reference sites. Caution must be applied when interpreting these results, as there is only one set of pre-construction data against which they can be compared.

4.2 Results

4.2.1 Species Recorded

Thirty seven species were observed in the April 2013 – March 2013 survey period (**Table 7**).

Table 7 Species observed April 2012 - March 2013 (listed in taxonomic order) and conservation status

Common name	Diurnal	Nocturnal	EPBC	TSC
Chestnut Teal	✓			
Pacific Black Duck	✓	✓		
Australasian Darter	✓			
Little Pied Cormorant	✓			
Great Cormorant	✓	✓		
Little Black Cormorant	✓			
Pied Cormorant	✓			
Australian Pelican	✓	✓		
White-necked Heron	✓			
Eastern Great Egret	✓			
Striated Heron	✓			
White-faced Heron	✓			
Little Egret	✓			
Australian White Ibis	✓			
Royal Spoonbill	✓	✓		
Eastern Osprey	✓		M	V
Australian Pied Oystercatcher	✓	✓		E
Black-winged Stilt	✓	✓		
Pacific Golden Plover*	✓	✓	M	
Red-capped Plover	✓	✓		
Double-banded Plover*	✓	✓	M	
Lesser Sand Plover	✓		M	V
Masked Lapwing	✓	✓		
Bar-tailed Godwit*	✓	✓	M	
Terek Sandpiper	✓		M	V
Grey-tailed Tattler	✓	✓	M	
Sanderling	✓		M	V
Red-necked Stint*	✓	✓	M	
Sharp-tailed Sandpiper	✓	✓	M	
Long-tailed Jaeger	✓			
Sooty Tern	✓			V
Little Tern	✓	✓	M	E
Caspian Tern	✓			

Common name	Diurnal	Nocturnal	EPBC	TSC
Common Tern	✓		M	
Crested Tern	✓			
Kelp Gull	✓			
Silver Gull	✓	✓		

* Key species for Penrhyn Estuary
EPBC Species protected under the Environment Protection and Biodiversity Conservation Act 1999 (Migratory species)
TSC Species protected under the Threatened Species Conservation Act 1995 (Vulnerable, Endangered)

4.2.2 Peak Counts of Key Species

Figures 6-11 show the peak count of key species of shorebirds during the three years of the construction phase and two years during the post-construction phase, compared to the long-term target. The long-term target represents pre-construction shorebird numbers at Penrhyn Estuary.

4.2.2.1 Bar-tailed Godwit

a) High tide (roosting) b) Low tide (feeding)

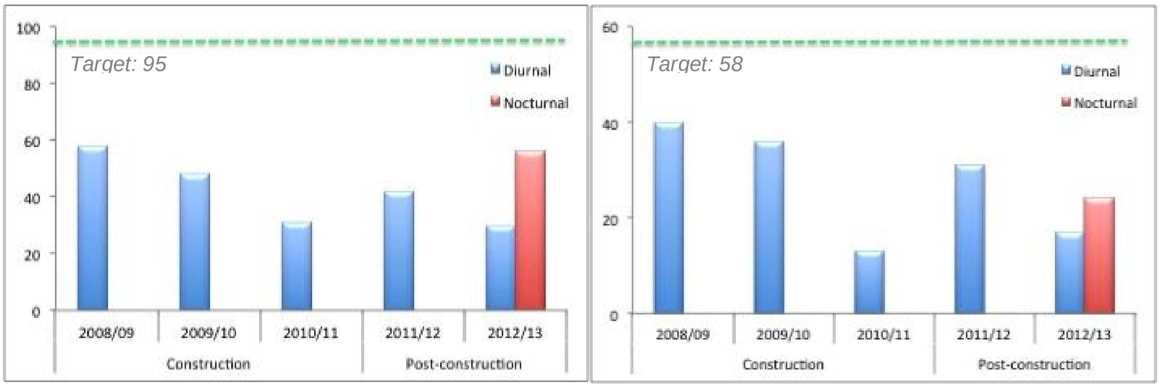

Figure 6 **Peak count of Bar-tailed Godwit during construction and post-construction phases, compared to the long-term target**

4.2.2.2 Red-necked Stint

a) High tide (roosting) b) Low tide (feeding)

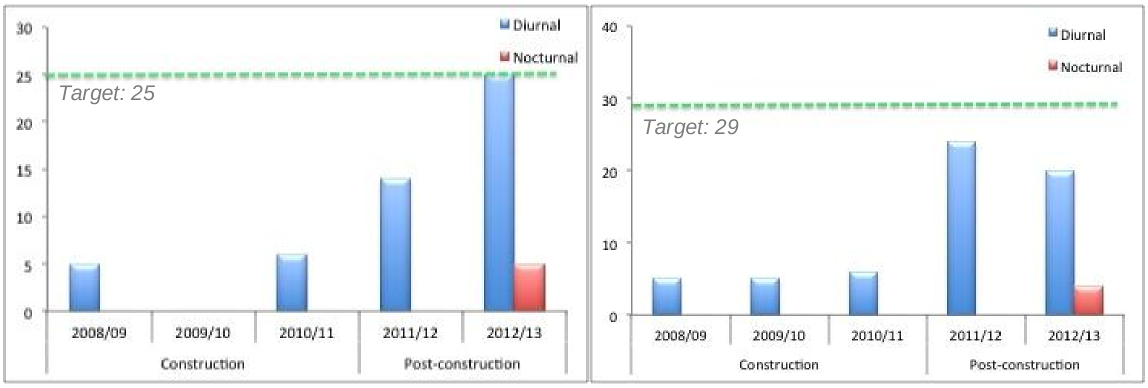

Figure 7 **Peak count of Red-necked Stint during construction and post-construction phases, compared to the long-term target**

4.2.2.3 Pacific Golden Plover

a) High tide (roosting) b) Low tide (feeding)

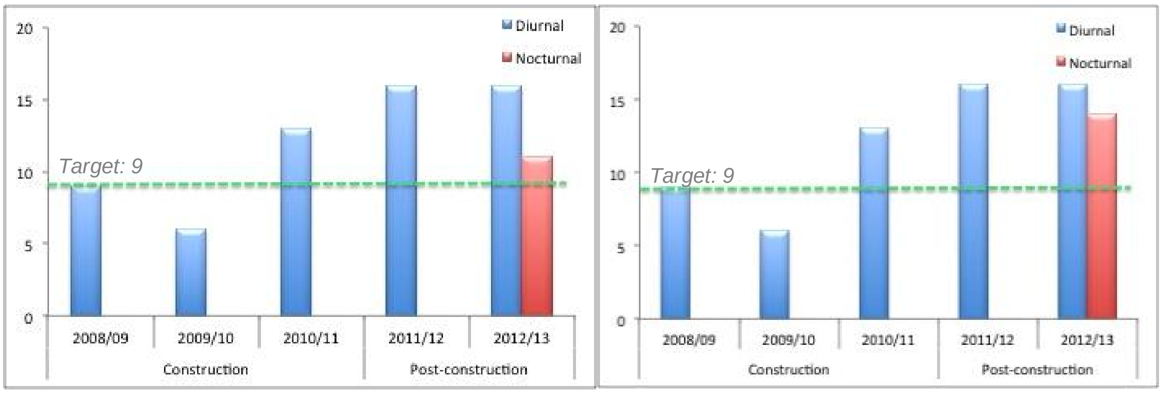

Figure 8 **Peak count of Pacific Golden Plover during construction and post-construction phases, compared to the long-term target**

4.2.2.4 Red Knot

a) High tide (roosting) b) Low tide (feeding)

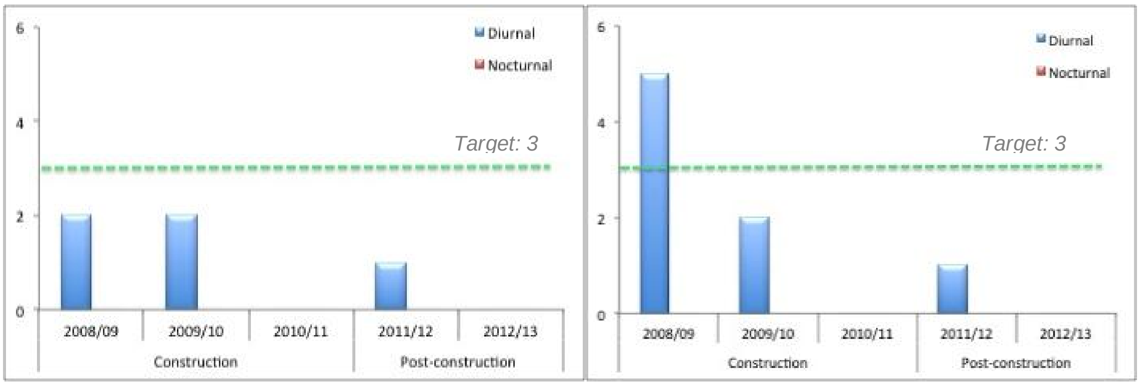

Figure 9 **Peak count of Red Knot during construction and post-construction phases, compared to the long-term target**

4.2.2.5 Curlew Sandpiper

a) High tide (roosting) b) Low tide (feeding)

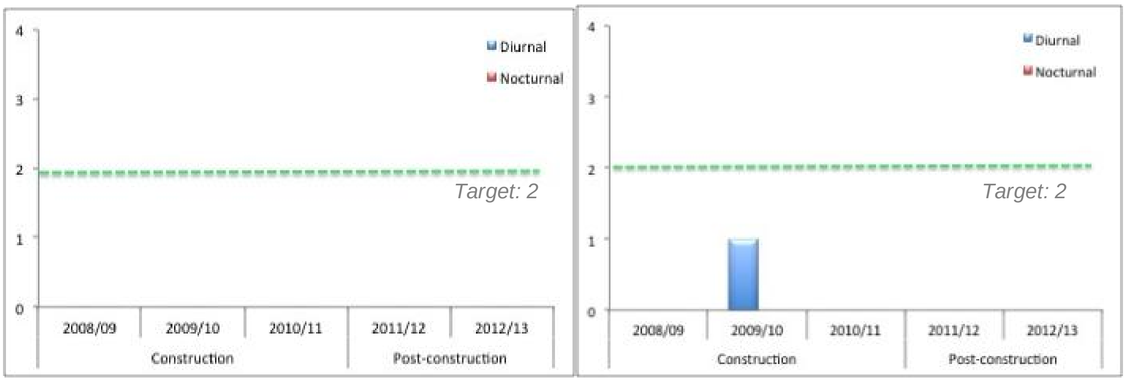

Figure 10 **Peak count of Curlew Sandpiper during construction and post-construction phases, compared to the long-term target**

4.2.2.6 Double-banded Plover

a) High tide (roosting) b) Low tide (feeding)

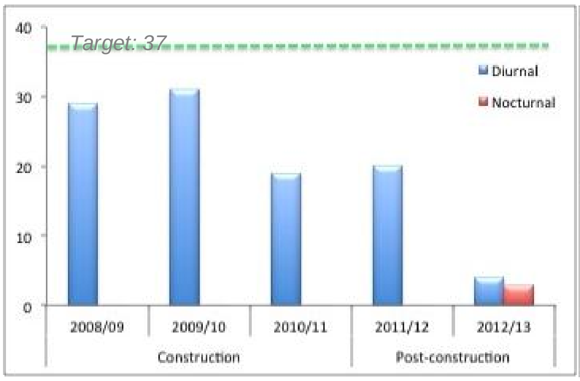

Figure 11 Peak count of Double-banded Plover during construction and post-construction phases, compared to the long-term target

4.2.3 Changes in Abundance of Key Species

4.2.3.1 Bar-tailed Godwit

The results of the ANOVA revealed a significant difference in numbers of Bar-tailed Godwit at both low and high tide, with an interaction between time, impact (pre, construction and post) and reference sites (**Table 8**). In the third year of the construction phase (Sept 2010- Mar 2011), there was a significant drop in numbers at Penrhyn Estuary during low tide, while numbers at the reference sites remained relatively stable with no significant difference over time (**Figure 12a**). Numbers have steadily increased at Penrhyn Estuary in recent years, coinciding with the post-construction phase of the PEHE. A similar pattern was observed at high tide (**Table 12b**), although there was also a slight drop during the third year of the construction phase at the reference locations, so may be caused by something at a larger scale than the works at Penrhyn Estuary.

Table 8 Summary of ANOVAs comparing numbers of Bar-tailed Godwit at Penrhyn Estuary to reference locations (Quibray Bay, Riverside Drive, Woodlands Road)

Bar-tailed Godwit		Low-tide		High-tide	
Source	*df*	MS	*F*	MS	*F*
Time (Ti)	5	252.89		8.68	
Location (Lo)	3	231.40		60.84	
Impact v Refs	1	504.87		0.59	
Refs	2	94.67		91.0	
Ti x Lo	15	102.59		2.04	
Ti x Impact v Refs	5	187.96	3.48 *	4.04	3.07 *
Ti x Refs	10	59.90	1.11 ns	1.04	0.79 ns
Residual	144	53.98		1.32	
Cochran's test			0.15 ns		0.11 ns
Transformation			none		Ln(x+1)

ns = not significant ($P > 0.05$)
* = significant ($P < 0.05$)
** = highly significant ($P < 0.01$)
Refs = References

Bar-tailed Godwit

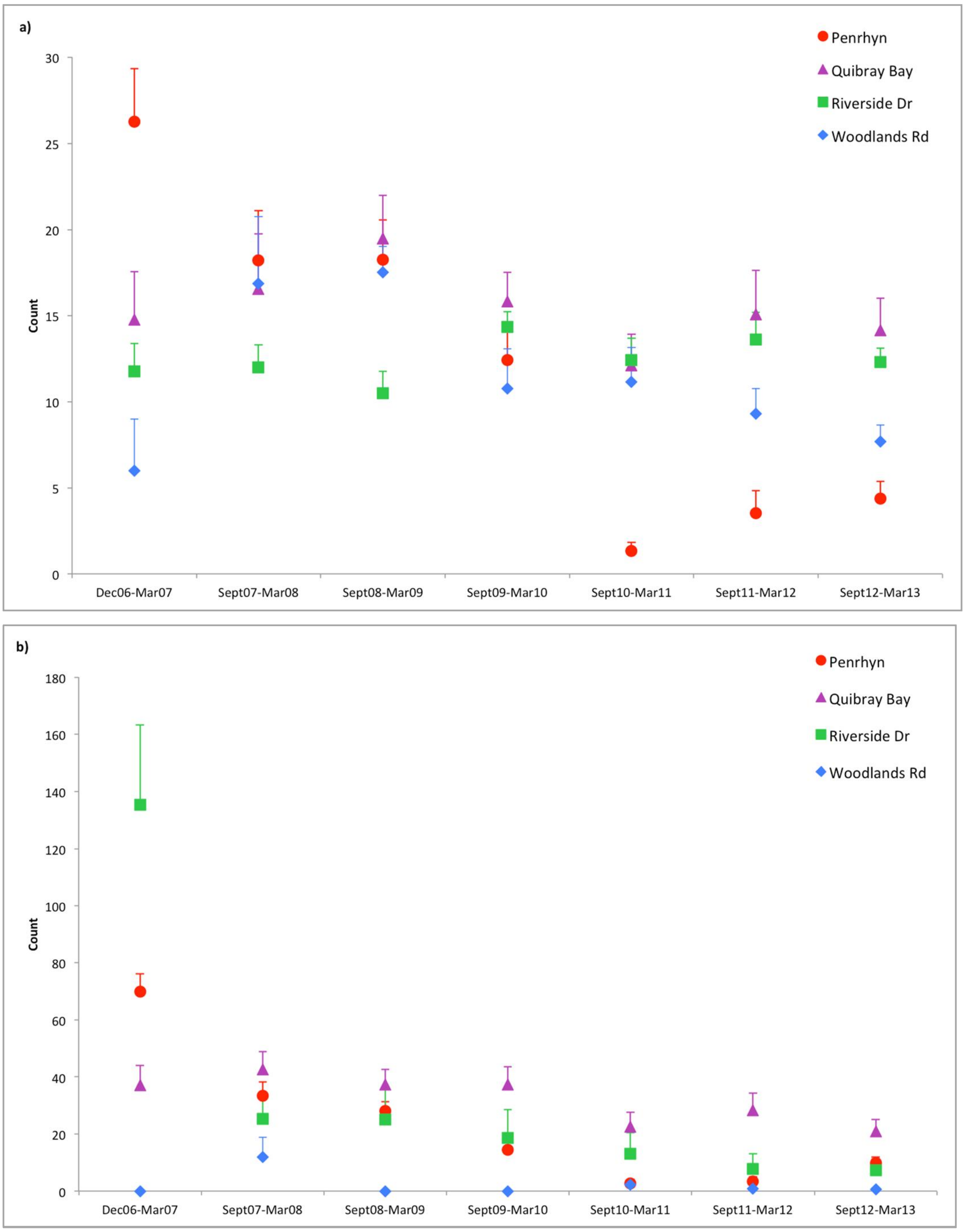

Figure 12 **Mean (+SE) number of Bar-tailed Godwit at a) low-tide and b) high-tide**

NB: data collected within the Dec06-Mar-07 season were not included in analyses

4.2.3.2 Curlew Sandpiper

Curlew Sandpiper did not visit Penrhyn Estuary in this period, and has not been sighted in the estuary since summer 2007/2008, except for one sighting in 2009. Mean counts of Curlew Sandpiper at both low and high tide were significantly greater at the reference site in the first four years (2007- 2010) (**Table 9, Figure 13**). Since 2010, sightings at Parramatta Estuary have declined to a similar state at Penrhyn Estuary, averaging less than two birds per season (**Figure 13**).

Table 9 Summary of ANOVAs comparing numbers of Curlew Sandpipers at Penrhyn Estuary compared to the reference location (Parramatta Estuary).

Curlew Sandpiper		Low-tide		High-tide	
Source	***df***	**MS**	***F***	**MS**	***F***
Time (Ti)	5	55.35		68.35	
Location (Lo)	1	309.99		313.78	
Ti x Lo	5	53.31	5.32 *	66.16	6.89 *
Residual	72	10.02		9.60	
Cochran's test			0.63 **		0.59 **
Transformation			none		none

ns = not significant ($P > 0.05$)
* = significant ($P < 0.05$)
** = significant ($P < 0.01$)
Refs = References

Curlew Sandpiper

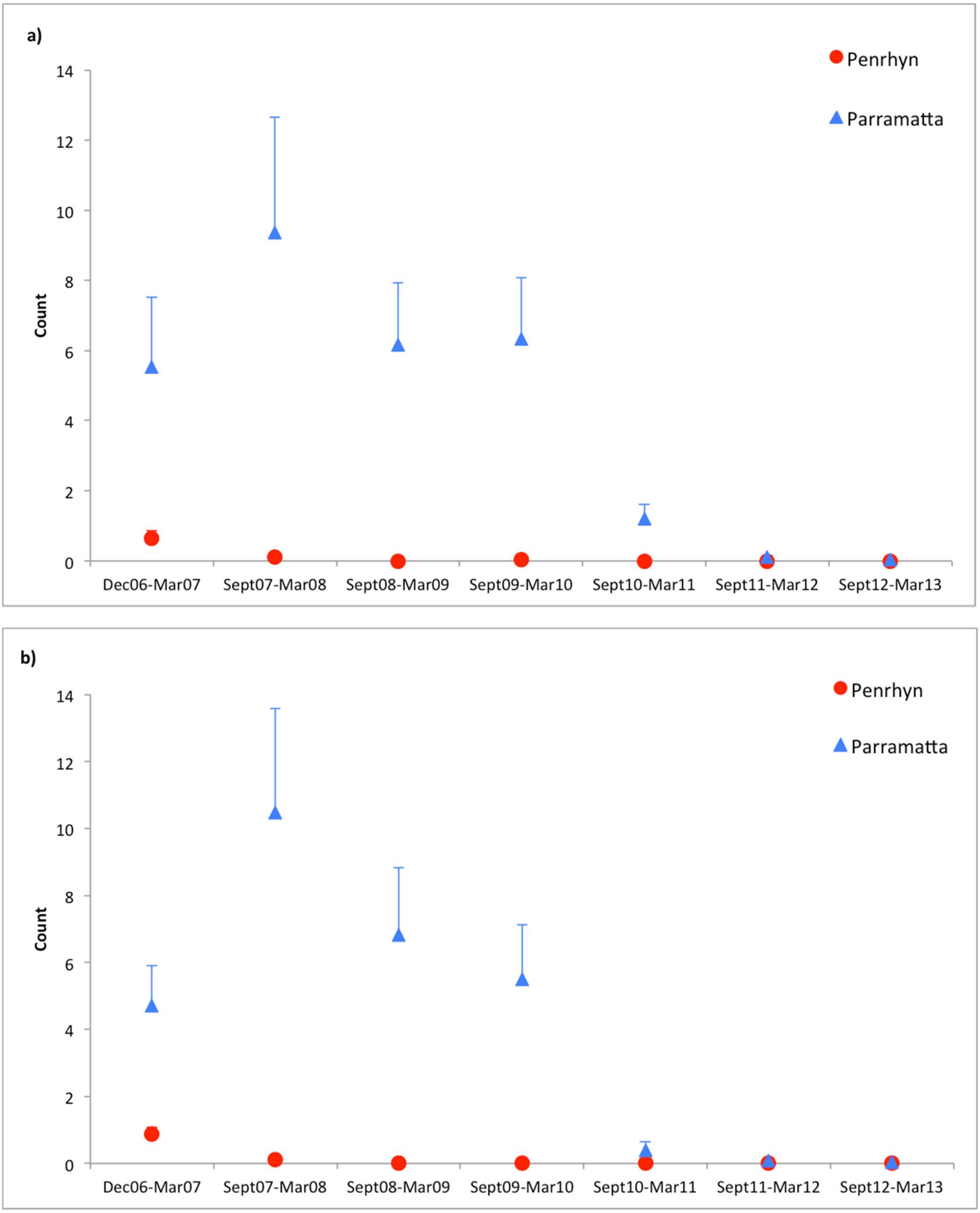

Figure 13 **Mean (+SE) number of Curlew Sandpiper at a) low-tide and b) high-tide**

NB: data collected within the Dec06-Mar-07 season were not included in analyses

4.2.3.3 Red-necked Stint

Peak count of Red-necked Stint in Penrhyn Estuary at low tide reached the target count (pre-construction) (**Figure 7**). Average counts of Red-necked Stint showed significant time and location interactions at both low and high tide (**Table 10**). Average numbers for this peak season have increased to the pre-construction average (2007/08) whereas at the reference location, there has been no significant change over time.

Table 10 Summary of ANOVAs comparing abundance of Red-necked Stint at Penrhyn Estuary to the reference location (Boat Harbour)

Red-necked Stint		Low-tide		High-tide	
Source	***df***	**MS**	***F***	**MS**	***F***
Time (Ti)	5	1.34	0.89 ns	1.34	1.04 ns
Location (Lo)	1	172.66	371.63 **	288.49	621.99 **
Ti x Lo	5	1.50	3.22 *	1.29	2.78 *
Residual	72	0.46		0.46	
Cochran’s test			0.22 ns		0.24 ns
Transformation			Ln(x+1)		Ln(x+1)

ns = not significant ($P > 0.05$)
* = significant ($P < 0.05$)
** = significant ($P < 0.01$)
Refs = References

Red-necked Stint

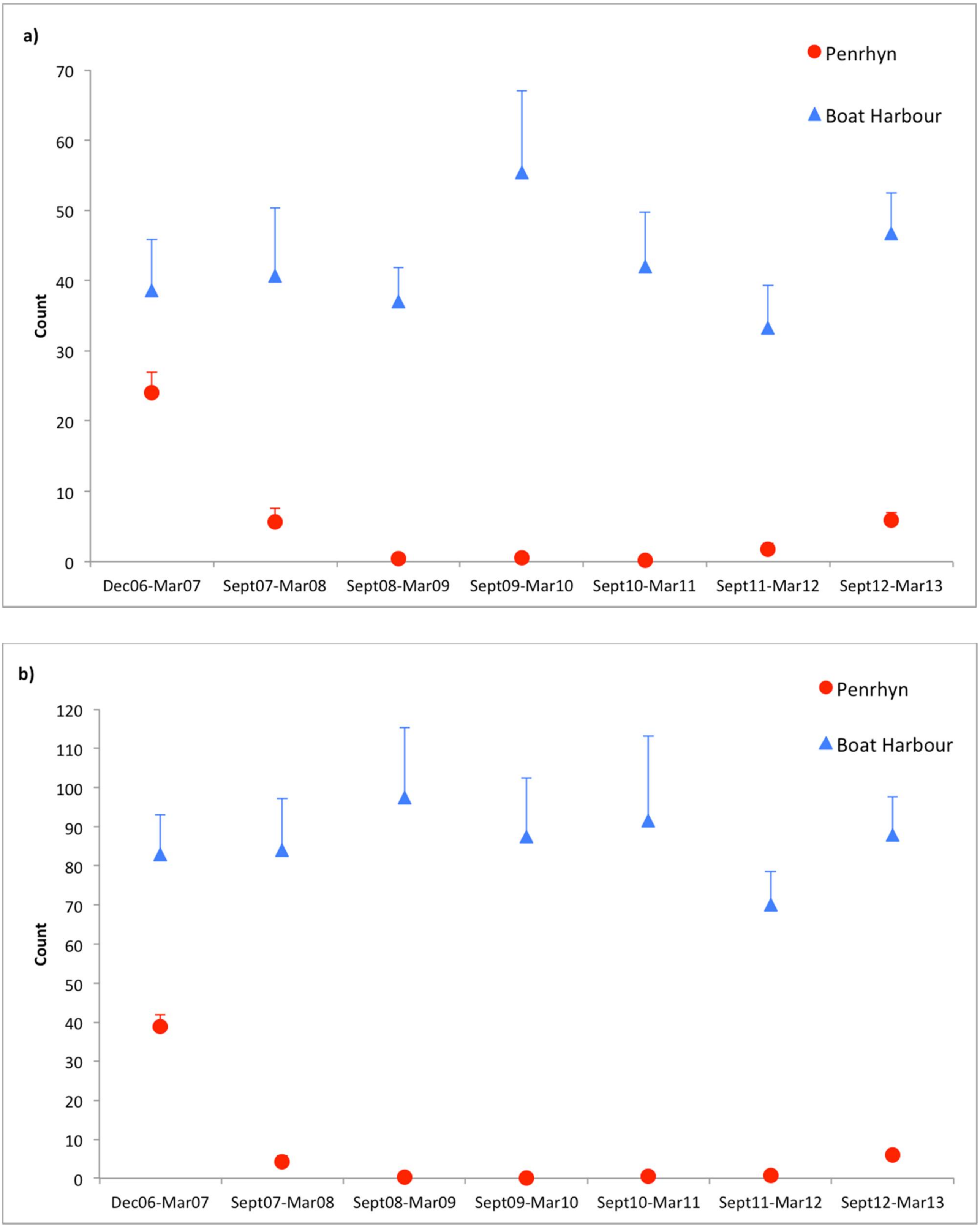

Figure 14 **Mean (+SE) number of Red-necked Stint at a) low-tide and b) high-tide**

NB: data collected within the Dec06-Mar-07 season were not included in analyses

4.2.3.4 Pacific Golden Plover

Average numbers of Pacific Golden Plover sighted at the Hunter Estuary during low tide were significantly greater than at Penrhyn throughout the study period ($F_{1,72}$ = 64.41, P<0.05; **Figure 15**). Notably, differences among summer seasons were not significant ($F_{5,5}$ = 0.95, P>0.05; **Figure 15**). There has been an overall gradual increase at Penrhyn Estuary coinciding with the post-construction phase (**Figure 15**); however this was not a significant result.

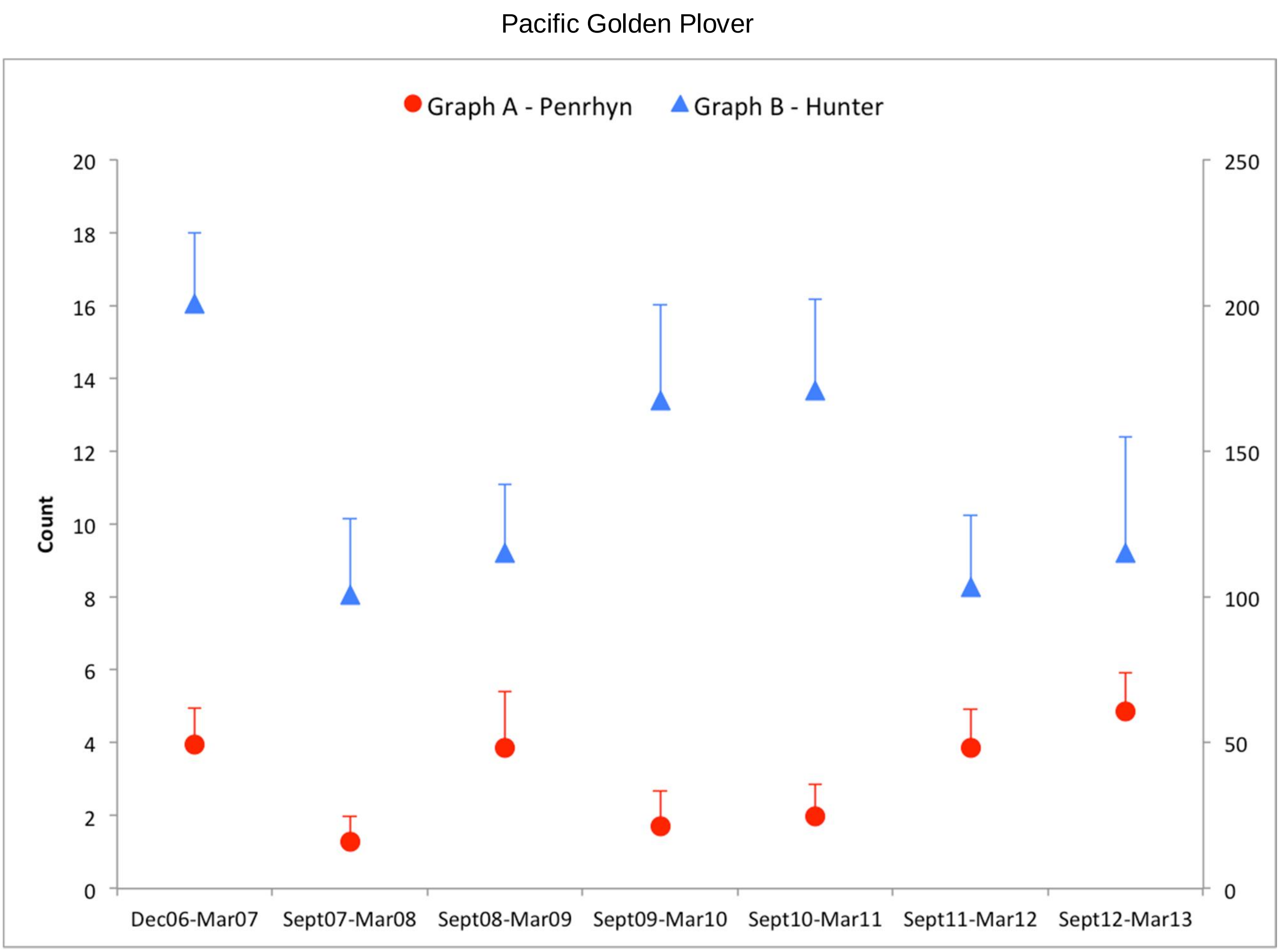

Figure 15 **Mean (+SE) number of Pacific Golden Plover at low-tide**

NB: data collected within the Dec06-Mar-07 season were not included in analyses

4.2.3.5 Double-banded Plover

No significant differences in abundance of Double-banded Plover were found at any spatial scales examined for low and high tides (**Table 11**). In general, numbers of Double-banded Plover were extremely variable at Penrhyn within and among seasons (**Figure 16**). The lowest count during low tide at Penrhyn Estuary was at "Year 4" (2010), during the construction phase. However, the results show much variation with no clear pattern of population change.

Table 11 Summary of ANOVAs comparing numbers of Double-banded Plover at Penrhyn Estuary to the reference location

Double-banded Plover		Low-tide		High-tide	
Source	***df***	**MS**	***F***	**MS**	***F***
Time (Ti)	5	1.83	1.48 ns	2.05	1.12 ns
Location (Lo)	1	3.03	3.08 ns	2.27	2.34 ns
Ti x Lo	5	1.24	1.26 ns	1.84	1.90 ns
Residual	48	0.98		0.97	
Cochran's test			0.20 ns		0.25 ns
Transformation			Ln(x+1)		Ln(x+1)

ns = not significant (P > 0.05)
* = significant (P < 0.05)
** = significant (P < 0.01)
Refs = References

Double-banded Plover

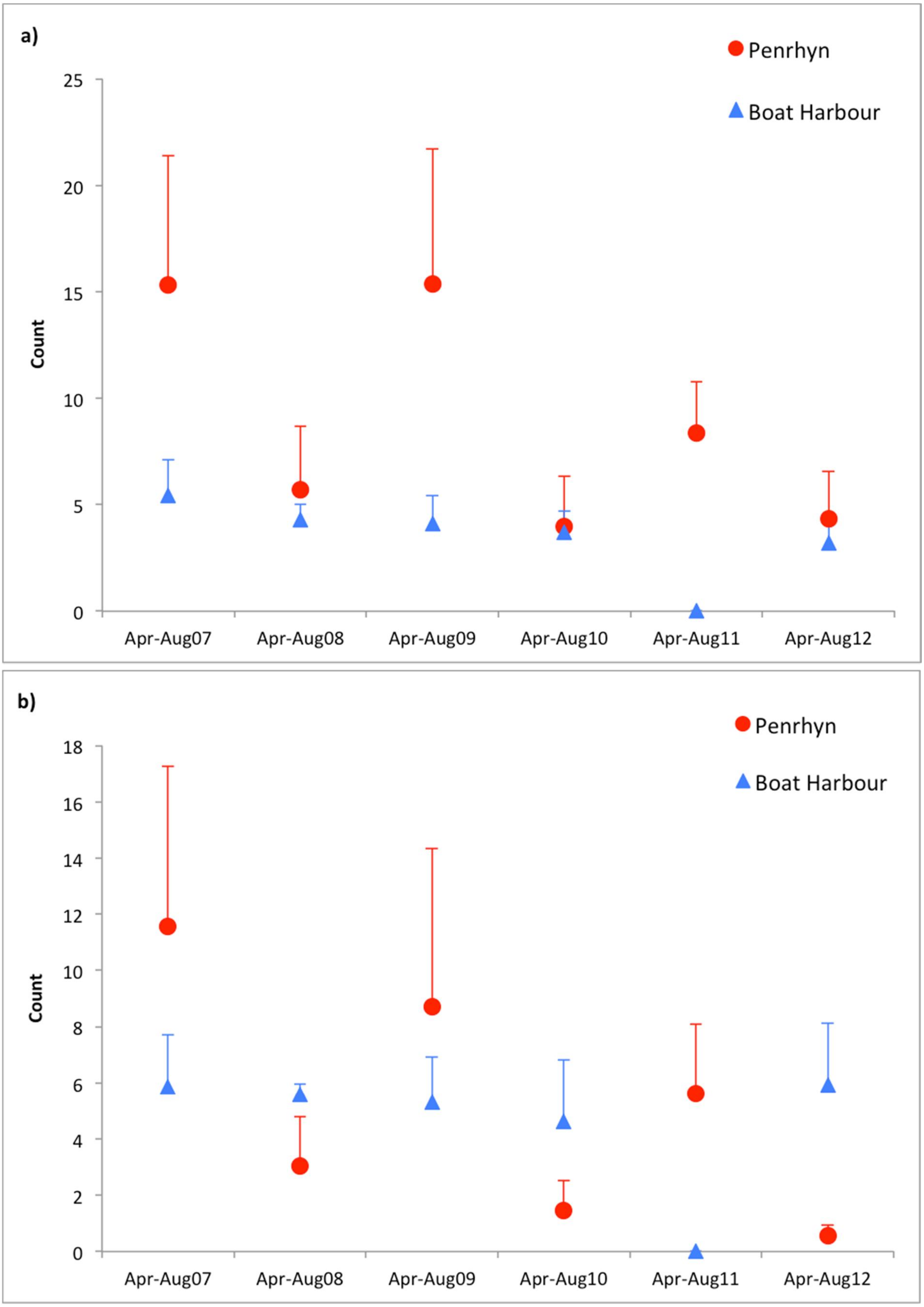

Figure 16 **Mean (+SE) number of Double-banded Plover at a) low-tide and b) high-tide**

NB: data collected within the Dec06-Mar-07 season were not included in analyses

4.3 Interpretation

The peak count of Bar-tailed Godwit were lower than the previous season, however, the results from the first year of nocturnal monitoring revealed a higher number of Bar-tailed Godwit using the estuary as a nocturnal feeding (peak count of 30 birds) and roosting site (peak count of 56 birds). Of these, 90% were juveniles, which were present in the estuary for a few weeks during the start of the peak season but then moved on, as they are yet to establish site preference. There was a significant interaction between time, impact and reference locations for the Bar-tailed Godwit at low tide, indicating an effect of the Port Botany Expansion. Closer analysis revealed there was a significant drop in numbers in the third year of the construction phase, while numbers remained relatively stable with no significant difference over time, suggesting Bar-tailed Godwit at Penrhyn Estuary were impacted during the construction phase. Bar-tailed Godwit has since been increasing at Penrhyn Estuary, coinciding with the post-construction phase of the PEHE. Despite the average numbers remaining low, this indicates a positive result of the PEHE works, with populations becoming closer to those observed at the reference locations. A similar pattern was found at high tide, but while there was a drop at Penrhyn Estuary, there was also a drop at the reference sites. This is likely due to the impact of erosion in Botany Bay, causing a gradual loss of roosting habitat over time particularly at Riverside Drive.

Curlew Sandpiper has remained absent from the estuary during the construction and post-construction phases. The declining trend also observed at Parramatta Estuary suggests that populations of Curlew Sandpiper are being impacted at a larger scale than the activities associated with the Port Botany Expansion project.

The population of Red-necked Stint at Penrhyn Estuary has met the target peak count of 25 birds, although this was not consistent throughout the season, resulting in a low average. While numbers remained significantly greater at the reference location, Boat Harbour, a significant interaction between time and location was found at both low and high tide. Average counts increased similar to pre-construction counts, greater than all other years analysed. At Boat Harbour, there was no significant change over time. This indicates that Red-necked Stint populations are responding positively to the PEHE works, with a gradual increase coinciding with the post-construction phase.

Peak count of Pacific Golden Plover in Penrhyn Estuary exceeded the target, although this was not consistent throughout the season, causing a low average count. Despite there being no significant change over time, a gradual increase of the average count is apparent in post-construction years.

Numbers of Double-banded Plover were highly variable at both Penrhyn Estuary and at the reference location; hence no correlations can be made with the PEHE works. However, the amount of variability around the mean is becoming smaller, which may indicate that there are fewer disturbances in the estuary.

5 Conclusions

Tidal mudflats and saltmarsh at Penrhyn Estuary continue to mature, providing foraging habitat for migratory and non-migratory shorebirds. The second year of post-construction monitoring revealed a positive result for the Bar-tailed Godwit and Red-necked Stint, with populations becoming closer to the pre-construction conditions.

Peak counts of Pacific Golden Plover surpassed the target population for this species and were consistent with an increase during this period at the reference site in the Hunter River Estuary. Although counts of Red-necked Stint also met target numbers for the PEHE objectives, counts of both species were not consistent throughout the season, resulting in low averages.

Targets were not met for the Bar-tailed Godwit, Red Knot, Curlew Sandpiper and Double-banded Plover. It is expected that with the continued changes of the estuary, including invertebrate populations and diversity, species will return in greater numbers. The Bar-tailed Godwit is showing a gradual increase, however the Red Knot and Curlew Sandpiper have been almost completely absent in Penrhyn Estuary for some years. The Curlew Sandpiper has shown a decline of up to 80% decline in many areas of SE Australia, and so it is likely that this species is being impacted by issues at a much larger scale than the works at Port Botany.

Most species of shorebirds appear to be increasing in post-construction years. Analysis in further post-construction years will give a better understanding of the success of the PEHE works.

6 Recommendations

The issue of bright lights, especially white floodlights used to illuminate construction zones, shining directly onto the Estuary tidal flats potentially disturbing shorebirds at night should be communicated to contractors. Moving lights, such as vehicle headlights, are particularly likely to disturb roosting and feeding shorebirds at night. Indirect, static lighting has not shown to be detrimental to shorebirds in the estuary at night. These impacts are likely to be greatly reduced with the construction of the sound barriers scheduled to be constructed during the current off-peak period.

A fox control program has been successful in protecting shorebirds, including roosting birds and eggs and chicks of Little Terns and non-migratory shorebirds such as the (Endangered) Pied Oystercatcher as well as Red-capped Plover. A continuation of fox-baiting is essential due to the continued recruitment of animals from neighbouring properties and is likely to be a long term commitment. This is particularly important during the peak season when migratory shorebirds are at their peak numbers and when shorebirds and Little Terns are nesting in the estuary.

Nesting of birds at the SICTL construction site has proved to be difficult to stop even with diligent daily observations. This meant the commitment of substantial time and other resources by SICTL environmental and construction team members. For example, an incident when a Little Tern chick fell down a drainage pit involved the efforts of SICTL and Avifauna Research & Services staff to rescue it and return it to its parents. It is important to continue to deter birds from using the Port for their own welfare although this should become less of a problem once the site has been hard surfaced.

It is important to prevent weed invasion by tall vegetation which reduces the value of foraging and roosting habitat as well as saltmarsh communities. These include mangroves, Casuarinas growing anywhere in the estuary and high marsh species such as *Juncus kraussii* and *Suaeda australis* growing in low marsh saltmarsh areas where low marsh plants and shorebird roosting habitat is threatened. The ongoing management of weed species in the estuary should be managed when plants are small and can be removed by hand.

Monitoring and maintenance of roosting/nesting islands for wind and water erosion as well as weed control is important and needs to be acted on quickly to reduce the need for costly remediation action if allowed to go unchecked. Works are planned to begin in August or early September 2013 to reinforce the Big Island again. The proposed works include placement of coarse materials, for example shell grit or gravel, to reduce or prevent further loss of sand material from the roosting habitat.

Figure 17 Erosion of roosting islands. Big Island flooded 12/01/2013. Photo by Chelsea Hankin

7 Acknowledgements

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APPENDIX A

SHOREBIRD SURVEYS: PENRHYN ESTUARY AND REFERENCE SITES

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Appendix A: Shorebird Surveys: Penrhyn Estuary and Reference Sites

A-1: Diurnal Shorebird Surveys: Penrhyn Estuary (Key Species)

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Big Island	Bar-tailed Godwit	5	02/10/2012	Roosting	Rocks	High
Corner Saltmarsh	Bar-tailed Godwit	1	02/10/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Bar-tailed Godwit	8	09/10/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	15	23/10/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Bar-tailed Godwit	13	30/10/2012	Roosting	Saltmarsh	High
Outer Flushing Channel	Bar-tailed Godwit	9	30/10/2012	Roosting	Exposed mud/sand	High
Corner Island	Bar-tailed Godwit	30	06/11/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	27	13/11/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	27	20/11/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	28	27/11/2012	Roosting	Saltmarsh	High
Outer Flushing Channel	Bar-tailed Godwit	2	03/12/2012	Roosting	Rocks	High
Corner Saltmarsh	Bar-tailed Godwit	25	03/12/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Bar-tailed Godwit	23	11/12/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	15	18/12/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	2	24/12/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Bar-tailed Godwit	12	24/12/2012	Roosting	Saltmarsh	High
Big Island	Bar-tailed Godwit	2	31/12/2012	Roosting	Exposed mud/sand	High
Outer Flushing Channel	Bar-tailed Godwit	4	31/12/2012	Roosting	Rocks	High
Big Island	Bar-tailed Godwit	6	09/01/2013			High
Outer Flushing Channel	Bar-tailed Godwit	2	22/01/2013	Roosting	Rocks	High
Outer Flushing Channel	Bar-tailed Godwit	7	29/01/2013	Roosting	Rocks	High
Outer Flushing Channel	Bar-tailed Godwit	8	05/02/2013	Roosting	Exposed mud/sand	High
Small Island	Bar-tailed Godwit	1	05/02/2013	Feeding	Shallow water	High
Corner Mudflats	Bar-tailed Godwit	1	04/03/2013	Roosting	Exposed mud/sand	High
Outer Reaches	Bar-tailed Godwit	10	09/05/2012	Feeding	Shallow water	Low
Corner Mudflats	Bar-tailed Godwit	3	24/05/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	4	02/10/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	3	23/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	8	30/10/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Bar-tailed Godwit	1	30/10/2012	Feeding	Shallow water	Low
Springvale Creek	Bar-tailed Godwit	2	30/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	6	06/11/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Bar-tailed Godwit	1	06/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	8	13/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	12	20/11/2012	Feeding	Shallow water	Low
Upper Reaches	Bar-tailed Godwit	4	20/11/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	7	27/11/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Bar-tailed Godwit	1	27/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	17	03/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	14	11/12/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	16	18/12/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	5	24/12/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Bar-tailed Godwit	2	24/12/2012	Feeding	Exposed mud/sand	Low

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Outer Reaches	Bar-tailed Godwit	5	31/12/2012	Feeding	Shallow water	Low
Outer Flushing Channel	Bar-tailed Godwit	2	31/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	1	09/01/2013	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Bar-tailed Godwit	5	15/01/2013	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Bar-tailed Godwit	2	22/01/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	1	05/02/2013	Feeding	Shallow water	Low
Outer Flushing Channel	Bar-tailed Godwit	2	05/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	1	04/03/2013	Feeding	Exposed mud/sand	Low
Big Island	Double-banded Plover	4	24/05/2012	Roosting	Exposed mud/sand	High
Big Island	Double-banded Plover	2	18/07/2012	Roosting	Exposed mud/sand	High
Big Island	Double-banded Plover	1	05/02/2013	Roosting	Rocks	High
Big Island	Double-banded Plover	1	25/02/2013	Roosting	Exposed mud/sand	High
Big Island	Double-banded Plover	2	04/03/2013	Roosting	Rocks	High
Big Island	Double-banded Plover	3	26/03/2013	Roosting	Exposed mud/sand	High
Outer Reaches	Double-banded Plover	21	09/05/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Double-banded Plover	2	09/05/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Double-banded Plover	1	24/05/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Double-banded Plover	2	06/06/2012	Feeding	Exposed mud/sand	Low
Big Island	Double-banded Plover	2	18/07/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	5	18/07/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Double-banded Plover	2	18/07/2012	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Double-banded Plover	12	15/08/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	1	15/08/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Double-banded Plover	1	04/09/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	1	05/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	2	04/03/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	2	12/03/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	4	19/03/2013	Feeding	Exposed mud/sand	Low
Upper Reaches	Double-banded Plover	17	26/03/2013	Feeding	Exposed mud/sand	Low
Subsite	**Common Name**	**Count**	**Date**	**Behaviour**	**Habitat**	**Tide**
Corner Island	Pacific Golden Plover	1	23/10/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Pacific Golden Plover	2	23/10/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Pacific Golden Plover	4	30/10/2012	Roosting	Saltmarsh	High
Corner Island	Pacific Golden Plover	5	06/11/2012	Roosting	Saltmarsh	High
Corner Island	Pacific Golden Plover	5	13/11/2012	Roosting	Saltmarsh	High
Corner Island	Pacific Golden Plover	2	20/11/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Pacific Golden Plover	3	20/11/2012	Roosting	Saltmarsh	High
Big Island	Pacific Golden Plover	3	11/12/2012	Roosting	Exposed mud/sand	High
Big Island	Pacific Golden Plover	14	24/12/2012	Roosting	Exposed mud/sand	High

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Corner Island	Pacific Golden Plover	1	31/12/2012	Roosting	Saltmarsh	High
Outer Flushing Channel	Pacific Golden Plover	11	22/01/2013	Roosting	Rocks	High
Outer Flushing Channel	Pacific Golden Plover	1	29/01/2013	Roosting	Rocks	High
Outer Flushing Channel	Pacific Golden Plover	15	12/02/2013	Roosting	Rocks	High
Outer Flushing Channel	Pacific Golden Plover	13	19/02/2013	Roosting	Rocks	High
Outer Flushing Channel	Pacific Golden Plover	16	25/02/2013	Roosting	Rocks	High
Outer Flushing Channel	Pacific Golden Plover	14	04/03/2013	Roosting	Rocks	High
Outer Flushing Channel	Pacific Golden Plover	10	19/03/2013	Roosting	Rocks	High
Big Island	Pacific Golden Plover	16	26/03/2013	Roosting	Exposed mud/sand	High
Outer Flushing Channel	Pacific Golden Plover	15	26/03/2013	Roosting	Rocks	High
Corner Mudflats	Pacific Golden Plover	1	02/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	1	23/10/2012	Feeding	Exposed mud/sand	Low
Corner Saltmarsh	Pacific Golden Plover	2	23/10/2012	Roosting	Saltmarsh	Low
Corner Mudflats	Pacific Golden Plover	11	30/10/2012	Feeding	Exposed mud/sand	Low
Springvale Creek	Pacific Golden Plover	4	30/10/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Pacific Golden Plover	5	06/11/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Pacific Golden Plover	2	13/11/2012	Feeding	Exposed mud/sand	Low
Corner Saltmarsh	Pacific Golden Plover	2	20/11/2012	Roosting	Saltmarsh	Low
Corner Island	Pacific Golden Plover	4	20/11/2012	Roosting	Saltmarsh	Low
Outer Reaches	Pacific Golden Plover	2	03/12/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Pacific Golden Plover	3	11/12/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Pacific Golden Plover	14	24/12/2012	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Pacific Golden Plover	4	31/12/2012	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Pacific Golden Plover	4	15/01/2013	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Pacific Golden Plover	5	22/01/2013	Roosting	Rocks	Low
Outer Flushing Channel	Pacific Golden Plover	12	05/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	9	12/02/2013	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Pacific Golden Plover	8	19/02/2013	Roosting	Rocks	Low
Outer Reaches	Pacific Golden Plover	14	25/02/2013	Feeding	Exposed mud/sand	Low
Foreshore beach	Pacific Golden Plover	2	25/02/2013	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Pacific Golden Plover	14	04/03/2013	Roosting	Rocks	Low
Outer Flushing Channel	Pacific Golden Plover	5	12/03/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	8	12/03/2013	Feeding	Exposed mud/sand	Low
Outer Flushing Channel	Pacific Golden Plover	16	19/03/2013	Roosting	Rocks	Low
Upper Reaches	Pacific Golden Plover	8	26/03/2013	Feeding	Exposed mud/sand	Low
Corner Saltmarsh	Red-necked Stint	2	28/08/2012	Roosting	Saltmarsh	High
Big Island	Red-necked Stint	1	16/10/2012	Roosting	Exposed mud/sand	High
Corner Island	Red-necked Stint	5	30/10/2012	Roosting	Saltmarsh	High

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Corner Island	Red-necked Stint	11	06/11/2012	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	2	13/11/2012	Roosting	Exposed mud/sand	High
Corner Island	Red-necked Stint	8	13/11/2012	Roosting	Saltmarsh	High
Corner Island	Red-necked Stint	4	20/11/2012	Roosting	Saltmarsh	High
Big Island	Red-necked Stint	8	27/11/2012	Roosting	Exposed mud/sand	High
Corner Island	Red-necked Stint	9	27/11/2012	Roosting	Saltmarsh	High
Big Island	Red-necked Stint	5	03/12/2012	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	25	11/12/2012	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	13	18/12/2012	Roosting	Exposed mud/sand	High
Corner Saltmarsh	Red-necked Stint	4	18/12/2012	Roosting	Rocks	High
Big Island	Red-necked Stint	13	24/12/2012	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	1	31/12/2012	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	15	09/01/2013			High
Big Island	Red-necked Stint	11	15/01/2013	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	6	22/01/2013	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	7	29/01/2013	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	9	05/02/2013	Roosting	Rocks	High
Big Island	Red-necked Stint	9	12/02/2013	Roosting	Exposed mud/sand	High
Big Island	Red-necked Stint	2	19/02/2013	Roosting	Rocks	High
Big Island	Red-necked Stint	10	26/03/2013	Roosting	Exposed mud/sand	High
Springvale Creek	Red-necked Stint	1	19/06/2012	Feeding	Exposed mud/sand	Low
Springvale Creek	Red-necked Stint	2	28/08/2012	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Red-necked Stint	2	09/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	3	23/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	3	30/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	10	06/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	7	13/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	16	20/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	11	27/11/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Red-necked Stint	3	27/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	20	03/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	6	11/12/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Red-necked Stint	4	11/12/2012	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Red-necked Stint	8	11/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	12	18/12/2012	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Red-necked Stint	4	18/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	4	24/12/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Red-necked Stint	7	24/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	1	31/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	4	09/01/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	4	15/01/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	1	22/01/2013	Feeding	Exposed mud/sand	Low
Upper Reaches	Red-necked Stint	3	22/01/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	7	29/01/2013	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Red-necked Stint	1	05/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	7	05/02/2013	Feeding	Exposed mud/sand	Low

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Outer Reaches	Red-necked Stint	11	12/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	2	19/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	2	25/02/2013	Feeding	Exposed mud/sand	Low
Corner Island	Sharp-tailed Sandpiper	1	11/09/2012	Roosting	Saltmarsh	High
Corner Island	Sharp-tailed Sandpiper	1	23/10/2012	Roosting	Saltmarsh	High
Corner Island	Sharp-tailed Sandpiper	3	06/11/2012	Roosting	Saltmarsh	High
Corner Island	Sharp-tailed Sandpiper	7	13/11/2012	Roosting	Saltmarsh	High
Corner Island	Sharp-tailed Sandpiper	2	20/11/2012	Roosting	Saltmarsh	High
Corner Island	Sharp-tailed Sandpiper	3	27/11/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Sharp-tailed Sandpiper	2	03/12/2012	Roosting	Saltmarsh	High
Corner Saltmarsh	Sharp-tailed Sandpiper	2	18/12/2012	Roosting	Saltmarsh	High
Big Island	Sharp-tailed Sandpiper	2	05/02/2013	Roosting	Exposed mud/sand	High
Corner Island	Sharp-tailed Sandpiper	1	05/02/2013	Roosting	Saltmarsh	High
Big Island	Sharp-tailed Sandpiper	3	12/02/2013	Roosting	Saltmarsh	High
Big Island	Sharp-tailed Sandpiper	4	19/02/2013	Roosting	Saltmarsh	High
Big Island	Sharp-tailed Sandpiper	1	25/02/2013	Roosting	Saltmarsh	High
Corner Mudflats	Sharp-tailed Sandpiper	1	11/09/2012	Feeding	Exposed mud/sand	Low
Floodvale Creek	Sharp-tailed Sandpiper	1	23/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	3	30/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	4	06/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	2	13/11/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Sharp-tailed Sandpiper	4	13/11/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Sharp-tailed Sandpiper	1	13/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	2	20/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	4	27/11/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	2	03/12/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Sharp-tailed Sandpiper	1	11/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	1	24/12/2012	Feeding	Exposed mud/sand	Low
Big Island	Sharp-tailed Sandpiper	1	09/01/2013	Roosting	Saltmarsh	Low
Outer Reaches	Sharp-tailed Sandpiper	1	05/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	5	12/02/2013	Feeding	Exposed mud/sand	Low

A-2: Reference Site Monitoring: Botany Bay (Bar-tailed Godwit)

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Carters Shoals	Bar-tailed Godwit	104	12/04/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	128	26/04/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	145	10/05/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	125	23/05/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	114	08/06/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	86	20/06/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	120	05/07/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	125	19/07/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	130	02/08/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	161	16/08/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	16	30/08/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	50	07/09/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	168	14/09/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	266	08/11/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	316	22/11/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	4	29/11/2012	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	58	17/01/2013	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	229	07/02/2013	Roosting	Exposed mud/sand	High
Carters Shoals	Bar-tailed Godwit	321	14/02/2013	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	243	21/02/2013	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	178	07/03/2013	Roosting	Sand spit	High
Carters Shoals	Bar-tailed Godwit	172	20/03/2013	Roosting	Sand spit	High
Oyster leases Quibray	Bar-tailed Godwit	2	12/04/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	5	19/07/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	3	16/08/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	6	07/09/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	4	14/09/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	15	04/10/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	33	11/10/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	1	18/10/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	27	25/10/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	4	01/11/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	2	29/11/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	37	06/12/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	4	13/12/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	26	21/12/2012	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	0	27/12/2012			High
Oyster leases Quibray	Bar-tailed Godwit	33	17/01/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	11	24/01/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	2	07/02/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	41	14/02/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	6	21/02/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	17	28/02/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	3	07/03/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	16	14/03/2013	Roosting	Artificial structure	High
Oyster leases Quibray	Bar-tailed Godwit	1	28/03/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	2	26/04/2012	Roosting	Artificial structure	High

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Posts opposite Bonna Point	Bar-tailed Godwit	28	18/10/2012	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	22	01/11/2012	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	18	15/11/2012	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	13	29/11/2012	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	3	13/12/2012	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	36	27/12/2012	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	5	02/01/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	38	10/01/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	4	17/01/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	12	31/01/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	2	07/02/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	5	21/02/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	13	28/02/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	11	14/03/2013	Roosting	Artificial structure	High
Posts opposite Bonna Point	Bar-tailed Godwit	20	28/03/2013	Roosting	Artificial structure	High
Quibray Bay	Bar-tailed Godwit	18	12/04/2012	Roosting	Exposed mud/sand	High
Quibray Bay	Bar-tailed Godwit	8	20/06/2012	Roosting	Shallow water	High
Quibray Bay	Bar-tailed Godwit	16	07/09/2012	Roosting	Exposed mud/sand	High
Quibray Bay	Bar-tailed Godwit	0	20/09/2012			High
Quibray Bay	Bar-tailed Godwit	28	25/10/2012	Roosting	Shallow water	High
Quibray Bay	Bar-tailed Godwit	54	08/11/2012	Roosting	Shallow water	High
Quibray Bay	Bar-tailed Godwit	63	22/11/2012	Roosting	Shallow water	High
Quibray Bay	Bar-tailed Godwit	4	06/12/2012	Roosting	Beach	High
Quibray Bay	Bar-tailed Godwit	27	21/12/2012	Roosting	Exposed mud/sand	High
Quibray Bay	Bar-tailed Godwit	1	24/01/2013	Roosting	Exposed mud/sand	High
Quibray Bay	Bar-tailed Godwit	0	31/01/2013			High
Quibray Bay	Bar-tailed Godwit	29	07/02/2013	Roosting	Shallow water	High
Quibray Bay	Bar-tailed Godwit	21	21/02/2013	Roosting	Shallow water	High
Quibray Bay	Bar-tailed Godwit	55	07/03/2013	Roosting	Exposed mud/sand	High
Quibray Bay	Bar-tailed Godwit	67	20/03/2013	Roosting	Exposed mud/sand	High
Quibray Bay	Bar-tailed Godwit	7	12/04/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	10	26/04/2012	Feeding	Shallow water	Low
Quibray Bay	Bar-tailed Godwit	7	10/05/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	5	23/05/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	4	08/06/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	1	20/06/2012	Feeding	Shallow water	Low
Quibray Bay	Bar-tailed Godwit	4	05/07/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	3	19/07/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	2	02/08/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	3	16/08/2012	Feeding	Exposed	Low

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
					mud/sand	
Quibray Bay	Bar-tailed Godwit	5	30/08/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	1	07/09/2012	Feeding	Shallow water	Low
Quibray Bay	Bar-tailed Godwit	9	14/09/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	0	20/09/2012			Low
Quibray Bay	Bar-tailed Godwit	6	11/10/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	23	18/10/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	25	25/10/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	17	01/11/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	23	08/11/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	15	15/11/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	22	22/11/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	16	29/11/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	42	06/12/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	14	13/12/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	28	20/12/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	4	27/12/2012	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	15	02/01/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	5	10/01/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	13	17/01/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	9	24/01/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	16	31/01/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	7	07/02/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	12	14/02/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	24	21/02/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	22	28/02/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	17	07/03/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	11	14/03/2013	Feeding	Exposed mud/sand	Low
Quibray Bay	Bar-tailed Godwit	31	20/03/2013	Feeding	Shallow water	Low
Quibray Bay	Bar-tailed Godwit	16	28/03/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	17	23/05/2012	Roosting	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	9	08/06/2012	Feeding	Shallow water	High
Riverside Drive	Bar-tailed Godwit	26	20/06/2012	Roosting	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	3	05/07/2012	Feeding	Shallow water	High
Riverside Drive	Bar-tailed Godwit	2	21/12/2012	Roosting	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	3	10/01/2013	Feeding	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	60	07/02/2013	Roosting	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	58	21/02/2013	Roosting	Exposed mud/sand	High

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Riverside Drive	Bar-tailed Godwit	81	07/03/2013	Roosting	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	7	20/03/2013	Roosting	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	6	28/03/2013	Roosting	Exposed mud/sand	High
Riverside Drive	Bar-tailed Godwit	12	12/04/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	8	26/04/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	7	10/05/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	7	23/05/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	8	08/06/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	8	20/06/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	4	05/07/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	9	19/07/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	12	02/08/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	9	16/08/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	27	30/08/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	16	07/09/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	9	14/09/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	11	20/09/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	4	27/09/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	9	04/10/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	11	11/10/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	11	18/10/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	20	25/10/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	9	01/11/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	11	08/11/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	15	15/11/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	7	22/11/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	17	29/11/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	9	06/12/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	23	13/12/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	16	20/12/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	13	27/12/2012	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	11	02/01/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	13	10/01/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	12	17/01/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	9	24/01/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	11	31/01/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	16	07/02/2013	Feeding	Exposed mud/sand	Low

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Riverside Drive	Bar-tailed Godwit	12	14/02/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	14	21/02/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	10	28/02/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	19	07/03/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	6	14/03/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	6	20/03/2013	Feeding	Exposed mud/sand	Low
Riverside Drive	Bar-tailed Godwit	10	28/03/2013	Feeding	Exposed mud/sand	Low
Sandringham	Bar-tailed Godwit	284	15/11/2012	Roosting	Beach	High
Sandringham	Bar-tailed Godwit	70	07/02/2013	Roosting	Beach	High
Sandringham	Bar-tailed Godwit	13	14/03/2013	Roosting	Beach	High
Spit Island	Bar-tailed Godwit	131	30/08/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	90	07/09/2012	Roosting	Grass	High
Spit Island	Bar-tailed Godwit	172	20/09/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	247	04/10/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	265	11/10/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	322	18/10/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	395	25/10/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	488	01/11/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	87	08/11/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	180	15/11/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	48	22/11/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	395	29/11/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	355	06/12/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	410	13/12/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	351	27/12/2012	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	360	02/01/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	285	10/01/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	252	17/01/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	340	24/01/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	356	31/01/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	10	07/02/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	39	14/02/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	332	28/02/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	324	14/03/2013	Roosting	Exposed mud/sand	High
Spit Island	Bar-tailed Godwit	326	28/03/2013	Roosting	Exposed mud/sand	High
Woodlands Rd	Bar-tailed Godwit	2	12/04/2012	Roosting	Exposed mud/sand	High
Woodlands Rd	Bar-tailed Godwit	20	20/06/2012	Roosting	Exposed mud/sand	High
Woodlands Rd	Bar-tailed Godwit	3	07/02/2013	Feeding	Shallow water	High

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Woodlands Rd	Bar-tailed Godwit	1	21/02/2013	Feeding	Shallow water	High
Woodlands Rd	Bar-tailed Godwit	12	07/03/2013	Feeding	Exposed mud/sand	High
Woodlands Rd	Bar-tailed Godwit	10	20/03/2013	Roosting	Shallow water	High
Woodlands Rd	Bar-tailed Godwit	8	12/04/2012	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	20	26/04/2012	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	3	10/05/2012	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	7	23/05/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	2	20/06/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	9	05/07/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	5	19/07/2012	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	3	02/08/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	4	16/08/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	21	07/09/2012	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	1	14/09/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	2	20/09/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	3	27/09/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	7	04/10/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	17	11/10/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	5	18/10/2012	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	7	25/10/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	6	01/11/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	12	08/11/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	4	15/11/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	8	22/11/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	6	29/11/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	11	06/12/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	3	13/12/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	16	20/12/2012	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	3	27/12/2012	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	5	02/01/2013	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	6	10/01/2013	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	7	17/01/2013	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	6	24/01/2013	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	1	31/01/2013	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	15	07/02/2013	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	6	14/02/2013	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	7	21/02/2013	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	9	28/02/2013	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	11	07/03/2013	Feeding	Exposed mud/sand	Low
Woodlands Rd	Bar-tailed Godwit	10	14/03/2013	Feeding	Exposed mud/sand	Low

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Woodlands Rd	Bar-tailed Godwit	12	20/03/2013	Feeding	Shallow water	Low
Woodlands Rd	Bar-tailed Godwit	6	28/03/2013	Feeding	Exposed mud/sand	Low

A-3: Reference Site Monitoring: Parramatta River Estuary (Curlew Sandpiper)

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Waterbird Refuge	Curlew Sandpiper	1	10/10/2012	Feeding	Shallow water	High
Waterbird Refuge	Curlew Sandpiper	2	31/08/2012	Feeding	Saltmarsh	Low
Waterbird Refuge	Curlew Sandpiper	1	12/10/2012	Feeding	Exposed mud/sand	Low

A-4: Reference Site Monitoring: Boat Harbour (Double-banded Plover)

Common Name	Count	Date	Behaviour	Habitat	Tide
Double-banded Plover	22	24/04/2012	Roosting	Rocks	High
Double-banded Plover	8	09/05/2012	Roosting	Rocks	High
Double-banded Plover	1	25/05/2012	Roosting	Rocks	High
Double-banded Plover	6	04/07/2012	Feeding	Rocks	High
Double-banded Plover	5	20/07/2012	Roosting	Rocks	High
Double-banded Plover	16	01/08/2012	Roosting	Rocks	High
Double-banded Plover	7	15/08/2012	Roosting	Rocks	High
Double-banded Plover	9	21/03/2013	Roosting	Rocks	High
Double-banded Plover	7	27/03/2013	Roosting	Rocks	High
Double-banded Plover	4	09/05/2012	Feeding	Rocks	Low
Double-banded Plover	9	20/07/2012	Feeding	Rocks	Low
Double-banded Plover	12	01/08/2012	Feeding	Rocks	Low
Double-banded Plover	8	15/08/2012	Feeding	Rocks	Low
Double-banded Plover	2	29/08/2012	Feeding	Rocks	Low
Double-banded Plover	1	05/09/2012	Feeding	Rocks	Low
Double-banded Plover	5	13/03/2013	Feeding	Rocks	Low
Double-banded Plover	7	21/03/2013	Feeding	Rocks	Low
Double-banded Plover	2	27/03/2013	Feeding	Rocks	Low

A-5: Reference Site Monitoring: Boat Harbour (Red-necked Stint)

Common Name	Count	Date	Behaviour	Habitat	Tide
Red-necked Stint	28	11/04/2012	Roosting	Rocks	High
Red-necked Stint	40	09/05/2012	Roosting	Rocks	High
Red-necked Stint	3	21/06/2012	Roosting	Rocks	High
Red-necked Stint	4	04/07/2012	Feeding	Rocks	High
Red-necked Stint	16	20/07/2012	Roosting	Rocks	High
Red-necked Stint	10	01/08/2012	Roosting	Rocks	High
Red-necked Stint	14	29/08/2012	Roosting	Rocks	High
Red-necked Stint	32	12/09/2012	Roosting	Rocks	High
Red-necked Stint	46	19/09/2012	Roosting	Rocks	High
Red-necked Stint	54	26/09/2012	Roosting	Rocks	High
Red-necked Stint	56	03/10/2012	Roosting	Rocks	High
Red-necked Stint	72	10/10/2012	Roosting	Rocks	High
Red-necked Stint	86	17/10/2012	Roosting	Rocks	High
Red-necked Stint	41	24/10/2012	Roosting	Rocks	High
Red-necked Stint	139	31/10/2012	Roosting	Rocks	High
Red-necked Stint	75	07/11/2012	Roosting	Rocks	High
Red-necked Stint	134	14/11/2012	Roosting	Rocks	High
Red-necked Stint	126	21/11/2012	Roosting	Rocks	High
Red-necked Stint	190	28/11/2012	Roosting	Rocks	High
Red-necked Stint	112	05/12/2012	Roosting	Rocks	High

Common Name	Count	Date	Behaviour	Habitat	Tide
Red-necked Stint	141	12/12/2012	Roosting	Rocks	High
Red-necked Stint	133	19/12/2012	Roosting	Rocks	High
Red-necked Stint	127	26/12/2012	Roosting	Rocks	High
Red-necked Stint	76	01/01/2013	Roosting	Rocks	High
Red-necked Stint	224	08/01/2013	Roosting	Rocks	High
Red-necked Stint	91	16/01/2013	Roosting	Rocks	High
Red-necked Stint	111	23/01/2013	Roosting	Rocks	High
Red-necked Stint	39	30/01/2013	Roosting	Rocks	High
Red-necked Stint	102	06/02/2013	Roosting	Rocks	High
Red-necked Stint	95	13/02/2013	Roosting	Rocks	High
Red-necked Stint	58	20/02/2013	Roosting	Rocks	High
Red-necked Stint	18	27/02/2013	Roosting	Rocks	High
Red-necked Stint	34	08/03/2013	Roosting	Rocks	High
Red-necked Stint	48	13/03/2013	Roosting	Rocks	High
Red-necked Stint	22	21/03/2013	Roosting	Rocks	High
Red-necked Stint	66	27/03/2013	Roosting	Rocks	High
Red-necked Stint	8	11/04/2012	Feeding	Rocks	Low
Red-necked Stint	2	24/04/2012	Feeding	Rocks	Low
Red-necked Stint	5	09/05/2012	Feeding	Rocks	Low
Red-necked Stint	2	25/05/2012	Feeding	Rocks	Low
Red-necked Stint	10	07/06/2012	Feeding	Rocks	Low
Red-necked Stint	2	04/07/2012	Feeding	Rocks	Low
Red-necked Stint	3	20/07/2012	Feeding	Rocks	Low
Red-necked Stint	7	01/08/2012	Feeding	Rocks	Low
Red-necked Stint	5	15/08/2012	Feeding	Rocks	Low
Red-necked Stint	13	29/08/2012	Feeding	Rocks	Low
Red-necked Stint	11	05/09/2012	Feeding	Rocks	Low
Red-necked Stint	19	19/09/2012	Feeding	Rocks	Low
Red-necked Stint	30	26/09/2012	Feeding	Rocks	Low
Red-necked Stint	13	03/10/2012	Feeding	Rocks	Low
Red-necked Stint	29	10/10/2012	Feeding	Rocks	Low
Red-necked Stint	35	17/10/2012	Feeding	Rocks	Low
Red-necked Stint	14	24/10/2012	Feeding	Rocks	Low
Red-necked Stint	67	31/10/2012	Feeding	Rocks	Low
Red-necked Stint	37	07/11/2012	Feeding	Rocks	Low
Red-necked Stint	101	14/11/2012	Feeding	Rocks	Low
Red-necked Stint	38	21/11/2012	Feeding	Rocks	Low
Red-necked Stint	76	28/11/2012	Feeding	Rocks	Low
Red-necked Stint	127	05/12/2012	Feeding	Rocks	Low
Red-necked Stint	84	12/12/2012	Feeding	Rocks	Low
Red-necked Stint	52	19/12/2012	Feeding	Rocks	Low
Red-necked Stint	46	26/12/2012	Feeding	Rocks	Low
Red-necked Stint	91	01/01/2013	Feeding	Rocks	Low
Red-necked Stint	1	08/01/2013	Feeding	Rocks	Low
Red-necked Stint	28	08/01/2013	Feeding	Rocks	Low
Red-necked Stint	61	16/01/2013	Feeding	Rocks	Low
Red-necked Stint	93	23/01/2013	Feeding	Rocks	Low
Red-necked Stint	31	30/01/2013	Feeding	Rocks	Low
Red-necked Stint	38	06/02/2013	Feeding	Rocks	Low

Common Name	Count	Date	Behaviour	Habitat	Tide
Red-necked Stint	55	13/02/2013	Feeding	Rocks	Low
Red-necked Stint	59	20/02/2013	Feeding	Rocks	Low
Red-necked Stint	13	27/02/2013	Feeding	Rocks	Low
Red-necked Stint	33	08/03/2013	Feeding	Rocks	Low
Red-necked Stint	24	13/03/2013	Feeding	Rocks	Low
Red-necked Stint	13	21/03/2013	Feeding	Rocks	Low
Red-necked Stint	38	27/03/2013	Feeding	Rocks	Low

A-6: Reference Site Monitoring: Hunter River Estuary (Pacific Golden Plover)

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Stockton Channel	Pacific Golden Plover	0	29/08/2012			falling
Stockton Sand spit	Pacific Golden Plover	0	29/08/2012			falling
North Arm Sand flats	Pacific Golden Plover	1	29/08/2012	foraging	sand flat	falling
Kooragang Dykes	Pacific Golden Plover	5	06/09/2012	roosting	rock wall	falling
Stockton Sand spit	Pacific Golden Plover	0	06/09/2012			falling
Stockton Channel	Pacific Golden Plover	0	12/09/2012			falling
Kooragang Dykes	Pacific Golden Plover	9	12/09/2012	roosting	rock wall	falling
Stockton Sand spit	Pacific Golden Plover	0	12/09/2012			falling
Stockton Sand spit	Pacific Golden Plover	0	19/09/2012			falling
Stockton Channel	Pacific Golden Plover	0	26/09/2012			falling
Kooragang Dykes	Pacific Golden Plover	57	26/09/2012	roosting	rock wall	falling
Stockton Sand spit	Pacific Golden Plover	0	26/09/2012			falling
Stockton Sand spit	Pacific Golden Plover	0	03/10/2012			falling
Stockton Channel	Pacific Golden Plover	1	04/10/2012	roosting	rocks	falling
Stockton Sand spit	Pacific Golden Plover	0	04/10/2012			falling
Stockton Channel	Pacific Golden Plover	6	10/10/2012	roosting	rocks	falling
Stockton Sand spit	Pacific Golden Plover	0	10/10/2012			falling
Stockton Channel	Pacific Golden Plover	6	16/10/2012	roosting	driftwood	falling
Stockton Channel	Pacific Golden Plover	5	17/10/2012	roosting	rocks & driftwood	falling
Stockton Sand spit	Pacific Golden Plover	0	17/10/2012			falling
Stockton Channel	Pacific Golden Plover	7	19/10/2012	roosting	rocks & driftwood	falling
Stockton Channel	Pacific Golden Plover	11	21/10/2012	roosting	rocks & driftwood	falling
Stockton Channel	Pacific Golden Plover	10	23/10/2012	roosting	rocks & driftwood	falling
Stockton Sand spit	Pacific Golden Plover	3	23/10/2012	foraging	mudflat	falling
Stockton Channel	Pacific Golden Plover	11	26/10/2012	roosting	rocks & driftwood	falling
Stockton Sand spit	Pacific Golden Plover	0	31/10/2012			falling
Stockton Sand spit	Pacific Golden Plover	0	07/11/2012			falling
Stockton Channel	Pacific Golden Plover	12	14/11/2012	roosting	rocks & driftwood	falling
Stockton Sand spit	Pacific Golden Plover	0	14/11/2012			falling
Stockton Sand spit	Pacific Golden Plover	0	21/11/2012			falling
Stockton Channel	Pacific Golden Plover	14	28/11/2012	roosting	rocks & driftwood	falling
Stockton Sand spit	Pacific Golden Plover	1	28/11/2012	foraging	oyster bank	falling
North Arm Sand flats	Pacific Golden Plover	340	29/11/2012	roosting & foraging	oyster bank & sand flat	falling
Stockton Sand spit	Pacific Golden Plover	0	05/12/2012			falling
Stockton Sand spit	Pacific Golden Plover	7	12/12/2012	roosting	saltmarsh	falling
Stockton Sand spit	Pacific Golden Plover	37	19/12/2012	foraging	mudflat	falling
Stockton Sand spit	Pacific Golden Plover	6	27/12/2012	foraging	mudflat	falling
Stockton Sand spit	Pacific Golden Plover	4	02/01/2013	foraging	mudflat	falling

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Stockton Sand spit	Pacific Golden Plover	8	09/01/2013	foraging	mudflat	falling
Stockton Sand spit	Pacific Golden Plover	8	16/01/2013	foraging	mudflat	falling
Stockton Channel	Pacific Golden Plover	3	23/01/2013	roosting	rocks and rusty wreck	falling
Kooragang Dykes	Pacific Golden Plover	357	23/01/2013	roosting	rock wall	falling
Stockton Sand spit	Pacific Golden Plover	19	23/01/2013	roosting	saltmarsh	falling
Stockton Channel	Pacific Golden Plover	4	06/02/2013	roosting	rocks and rusty wreck	falling
Stockton Sand spit	Pacific Golden Plover	28	06/02/2013	roosting	saltmarsh	falling
Kooragang Dykes	Pacific Golden Plover	371	06/02/2013	roosting	rock wall	falling
Stockton Channel	Pacific Golden Plover	8	20/02/2013	roosting	rocks and rusty wreck	falling
Stockton Sand spit	Pacific Golden Plover	17	20/02/2013	roosting	saltmarsh and scattered grass on sand	falling
Fullerton Cove	Pacific Golden Plover	450	24/11/2012	foraging	mudflat	falling to low
North Arm Sand flats	Pacific Golden Plover	380	20/02/2013	roosting	oyster bank and sand flat	falling to low
Stockton Channel	Pacific Golden Plover	0	06/09/2012			high
Stockton Channel	Pacific Golden Plover	0	19/09/2012			high
Kooragang Dykes	Pacific Golden Plover	36	19/09/2012	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	0	03/10/2012			high
Kooragang Dykes	Pacific Golden Plover	88	04/10/2012	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	3	07/10/2012	roosting	rocks	high
Kooragang Dykes	Pacific Golden Plover	125	13/10/2012	roosting	rock wall	high
Kooragang Dykes	Pacific Golden Plover	162	17/10/2012	roosting	rock wall	high
Kooragang Dykes	Pacific Golden Plover	167	23/10/2012	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	10	31/10/2012	roosting	rocks & driftwood	high
Stockton Channel	Pacific Golden Plover	14	07/11/2012	roosting	rocks & driftwood	high
Kooragang Dykes	Pacific Golden Plover	295	21/11/2012	roosting	rock wall	high
Kooragang Dykes	Pacific Golden Plover	285	28/11/2012	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	16	05/12/2012	roosting	rocks & driftwood	high
Stockton Channel	Pacific Golden Plover	9	12/12/2012	roosting	rocks & driftwood	high
Kooragang Dykes	Pacific Golden Plover	340	15/12/2012	roosting	rock wall	high
Stockton Sand spit	Pacific Golden Plover	0	15/12/2012	roosting	saltmarsh	high
Stockton Channel	Pacific Golden Plover	21	19/12/2012	roosting	rocks & driftwood	high
Stockton Channel	Pacific Golden Plover	21	02/01/2013	roosting	rocks & driftwood	high
Stockton Channel	Pacific Golden Plover	5	09/01/2013	roosting	rocks, driftwood & iron wreck	high
Stockton Channel	Pacific Golden Plover	21	16/01/2013	roosting	rocks, driftwood & iron wreck	high
Kooragang Dykes	Pacific Golden Plover	353	16/01/2013	roosting	rock wall	high
Stockton Sand spit	Pacific Golden Plover	14	30/01/2013	roosting	saltmarsh	high
Kooragang Dykes	Pacific Golden Plover	337	30/01/2013	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	5	09/02/2013	roosting		high
Stockton Sand spit	Pacific Golden Plover	48	09/02/2013	roosting	saltmarsh	high
Kooragang Dykes	Pacific Golden Plover	404	09/02/2013	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	6	13/02/2013	roosting	rusty steel wreck	high
Stockton Sand spit	Pacific Golden Plover	30	13/02/2013	roosting	saltmarsh and scattered grass on sand	high
Kooragang Dykes	Pacific Golden Plover	267	13/02/2013	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	7	27/02/2013	roosting	rusty steel wreck	high
Stockton Sand spit	Pacific Golden Plover	22	27/02/2013	roosting	lagoon	high

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Kooragang Dykes	Pacific Golden Plover	402	27/02/2013	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	5	09/03/2013	roosting	rusty steel wreck	high
Stockton Sand spit	Pacific Golden Plover	16	09/03/2013	roosting	saltmarsh and scattered grass on sand	high
Kooragang Dykes	Pacific Golden Plover	396	09/03/2013	roosting	rock wall	high
Stockton Channel	Pacific Golden Plover	0	13/03/2013			high
Stockton Sand spit	Pacific Golden Plover	361	13/03/2013	roosting	saltmarsh	high
Kooragang Dykes	Pacific Golden Plover	0	13/03/2013			high
Stockton Channel	Pacific Golden Plover	0	21/03/2013			high
Kooragang Dykes	Pacific Golden Plover	8	21/03/2013	roosting	rock wall	high
Stockton Sand spit	Pacific Golden Plover	151	21/03/2013	roosting	saltmarsh	high
Stockton Channel	Pacific Golden Plover	1	28/03/2013	roosting	rusty steel wreck	high
Stockton Sand spit	Pacific Golden Plover	101	28/03/2013	roosting	saltmarsh	high
Kooragang Dykes	Pacific Golden Plover	293	28/03/2013	roosting	rock wall	high
Kooragang Dykes	Pacific Golden Plover	19	03/10/2012	roosting	rock wall	high & falling
Kooragang Dykes	Pacific Golden Plover	193	31/10/2012	roosting	rock wall	high & falling
Kooragang Dykes	Pacific Golden Plover	399	07/11/2012	roosting	rock wall	high & falling
Kooragang Dykes	Pacific Golden Plover	452	14/11/2012	roosting	rock wall	high & falling
Kooragang Dykes	Pacific Golden Plover	430	05/12/2012	roosting	rock wall	high & falling
Kooragang Dykes	Pacific Golden Plover	320	12/12/2012	roosting	rock wall	high & falling
Stockton Channel	Pacific Golden Plover	16	15/12/2012	roosting	rocks & driftwood	high & falling
Kooragang Dykes	Pacific Golden Plover	240	19/12/2012	roosting	rock wall	high & falling
Stockton Channel	Pacific Golden Plover	13	27/12/2012	roosting	rocks and rusty steel wreck	high & falling
Kooragang Dykes	Pacific Golden Plover	355	27/12/2012	roosting	rock wall	high & falling
Kooragang Dykes	Pacific Golden Plover	375	02/01/2013	roosting	rock wall	high & falling
Kooragang Dykes	Pacific Golden Plover	307	09/01/2013	roosting	rock wall	high & falling
North Arm Sand flats	Pacific Golden Plover	99	10/10/2012	roosting & foraging	oyster bank & sand flat	low
North Arm oyster bank	Pacific Golden Plover	102	06/03/2013	roosting	oyster bank	rising
Stockton Channel	Pacific Golden Plover	6	06/03/2013	roosting	rocks	rising
Stockton Channel	Pacific Golden Plover	13	21/11/2012	roosting	steel wreck	rising to high
Stockton Channel	Pacific Golden Plover	14	30/01/2013	roosting	rocks and rusty wreck	rising to high
Stockton Sand spit	Pacific Golden Plover	6	06/03/2013	roosting	saltmarsh	rising to high

A-7: Nocturnal Shorebird Surveys: Penrhyn Estuary (Key Species)

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
Big Island	Bar-tailed Godwit	4	20/04/2012	Roosting	Exposed mud/sand	High
Corner Island	Bar-tailed Godwit	14	02/07/2012	Roosting	Shallow water	High
Corner Saltmarsh	Bar-tailed Godwit	7	02/07/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	16	01/08/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	1	17/09/2012	Roosting	Saltmarsh	High
Corner Island	Bar-tailed Godwit	4	15/10/2012	Roosting	Shallow water	High
Corner Saltmarsh	Bar-tailed Godwit	4	15/10/2012	Roosting	Shallow water	High
Corner Saltmarsh	Bar-tailed Godwit	56	13/11/2012	Roosting	Shallow water	High
Big Island	Bar-tailed Godwit	24	13/12/2012	Roosting	Shallow water	High
Corner Island	Bar-tailed Godwit	1	13/12/2012	Roosting	Saltmarsh	High
Foreshore saltmarsh	Bar-tailed Godwit	14	13/12/2012	Roosting	Shallow water	High
Big Island	Bar-tailed Godwit	15	13/01/2013	Roosting	Shallow water	High
Corner Saltmarsh	Bar-tailed Godwit	10	13/01/2013	Roosting	Shallow water	High
Big Island	Bar-tailed Godwit	7	11/02/2013	Roosting	Shallow water	High
Upper Reaches	Bar-tailed Godwit	6	03/04/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	2	03/04/2012	Feeding	Shallow water	Low
Mill Stream/Boat Ramp Beach	Bar-tailed Godwit	14	03/04/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	4	27/05/2012	Feeding	Shallow water	Low
Mill Stream/Boat Ramp Beach	Bar-tailed Godwit	6	27/05/2012	Feeding	Shallow water	Low
Upper Reaches	Bar-tailed Godwit	22	28/06/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	8	24/07/2012	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Bar-tailed Godwit	2	23/08/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	6	23/08/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	15	08/10/2012	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	18	20/11/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Bar-tailed Godwit	2	20/11/2012	Feeding	Shallow water	Low
Springvale Creek	Bar-tailed Godwit	2	06/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	13	06/12/2012	Feeding	Shallow water	Low
Corner Mudflats	Bar-tailed Godwit	2	06/12/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Bar-tailed Godwit	4	07/01/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Bar-tailed Godwit	14	07/01/2013	Feeding	Exposed mud/sand	Low
Corner Mudflats	Bar-tailed Godwit	3	07/01/2013	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Bar-tailed Godwit	3	07/01/2013	Feeding	Exposed mud/sand	Low
Upper Reaches	Bar-tailed Godwit	3	04/02/2013	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	12	04/02/2013	Feeding	Shallow water	Low
Outer Reaches	Bar-tailed Godwit	6	05/03/2013	Feeding	Shallow water	Low
Upper Reaches	Bar-tailed Godwit	1	05/03/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	1	03/04/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Double-banded Plover	3	23/08/2012	Feeding	Exposed mud/sand	Low
Big Island	Pacific Golden Plover	4	20/04/2012	Roosting	Exposed mud/sand	High
Corner Island	Pacific Golden Plover	5	13/11/2012	Roosting	Saltmarsh	High
Big Island	Pacific Golden	4	13/12/2012	Roosting	Exposed	High

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
	Plover				mud/sand	
Corner Island	Pacific Golden Plover	2	13/12/2012	Roosting	Saltmarsh	High
Corner Island	Pacific Golden Plover	4	13/01/2013	Roosting	Saltmarsh	High
Big Island	Pacific Golden Plover	3	11/02/2013	Roosting	Exposed mud/sand	High
Corner Saltmarsh	Pacific Golden Plover	8	11/02/2013	Roosting	Saltmarsh	High
Floodvale Creek	Pacific Golden Plover	1	03/04/2012	Feeding	Exposed mud/sand	Low
Springvale Creek	Pacific Golden Plover	1	03/04/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	3	03/04/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	1	21/09/2012	Feeding	Exposed mud/sand	Low
Springvale Creek	Pacific Golden Plover	1	08/10/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Pacific Golden Plover	1	08/10/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	3	20/11/2012	Feeding	Exposed mud/sand	Low
Springvale Creek	Pacific Golden Plover	1	20/11/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Pacific Golden Plover	1	20/11/2012	Feeding	Exposed mud/sand	Low
Springvale Creek	Pacific Golden Plover	4	06/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	2	06/12/2012	Feeding	Exposed mud/sand	Low
Corner Mudflats	Pacific Golden Plover	1	06/12/2012	Feeding	Exposed mud/sand	Low
Big Island	Pacific Golden Plover	1	06/12/2012	Feeding	Exposed mud/sand	Low
Springvale Creek	Pacific Golden Plover	3	07/01/2013	Feeding	Exposed mud/sand	Low
Upper Reaches	Pacific Golden Plover	5	07/01/2013	Feeding	Exposed mud/sand	Low
Corner Mudflats	Pacific Golden Plover	1	07/01/2013	Feeding	Exposed mud/sand	Low
Springvale Creek	Pacific Golden Plover	3	04/02/2013	Feeding	Exposed mud/sand	Low
Upper Reaches	Pacific Golden Plover	2	04/02/2013	Feeding	Exposed mud/sand	Low
Beach in front of Bird Hide	Pacific Golden Plover	1	04/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Pacific Golden Plover	8	05/03/2013	Feeding	Exposed mud/sand	Low
Upper Reaches	Pacific Golden Plover	5	05/03/2013	Feeding	Exposed mud/sand	Low
Corner Mudflats	Pacific Golden Plover	1	05/03/2013	Feeding	Exposed mud/sand	Low
Big Island	Red-necked Stint	4	13/12/2012	Roosting	Exposed mud/sand	High
Corner Island	Red-necked Stint	2	13/01/2013	Roosting	Saltmarsh	High
Big Island	Red-necked Stint	1	11/02/2013	Roosting	Exposed mud/sand	High
Corner Island	Red-necked Stint	4	11/02/2013	Roosting	Saltmarsh	High
Outer Reaches	Red-necked Stint	2	06/12/2012	Feeding	Exposed mud/sand	Low
Upper Reaches	Red-necked Stint	3	04/02/2013	Feeding	Exposed mud/sand	Low
Outer Reaches	Red-necked Stint	1	04/02/2013	Feeding	Exposed mud/sand	Low
Corner Island	Sharp-tailed Sandpiper	1	17/09/2012	Roosting	Saltmarsh	High
Corner Island	Sharp-tailed Sandpiper	4	13/11/2012	Roosting	Saltmarsh	High
Big Island	Sharp-tailed Sandpiper	1	13/12/2012	Roosting	Exposed mud/sand	High
Corner Island	Sharp-tailed	2	13/12/2012	Roosting	Saltmarsh	High

Subsite	Common Name	Count	Date	Behaviour	Habitat	Tide
	Sandpiper					
Outer Reaches	Sharp-tailed Sandpiper	1	06/12/2012	Feeding	Exposed mud/sand	Low
Outer Reaches	Sharp-tailed Sandpiper	1	04/02/2013	Feeding	Exposed mud/sand	Low

Port Botany Post Construction Monitoring
Annual Report 2013

APPENDIX B
BENTHOS ANNUAL MONITORING REPORT 2013

Cardno
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Port Botany Post Construction Environmental Monitoring

Benthos Annual Report 2013

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Executive Summary

This report summarises the findings of the first year of Benthos Monitoring Program and seeks to verify the success of one component of the Penrhyn Estuary Habitat Enhancement Plan (PEHEP). It compares results of three surveys of intertidal benthic invertebrates undertaken 15, 23 and 27 months after completion of habitat creation (March 2012, November 2012 and March 2013) to three surveys before enhancement works (March 2007, November 2007 and March 2008).

The aims of the Benthos Monitoring Plan are:

1. To monitor changes in benthic invertebrate communities in existing and new intertidal/shallow subtidal habitats in terms of their impacts on food items for shorebirds.

2. To assess changes in benthic communities in different feeding subhabitats used by shorebirds.

3. To assess the sustainability of created habitats with respect to their provision of food items for shorebirds.

Criteria for the success of the benthic component of PEHEP were derived from:

1. Comparison to target values derived from average values over three pre-enhancement ("Before") surveys of muddy sand areas ("mud") in inner Penrhyn Estuary which had been shown to be consistently utilised by shorebirds. Values for abundance and biomass in these areas were higher than for sand areas in outer Penrhyn Estuary, had smaller median grain size and greater proportion of fine sediment particles (% fines, combined % clay and silt –sized particles that pass through 0.074 mm mesh), and were appropriate targets for newly created habitat designed to support migratory shorebird populations.

2. Comparison of change in key indicators at Penrhyn Estuary to change at two reference locations.

Sediment parameter selected were median grain size (MGS) and % fine sediment. Biological indicators selected were invertebrate abundance and wet-weight biomass.

The BACI (Before, After, Control, Impact) sampling design took into account sand and mud sediment types and amendments added to imported sand used to create intertidal habitat in outer Penrhyn Estuary. Mud and seagrass wrack were added to sand in large quantities in some areas of the created habitat ("Treated") and at small quantities in other areas ("Üntreated").

Samples were collected by hand using plastic sediment cores. Analysis of sediment particle size distribution was done by commercial laboratories. Biological samples were preserved, animals removed from sediment, weighted, identified and counted.

Samples of invertebrates living on sparse, isolated hard substrata within and along the edges of the estuary were collected and processed to determine if they supply food types utilised by shorebirds that differ from those in the dominant soft sediment habitat.

In sand habitats a total of 83 taxa were found across six surveys and a total of 15,939 individuals were counted. The average abundance of macroinvertebrates decreased at Penrhyn Estuary and at both reference locations in Quibray Bay after habitat enhancement. In contrast, biomass of macrobenthos increased after enhancement, with the largest increase recorded at Penrhyn Estuary where the average biomass after habitat enhancement increased by about 66 %. Median grain size (MGS) was smaller after habitat enhancement at all locations but also more variable compared to the three pre-enhancement surveys The % fine sediment content at Penrhyn Estuary increased by about 40 % compared to pre-enhancement levels and decreased at both Reference locations.

Prior to enhancement polychaetes worms made up 73% of all invertebrates in sand habitats, but declined to an average of 52% after enhancement, while molluscs increased on average from 19% before enhancement to 53% after enhancement. Changes in the contributions of polychaetes and molluscs to the assemblage observed in March 2013 suggests that community structure has not yet stabilised.

In mud habitats a total of 50 taxa were found across six surveys and a total of 15,180 individuals were counted. The average abundance of macrobenthic invertebrates decreased at all sites after habitat enhancement, but significant differences were masked by variability at the small scale of sites. The decrease was particularly marked in mud flats at Penrhyn Estuary where macrobenthos abundance was

about half that recorded pre-enhancement. Macrobenthos biomass increased markedly at Penrhyn Estuary after habitat enhancement works but not at the Reference locations. Median grain size was smaller after habitat enhancement works at all locations but also more variable compared to the three pre-enhancement surveys. The fine sediment content at Penrhyn Estuary was similar to pre-enhancement levels, but decreased at both Reference locations.

Across the three surveys, MGS and the abundance of macrobenthic invertebrates varied but were similar in Treated and Untreated sites within Penrhyn Estuary. Wet weight biomass was higher (about 40 %) and more variable in Untreated sites compared to Treated sites, but the fine sediment content was higher in Treated than Untreated sites. This suggests that considerable redistribution of soil amendments had occurred but not uniformly once placed within the estuary.

The faunal assemblage living on hard substratum at Penrhyn Estuary showed marked temporal differences before compared to after habitat enhancement. The assemblage was more variable before compared to after habitat enhancement works, likely relating to the increase in rock substrata after enhancement compared to oyster clumps and flotsam before enhancement. After enhancement hard substrata provide different, but variable food sources for shorebirds.

The following table summarises the performance of indicators against target values:

Habitat	Sediment Parameters		Biological Indicators		
Created Sand flats	**MGS (mm)**	**% Fine sediments (< 0.074 mm)**	**Macrobenthos biomass (g/sample)**	**Macrobenthos biomass (g/m^2)**	**Abundance (individuals/ sample)**
Target	0.31 - 0.33	2 to 4 %	≥ 0.7	89.1	Average ≥ 39
Values for three surveys after enhancement	Av: 0.24 Min: 0.18 Max: 0.34	Av: 5.2 % Min: 0.7 % Max: 14.3 %	Av: 1.08 Min: 0.11 Max: 6.56	Av: 137.9 Min: 13.6 Max: 834.8	Av: 22.5 Min: 1.3 Max: 70.7
Change in comparison to pre-enhancement levels	↓	↑	↑	↑	↓
Outcome in relation to target levels					
Target met?	**YES**	**YES**	**YES**	**YES**	**NO**

The addition of organic material in the form of mud and seagrass wrack to imported sand has resulted in an increase in the proportion of fine sediments to which organic material readily binds. While the overall abundance of invertebrates did not achieve target values, biomass exceeded targets, and the changing composition of the macroinvertebrate assemblage suggests that the sedimentary system has not yet reached equilibrium. Due to the inherently variable nature of intertidal benthic populations, further surveys we be required to demonstrate long-term capacity of the created habitat to sustain sufficient productivity to supply adequate food for shorebirds.

No changes to the Benthos Monitoring Program are recommended at this time.

Glossary

Term or Acronym	Definition
Benthic	Living on or in the seabed
Benthos	The collection of organisms attached to or resting on the bottom sediments (i.e. epifauna) and those which burrow into the sediments (i.e. infauna).
Infauna	Aquatic animals living within the sediment
Intertidal	The portion of shoreline between low and high tide marks, that is intermittently submerged
Macrofauna, Macrobenthos	Organisms associated with sediment and retained in a sieve of 1.0 mm mesh aperature
Macroinvertebrates	Invertebrates animals such a segmented worms, crustaceans and molluscs that are retained in a sieve of 1.0 mm mesh aperature
NATA	National Association of Testing Authorities Australia
nMDS	Non-metric multidimensional scaling ordination
PEHEP	Penrhyn Estuary Habitat Enhancment Plan
PERMANOVA	Permutational Ananlysis of Variance
PSD	Particle Size Distribution
SE	Standard Error
Subtidal	Waters below the low-tide mark
Taxon (plural taxa)	The named taxonomic unit to which individuals, or sets of species, are assigned (e.g. genus, species, family etc)

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Appendix

Appendix A Results of Statistical Analysis

1 Introduction

1.1 Background

As part of the Port Botany Expansion Project, Sydney Ports has rehabilitated Penrhyn Estuary, located adjacent to the port expansion. Penrhyn Estuary is a small waterway of approximately 80 ha located to the north of Brotherson Dock which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978. The underlying substratum was formed by placement of coastal sand and accumulated mud through time, with sediment in the inner estuary overlain by a mud veneer of varying thicknesses. It receives water from two creeks that drained the Botany Industrial Park, originally developed at Banksmeadow in 1942. Sediments receive contaminated runoff via Floodvale and Springdale creeks that drain industrial and urbanised catchment and are known to contain mercury, chromium, Hexachlorobenzene (HCB), organotin compounds and pesticides DDT and DDE (URS 2003). Other sources of contamination include groundwater which contains elevated levels of volatile halogenated compounds including EDC (1,2 dichloroethane) and has been intercepted upstream of Penrhyn Estuary since late 2004 (URS 2004).

Since its creation, the estuary has been utilised by a diverse group of migratory, including migratory shorebirds protected under international agreements birds (Avifauna Research & Services 2003). Despite the decades-long presence of contaminants, the benthic fauna of the inner estuary, dominated by muddy sands had abundance and diversity indices not dissimilar to estuarine habitats with similar sediment characteristics (The Ecology Lab 2008).

The purpose of the rehabilitation works was to enhance the existing intertidal habitat and to expand the estuary as a long term habitat for migratory shorebirds. Enhancement works included the removal of mangroves, weeds and introduced species, the enhancement of existing saltmarsh and the creation of new saltmarsh habitat. An extensive area of foredune was levelled to create an intertidal feeding and roosting habitat for key species of migratory shorebirds that currently use the estuary, and to potentially attract a greater number of shorebirds upon completion (**Figure 1**). To facilitate productivity and recovery of benthic macrofauna sand used to create intertidal habitat was augmented with seagrass wrack sourced from Lake Macquarie and mud dredged from the Nepean River. The design, methodology and ongoing maintenance for the estuary are outlined within the Penrhyn Estuary Habitat Enhancement Plan (PEHEP) (Sydney Ports Corporation 2007).

Table 1 Timeline of important dates for the rehabilitation works within Penrhyn Estuary in relation to creation of intertidal sand flats, 2007 to 2013.

Activity	Date	Comments
Before Enhancement Survey 1	19 - 30 March 2007	(*Source: The Ecology Lab 2008*)
Before Enhancement Survey 2	20 -22 November 2007	(*Source: The Ecology Lab 2008*)
Before Enhancement Survey 3	17 – 22 March 2008	(*Source: The Ecology Lab 2008*)
Construction	January - July 2008	Removal and relocation of sand dunes Construction of temporary roosting island
Construction	August 2008 – end March 2009	Mangrove removal by hand, weed clearing Saltmarsh transplanting No machine work in inner estuary (peak bird season) CSD dredging in Botany Bay from September
Construction	End March - July 2009	Central estuary filled, sand augmented with mud and seagrass wrack Filamentous algal bloom (until September 2009) Sand stockpiled for later filling outer estuary (80,000 m^3) Dredging in Botany Bay complete April 2009

Activity	Date	Comments
Construction	August 2009 – March 2010	Saltmarsh area augmented (Nov) and planted (Dec) New boat ramp opened (Nov) Filling of outer estuary begins, less seagrass wrack than in inner estuary Tidal flow maintained throughout filling/contouring
Construction	April 2010 – July 2011	Further saltmarsh planting Flushing channel contoured using small dredger Filling outer estuary complete by end Dec 2010
After Enhancement Survey 1	5-7 March, 2012	(*Source: Cardno Ecology Lab 2012*)
After Enhancement Survey 2	12-14 November, 2012	(*Source: Cardno Ecology Lab 2013a*)
After Enhancement Survey 3	8-12 March, 2013	(*Source: Cardno Ecology Lab 2013b*)

1.2 Aims

The main aim of the Penrhyn Estuary habitat enhancement was to create new and maintain existing or altered roosting and feeding habitats for migratory shorebirds that use Penrhyn Estuary. The focus of the benthic monitoring plan, therefore, was to monitor benthic invertebrates from the point of view of their importance as food for shorebirds. This approach required consideration of specific subhabitats in which shorebirds have been observed to forage.

The aims of the Benthos Monitoring Plan are summarised as:

1. To monitor changes in benthic invertebrate communities in existing and new intertidal/shallow subtidal habitats in terms of their impacts on food items for shorebirds.

2. To assess changes in benthic communities in different feeding subhabitats used by shorebirds.

3. To assess the sustainability of created habitats with respect to their provision of food items for shorebirds.

The specific aims of this Annual report are to summarise the findings of the monitoring program after three “after” enhancement surveys, corresponding to 15, 23 and 27 months after the completion of enhancement activities, and compare them to the baseline established in three “before” enhancement surveys.

Figure 1 Penrhyn Estuary (top) in August 2008 before habitat enhancement and (bottom) after habitat enhancement in November 2012

1.3 Review of Existing Information

Data on intertidal benthos collected in October 2002 (The Ecology Lab 2003) comprised 30 taxa with crustaceans (dominated by amphipods) the most abundant group (46.5% of all individuals), followed by polychaete worms (34% of total individuals) with oligochaete worms comprising 17% of individuals.

"Before" Enhancement Surveys (Cardno Ecology Lab 2008)

Data collected in the "before" enhancement surveys included the following trends:

The total number of taxa per sample recorded from sandy sediments at all localities in March 2007 varied from 3 to 12. Nereidid polychaetes were numerically dominant, followed by galeommatid bivalve molluscs, and spionid polychaetes. In November 2007, the number of taxa recorded per sample varied between 2 and 16 with galeommatids, oligochaetes and urothoidid amphipods dominant. The number of taxa recorded in sandy sediments in March 2008 varied from 1 to 8 per sample and were dominated by nereidids, galeommatids and capitellids.

The total number of taxa per sample recorded from muddy sediments in the inner estuary in March 2007 varied from 3 to 11. These were dominated numerically by galeommatid bivalves, and by capitellid and nereidid polychaetes. In November 2007, the total number of taxa varied from 3 to 9 and these were dominated by galeommatids, nereidids and capitellids. In March 2008 the total number of taxa per sample varied from 1 to 13 and was dominated by nereidids, galeommatids and capitellids.

Based on casual observations, shorebirds appeared to spend more time feeding in or near small channels within mud and sand flat habitats. The "before" sampling design discreetly sampled these subhabitats to determine their relative value as habitat for macroinvertebrates. No significant differences in the structure of invertebrate assemblages were found between sand flats and sand flat micro-channels in Penrhyn Estuary in any of the surveys, and spatial variability was similar in each habitat. Dissimilarities between these habitats were small and due mainly to galeommatid bivalves. There were no significant temporal or spatial differences in mean numbers of taxa, abundance or wet mass between sand flats and sand flat micro-channels or between sites within the latter in Penrhyn Estuary. Based on this finding, the "after" enhancement sampling design did not differentiate between featureless sand or mud flat and microchannel subhabitats.

Shorebirds were also seen feeding near the sparse hard substrata in the inner estuary, which included small, isolated clumps of oysters, rocks and flotsam. Semi quantitative samples were collected to determine if these hard substrata microhabitats provided different types of food than the dominant soft sediment habitat. There was considerable temporal variability in invertebrate assemblages associated with hard substrata. In March 2007, rocky substrata were dominated numerically by isopods (Sphaeromatidae), gastropod snails (Littorinidae) and limpets (Siphonariidae), while oyster clumps were dominated by gastropod snails (Lottiidae and Littorinidae). In November 2007, rocks were dominated by anemones (Anthozoa), tanaiid crustaceans (Leptocheliidae) and polychaetes (Nereididae and Spionidae) and oyster clumps by polychaetes (Nereididae, Capitellidae and Spionidae), crabs (Ocypodidae), gastropods (Lottiidae) and bivalves (Galeommatidae). Taxa dominating on rocks in March 2008 included gastropods (Lottiidae and Littorinidae), isopods (Sphaeromatidae) and polychaetes (Capitellidae).

Assemblages on both rock and oyster clumps in March 2007 and 2008 were significantly different from those in November although the difference were more significant for rock than for oysters. Hard substrata appear to provide a variable food source that includes some food types not present in the dominant soft sediment habitat.

The following trends were identified in the "after" enhancement surveys:

"After" Survey 1 - March 2012 (Cardno Ecology Lab 2012b):

The most abundant taxa in the sand flat sites were Veneridae (bivalve), Naticidae (gastropod), and Nereididae and Capitellidae (polychaetes), which contributed 31%, 21%, 16% and 11% respectively to the total number of individual animals sampled. The most abundant taxa in the mud flat sites were Veneridae (bivalve) and Capitellidae (polychaete), which contributed 47% and 15% respectively. The most abundant taxa on the hard substrata were Littorinidae (periwinkle gastropod), Ostreidae (oyster) and Grapsidae (crab), which contributed 32%, 13% and 10% respectively.

There was a greater abundance of animals in the mud flats than the sand flats across the survey sites (a mean value of 32 compared to 15 for sand flats). However, the sand flats had greater taxon richness (35 taxa across all the sand flat sites compared to 24 for mud flat sites).

All the sand flat sites were classified as medium sand, with median particle size ranging from 0.15 – 0.3 mm. The mud flat sites classification ranged from medium sand to medium sand and clay, with median particle size ranging from 0.15 – 0.23 mm.

"After" Survey 2 - November 2012 (Cardno Ecology Lab 2013a):

The most abundant taxa in the sand flat sites were Tellinidae (bivalve), Capitellidae (polychaete), Nereididae (polychaete), Veneridae (bivalve) and Mactridae (bivalve) which contributed 49%, 15%, 8%, 6% and 5% respectively to the total number of individual animals sampled. The most abundant taxa in the mud flat sites were bivalves from the families Tellinidae and Veneridae, followed by Capitellidae (polychaete), Mactridae (bivalve) and Nephtyidae (polychaete). These taxa contributed to 56%, 20%, 5%, 5% and 4% respectively to the total number of individuals sampled.

The most abundant taxa on the hard substratum were gastropods from the families Lottiidae and Littorinidae, and Ostreidae (oyster), with each group contributing approximately 22% to the total taxa recorded.

The total abundance recorded in sand and mud flats was similar, with 31 individuals on average found in sand flats compared with 30 in mud flats. Mean taxon richness was also similar, with a mean of 5.4 taxa recorded in sand flats and 4.7 in mud flats.

Sand flat sites were all classified as dark brown, brown or yellow sand, with median particle size ranging from 0.23 – 0.36 mm. The mud flat site classifications ranged from dark brown/brown sand to silty sand and with median particle size ranging from 0.23 – 0.32 mm.

"After" Survey 3 - March 2013 (Cardno Ecology Lab 2013b):

The most abundant taxa in the sand flat sites were Nereididae (polychaete), Capitellidae (polychaete), Galeommatidae (bivalve), Veneridae (bivalve), Naticidae (snail) and Tellinidae (bivalve) which contributed 27%, 23%, 14%, 7%, 6% and 5% respectively to the total number of individual animals sampled. The most abundant taxa in the mud flat sites were from the families Galeommatidae (bivalve) and Capitellidae (polychaete), followed by Veneridae (bivalve), Nephtyidae (polychaete) and Nereididae (polychaetes). These taxa contributed to 30%, 18%, 12%, 10% and 9% respectively to the total number of individuals sampled.

The most abundant taxa on hard substratum were gastropods from the families Littorinidae (limpets) and Ostreidae (oysters) and Lottiidae (periwinkles), with the groups contributing approximately 30%, 25% and 23% respectively, to the total taxa recorded.

The total abundance recorded in sand and mud flats was similar, with 21 individuals on average found in sand flat samples compared with 29 in mud flats. Mean taxon richness was also similar, with a mean of 5.4 taxa recorded in sand flat samples and 5.9 in mud flat samples.

Sand flat sites were all classified as medium fine sand to medium fine sand and shell, with median particle size ranging from 0.150 – 0.300 mm. The mud flat site classifications ranged from medium fine sand and shell, to medium fine sand to silty clay with median particle size ranging from 0.15 – 0.23 mm.

2 Methods

2.1 Indicators

Criteria for the success of habitat enhancement were derived from:

1. Comparison to target values derived from values over three pre-enhancement ("Before") surveys of muddy sand areas ("mud") in inner Penrhyn Estuary which had been shown to be consistently utilised by shorebirds. Values for abundance and biomass in these areas were higher than for sand areas in outer Penrhyn Estuary, had smaller median grain size and greater proportion of fine sediment particles (% fines, combined % clay and silt –sized particles that pass through 0.074 mm mesh) (**Table 2**).
2. Comparison of change at Penrhyn Estuary to change at two reference locations.

Physical indicators selected were median grain size (MGS) and % of fine sediment particles (combined % clay and silt fractions). Biological indicators selected were invertebrate abundance and biomass. Indicative target values for successful habitat enhancement are listed in **Table 2**.

Table 2 Indicators and target values for habitat enhancement. Source: The Ecology Lab 2008.

Habitat	Indicator	Before Sand (Outer PE)	Before Mud (Inner PE)	After (Long-term Target) Sand
Sediment indicators	Median Grain Size (MGS) (mm)	0.33 – 0.34	0.31 – 0.33	0.31 – 0.34
	% Fines (clay), (silt +clay)	1.3 - 1.8% (clay), 3.3 - 4.0 (silt + clay)	3 - 7% (clay) 3.7 - 23.5% (silt + clay)	2 to 4%
Biotic indicators	Biomass: g /sample (10 x 20 cm core)	0.72	0.98	≥ 0.7
	Biomass: g/ m	5.67x 10-5	7.69 x 10-5	≥5 x 10-5
	Abundance (# /sample, 10 x 20 cm core)	Range: 4 to 136, Average 39	Range: 11 to 171, Average 71	Average: ≥ 39

No target was set for the number of taxa that should ultimately be present in the created intertidal sand flat habitat. The number of taxa *per se* is less important in terms of providing food for shorebirds than abundance and biomass targets, particularly in the early stages of colonisation. It is likely that several years would be required before the typical 10 or 11 taxa are present, due to both variability in the recruitment of different species and the survivorship of species that first colonise the habitat.

2.2 Sampling Design

As nominated in the PEHEP (Sydney Ports Corporation 2007), the overall design to determine the success of the habitat enhancement was set within a Before, After, Control Impact (or Reference) BACI framework comparing changes in key indicators before versus after enhancement at Penrhyn Estuary and at reference locations within Botany Bay. The hypotheses (stated as null hypotheses) tested, statistical designs and data used are summarised in **Table 3, Table 4** and **Table 5** below.

Table 3 Null hypotheses, statistical design and data used for the Benthos Monitoring Program to 2013 for sandy substrata

Table 3a: Hypothesis relating to Created Sand Habitat

Null Hypothesis	Analysis	Data
1. No differences in abundance of benthos in sand substrata before vs after habitat enhancement 2. No differences in biomass of benthos in sand substrata before vs after habitat enhancement 3. No differences in median grain size of benthos in sand substrata before vs after habitat enhancement	PERMANOVA Phase (fixed factor) two levels: Before vs After	
	Treatment (fixed factor) two levels: Impact vs Reference	
	Survey (random factor, nested in Phase) six levels: Before – 1,2,3; After - 1,2,3	Before: Mar 07, Nov 07, Mar 08 After: Mar 12, Nov 12, Mar 13
	Location (random factor, nested in Treatment) two levels: Penrhyn Estuary nested in Impact level of Treatment; Reference locations nested in the Reference level of Treatment	Penrhyn Estuary - PE (sand flat) Quibray Bay North -QBN (sand flat) Quibray Bay South - QBS (sand flat)
	Sites (random factor nested in Location): Before: PE, QBN, QBS: 3 Sites After: PE 12 sites, QBN 3, QBS 3 Sites	PE CS1-CS3 QBN CS6- CS8 QBS CS11 –CS13 PE Untreated Sand 1-4 and PE Treated Sand 5-12 QBN Sand 13-15 QBS: Sand 16-18
	Replicate samples: 6 (all times/locations) 2 (grain size samples)	
No differences in assemblage of benthos in sand substrata before vs after habitat enhancement	MDS/SIMPER	As above

Table 3B: Hypotheses relating the effect of amendments to sediment in Penrhyn Estuary

Null Hypothesis	Analysis	Data
At Penrhyn Estuary there were no differences in abundance, biomass of benthos or median grain size in enhanced areas that received treated sand substrata (seagrass wrack and Nepean River mud) compared to those that received untreated substrata (locally dredged sand)	PERMANOVA Treatment (fixed) two levels: Untreated vs Treated	 PE Untreated Sand PE Treated Sand
	Surveys (random) three levels: After 1,2,3	After: Mar 12, Nov 12, Mar 13
	Site (random) levels: 4 for Untreated, 8 for Treated	PE Untreated Sand 1 - 4 PE Treated Sand 5-12
	Replicate samples: 6 (all times/locations) 2 (grain size samples)	
No differences in assemblage of benthos in treated vs untreated substrata after enhancement	MDS/SIMPER	As above

Construction activities were planned so as to have the least disturbance possible to the inner, muddy sand areas of the estuary, with the aims to preserve a local populations of invertebrates that would propagate into newly created habitat, and to provide some feeding habitat for shorebirds during the construction period. To determine if the first of these aims was achieved, additional hypotheses tested as detailed in **Table 4** below.

Table 4 Null hypotheses, statistical design and data used for the Benthos Monitoring Program to 2013 for mud substrata

Null Hypothesis	Analysis	Data
No differences in abundance or biomass of benthos, or in median grain size and % fines of muddy substrata before vs after habitat enhancement	PERMANOVA Phase (fixed factor) two levels: Before vs After	
	Treatment (fixed factor) two levels: Impact vs Reference	
	Survey (random factor, nested in Phase) six levels: Before – 1,2,3; After - 1,2,3	Before: Mar 07, Nov 07, Mar 08 After: Mar 12, Nov 12, Mar 13
	Location (random factor, nested in Treatment) two levels: Penrhyn Estuary nested in Impact level of Treatment; Reference locations nested in the Reference level of Treatment	PE (mud flat) Woolooware Bay - WB (mud flat) Georges River - GR (mud flat)
	Sites (random factor nested in Location): Before: PE, WB, GR: 3 Sites After: PE, WB , GR: 3 Sites	PE MF1-MF3 WB MF4-MF6 GR MF7-MF9 PE Mud 1-3 WB Mud 4-6 GR Mud 7-9
	Replicate samples: 6 (benthos samples) 2 (grain size samples)	
No difference in assemblage of benthos in muddy substrata before vs after habitat enhancement	MDS/SIMPER	As above

Shorebirds in Penrhyn Estuary have been observed feeding among the few hard objects in the inner estuary, including rocks, isolated clumps of oysters and flotsam. Prior to habitat enhancement invertebrates living attached to or in the near vicinity of such hard substrata were sampled to provide an indication of the amount of potential food items present. **Table 5** below details the hypothesis tested, statistical analyses and data used relating changes in assemblages of invertebrates associated with hard substrata in Penrhyn Estuary.

Table 5 Null hypothesis, statistical design and data used for the Benthos Monitoring Program to 2013 for hard substrata

Null Hypothesis	Analysis	Data
No difference in assemblage of benthos associated with hard substrata in Penrhyn Estuary before vs after habitat enhancement	MDS/SIMPER Before vs After Three sites per survey	Before: Mar 07, Nov 07, Mar 08 After: Mar 12, Nov 12, Mar 13 PE HS1-3
	Replicate samples: 4 (all times/sites)	

2.3 Statistical Analyses

Permutational analysis of variance (PERMANOVA+ in Primer v6.0) was used to test for significant differences in the biological and physical indicators of the sediment between Impact and Reference treatments before and after rehabilitation using a BACI (Before-After, Control (Reference)-Impact) design. Separate analyses were run for sand and mud substrata. Euclidian distance was used for univariate indicators (i.e. macrobenthos abundance and biomass and MGS and % fines content). Bray-Curtis dissimilarity was used for the multivariate analysis of macrobenthos assemblage.

Post hoc pair-wise comparisons were run where PERMANOVA detected significant interactions between the main factors (i.e. interaction between Phase and Treatment) or a main factor and Location or Survey (e.g. interaction between Treatment and Survey). Monte Carlo simulations were used to calculate p-values where unique permutations were less than 100.

Mean values with error bars representing standard error of each Location and Survey combination were presented for all biological and physical indicators. In addition, mean values (±SE) were plotted to visualise significant patterns detected by PERMANOVA.

Non-metric multidimensional scaling ordination (nMDS) was used to visualise patterns in multivariate datasets (e.g. assemblage data). All data points were used to create the nMDS plot for the hard substratum fauna assemblage. For macrobenthos centroids were calculated for each survey and site combination (i.e. corresponding to the average assemblage across six replicates for macrobenthos hard substrata benthos at one site on a given survey) and were used to reduce the stress value allowing accurate interpretation of the nMDS plots (Clarke and Warwick 2001). Vectors were superimposed on the nMDS plots in order to graphically represent the variables (i.e. taxa) that most strongly correlated with the variability in the multivariate data. Multiple correlation was used because, when calculating the correlation coefficient for each variable, all the other variables are taken into consideration and included in the model (Anderson *et al.* 2008). Only vectors with a multiple correlation coefficient of at least 0.35 were shown in the plot. The length and orientation of a vector show the strength and sign of the correlation between a variable and the two axes of the nMDS plot. Thus, a vector indicates a gradient in the abundance of the variable (a taxon in this case) that it represents.

Figure 2 Location of sandy and muddy sampling sites at Penrhyn Estuary for “after”surveys in March 2012, November 2012 and March 2013

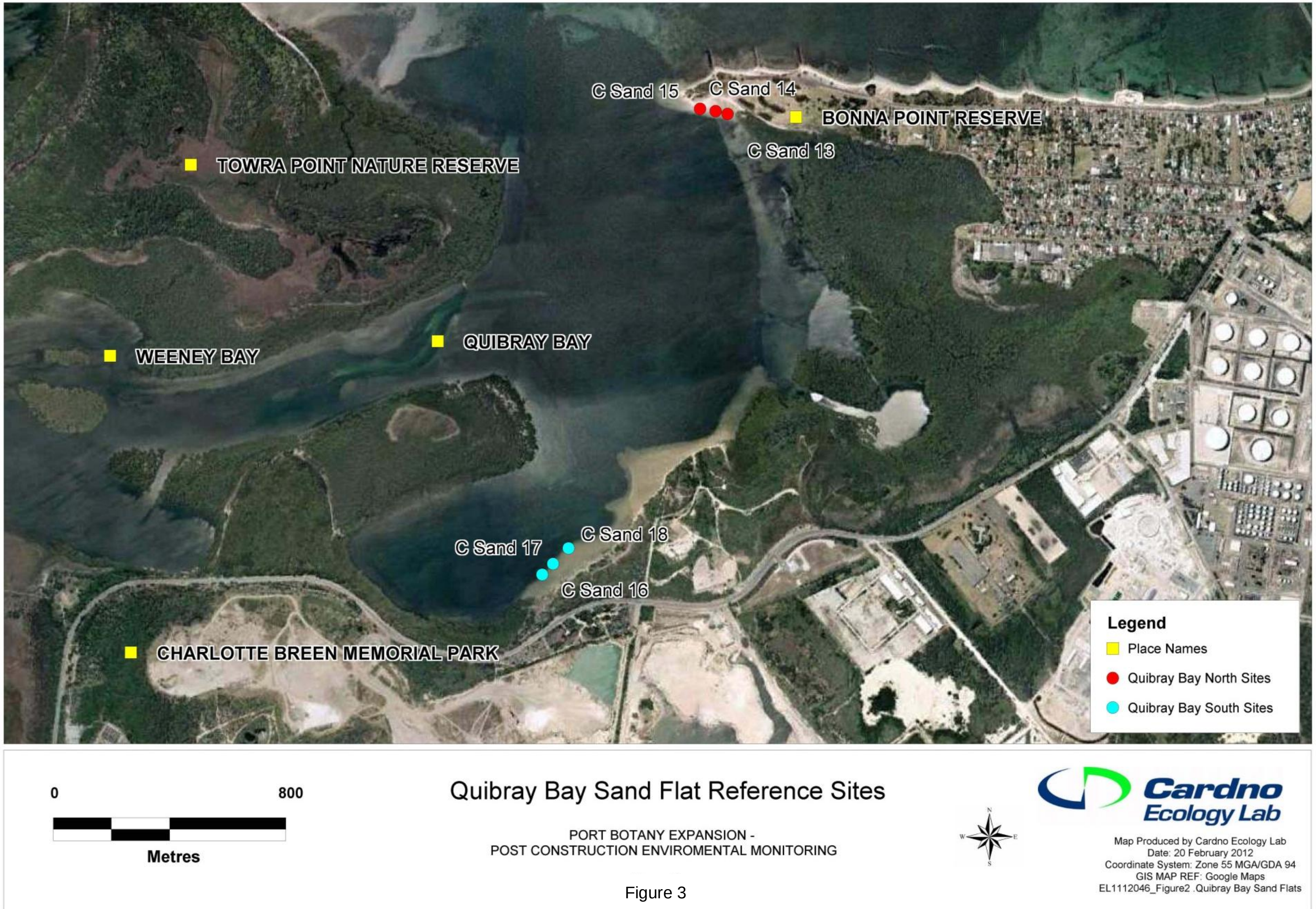

Figure 3 Location of sand substata benthos sampling sites at Quibray Bay (Reference Sites) for before and after surveys

Figure 4 Location of mud substrata benthos sampling sites at Woolooware Bay (Reference Sites) for before and after surveys

2.4 Summary of Sampling Procedures

2.4.1 Field Procedures

Eight replicate core samples (six biological and two grain size) were collected at each site on the sand flats and mud flats, and four replicate samples at each hard substrata site.

GPS coordinates recorded in previous surveys were used to accurately relocate the sampling sites for this survey.

Replicate sediment samples were collected on foot using a 10 x 20 cm plastic corer, yielding samples of approximately 1.57 L in volume. Samples were sealed in labelled plastic bags on site and transported back to the Cardno in-house laboratory for processing.

Fauna on hard substrata were sampled by collecting stones/oyster clumps of similar sizes. Each stone or clump of oysters was placed in a tear-resistant bag (Calico bag) before being sealed in a plastic bag and preserved with formalin.

2.4.2 Laboratory Procedures

Formalin solution was added to each sample at the end of the sampling day in the Cardno lab to fix and preserve the animals for a minimum period of 24 hours. Excess formalin was drained into appropriate storage drum and sediment was rinsed over a 1 mm mesh sieve, using tap water. Samples were stored in jars for same day sorting, where animals and any animal fragments (e.g. tentacles, bodies without heads) were removed from the sediment under a binocular microscope. Wet weights were recorded for the fauna present in each soft sediment sample, including fragments of animals.

All animals were identified by an experienced in-house taxonomist, counted and placed in separate vials for each taxon. Each vial contained a 70% alcohol solution for long term preservation of the animals and was labelled with the project details, sample information and taxon identification name. A reference collection of all taxa found was compiled and added to the existing reference collection held by Cardno Ecology Lab.

Grain size samples were analysed by NATA accredited laboratories (AST/SGS Laboratories for Before surveys and November 2012, ALS Laboratories, Sydney for March 2012 and March 2013 surveys) using the dry sieve method (AS 1289.3.6.11-1995), yielding the distribution of particles sizes greater than 0.074mm and median grain size.

2.4.3 Quality Control Procedures

All field data and laboratory data were entered into separate spread sheets, and printed out for a second staff member to data check and correct any errors. The data corrected final spread sheets were saved as read only files. All original field and laboratory data sheets were photocopied and originals and copies were stored in separate filing cabinets to create backup copies.

3 Summary of Results

3.1 Survey Dates

Dates for before and after enhancement surveys are given in **Table 6**. All sampling was successfully completed and consistent with the Benthos Monitoring Services Management Plan (Cardno 2012a). GPS co-ordinates were recorded at each site on each survey date.

During the field work no HSE incidents or near misses were recorded and non-compliance reports (NCR) were not required.

Table 6 Sampling dates for monitoring surveys

Activity	Date	Code
Before Construction Survey 1	19 - 30 March 2007	M07
Before Construction Survey 2	20 -22 November 2007	N07
Before Construction Survey 3	17 – 22 March 2008	M08
After Survey 1	5-7 March 2012	M12
After Survey 2	12-14 November 2012	N12
After Survey 3	8-12 March 2013	M13

Raw data for After Surveys 1-3 were presented in Summary Reports (Cardno Ecology Lab 2102b, 2013a, 2103b).

3.2 Sand Habitat

3.2.1 Macrobenthos

A total of 83 taxa were found across six surveys and a total of 15,939 individuals were counted.

The average abundance of macroinvertebrates decreased at all sites after habitat enhancement (**Table 7; Figure 5**). This pattern was more evident at Quibray Bay North where abundance decreased about five fold (**Table 7**). At Quibray Bay South, however, the trend of decreasing abundance after habitat enhancement was less evident because of the higher temporal variability across surveys (**Table 7; Figure 5**).

In contrast to abundance, macrobenthos biomass increased after enhancement, with the largest increase recorded at Penrhyn Estuary where the average biomass after habitat enhancement increased by about 66 % (**Table 7; Figure 6**).

Table 7 Mean (±SE) macrobenthos abundance and wet biomass at Impact and Reference locations in sand flat habitat, before and after habitat enhancement

		Abundance (no. of individuals per sample)		Biomass (g/sample)	
Treatment	**Location**	**Before**	**After**	**Before**	**After**
Impact	Penrhyn Estuary	36.8 ± 2.9	22.5 ± 1.0	0.65 ± 0.11	1.08 ± 0.11
Reference	Quibray Bay North	48.3 ± 4.3	8.8 ± 1.4	0.70 ± 0.18	0.96 ± 0.45
	Quibray Bay South	54.1 ± 6.2	35.2 ± 4.0	0.59 ± 0.13	0.83 ± 0.13

Table 14Figure 19

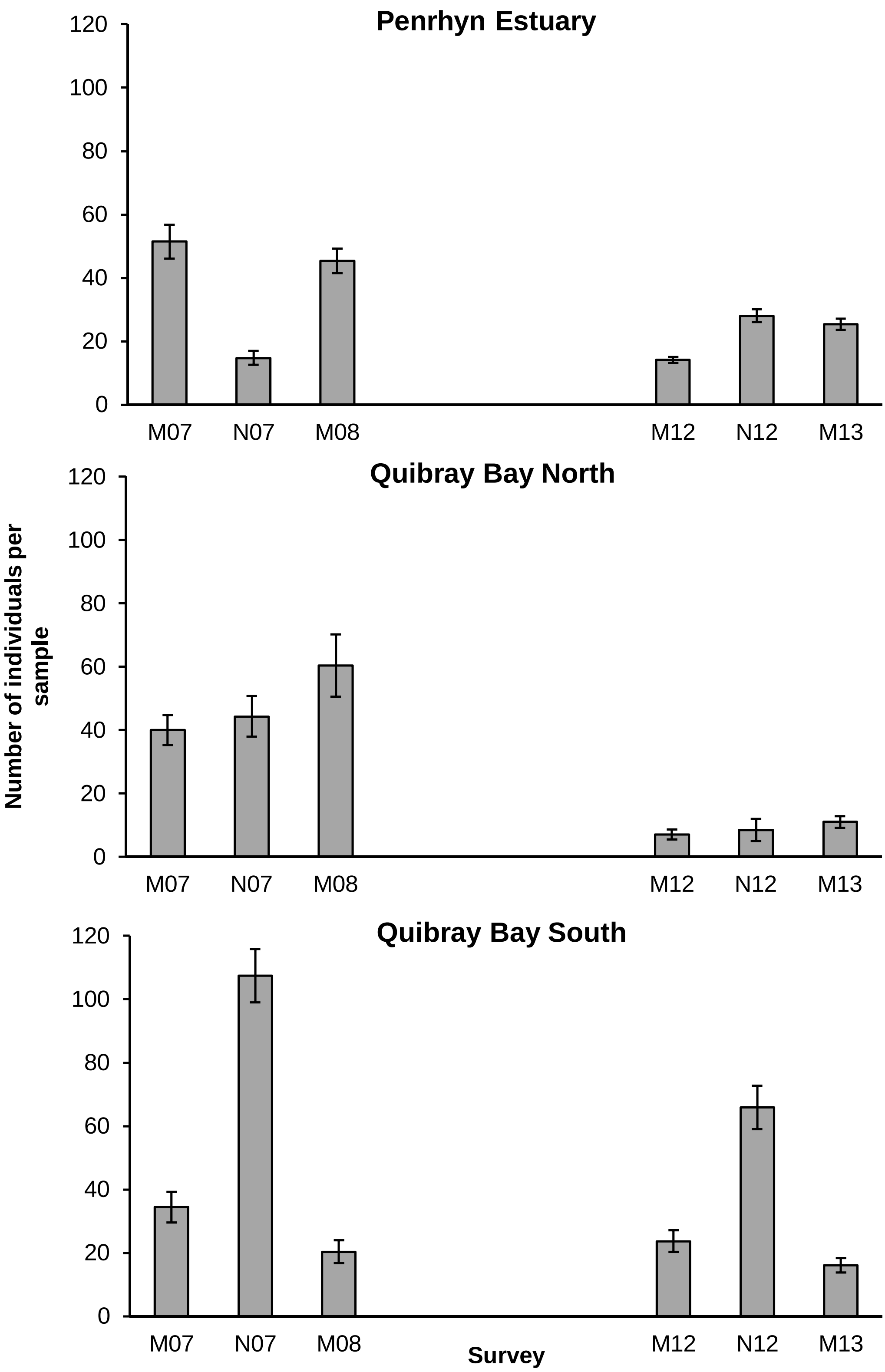

Figure 5 **Abundance of macrobenthos in sand flat habitat in Before (M07 to M08) and After (M12 to M13) surveys at Impact (Penrhyn Estuary) and Reference (Quibray Bay North and Quibray Bay South)**

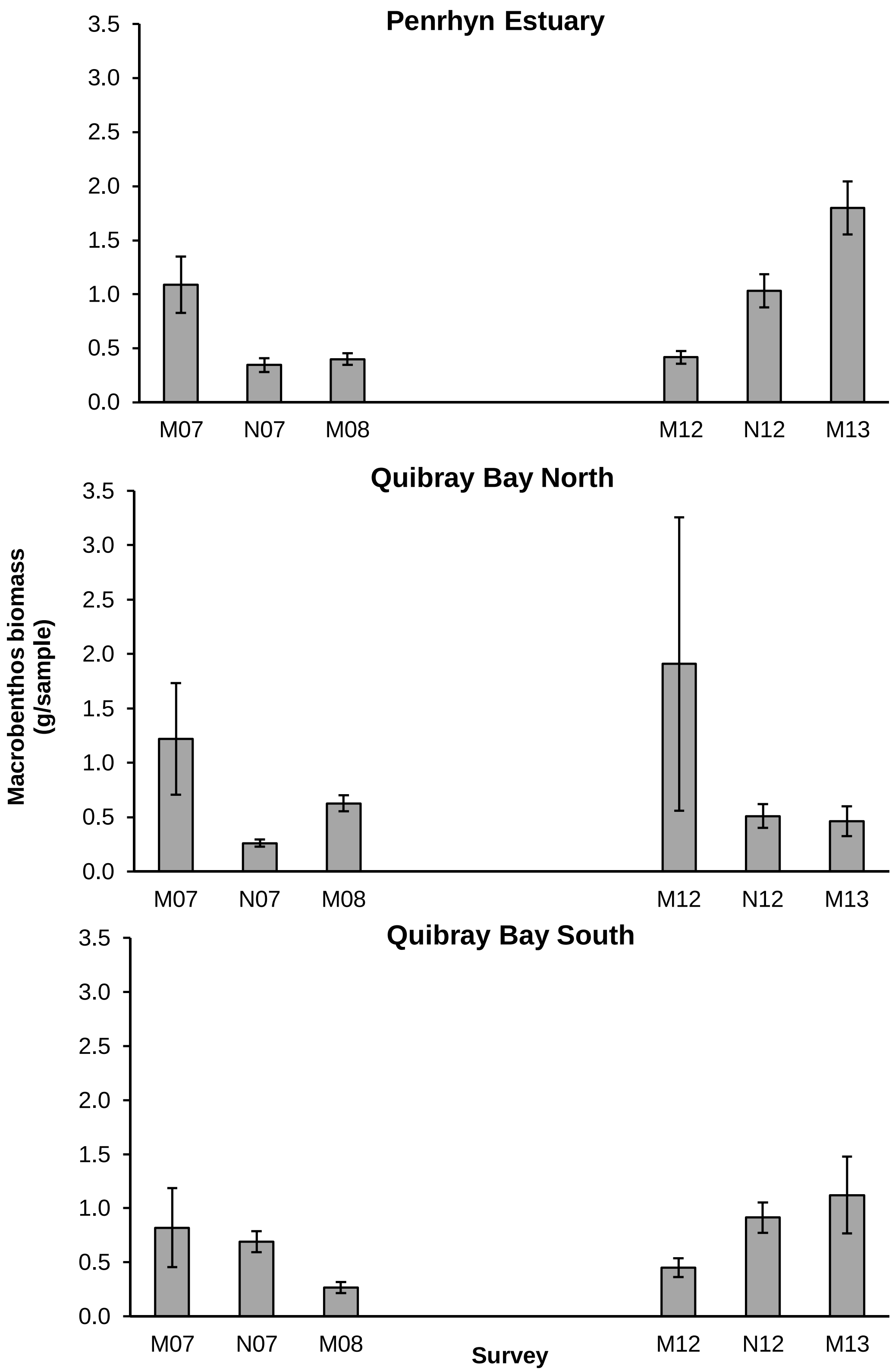

Figure 6 **Mean (±SE) macrobenthos wet biomass in sand flat habitat in Before (M07 to M08) and After (M12 to M13) surveys at Impact (Penrhyn Estuary) and Reference (Quibray Bay North and Quibray Bay South)**

3.2.2 Particle Size Distribution

Median grain size (MGS) was smaller after habitat enhancement at all locations but also more variable compared to the three pre-enhancement surveys (**Table 8; Figure 7**). After habitat enhancement MGS was more variable compared to post-enhancement surveys, all locations had a maximum in the November 2012 survey, whereas March 2012 and 2013 surveys had similar values (**Figure 7**).

The % fine sediment content at Penrhyn Estuary increased by about 40 % compared to pre-enhancement levels. Conversely, the fine sand fraction decreased at both Reference locations, especially at Quibray Bay South where fine sand content decreased from 14.1 to 1.9 % (**Table 8**). Moreover, while Penrhyn Estuary had the lowest fines content before habitat enhancement, the opposite pattern was evident after enhancement (**Table 8**).

Table 8 Mean (±SE) median grain size and fine sediment content in sand flat habitat at Impact and Reference locations before and after the rehabilitation program.

		Median Grain Size (mm)		% Fines content	
Treatment	**Location**	**Before**	**After**	**Before**	**After**
Impact	Penrhyn Estuary	0.33 ± 0.01	0.24 ± 0.01	3.7 ± 0.5	5.2 ± 0.5
Reference	Quibray Bay North	0.23 ± 0.01	0.21 ± 0.02	6.2 ± 0.4	3.3 ± 0.9
	Quibray Bay South	0.27 ± 0.01	0.18 ± 0.01	14.1 ± 2.6	1.9 ± 0.2

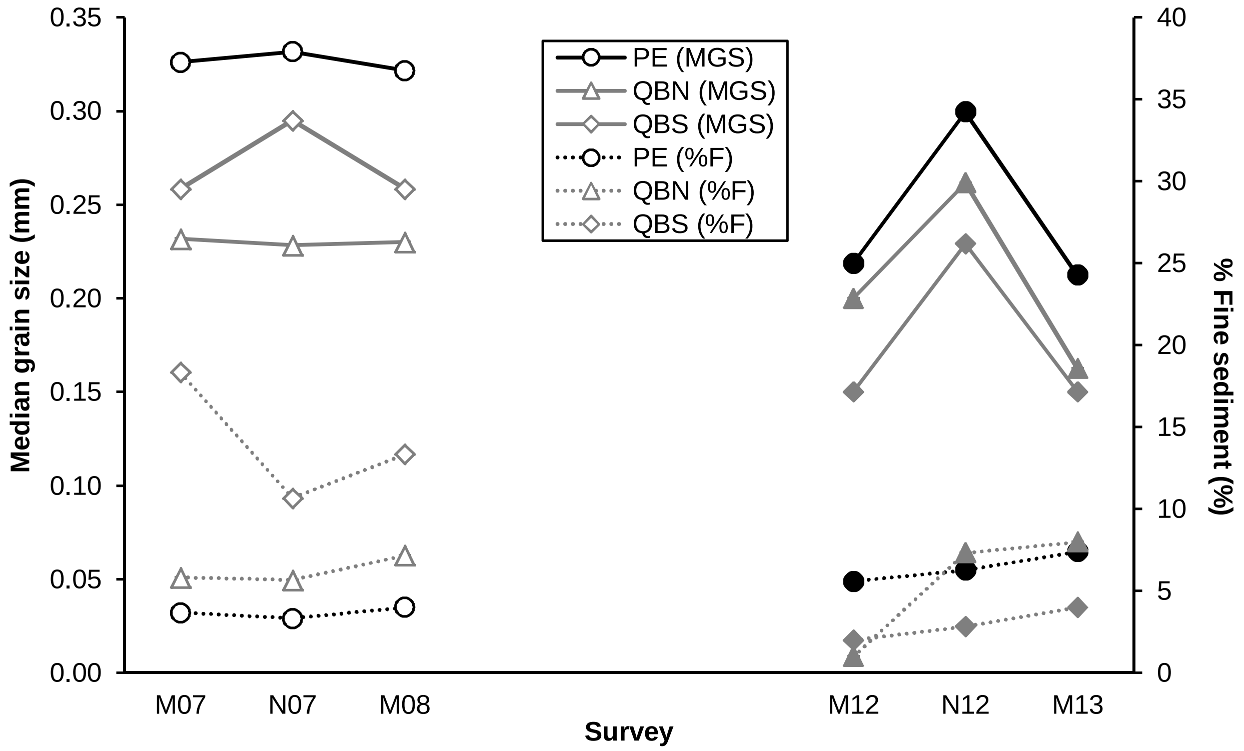

Figure 7 Mean median grain size (MGS; continuous line) and fine sediment content (% F; dotted line) in sand substratum in surveys Before (empty symbol) and After (filled symbol) habitat enhancement at Penrhyn Estuary (PE), Quibray Bay North (QBN) and Quibray Bay South (QBS)

3.3 Muddy Substratum

3.3.1 Macrobenthos

A total of 50 taxa were found across six surveys and a total of 15,180 individuals were counted.

The average abundance of macrobenthic invertebrates decreased at all sites after habitat enhancement, but significant differences were masked by variability at the small scale of sites. The decrease was particularly marked in mud flats at Penrhyn Estuary where macrobenthos abundance was about half that recorded pre-enhancement (**Table 9**).

Macrobenthos biomass increased markedly at Penrhyn Estuary after habitat enhancement works but not at the Reference locations (**Table 9; Figure 9**).

Table 9 Mean (±SE) macrobenthos abundance and wet biomass in mud flat habitat at Impact and Reference locations before and after the rehabilitation program.

		Abundance (no. of individuals per sample)		Biomass (g/sample)	
Treatment	**Location**	**Before**	**After**	**Before**	**After**
Impact	Penrhyn Estuary	72.7 ± 3.8	36.6 ± 2.8	1.00 ± 0.20	1.82 ± 0.17
Reference	Georges River	18.5 ± 1.6	17.9 ± 1.9	0.55 ± 0.09	0.48 ± 0.07
	Woolooware Bay	40.5 ± 1.5	35.6 ± 1.8	0.57 ± 0.10	0.44 ± 0.04

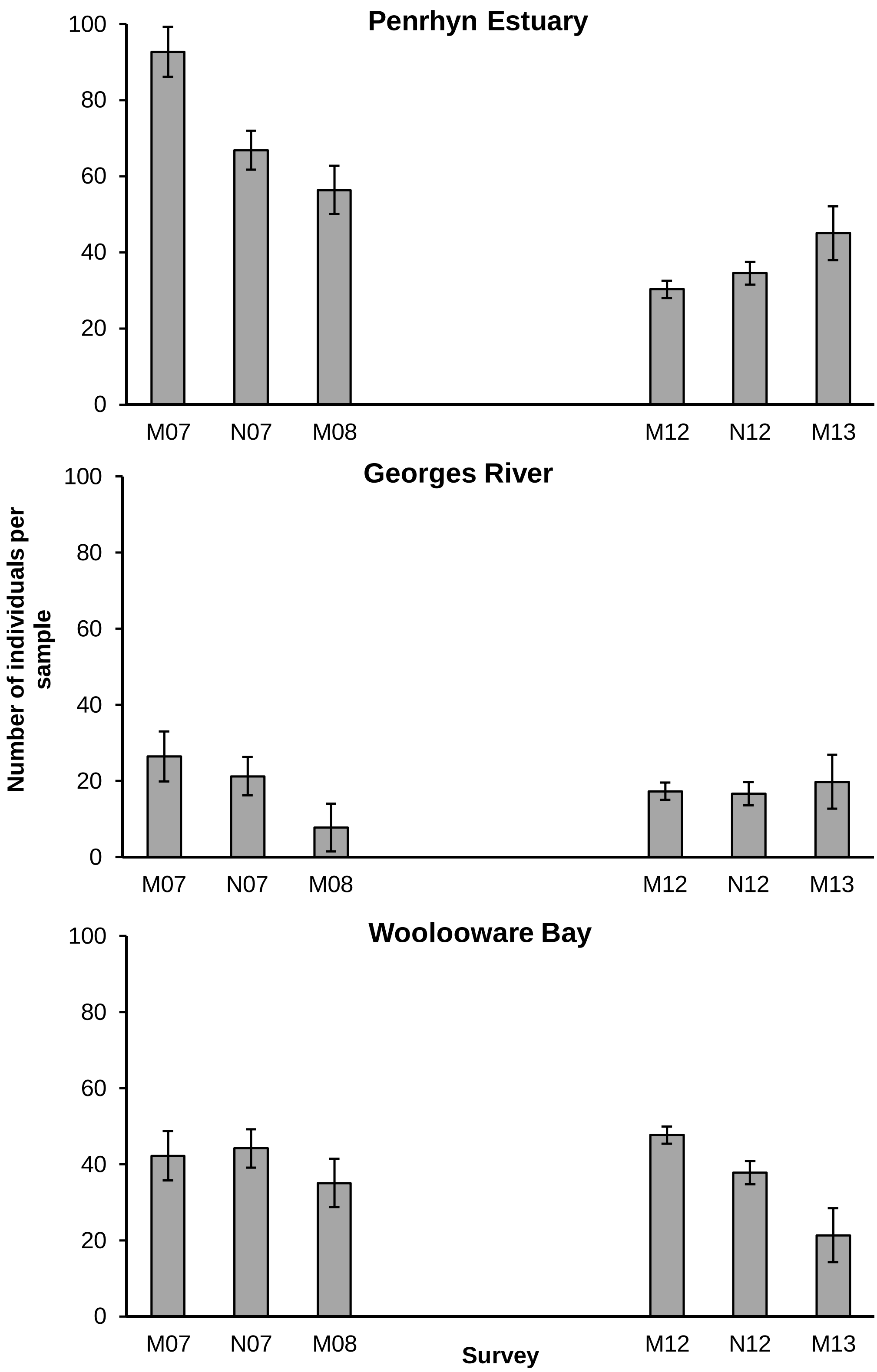

Figure 8 **Abundance of macrobenthos in mud flat habitat in surveys Before (M07 to M08) and After (M12 to M13) habitat enhancement at Impact (Penrhyn Estuary) and Reference (Georges River and Woolooware Bay) locations.**

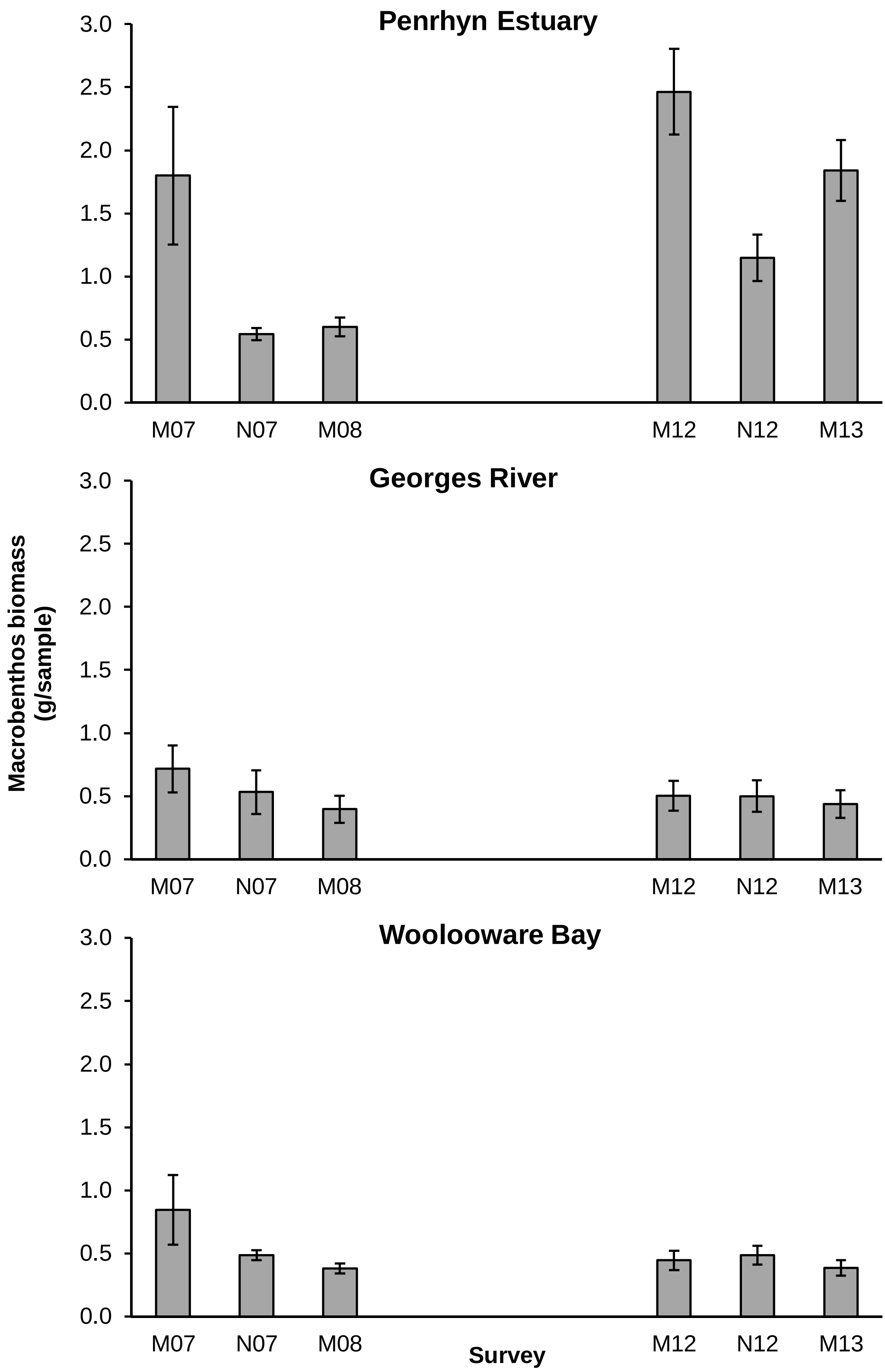

Figure 9 **Mean (±SE) macrobenthos wet biomass in sand flat habitat during surveys before (M07 to M08) and after (M12 to M13) habitat enhancement at Impact (Penrhyn Estuary) and Reference (Georges River and Woolooware Bay) locations.**

3.3.2 Particle Size Distribution

Median grain size was smaller after habitat enhancement works at all locations but also more variable compared to the three pre-enhancement surveys (**Table 10; Figure 10**). After habitat enhancement MGS was more variable compared to post-enhancement surveys, all locations had a maximum in the November 2012 survey, whereas March 2012 and 2013 surveys had similar values (**Figure 10**).

The fine sediment content at Penrhyn Estuary was similar to pre-enhancement levels (**Table 10**). Conversely, the fine sediment fraction decreased at both Reference locations (**Table 10; Figure 10**).

Table 10 Mean (±SE) median grain size and fine sediment content at Impact and Reference locations in mud substratum, before and after the rehabilitation program.

		Median Grain Size (mm)		% Fines	
Substrate/Treatment	**Location**	**Before**	**After**	**Before**	**After**
Impact	Penrhyn Estuary	0.32 ± 0.01	0.25 ± 0.01	8.8 ± 0.9	6.3 ± 0.7
Reference	Georges River	0.27 ± 0.01	0.20 ± 0.01	42.1 ± 2.9	19.9 ± 2.4
	Woolooware Bay	0.26 ± 0.01	0.19 ± 0.01	15.1 ± 1.0	3.8 ± 0.7

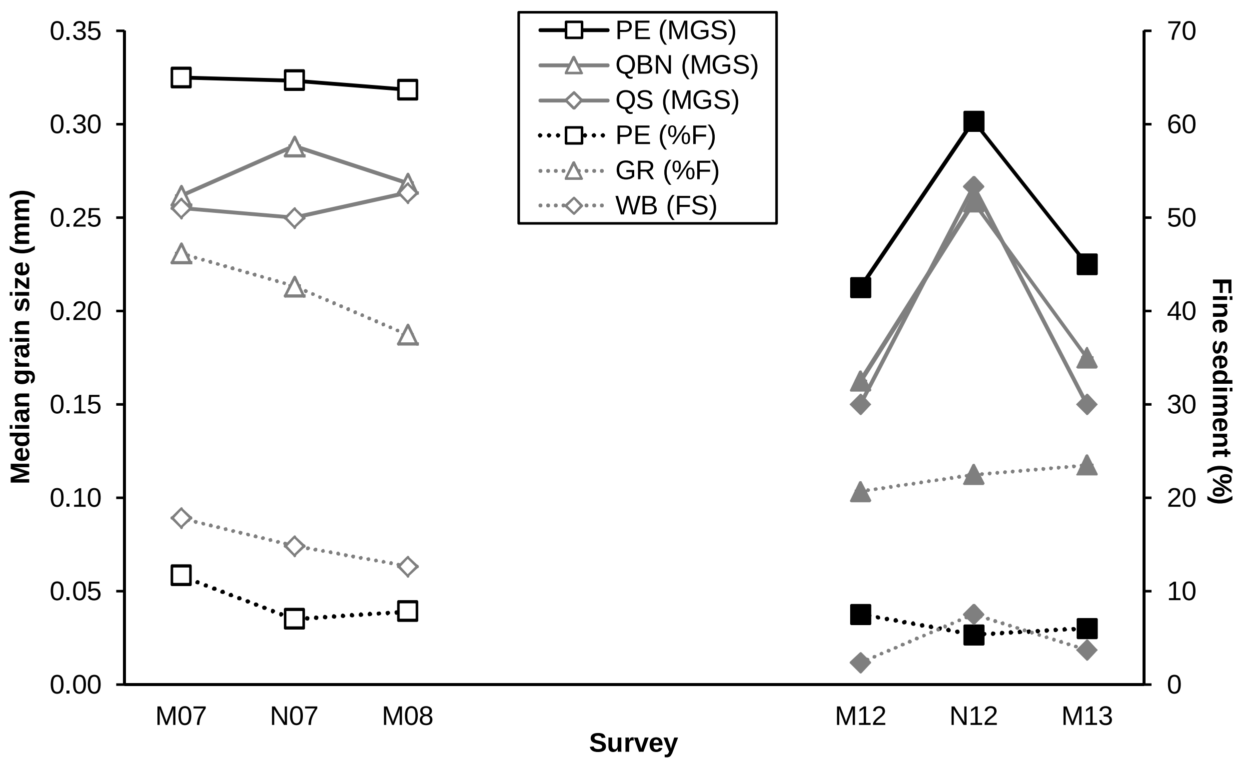

Figure 10 Mean median grain size (MGS; continuous line) and fine sediment content (dotted line) in mud substratum during surveys before (empty symbol) and after (filled symbol) habitat enhancement at Penrhyn Estuary (PE), Georges River (GR) and Woolooware Bay (WB).

3.4 Treated Sand Flats at Penrhyn Estuary

3.4.1 Macrobenthos

Across the three surveys, the abundance of macrobenthic invertebrates was similar in Treated and Untreated sites (**Table 11**). Despite an overall temporal variability in both Treated and Untreated sites, the number of individuals was similar in the two treatments during each of the three surveys (**Figure 11A**).

Over the three surveys, wet macrobenthos biomass was higher (about 40 %) and more variable in Untreated sediment compared to Treated sediment (**Table 11**). This general pattern, however, was mostly due to higher values in the last survey (March 2013) when biomass had an average value of 2.4 ± 0.6 g per sample (**Figure 11B**). Across Treated and Untreated sites, there was a general trend of increase in biomass which was more evident for Untreated sites (**Figure 11B**).

Table 11 Mean (±SE) macrobenthos abundance and wet biomass in Treated and Untreated sand at Penrhyn Estuary across three surveys (March and November 2012 and March 2013) after habitat enhancement.

Treatment	Abundance (no. of individuals per sample)	Biomass (g/sample)
Treated	22.0 ± 1.3	0.94 ± 0.10
Untreated	23.6 ± 1.5	1.35 ± 0.23

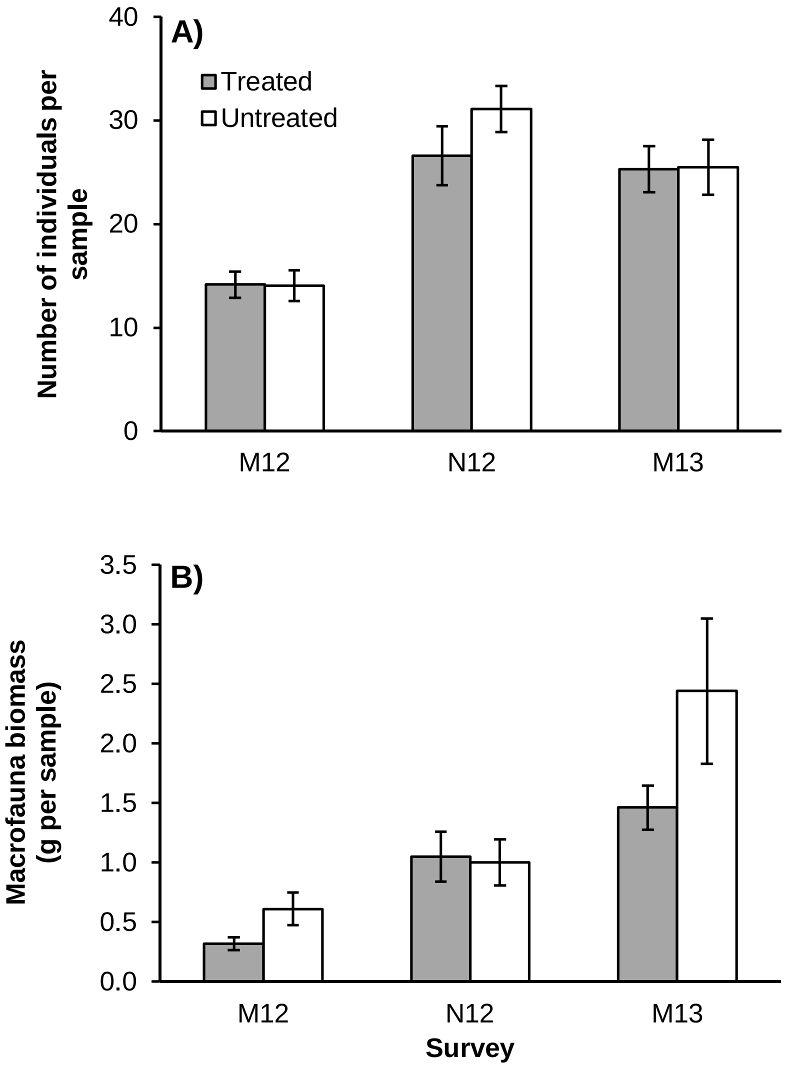

Figure 11 Mean (±SE) macrobenthos A) abundance and B) wet weight biomass in Treated and Untreated sand at Penrhyn Estuary during three surveys (March and November 2012 and March 2013) after habitat enhancement

3.4.2 Particle Size Distribution

MGS was similar at Treated and Untreated sites (**Table 12**) across the three surveys (**Figure 12**). Untreated sites had a higher MGS compared to Treated sites during the first survey (March 2012) but both treatments had similar values during the two following surveys. This indicates that soil amendments likely mixed, but not uniformly once placed within the estuary.

Overall, the fine sediment content was higher in Treated than Untreated sand flats (**Table 12**). This pattern was the reflection of larger values during the first (March 2012) and third (March 2013) surveys (**Figure 12**), and indicates that the amendments to the sand resulted in increasing the fine sediment fraction and likely the organic content of the sediment.

Table 12 Mean (± SE) median grain size and fine sediment content at Treated and Untreated sites in Penrhyn Estuary after habitat enhancement

Treatment	Median Grain Size (mm)	Fine sand (%)
Treated	0.24 ± 0.01	5.9 ± 0.7
Untreated	0.25 ± 0.01	3.8 ± 0.5

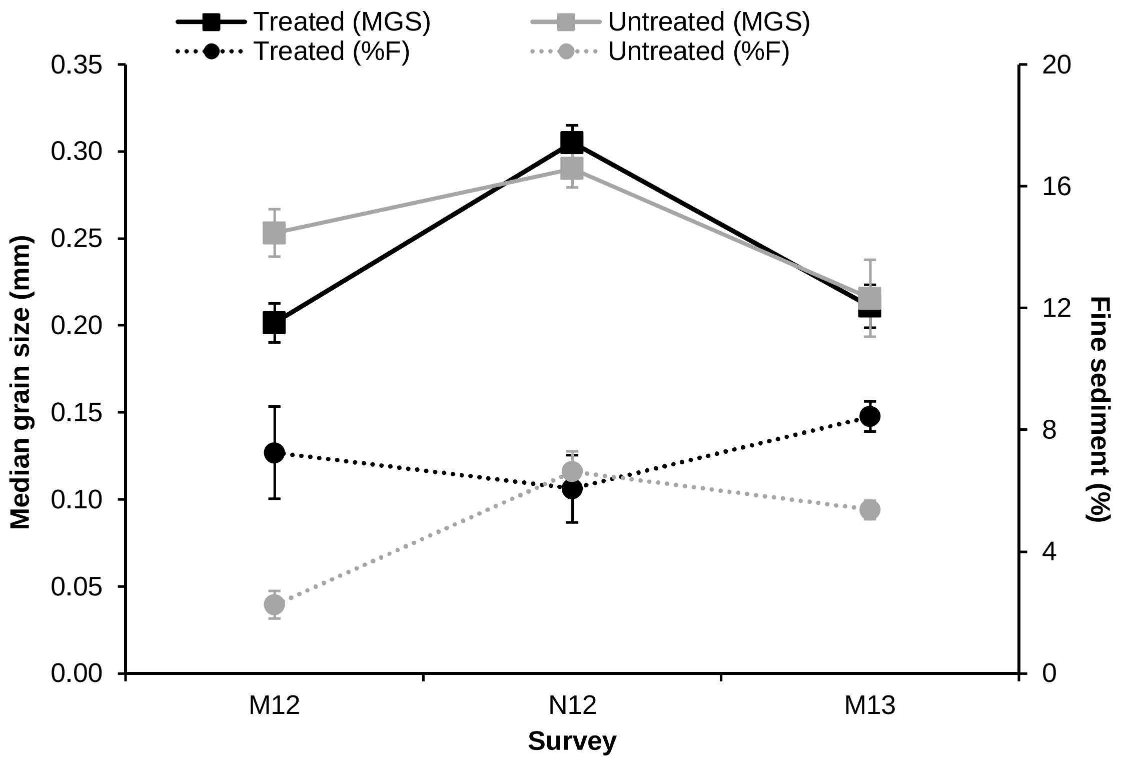

Figure 12 Mean median grain size (MGS; continuous line) and fine sediment content (FS, dotted line) in Treated and Untreated sand at Penrhyn Estuary during three surveys (March and November 2012 and March 2013) after habitat enhancement.

3.5 Hard Substratum Fauna

The faunal assemblage living on hard substratum at Penrhyn Estuary showed marked temporal differences which were very evident between before and after habitat enhancement (**Figure 13**). The assemblage was more variable before compared to after habitat enhancement works (**Figure 13**). This pattern was the result of 1) a higher within-survey spatial variability, particularly during the first before survey (March 2007), and 2) temporal differences among each baseline survey (**Figure 13**). This is in contrast with the low temporal variability after habitat enhancement, seen by the closely clustering of post-enhancement samples in the nMDS plot (**Figure 13**). An increase in Ostreidae and Littorinidae and a decrease in Siphonariidae were the taxa that drove the differences between pre- and post-enhancement (**Figure 13**).

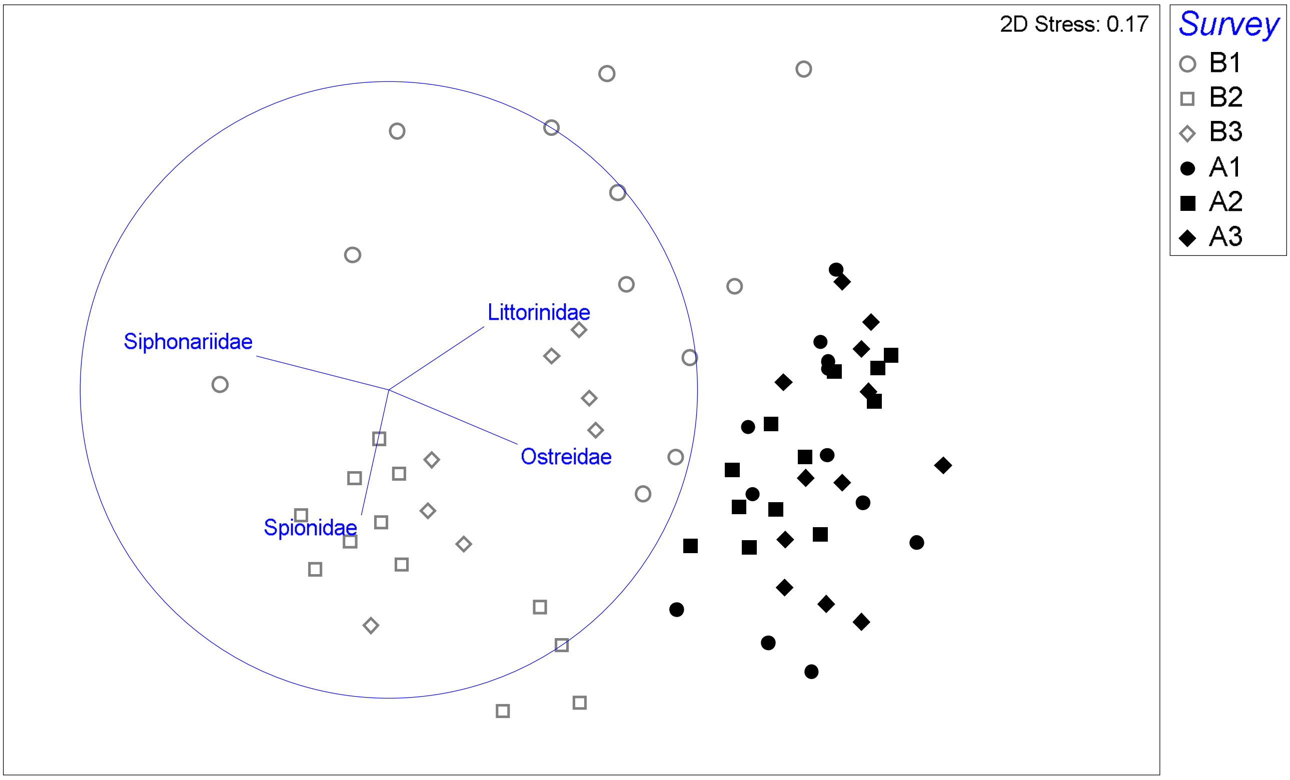

Figure 13 nMDS representing the hard substratum faunal assemblage at Penrhyn Estuary during before (B1 to B3) and after (A1 to A3) habitat enhancement surveys. Each point represents a sample. Vectors represent the multiple correlation coefficient between the nMDS axes and the abundance of each taxon. Only taxa with a multiple correlation coefficient of at least 0.35 were shown in the plot.

4 Data Analysis

4.1 Sand substratum

4.1.1 Macrobenthos

Although the abundance of macrobenthos invertebrates in sand substratum was highly variable at the smaller spatial and temporal scales investigated, significantly more individuals were present before (47.5 ± 1.8 individuals per sample) compared to after (24.9 ± 0.9) habitat rehabilitation works across Impact and Reference treatments (**Table 13**).

The biomass of macrobenthos did not show any spatial or temporal pattern, but only small scale variability across sites and surveys (**Table 13**).

There were differences in the macrobenthos assemblage between Impact and Reference treatments which were evident despite significant lower scale variability (**Table 13; Figure 14**). These differences were mainly driven by tellinid and galeommatid bivalves, whereas polychaetes of the Nereididae, Capitellidae and Spionidae families explained the spatial variability across the Impact and Reference Treatments (**Figure 14**).

Table 13 Summary of PERMANOVA results for biological and physical indicators in sand flat habitat. NS = not significant, RED = redundant due to a significant interaction with another factor, * = p < 0.05, ** = p < 0.01 and *** = p < 0.001. See Appendix A for the complete analyses.

Source	Abundance	Biomass	Assemblage	MGS	% Fines
Sand Substratum					
Phase (Before vs After)	*	NS	NS	RED	RED
Treatment (Penrhyn Estuary vs References)	NS	NS	**	***	NS
Survey(Ph)	RED	RED	RED	RED	RED
Location(Tr)	RED	NS	RED	RED	RED
Phase x Treatment	NS	NS	NS	NS	NS
Phase x Location(Tr)	NS	NS	NS	*	*
Treatment x Survey(Ph)	NS	NS	NS	NS	NS
Site(Loc(Tr) x Ph)	RED	RED	RED	RED	RED
Survey(Ph) x Location(Tr)	***	NS	***	NS	NS
Survey(Ph) x Site(Loc(Tr) x Ph)	***	***	***	***	***

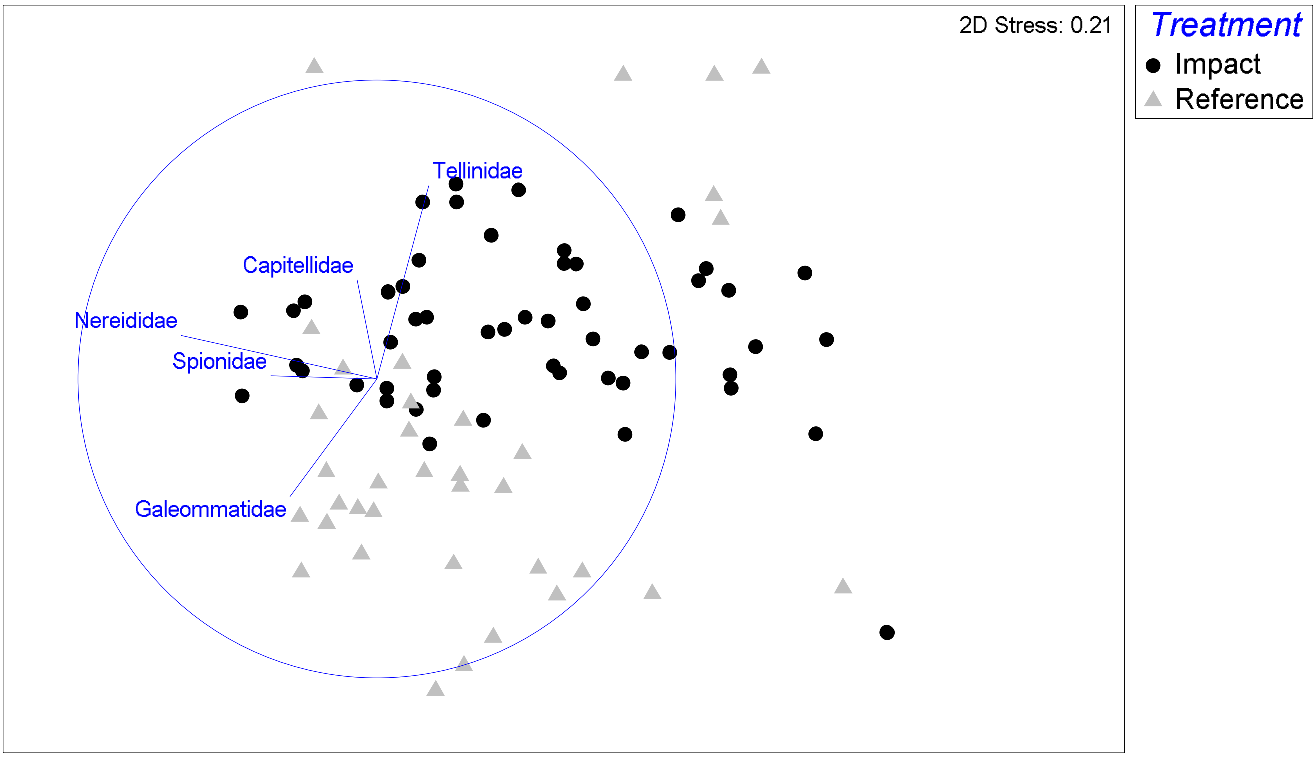

Figure 14 nMDS representing the macrobenthos assemblage of sand flat habitat at Impact (Penrhyn Estuary) and Reference (Quibray Bay North and South). Points represent centroids of each site by survey combination. Vectors represent the multiple correlation coefficient between the nMDS axes and the abundance of each taxon. Only taxa with a multiple correlation coefficient of at least 0.35 were shown in the plot.

Prior to enhancement polychaetes worms made up 73% of all invertebrates, but declined to an average of 52% after enhancement, while molluscs increased on average from 19% before enhancement to 53% after enhancement (**Figure 15**). Changes in the contributions of polychaetes and molluscs to the assemblage observed in March 2013 suggests that community structure has not yet stabilised.

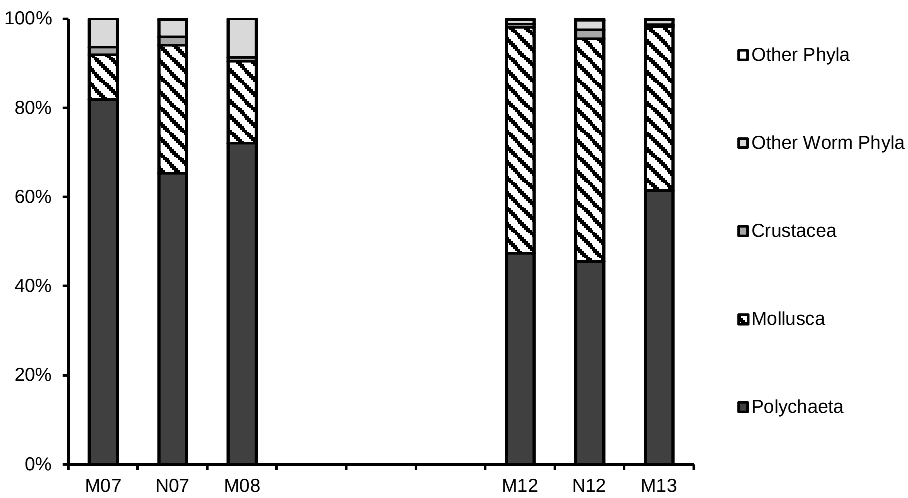

Figure 15 Composition of benthic assemblages at Penrhyn Estuary before and after enhancement by taxonomic group.

4.1.2 Particle Size Distribution

Differences in median grain size between phases were dependent on the location investigated (**Table 13**). *Post hoc* pair-wise comparisons indicated that the only significant difference was between before and after habitat rehabilitation at Penrhyn Estuary (**Appendix A; Figure 16A**). Across the entire sampling period, MGS at Penrhyn Estuary was 0.26 ± 0.01 and was significantly higher compared to Impact locations where the average value was 0.22 ± 0.01 (**Appendix A; Figure 16A**).

Differences in the content of fine sand between phases were dependent on the location investigated (**Table 13**). *Post hoc* pair-wise comparisons, however, indicated that there were no significant differences between phases within each location or *vice versa* at Quibray South (**Appendix A; Figure 16B**).

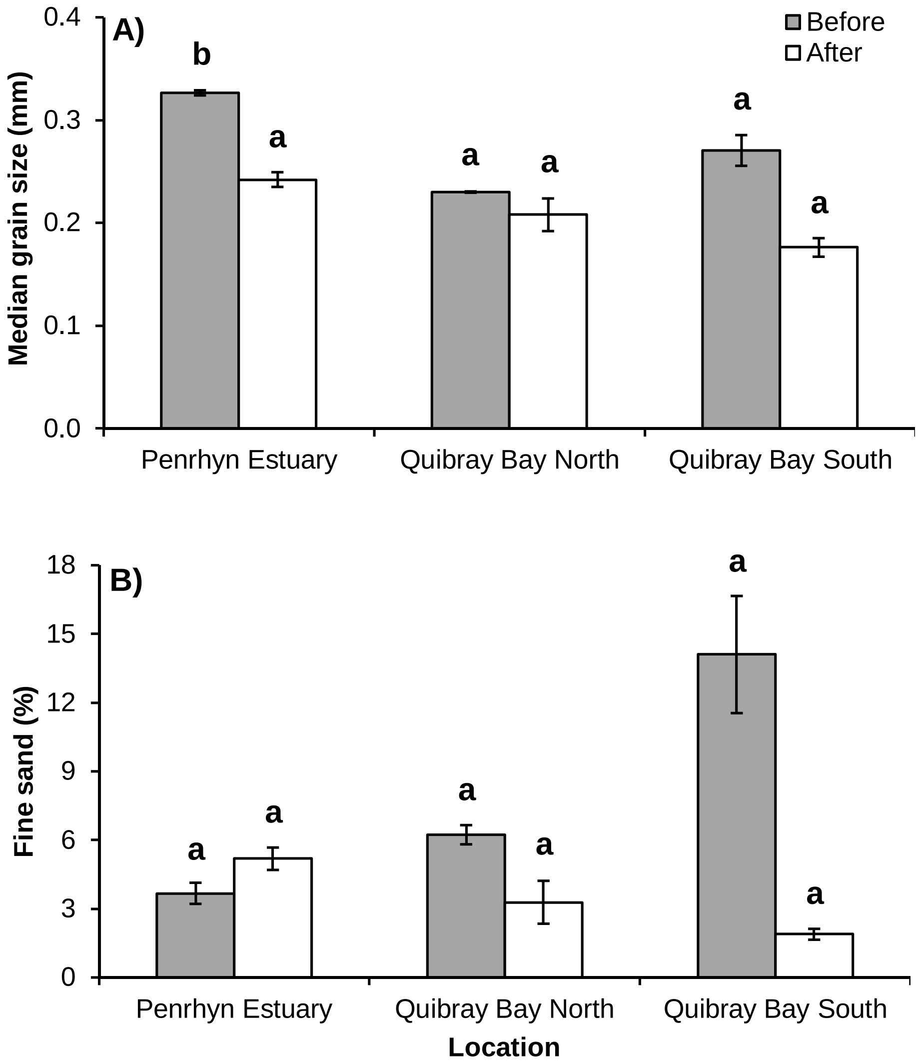

Figure 16 Mean (±SE) (A) median grain size and (B) fine sediment content of sand flat habitat at Impact (Penrhyn Estuary) and Reference (Quibray Bay North and South) locations. Letters indicate results of pair-wise comparisons (see Appendix A for details).

4.2 Mud Substratum

4.2.1 Macrobenthos

The abundance of macrobenthos in mud substratum varied significantly across phases, treatments and locations (**Table 14; Figure 17**). *Post hoc* pair-wise comparisons, however, did not show significant difference between Impact and Reference treatments within each Phase and *vice versa* (**Appendix A**).

Similarly to macrobenthos abundance, PERMANOVA detected significant differences in the biomass of macrobenthos between Phases that were dependent on Treatment and *vice versa*. In addition, there were significant differences between Impact and Reference treatments that were dependent on the factor Survey (**Table 14**). *Post hoc* pair-wise comparisons detected a significant difference between Impact and Reference Treatments after rehabilitation works when biomass was higher at Penrhyn Estuary compared to Reference locations (**Appendix A; Figure 17**).

Although the macrobenthos assemblage was very variable at the smaller spatial and temporal scales investigated, there were significant differences between phases (**Table 14; Figure 17**). These differences were mostly due to the abundance of magelonid, nereidid and nephtyid polychaetes and tellinid and galeommatid bivalves (**Figure 17**).

Table 14 Summary of PERMANOVA results for biological and physical indicators in mud flat habitat. NS = not significant, RED = redundant due to a significant interaction with another factor, * = p < 0.05, ** = p < 0.01 and *** = p < 0.001. See Appendix A for complete analyses.

Source	Abundance	Biomass	Assemblage	MGS	% Fines
Phase	RED	RED	*	NS	NS
Treatment	RED	RED	NS	**	NS
Survey(Ph)	RED	RED	RED	**	RED
Location(Tr)	**	NS	RED	NS	***
Phase x Treatment	*	*	NS	NS	NS
Phase x Location(Tr)	NS	NS	NS	NS	NS
Treatment x Survey(Ph)	NS	**	NS	NS	NS
Site(Loc(Tr) x Ph)	RED	RED	RED	***	RED
Survey(Ph) x Location(Tr)	NS	NS	***	NS	NS
Survey(Ph) x Site(Loc(Tr) x Ph)	***	**	***	NS	***

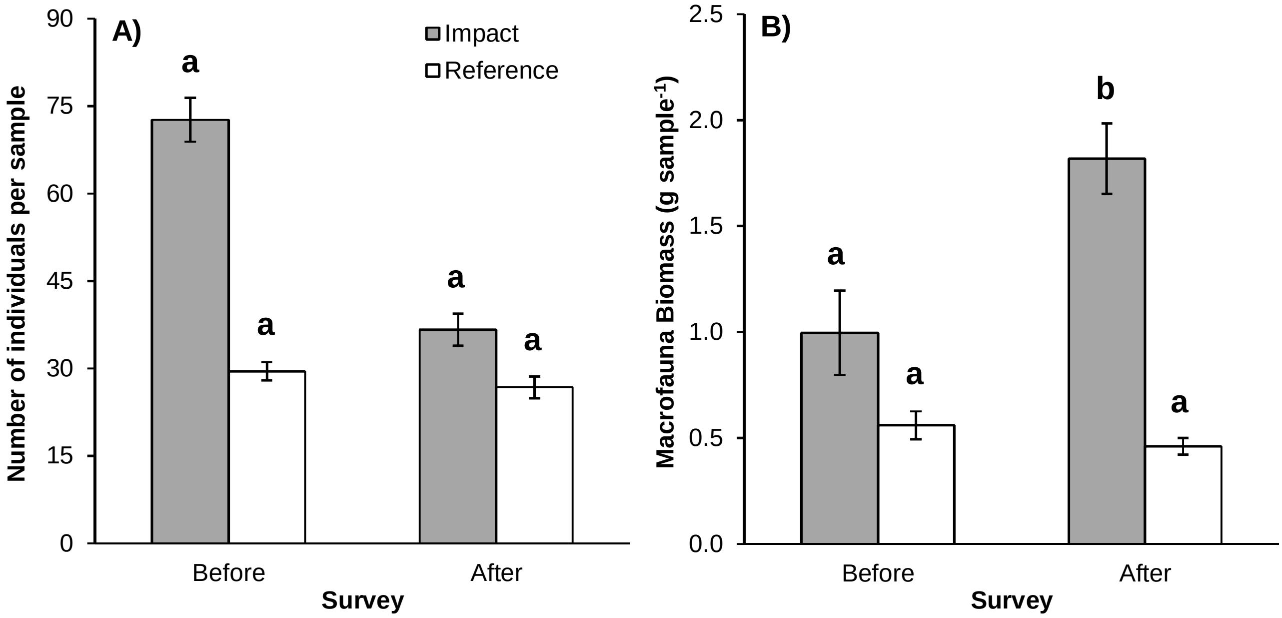

Figure 17 Mean (±SE) A) macrobenthos abundance and B) wet weight biomass in mud flat habitat at Impact (Penrhyn Estuary) and Reference (Georges River and Woolooware Bay) treatments before and after habitat enhancement. Letters indicate results of pair-wise comparisons (see Appendix A for details).

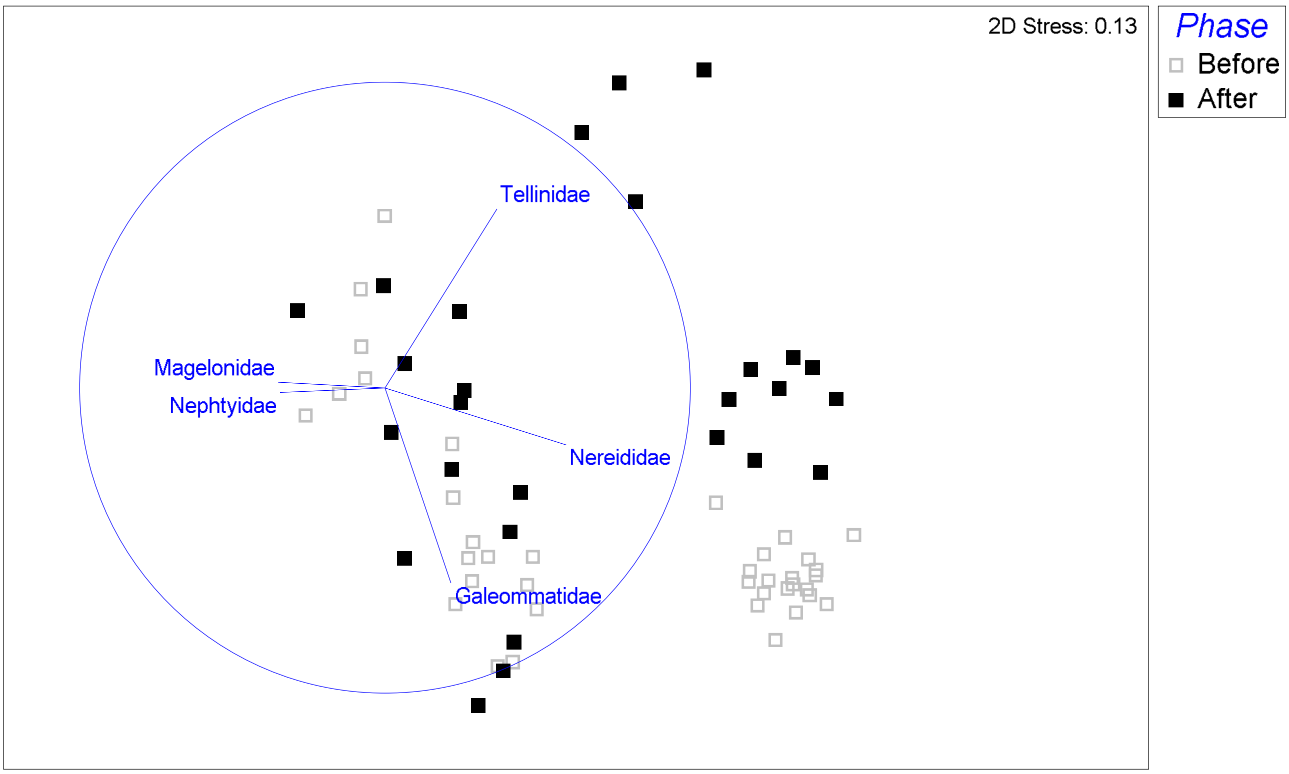

Figure 18 nMDS representing the macrobenthos assemblage of mud flat habitat at Impact (Penrhyn Estuary) and Reference (Georges River and Woolooware Bay). Points represent centroids of each site by survey combination. Vectors represent the multiple correlation coefficient between the nMDS axes and the abundance of each taxon. Only taxa with a multiple correlation coefficient of at least 0.35 were shown in the plot.

4.2.2 Particle Size Distribution

Median grain size at mud sites varied significantly between Treatments and among Surveys (**Figure 19**). MGS at Penrhyn Estuary was 0.32 ± 0.01 and was significantly higher compared to Reference locations, which had an overall mean value of 0.26 ± 0.01. Despite the general significant temporal variability among surveys, *post hoc* pair-wise comparisons indicated that there were no differences in any of the survey pair (**Appendix A; Table 10; Figure 10**).

There were no differences in the content of fines between Phases or Treatments, there were, however, significant differences between Reference locations. Specifically, fine sand content at Georges River (32.2 ± 2.5) was significantly higher than Woolooware Bay (9.8 ± 1.1). There was also a significant variability between sites that depended on the factor Survey (**Table 10**).

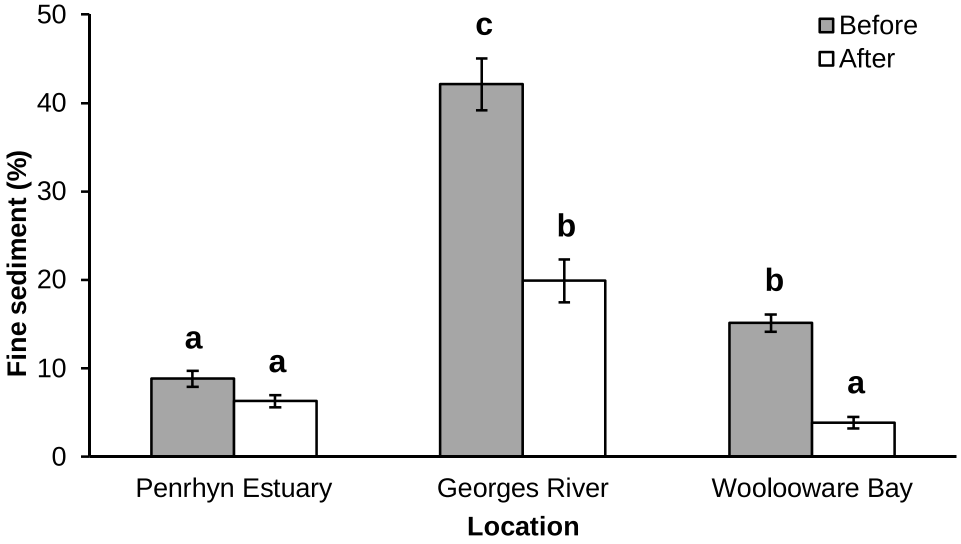

Figure 19 Mean (±SE) fine sediment content in mud flat habitat at Impact (Penrhyn Estuary) and Reference (Georges River and Woolooware Bay) treatments before and after habitat enhancement. Letters indicate results of pair-wise comparisons (see Appendix A for details).

4.3 Treated Sand Flats at Penrhyn Estuary

4.3.1 Macrobenthos

There were no significant differences in the abundance and biomass of macrobenthic invertebrates between before and after the treatment of the sand substratum in Penrhyn Estuary (**Table 15**). Most of the variability was observed at the smaller spatial and temporal scales (**Table 15**).

There were significant differences in the macrobenthic assemblage between Treatments and these differences were dependent on the survey considered (**Table 15**). *Post hoc* pair-wise comparisons indicated that assemblages differed significantly during Surveys 1 and 2 between Treated and Untreated sites but there were no differences during Survey 3 (**Appendix A**). Furthermore, the macrobenthic assemblage within each Treatment varied significantly among Surveys (**Appendix A**), in most cases with exception of Survey 2 and 3 in Treated sites (**Appendix A**). A higher abundance of gastropods of the family Naticidae and a lower abundance of nereidid polychaetes were partially responsible for the differences between Treated and Untreated sites. Bivalves of the Galeommatidae, Tellinidae and Mactridae families were also responsible for the general spatial variability across sites and these families were also more common in Untreated sites (**Figure 20**).

Table 15 Summary of PERMANOVA results for biological and physical indicators in treated and untreated sand flats at Penrhyn Estuary. NS = not significant, RED = redundant due to a significant interaction with another factor, * = p < 0.05, ** = p < 0.01 and *** = p < 0.001. See Appendix A for the complete analyses. for enhanced

Source	Abundance	Biomass	Assemblage	MGS	% Fines
Treatment	NS	NS	RED	RED	NS
Survey	RED	RED	RED	RED	RED
Site(Survey)	RED	RED	RED	*	RED
Treatment x Survey	NS	NS	*	*	NS
Survey x Site(Treatment)	***	***	***	NS	***

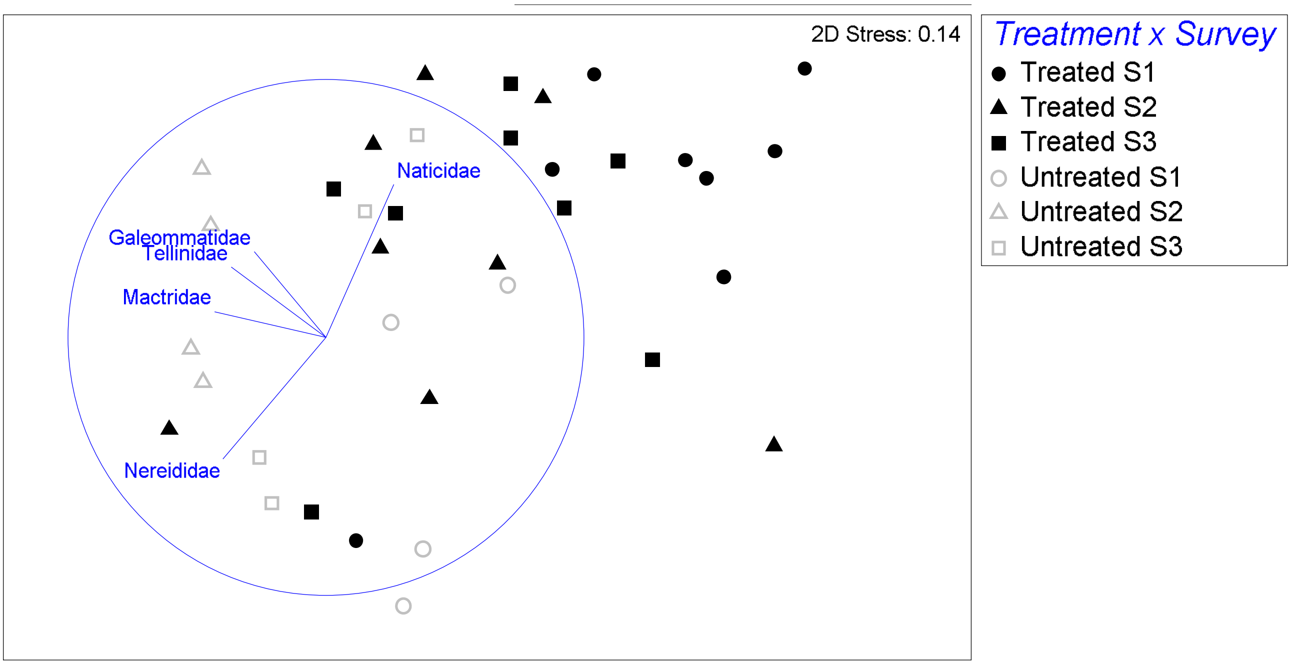

Figure 20 nMDS representing the macrobenthos assemblage of Treated and Untreated sand flat habitat at Penrhyn Estuary. Each point represents a sample. Vectors represent the multiple correlation coefficient between the nMDS axes and the abundance of each taxon. Only taxa with a multiple correlation coefficient of at least 0.35 were shown in the plot.

4.3.2 Particle Size Distribution

Differences in median grain size between treated and untreated sand at Penrhyn Estuary were dependent on the survey considered (**Table 15**). *Post hoc* pair-wise comparisons indicated that only on the first survey after habitat rehabilitation (i.e. March 2012), Treated sites had a lower MGS compared to Untreated sites (**Appendix A; Figure 12**).

There were no significant differences in the sediment content of fine sediment between before and after for the treated sand substrata in Penrhyn Estuary due to significant variability at the smaller spatial (i.e. among sites) and temporal (i.e. among survey) scales (**Table 15**).

4.4 Comparison to Targets

Physical and biological indicators suggest that habitat enhancement works done at Penrhyn Estuary were successful in improving and maintaining food resources for the resident and migratory avifauna (**Table 16**).

Median grain size in sand flats at Penrhyn Estuary decreased significantly after habitat enhancement and the average MGS was well below the value set as target (**Table 16**). There was also an increase in the fine sediment content which, although not significantly different from pre-enhancement levels, was evidence of the addition of mud and seagrass wrack and consistent with the desired outcome of increasing organic content to support greater invertebrate biomass (**Table 16**).

Macrobenthos biomass increased by about 66 % after the enhancement works (**Table 7**) and reached values well above the set target and was comparable with the average biomass supported by mud flat habitats. This increase in biomass, however, was accompanied by a decrease in the overall abundance of individuals (**Table 16**). The average number of individuals of 22.5 found after habitat enhancement is below the target value of 39 individuals per sample. This may be the consequence of changes in community composition, from smaller to larger and heavier animals. This hypothesis is supported by the significant differences between phases detected by multivariate analysis of the benthic assemblage (**Figure 14**), and the increase in the proportion of molluscs observed post-enhancement (**Figure 15**).

Table 16 Comparison of key indicators against target values after the first year of post-enhancement monitoring

Habitat	Sediment parameters		Biological indicators		
	MGS (mm)	**% Fine sediments (< 0.074 mm)**	**Macrobenthos biomass (g/sample)**	**Macrobenthos biomass (g/m^2)**	**Abundance (individuals/ core)**
Before					
Existing Sand flats in Reference sites	0.33 - 0.44	1.3 to 1.8 %	0.72	91.7	Av: 51.2 Min: 6.0 Max: 134.3
Pre-existing Mud flats in Penrhyn Estuary	0.31 - 0.33	3 to 7 %	0.98	124.8	Av: 72.0 Min: 18.0 Max: 157.7
After					
Created Sand flats in Penrhyn Estuary after habitat restoration (A1-A3 surveys)	Av: 0.24 Min: 0.18 Max: 0.34	Av: 5.2 % Min: 0.7 % Max: 14.3 %	Av: 1.08 Min: 0.11 Max: 6.56	Av: 137.9 Min: 13.6 Max: 834.8	Av: 22.5 Min: 1.3 Max: 70.7
Created Mud flats in Reference sites after habitat restoration (A1-A3 surveys)	Av: 0.19 Min: 0.18 Max: 0.29	Av: 2.6 % Min: 0.3 % Max: 6.3 %	Av: 0.89 Min: 0.01 Max: 11.01	Av: 113.8 Min: 1.6 Max: 1402.1	Av: 22.0 Min: 1.7 Max: 77.3
Target					
Long-term target for created Sand flats	0.31 - 0.33	2 to 4 %	≥ 0.7	89.1	Average ≥ 39
Change in comparison to pre-enhancement levels					
Created Sand flats in Penrhyn Estuary after habitat restoration (A1-A3 surveys)	↓	↑	↑	↑	↓
Outcome in relation to target levels					
Target met?	**YES**	**YES**	**YES**	**YES**	**NO**

5 Conclusions

Twenty seven months after completion of habitat enhancement benthic habitats in Penrhyn Estuary have either achieved the desired target values, suggesting they have capacity to sustainably produce food items for shorebirds, or are trending in the appropriate direction.

The addition of organic material in the form of mud and seagrass wrack to imported sand has resulted in an increase in the proportion of fine sediments to which organic material readily binds. While the overall abundance of invertebrates did not achieve target values, biomass exceeded targets, and the changing composition of the macroinvertebrate assemblage suggests that the sedimentary system has not yet reached equilibrium.

The enhancement works plan included the goal of minimal disturbance to the inner estuary, where birds were most abundant and feed in the more productive muddy sediments. While abundance of macroinvertebrates decreased in this area post-enhancement, it may have been sufficient to serve as a local source of propagules for the recolonisation of imported sediment. The relative protection afforded this area, together with the maintenance of tidal flow throughout the enhancement works period probably altered the starting conditions for recolonisation compared to other enhancement, habitat creation or habitat nourishment projects. The early stages of recolonisation of “new” benthic habitats in the few existing Australian examples (French *et al*. 2004) and many overseas examples (Atkinson *et al* 2001, Mazik *et al*. 2007) are characterised by high abundance of small invertebrates, typically polychaete worms, a pattern not observed here. The earliest stages of recolonisation in Penrhyn Estuary may not have been observed because the first “after” monitoring event was done 15 months after completion of the filling of the outer estuary, but it is more likely that that the patterns observed relate to the relatively advanced condition of the substrata, continuous tidal exchange and local source of propagules from the inner, muddy habitats.

Further surveys will verify that the observed trends are sustainable and if these relate to increased numbers of key shorebird species.

6 Recommendations

There are no recommended changes to the overall benthos monitoring program at this time.

7 Acknowledgements

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APPENDIX A
RESULTS OF STATISTICAL ANALYSIS

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Appendix A: Results of Statistical Analysis

A-1a: Results of PERMANOVA testing for differences in the abundance of macrobenthos in sand substratum. Significant factors in **bold** typeface.

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	1	5597	5597	0.83	0.6330
Phase	**1**	**51460**	**51460**	**5.67**	**0.0110**
Survey(Phase)	4	16674	4168	0.19	0.9937
Location(Treatment)	1	14033	14033	0.91	0.4614
Treatment x Phase	1	6404	6404	1.32	0.4002
Treatment x Survey(Phase)	4	60474	15119	0.61	0.7772
Phase x Location(Treatment)	1	5714	5714	0.41	0.9053
Site(Location(Treatment) x Phase)	24	19200	800	0.76	0.7675
Survey(Phase) x Location(Treatment)	**4**	**63217**	**15804**	**14.49**	**0.0001**
Survey(Phase) x Site(Location(Treatment)x Phase)**	**47**	**49724**	**1058**	**3.87**	**0.0001**
Res	429	117410	274		
Total	517	416640			

PAIR-WISE TESTS					
Term 'Survey(Phase)x Location(Treatment)' for pairs of levels of factor 'Location'					
Within level 'Before' of factor 'Phase'					
Within level 'Reference' of factor 'Treatment'					
Within level 'B1' of factor 'Survey'					
Groups	t	P(perm)	Unique perms	P(MC)	
Quibray North, Quibray South	0.50	0.6082	10	0.6428	
Within level 'Before' of factor 'Phase'					
Within level 'Reference' of factor 'Treatment'					
Within level 'B2' of factor 'Survey'					
Groups	t	P(perm)	Unique perms	P(MC)	
Quibray North, Quibray South	**6.01**	**0.1013**	**10**	**0.0044**	
Within level 'Before' of factor 'Phase'					
Within level 'Reference' of factor 'Treatment'					
Within level 'B3' of factor 'Survey'					
Groups	t	P(perm)	Unique perms	P(MC)	
Quibray North, Quibray South	1.81	0.1024	9	0.1473	
Within level 'After' of factor 'Phase'					
Within level 'Reference' of factor 'Treatment'					
Within level 'A1' of factor 'Survey'					
Groups	t	P(perm)	Unique perms	P(MC)	

Quibray North, Quibray South	3.91	0.0994	10	0.0186

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	5.70	0.1004	10	0.0051

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'A3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	1.31	0.5092	10	0.2624

Term 'Survey(Phase)x Location(Treatment)' for pairs of levels of factor 'Survey'				
Within level 'Before' of factor 'Phase'				
Within level 'Impact' of factor 'Treatment'				
Within level 'Penrhyn Estuary' of factor 'Location'				
Groups	t	P(perm)	perms	P(MC)
B1, B2	3.98	0.0101	9875	0.0093
B1, B3	1.04	0.3769	9804	0.3613
B2, B3	4.90	0.0134	9769	0.0079

Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray North' of factor 'Location'				
Groups	t	P(perm)	perms	P(MC)
B1, B2	0.48	0.6103	60	0.6710
B1, B3	0.72	0.6911	60	0.5506
B2, B3	0.64	0.7695	60	0.5926

Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray South' of factor 'Location'				
Groups	t	P(perm)	perms	P(MC)
B1, B2	4.24	0.1024	60	0.0488
B1, B3	3.01	0.1307	60	0.0955
B2, B3	6.91	0.0965	60	0.0204

Within level 'After' of factor 'Phase'
Within level 'Impact' of factor 'Treatment'
Within level 'Penrhyn Estuary' of factor 'Location'

Groups	t	P(perm)	perms	P(MC)
A1, A2	3.00	0.0042	9877	0.0112
A1, A3	4.25	0.0012	9848	0.0010
A2, A3	0.63	0.5635	9853	0.5446

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray North' of factor 'Location'				
Groups	t	P(perm)	perms	P(MC)
A1, A2	0.37	0.7626	30	0.7460
A1, A3	0.91	0.4370	60	0.4569
A2, A3	0.34	0.7870	60	0.7669

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray South' of factor 'Location'				
Groups	t	P(perm)	perms	P(MC)
A1, A2	5.14	0.0528	60	0.0330
A1, A3	2.71	0.1782	55	0.1208
A2, A3	4.81	0.0673	60	0.0398

A-1b: Macrobenthos wet biomass in sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	10.9	10.9	2.35	0.1225
Treatment	1	1.1	1.1	1.09	0.4621
Survey(Phase)	4	29.4	7.3	0.96	0.5912
Location(Treatment)	1	0.8	0.8	0.51	0.8596
Phase x Treatment	1	0.6	0.6	1.16	0.4330
Phase x Location(Treatment)	1	0.0	0.0	0.45	0.8965
Treatment x Survey(Phase)	4	37.3	9.3	1.14	0.5237
Site(Location(Treatment)x Phase)	24	128.0	5.3	1.01	0.4425
Survey(Phase) x Location(Treatment)	4	28.0	7.0	1.29	0.3044
Survey(Phase) x Site(Location(Treatment) x Phase)	**45**	**240.5**	**5.3**	**2.60**	**0.0001**
Res	421	865.8	2.1		
Total	507	1369.9			

A-1c: Macrobenthos assemblage in sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	74193	74193	1.9988	0.0572
Treatment	**1**	**56115**	**56115**	**2.7732**	**0.0049**
Survey(Phase)	4	93408	23352	1.3664	0.2163
Location(Treatment)	1	7903.6	7903.6	0.56919	0.9648
Phase x Treatment	1	34424	34424	1.397	0.2096
Phase x Location(Treatment)	1	15819	15819	0.99707	0.4579
Treatment x Survey(Phase)	4	60380	15095	0.91779	0.6287
Site(Location(Treatment)x Phase)	**24**	**1.67E+05**	**6978.3**	**2.7847**	**0.0001**
Survey(Phase) x Location(Treatment)	**4**	**44745**	**11186**	**4.3185**	**0.0001**
Survey(Phase) x Site(Location(Treatment) x Phase)	**47**	**1.18E+05**	**2516.6**	**3.4564**	**0.0001**
Res	429	3.12E+05	728.1		
Total	517	1.00E+06			

PAIR-WISE TESTS				
Term 'Survey(Phase)x Location(Treatment)' for pairs of levels of factor 'Location'				
Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	1.985	0.0993	10	0.0097
Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'B2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	2.4235	0.0992	10	0.0029
Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	2.2252	0.0978	10	0.0082
Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	2.3305	0.0999	10	0.0044
Within level 'After' of factor 'Phase'				

Within level 'Reference' of factor 'Treatment'				
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	1.9414	0.0961	10	0.0176

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'A3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray North, Quibray South	1.4873	0.0992	10	0.0734

Term 'Survey(Phase)x Location(Treatment)' for pairs of levels of factor 'Survey'				
Within level 'Before' of factor 'Phase'				
Within level 'Impact' of factor 'Treatment'				
Within level 'Penrhyn Estuary' of factor 'Location'				
Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	1.9182	0.0803	9744	0.0185
B1, B3	1.3929	0.1688	9877	0.1323
B2, B3	1.8572	0.1044	9862	0.0378

Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray North' of factor 'Location'				
Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	2.8282	0.1011	38	0.0073
B1, B3	1.7931	0.189	38	0.0671
B2, B3	2.7239	0.1038	38	0.009

Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray South' of factor 'Location'				
Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	3.0288	0.0929	38	0.003
B1, B3	2.4714	0.0988	38	0.0107
B2, B3	3.1387	0.1003	38	0.0036

Within level 'After' of factor 'Phase'				
Within level 'Impact' of factor 'Treatment'				
Within level 'Penrhyn Estuary' of factor 'Location'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	3.1683	0.0002	9950	0.0001
A1, A3	2.6909	0.0005	9941	0.0001

A2, A3	1.5074	0.0471	9948	0.0511

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray North' of factor 'Location'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	1.8059	0.1669	38	0.0481
A1, A3	0.9584	0.4042	38	0.5054
A2, A3	1.9988	0.1444	38	0.0316

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'Quibray South' of factor 'Location'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	4.9206	0.1009	38	0.0043
A1, A3	4.6145	0.1005	38	0.0024
A2, A3	4.6238	0.097	38	0.004

A-1d: Median grain size in sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	0.155	0.155	2.43	0.1650
Treatment	1	0.133	0.133	89.45	0.0001
Survey(Phase)	4	0.150	0.038	19.95	0.0068
Location(Treatment)	1	0.000	0.000	0.26	0.9857
Phase x Treatment	1	0.004	0.004	0.26	0.9364
Phase x Location(Treatment)	**1**	**0.023**	**0.023**	**3.07**	**0.0488**
Treatment x Survey(Phase)	4	0.001	0.000	0.60	0.7565
Site(Location(Treatment)x Phase)	**21**	**0.143**	**0.007**	**3.90**	**0.0003**
Survey(Phase) x Location(Treatment)	4	0.005	0.001	0.74	0.5742
Survey(Phase) x Site(Location(Treatment) x Phase)	**41**	**0.072**	**0.002**	**3.49**	**0.0001**
Res	80	0.040	0.000		
Total	159	0.667			

PAIR-WISE TESTS			
Term 'Phase x Location(Treatment)' for pairs of levels of factor 'Location'			
Within level 'Before' of factor 'Phase'			
Within level 'Reference' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Quibray North, Quibray South	1.08	0.3939	9908

Within level 'After' of factor 'Phase'

Within level 'Reference' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Quibray North, Quibray South	1.03	0.4459	9878

Term 'Phase x Location(Treatment)' for pairs of levels of factor 'Phase'			
Within level 'Impact' of factor 'Treatment'			
Within level 'Penrhyn Estuary' of factor 'Location'			
Groups	t	P(perm)	Unique perms
Before, After	**2.03**	**0.0326**	**9944**

Within level 'Reference' of factor 'Treatment'			
Within level 'Quibray North' of factor 'Location'			
Groups	t	P(perm)	Unique perms
Before, After	0.58	0.8861	8762

Within level 'Reference' of factor 'Treatment'			
Within level 'Quibray South' of factor 'Location'			
Groups	t	P(perm)	Unique perms
Before, After	2.01	0.0508	9848

A-1e: Fine sediment content in sand substratum.

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	87.0	87.0	0.25	0.9499
Treatment	1	151.4	151.4	1.22	0.4193
Survey(Phase)	4	201.2	50.3	1.03	0.5369
Location(Treatment)	1	130.7	130.7	0.97	0.4278
Phase x Treatment	1	594.0	594.0	1.02	0.5043
Phase x Location(Treatment)	**1**	**485.7**	**485.7**	**3.30**	**0.0288**
Treatment x Survey(Phase)	4	71.9	18.0	0.46	0.8533
Site(Location(Treatment)x Phase)	**21**	**2358.8**	**112.3**	**6.64**	**0.0001**
Survey(Phase)x Location(Treatment)	4	153.2	38.3	2.26	0.0879
Survey(Phase)x Site(Location(Treatment)x Phase)**	**41**	**693.6**	**16.9**	**4.16**	**0.0001**
Res	80	325.5	4.1		
Total	159	5237.7			

PAIR-WISE TESTS			
Term 'Phase x Location(Treatment)' for pairs of levels of factor 'Location'			
Within level 'Before' of factor 'Phase'			
Within level 'Reference' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Quibray North, Quibray South	0.99	0.4664	9919

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	
Quibray North, Quibray South	1.10	0.3744	9956	0.3222

Term 'Phase x Location(Treatment)' for pairs of levels of factor 'Phase'			
Within level 'Impact' of factor 'Treatment'			
Within level 'Penrhyn Estuary' of factor 'Location'			
Groups	t	P(perm)	Unique perms
Before, After	1.54	0.1055	9947

Within level 'Reference' of factor 'Treatment'			
Within level 'Quibray North' of factor 'Location'			
Groups	t	P(perm)	Unique perms
Before, After	0.40	0.9862	7830

Within level 'Reference' of factor 'Treatment'			
Within level 'Quibray South' of factor 'Location'			
Groups	t	P(perm)	Unique perms
Before, After	1.56	0.1138	9794

A-2a: Macrobenthos abundance in mud substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	**1**	**24934**	**24934**	**4.58**	**0.0476**
Treatment	1	49662	49662	1.87	0.2656
Survey(Phase)	4	22001	5500	4.22	0.0956
Location(Treatment)	**1**	**21301**	**21301**	**5.56**	**0.0081**
Phase x Treatment	**1**	**17696**	**17696**	**5.98**	**0.0281**
Phase x Location(Treatment)	1	256	256	0.30	0.9653
Treatment x Survey(Phase)	4	11350	2838	2.26	0.2255
Site(Location(Treatment) x Phase)	**16**	**42010**	**2626**	**3.01**	**0.0051**
Survey(Phase) x Location(Treatment)	4	4486	1122	1.22	0.3276
Survey(Phase) x Site(Location(Treatment) x Phase)**	**31**	**27196**	**877**	**2.73**	**0.0001**
Res	303	97441	322		
Total	367	358870			

PAIR-WISE TESTS			
Term 'Phase x Treatment' for pairs of levels of factor 'Phase'			
Within level 'Impact' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms

Before, After	1.80	0.0557	9954

Within level 'Reference' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Before, After	0.92	0.5562	9949

Term 'Phase x Treatment' for pairs of levels of factor 'Treatment'			
Within level 'Before' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Impact, Reference	1.88	0.0983	9967

Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Impact, Reference	0.72	0.6962	8513

A-2b: Macrobenthos wet weight biomass in mud substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	14.1	14.1	1.76	0.2702
Treatment	**1**	**57.0**	**57.0**	**12.27**	**0.0021**
Survey(Phase)	**4**	**31.7**	**7.9**	**60.09**	**0.0011**
Location(Treatment)	1	0.0	0.0	1.01	0.4300
Phase x Treatment	**1**	**21.6**	**21.6**	**4.68**	**0.0450**
Phase x Location(Treatment)	1	0.1	0.1	1.03	0.4082
Treatment x Survey(Phase)	**4**	**16.6**	**4.2**	**33.77**	**0.0039**
Site(Location(Treatment)x Phase)	16	38.1	2.4	0.97	0.4911
Survey(Phase) x Location(Treatment)	4	0.2	0.0	0.05	0.9922
Survey(Phase) x Site(Location(Treatment)x Phase)	**31**	**76.1**	**2.5**	**2.10**	**0.0041**
Res	301	351.6	1.2		
Total	365	595.4			

PAIR-WISE TESTS			
Term 'Treatment x Survey(Phase)' for pairs of levels of factor 'Treatment'			
Within level 'Before' of factor 'Phase'			
Within level 'B1' of factor 'Survey'			
Groups	t	P(perm)	Unique perms
Impact, Reference	3.91	0.2518	9886

Within level 'Before' of factor 'Phase'			
Within level 'B2' of factor 'Survey'			
Groups	t	P(perm)	Unique perms
Impact, Reference	1.67	0.4072	9903

Within level 'Before' of factor 'Phase'				
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Impact, Reference	6.14	0.1221	9728	

Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Impact, Reference	**40.38**	**0.3346**	**3**	**0.0138**

Within level 'After' of factor 'Phase'				
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Impact, Reference	**74.96**	**0.3322**	**3**	**0.0092**

Within level 'After' of factor 'Phase'				
Within level 'A3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Impact, Reference	**24.24**	**0.3302**	**3**	**0.0053**

Term 'Treatment x Survey(Phase)' for pairs of levels of factor 'Survey'				
Within level 'Before' of factor 'Phase'				
Within level 'Impact' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	1.45	0.2626	9810	
B1, B3	1.44	0.2526	9850	
B2, B3	0.14	0.8879	9816	

Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	3.09	0.3351	6	0.1953
B1, B3	5.46	0.3289	6	0.1219
B2, B3	7.49	0.1692	6	0.0850

Within level 'After' of factor 'Phase'				
Within level 'Impact' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	2.61	0.1818	60	0.1200
A1, A3	1.05	0.4546	180	
A2, A3	2.56	0.1599	180	

Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	0.77	0.6627	6	0.5793
A1, A3	**61.09**	**0.0001**	**6**	**0.0101**
A2, A3	3.21	0.1664	6	0.1930

Term 'Phase x Treatment' for pairs of levels of factor 'Treatment'			
Within level 'Before' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Impact, Reference	1.20	0.2925	9951

Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Impact, Reference	**3.45**	**0.0469**	**9422**

Term 'Phase x Treatment' for pairs of levels of factor 'Phase'			
Within level 'Impact' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Before, After	1.56	0.0972	9948

Within level 'Reference' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Before, After	0.83	0.6286	9951

A-2c: Macrobenthos assemblage in mud substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	45927	45927	3.42	0.0199
Treatment	1	140150	140150	2.46	0.1210
Survey(Phase)	4	35716	8929	1.49	0.1775
Location(Treatment)	1	45965	45965	6.18	0.0002
Phase x Treatment	1	9446	9446	1.21	0.3418
Phase x Location(Treatment)	1	5572	5572	0.88	0.6158
Treatment x Survey(Phase)	4	26765	6691	1.13	0.3951
Site(Location(Treatment) x Phase)	16	35721	2233	2.20	0.0001
Survey(Phase) x Location(Treatment)	4	20662	5166	4.76	0.0001
Survey(Phase) x Site(Location(Treatment) x Phase)	31	31622	1020	2.14	0.0001
Res	303	144530	477		
Total	367	573520			

PAIR-WISE TESTS				
Term 'Survey(Phase) x Location(Treatment)' for pairs of levels of factor 'Location'				
Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Georges River	**3.54**	**0.1045**	**10**	**0.0003**
Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'B2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Georges River	**2.25**	**0.0960**	**10**	**0.0091**
Within level 'Before' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Georges River	**2.17**	**0.1006**	**10**	**0.0240**
Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Georges River	**4.61**	**0.0993**	**10**	**0.0003**
Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Georges River	1.74	0.3050	10	0.0686
Within level 'After' of factor 'Phase'				
Within level 'Reference' of factor 'Treatment'				
Within level 'A3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Georges River	**2.32**	**0.0979**	**10**	**0.0055**
Term 'Survey(Phase) x Location(Treatment)' for pairs of levels of factor 'Survey'				
Within level 'Before' of factor 'Phase'				
Within level 'Impact' of factor 'Treatment'				
Within level 'Penrhyn Estuary' of factor 'Location'				

Groups	t	P(perm)	Unique perms
B1, B2	1.96	0.0236	9963
B1, B3	1.72	0.0485	9935
B2, B3	1.30	0.1936	9935

Within level 'Before' of factor 'Phase'
Within level 'Reference' of factor 'Treatment'
Within level 'Woolooware Bay' of factor 'Location'

Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	0.68	0.6641	38	0.7680
B1, B3	1.56	0.1675	38	0.1447
B2, B3	1.98	0.0996	38	0.0570

Within level 'Before' of factor 'Phase'
Within level 'Reference' of factor 'Treatment'
Within level 'Georges River' of factor 'Location'

Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	1.20	0.2992	38	0.2789
B1, B3	**2.74**	**0.0983**	**38**	**0.0174**
B2, B3	**5.00**	**0.1018**	**38**	**0.0022**

Within level 'After' of factor 'Phase'
Within level 'Impact' of factor 'Treatment'
Within level 'Penrhyn Estuary' of factor 'Location'

Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	**2.34**	**0.0995**	**38**	**0.0245**
A1, A3	1.49	0.2323	38	0.1605
A2, A3	1.77	0.1716	38	0.0802

Within level 'After' of factor 'Phase'
Within level 'Reference' of factor 'Treatment'
Within level 'Woolooware Bay' of factor 'Location'

Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	**8.81**	**0.0665**	**38**	**0.0022**
A1, A3	**4.25**	**0.0972**	**38**	**0.0032**
A2, A3	**5.23**	**0.1036**	**38**	**0.0042**

Within level 'After' of factor 'Phase'
Within level 'Reference' of factor 'Treatment'
Within level 'Georges River' of factor 'Location'

Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	**2.33**	**0.0950**	**38**	**0.0326**

A1, A3	**1.92**	**0.1037**	**38**	**0.0441**
A2, A3	**2.07**	**0.1016**	**38**	**0.0499**

A-2d: Median grain size in mud substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	0.1288	0.1288	5.52	0.0595
Treatment	**1**	**0.0732**	**0.0732**	**20.90**	**0.0056**
Survey(Phase)	**4**	**0.0932**	**0.0233**	**24.41**	**0.0042**
Location(Treatment)	1	0.0031	0.0031	1.18	0.3276
Phase x Treatment	1	0.0002	0.0002	1.77	0.2940
Phase x Location(Treatment)	1	0.0002	0.0002	0.21	0.9914
Treatment x Survey(Phase)	4	0.0016	0.0004	0.43	0.7858
Site(Location(Treatment)xPhase)	**12**	**0.0246**	**0.0021**	**5.07**	**0.0002**
Survey(Phase) x Location(Treatment)	4	0.0038	0.0010	2.36	0.0820
Survey(Phase) x Site(Location(Treatment) x Phase)	24	0.0097	0.0004	1.03	0.4484
Res	54	0.0213	0.0004		
Total	107	0.3918			

PAIR-WISE TESTS				
Term 'Survey(Phase)'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	10.83	0.0525	177	
A1, A3	1.73	0.3212	42	0.3340
A2, A3	6.12	0.1233	168	
Within level 'Before' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	0.33	0.7671	171	0.7993
B1, B3	0.58	0.7029	145	0.6657
B2, B3	0.29	0.8030	148	0.8240

A-2e: Fine sediment content in mud substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Phase	1	1902.2	1902.2	4.26	0.0975
Treatment	1	4329.1	4329.1	0.48	0.7469
Survey(Phase)	4	251.9	63.0	4.33	0.0942
Location(Treatment)	**1**	**9000.3**	**9000.3**	**46.01**	**0.0001**
Phase x Treatment	1	966.9	966.9	2.37	0.2220
Phase x Location(Treatment)	**1**	**387.4**	**387.4**	**2.38**	**0.0884**

Treatment x Survey(Phase)	4	108.1	27.0	1.86	0.2892
Site(Location(Treatment)x Phase)	**12**	**2194.4**	**182.9**	**2.21**	**0.0497**
Survey(Phase)x Location(Treatment)	4	58.2	14.6	0.18	0.9480
Survey(Phase)x Site(Location(Treatment)x Phase)	**24**	**1985.2**	**82.7**	**6.27**	**0.0001**
Res	54	712.5	13.2		
Total	107	23363.0			
PAIR-WISE TESTS					
Term 'Phase x Location(Treatment)' for pairs of levels of factor 'Location'					
Within level 'After' of factor 'Phase'					
Within level 'Reference' of factor 'Treatment'					
Groups	t	P(perm)	Unique perms		
Georges River, Woolooware Bay	**3.818**	**0.0040**	**9943**		
Within level 'Before' of factor 'Phase'					
Within level 'Reference' of factor 'Treatment'					
Groups	t	P(perm)	Unique perms		
Georges River, Woolooware Bay	**4.303**	**0.0021**	**9967**		
Term 'Phase x Location(Treatment)' for pairs of levels of factor 'Phase'					
Within level 'Reference' of factor 'Treatment'					
Within level 'Georges River' of factor 'Location'					
Groups	t	P(perm)	Unique perms		
After, Before	**2.863**	**0.0077**	**9932**		
Within level 'Reference' of factor 'Treatment'					
Within level 'Woolooware Bay' of factor 'Location'					
Groups	t	P(perm)	Unique perms		
After, Before	**3.981**	**0.0013**	**9620**		
Within level 'Impact' of factor 'Treatment'					
Within level 'Penrhyn Estuary' of factor 'Location'					
Groups	t	P(perm)	Unique perms		
After, Before	1.553	0.1230	6607		

A-3a: Macrobenthos abundance in Penrhyn Estuary amended sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	1	113.1	113.1	0.53	0.7847
Survey	**2**	**7624.6**	**3812.3**	**6.15**	**0.0086**
Site(Treatment)	10	12848.0	1284.8	2.07	0.0673
Treatment x Survey	2	214.9	107.5	0.17	0.8464
Survey x Site(Treatment)	**20**	**12389.0**	**619.5**	**7.11**	**0.0001**
Res	180	15684.0	87.1		
Total	215	49156.0			

PAIR-WISE TESTS			
Term 'Survey'			
Groups	t	P(perm)	Unique perms
A1, A2	2.88	0.0074	9884
A1, A3	3.84	0.0038	9837
A2, A3	0.72	0.5047	9852

A-3b: Macrobenthos wet weight biomass in Penrhyn Estuary amended sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	1	8.3	8.3	1.34	0.3000
Survey	**2**	**70.1**	**35.0**	**4.29**	**0.0191**
Site(Treatment)	10	76.3	7.6	0.94	0.5010
Treatment x Survey	2	9.1	4.6	0.56	0.6051
Survey x Site(Treatment)	**20**	**162.7**	**8.1**	**8.24**	**0.0001**
Res	178	175.7	1.0		
Total	213	498.6			

PAIR-WISE TESTS			
Term 'Survey'			
Groups	t	P(perm)	Unique perms
A1, A2	2.23	0.0411	9851
A1, A3	2.64	0.0087	9891
A2, A3	1.44	0.1736	9862

A-3c: Macrobenthos assemblage in Penrhyn estuary amended sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	**1**	**30609**	**30609**	**2.62**	**0.0208**
Survey	**2**	**29756**	**14878**	**7.12**	**0.0001**
Site(Treatment)	**10**	**76751**	**7675**	**3.67**	**0.0001**
Treatment x Survey	**2**	**9604**	**4802**	**2.30**	**0.0114**

Survey x Site(Treatment)	**20**	**41772**	**2089**	**3.07**	**0.0001**
Res	180	122520	681		
Total	215	312400			

PAIR-WISE TESTS			
Term 'Treatment x Survey' for pairs of levels of factor 'Treatment'			
Within level 'A1' of factor 'Survey'			
Groups	t	P(perm)	Unique perms
Untreated, Treated	**2.28**	**0.0187**	**495**
Within level 'A2' of factor 'Survey'			
Groups	t	P(perm)	Unique perms
Untreated, Treated	**1.82**	**0.0241**	**495**
Within level 'A3' of factor 'Survey'			
Groups	t	P(perm)	Unique perms
Untreated, Treated	1.38	0.1294	494
Term 'Treatment x Survey' for pairs of levels of factor 'Survey'			
Within level 'Untreated' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
A1, A2	**4.04**	**0.0332**	**424**
A1, A3	**2.38**	**0.0296**	**425**
A2, A3	**1.88**	**0.0486**	**425**
Within level 'Treated' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
A1, A2	**2.57**	**0.0052**	**9903**
A1, A3	**2.50**	**0.0042**	**9897**
A2, A3	1.01	0.4098	9890

A-3d: Median grain size in Penrhyn Estuary amended sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	1	0.002	0.002	0.29	0.9479
Survey	**2**	**0.092**	**0.046**	**24.41**	**0.0001**
Site(Treatment)	**10**	**0.058**	**0.006**	**3.12**	**0.0180**
Treatment x Survey	**2**	**0.015**	**0.007**	**3.93**	**0.0379**
Survey x Site(Treatment)	19	0.036	0.002	1.88	0.0502
Res	35	0.035	0.001		
Total	69	0.251			

PAIR-WISE TESTS				
Term 'Treatment x Survey' for pairs of levels of factor 'Treatment'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Untreated, Treated	**2.42**	**0.0483**	**10**	**0.0345**
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Untreated, Treated	0.77	0.4803	80	0.4614
Within level 'A3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Untreated, Treated	0.15	1.0000	11	0.8829
Term 'Treatment x Survey' for pairs of levels of factor 'Survey'				
Within level 'Untreated' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	1.57	0.2003	407	
A1, A3	1.10	0.3316	21	0.3610
A2, A3	3.99	0.0332	805	
Within level 'Treated' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	19.60	0.0001	9701	
A1, A3	0.55	0.5919	59	0.5947
A2, A3	7.40	0.0007	9697	

A-3e: Fine sediment content in Penrhyn Estuary amended sand substratum

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	1	82.394	82.394	1.0969	0.4095
Survey	2	50.191	25.096	1.082	0.3558
Site(Treatment)	10	450.42	45.042	1.9419	0.1089
Treatment x Survey	2	101.97	50.986	2.1982	0.1412
Survey x Site(Treatment)**	**19**	**440.69**	**23.194**	**5.8827**	**0.0001**
Res	35	138	3.9429		
Total	69	1255.1			

Port Botany Post Construction Monitoring
Annual Report 2013

APPENDIX C
SALTMARSH ANNUAL MONITORING REPORT 2013

Port Botany Post Construction Environmental Monitoring

Saltmarsh Annual Report 2013

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Prepared for Sydney Ports Corporation

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Shaping the Future

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Executive Summary

This report summarises the finding of the Saltmarsh Monitoring Program from March 2012 date to March 2013.

As part of the Port Botany Expansion Project, Sydney Ports has rehabilitated Penrhyn Estuary, which is located adjacent to the port expansion. Penrhyn Estuary is a small waterway of approximately 80 ha located to the north of Brotherson Dock, which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978 and utilised by a diverse group of migratory birds. The purpose of the rehabilitation works was to enhance the existing intertidal habitat and to expand the estuary as a long term habitat for migratory shorebirds. This involved the removal of mangroves, weeds and introduced species, the enhancement of existing saltmarsh and the creation of new saltmarsh habitat within the estuary. As part of the Penrhyn Estuary Habitat Enhancement Plan (PEHEP), a Saltmarsh Monitoring Plan was developed to examine the effect of the rehabilitation works done within Penrhyn Estuary and aimed to determine if saltmarsh habitat has been affected by port construction and if mitigation efforts and habitat creation have been successful. This was done by monitoring various indicators of vegetative growth and health condition, as well as saltmarsh ecological function (via epifaunal assemblages) and mangrove management using a BACI (Before-After Control-Impact) approach.

Results indicated that species diversity and abundance generally increased following the rehabilitation works within Penrhyn Estuary and saltmarsh vegetation was in better condition compared to that present prior to the works. Importantly, the distribution and abundance of newly planted saltmarsh vegetation along the northern and southern shorelines successively grew during post-rehabilitation surveys. It appeared that areas that were recipient of transplanted saltmarsh did not increase in cover or diversity, although these areas have appeared to maintain these vegetative indictors since baseline data was collected. The ecological functioning of many of the saltmarsh areas within the estuary have decreased slightly from baseline conditions following the rehabilitation works, with epifaunal assemblages generally slightly lower in diversity and abundance, although a successive increase was observed throughout the two post-rehabilitation surveys done to date. This suggests that epifaunal assemblages are recolonising areas that have been disturbed during the rehabilitation works and are also recruiting into newly planted areas of saltmarsh vegetation. Importantly, monitoring has shown that mangroves were not present within the estuary following the rehabilitation works, verifying the success of mangrove management implemented within the estuary.

In general, the majority of ecological targets set with respect to the saltmarsh vegetation with Penrhyn Estuary were met, although a number of areas did not respond as expected. These included areas that were transplanted with saltmarsh vegetation and areas that were cleared of mangroves and weeds. Notwithstanding this, both of these treatments generally maintained values similar to baseline values.

It is recommended that the monitoring program that is currently underway be continued unchanged for the next round of surveys. The monitoring plan that has been established for the saltmarshes within Penrhyn Estuary has so far been able to fulfil its aims and objectives and it is important to maintain consistency when collecting data for these sorts of programs.

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Appendices

1 Introduction

1.1 Background

As part of the Port Botany Expansion Project, Sydney Ports has rehabilitated Penrhyn Estuary, which is located adjacent to the port expansion. Penrhyn Estuary is a small waterway of approximately 30 ha located to the north of Brotherson Dock, which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978. Since its creation, it has been utilised by a diverse group of migratory birds. The purpose of the rehabilitation works was to enhance the existing intertidal habitat and to expand the estuary as a long term habitat for migratory shorebirds. This involved the removal of mangroves, weeds and introduced species, the enhancement of existing saltmarsh and the creation of new saltmarsh habitat. An extensive area of fore dune was also levelled to create an intertidal feeding and roosting habitat for key species of migratory shorebirds that currently use the estuary, and to potentially attract a greater number of shorebirds upon completion. The design, methodology and ongoing maintenance for the estuary are outlined within the Penrhyn Estuary Habitat Enhancement Plan (PEHEP).

As part of the Port Botany Expansion Project, extensive dredging and modifications have altered the saltmarsh habitat within Penrhyn Estuary. **Table 1** provides a timeline of important dates for the rehabilitation works within Penrhyn Estuary. Prior to habitat enhancement, approximately 1.5 ha of saltmarsh was present in Penrhyn Estuary, a relatively small proportion of the 736 ha present within Botany Bay. Habitat enhancement works has created an additional 2.4 ha of saltmarsh habitat, mostly along the northern boundary of the estuary and adjacent to the expanded port facility (**Figure 1**). This involved the removal of degraded foreshore dunes and weeds, surface levelling and contouring, and addition of organic material to the surface soil layers. New habitats were planted, with local saltmarsh species selected to maximise habitat for shorebird roosting. Additional works removed mangroves, weeds and introduced species from existing saltmarsh communities and adjacent areas. As Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions is listed as an Endangered Ecological Community in Part 3 of Schedule 1 of the *Threatened Species Conservation Act 1995* (TSC Act), existing areas of saltmarsh located within the modification footprint were removed and transplanted to areas within Penrhyn Estuary outside of the footprint as part of the PEHEP. Saltmarsh habitat creation, new plantings and weed removal were undertaken in accordance with the Saltmarsh & Mangrove Management Sub-Plan for “Design & Construction of Port Botany Expansion” on behalf of Sydney Ports Corporation. This plan included the implementation of appropriate mitigation measures and monitored the status of the created and altered saltmarsh habitat during the construction period.

Various monitoring plans were developed as part of the PEHEP to examine the effect of the rehabilitation works done within Penrhyn Estuary on various environmental aspects such as water quality, seagrasses, intertidal benthos, birds and saltmarsh, which is the subject of this report. The Saltmarsh Monitoring Plan relates to both the Water Quality Monitoring Plan and the Bird Monitoring Plan within the PEHEP. The Water Quality Plan has partly focused on providing adequate flushing of the rehabilitated area in the channel of Penrhyn estuary to support saltmarsh rehabilitation, whilst the Bird monitoring Plan aimed to identify and monitor areas within the Estuary used by shorebirds for roosting, including areas of saltmarsh.

Table 1 Timeline of key activities important dates for enhancement works within Penrhyn Estuary

Key Dates	Key Estuary Works and Activities
January 2008	• Contract Signed with BHJDN.
January 2008 - June 2008	• Saltmarsh seed collection, transplanting, commencement of propogation in nurseries. • Construction compound site established.
June 2008	• Overall Project Physical Starts
June 2008 - August 2008	• Site establishment. • Silt curtains installed. • Turbidity monitoring buoys installed. • Existing navigation aids relocated. • Removal of sand from sand dunes behind estuary and relocated to channel wall. • Water quality monitoring commenced.
September 2008 - November 2008	• Construction of concrete batch plant. • Formwork for caisson and infill blocks. • Counterfort formwork fabrication off-site. • Vibratory piling for temporary wharf.
August 2008 - March 2009 *(1st Exclusion Period - Shorebirds)*	• Excavation, transfer and re-contouring of estuary (including formation of main roosting island) from sand dune behind shorebird exclusion zone to the back of the island. • Hand removal of mangroves. • Saltmarsh transplantation from D to TA. • No work permitted in estuary exclusion zones other than transplanting and mangrove removal.
September 2008 - November 2008	• Dredging with CSD 'NU Bounty' from 19th September. • Reclamation of pre-cast yard. • Water quality monitoring.
December 2008 - February 2009	• Dredging with CSD 'NU Bounty' to 21st February. • Reclamation of pre-cast yard and berm. • Construction of pre-cast yard, including water treatment plant. • Casting of caisson and infill blocks. • Counterfort formwork fabrication off-site. • Mobilsation of CSD 'Leonardo Da Vinci' and spreader pontoon 'DN10'. • Dredging with CSD 'Leonardo Da Vinci' and spreader pontoon 'DN10' from 27th February. • Bulk reclamation. • Water quality monitoring.
March 2009 - August 2009	• Operation of concrete batch plant. • Operation of pre-cast yard including water treatment plant. • Establishment of counterfort formwork on-site. • Casting of counterfort components. • Sand stockpiled between the old historic wharf piles and old boat ramp ready for filling the outer estuary, was exposed tidal circulation. • Dredging with CSD 'Leonardo Da Vinci' and spreader pontoon 'DN10' to 15th April. • Bulk reclamation. • Filling and re-contouring the central section of the estuary (April-June). • July 2009 - Filamentous algal bloom through to September 2009. Geoff Sainty (writer). • July 2009 - Barrier 80 000m^3. • Mobilisation of split hopper barge 'De Bougainville'. • Water quality monitoring.
August 2009 - March 2010 *(2nd Exclusion Period - Shorebirds)*	• Shorebird exclusion zone to the back of the island (see plan). • No work permitted in exclusion zones other than saltmarsh transplantation and mangrove removal.
September 2009	• Test plots of soil improvement for the Saltmarsh planting zones.
November 2009 - January 2010	• Early November - Improvement of Saltmarsh planting zone (topsoil). • November 9th - New boat ramp opened and filling of outer estuary (nearing completion by 25th December 2009). • Mass Saltmarsh planting (NE side of estuary and 2 roosting islands nearing completion - 1st December).
July 2010 - July 2011	• Flushing channel contouring - very slow
December 2010	• Saltmarsh planting at the Southern corner and at the third island.
July 2011	• Flushing channel contouring nearing completion. • Small dredger. • Concrete blocks installed across estuary
September 2012	• Drain installed behind N2 (see map). Saltmarsh transplanted to Floodvale drain outlet.

Figure 1 Aerial photographs taken of Penrhyn Estuary prior to, and following rehabilitation works

1.2 Aims

The key objective of the PEHEP Saltmarsh Monitoring Plan is to determine if saltmarsh habitat has been affected by port construction and if mitigation efforts and habitat creation have been successful. This was assessed by:

> Monitoring new, retained and altered saltmarsh habitats within Penrhyn Estuary and reference locations during and after habitat enhancement; and

> Assessing the performance of all saltmarsh habitats with respect to their ability to sustain abundance and diversity through time.

Specific tasks of the monitoring program are to:

> Map the extent of saltmarsh habitat within Penrhyn Estuary over time to determine changes in areal extent;

> Examine distribution and abundance of saltmarsh species present, as well as their density, morphology and their ecological condition by undertaking statistical analyses to determine changes in various ecological variables associated with saltmarsh habitat;

> Identify any changes required to the Saltmarsh Monitoring Plan and its implementation due to changes in actual saltmarsh extent.

The PEHEP Saltmarsh Monitoring Program will run from March 2012 until March 2017. This annual report is the first of five annual reports documenting the results of saltmarsh monitoring undertaken between March 2012 and March 2013. It outlines the methodology that has been used throughout the monitoring program to date and discusses the results that were obtained from the field surveys as part of the program. It also highlights any recommendations for future surveys in regards to the monitoring program.

1.3 Review of Existing Information

1.3.1 Description of Penrhyn Estuary

Penrhyn Estuary is bounded by Foreshore Road to the north, Penrhyn Road to the east and the existing Port Botany container terminal to the south. The Estuary was formed as a result of development in Botany Bay in the 1970s. The topography of the area is low lying with sand dunes reaching 2.5 m to 3 m in elevation. Estuarine habitats present include saltmarsh, intertidal mud and sand flats, and seagrass. The Estuary receives flow from Floodvale Drain from the north-west and Springvale Drain from the north east as well as groundwater discharge to various intertidal areas. The drains carry shallow groundwater to the Estuary as well as stormwater during rainfall.

Prior to rehabilitation works, the Estuary consisted of two basins; a triangular “inner estuary” connected to an “outer estuary” via a narrow channel formed by sand accreted from Botany Bay and adjacent dunes. The bed of the inner estuary was dominated by muddy sand exposed at low tides and featured two incised channels approximately 1 m wide. A large sand flat formed the southern edge of the outer estuary. Vegetation on the fringes of the estuary included both mangroves and saltmarsh communities. As part of the rehabilitation works, the large sandmass situated on the northern side of the estuary, consisting mostly of dune habitat, was removed and reworked to allow for the establishment of new saltmarsh habitat and bird roosting sites within this area. The removal of this sandmass effectively transformed the ‘two basin’ system into a larger single basin waterbody.

1.3.2 Ecological Function of Saltmarsh Habitat

Saltmarshes are estuarine habitats that occur high on the shore between average high water of spring and neap tides. They are areas of intertidal soft sediments occupied by grasses, succulents, herbaceous and rush plants. Saltmarshes are usually waterlogged and frequently flooded with saltwater by the tide. In NSW, saltmarshes can be viewed as having zones; the lowest zone is generally occupied by *Sarcocornia quinqueflora* and *Sporobolus virginicus* which sometimes grades into the edge of the mangrove forest in areas where both habitats coincide and the upper zone is often colonised by sedges and rushes. Further landward, the saltmarsh grades into adjacent terrestrial vegetation such as swamp-oaks (*Casuarina* sp.) and paperbarks (*Melaleuca* sp.) (Adam 1981).

Saltmarshes are considered important ecosystems with substantial ecological value due to their high productivity and their reputation as being nursery grounds for many fauna such as fish and crustaceans of economic importance (Adam 1993, Connolly 2009). For example, a study by Thomas and Connolly (2001) in subtropical Queensland was one of the first in Australia to adequately demonstrate the widespread use of intertidal saltmarsh habitat by fish in this country. Another study (Hollingsworth and Connolly 2006), demonstrated the intensive feeding habits of fish visiting saltmarsh habitat, and thus, established the importance of saltmarsh to the trophic dynamics of the greater estuary. In addition, Mazumder *et al*. (2009) found that saltmarsh habitat was a net exporter of crab and gastropod larvae and also provided a much higher density of zooplankton to the estuary compared with other nearshore habitats such as mangroves, seagrass and open water.

1.3.3 Saltmarsh Habitats in Penrhyn Estuary

Estuarine habitats, including saltmarshes within Penrhyn Estuary were mapped as part of investigations for the port expansion (The Ecology Lab 2003, Roberts *et al*. 2006). Five main areas of saltmarsh were identified:

> A narrow strip of habitat comprised of mixed saltmarsh (*Suaeda australis, Sarcocornia quinqueflora*) along the north western boundary of the inner estuary, backed by kikuyu grass, bitou bush and acacias;

> a band of mixed saltmarsh fringing the seaward edge of the delta between the outlets of Springvale and Floodvale drains;

> a patch of saltmarsh mixed with *Juncus kraussii* behind mangroves on the northern bank of Springvale Drain;

> a band of mixed saltmarsh and rush grass on the southern bank of Springvale Drain; and

> a small patch of *Sarcocornia quinqueflora* on the southern bank of the Estuary south of the existing boat ramp.

To establish baseline information for the Habitat Enhancement Plan, saltmarsh habitats were remapped in January 2006 (Roberts *et al*. 2006). This survey recorded species present, percent cover and soil nutrients at 11 sites in the inner estuary. They recorded four species of indigenous saltmarsh species: *Suaeda australis, Sarcocornia quinqueflora, Sporobolus virginicus* and *Juncus kraussii*. These species were generally present as mosaics and occupied approximately 1.45 ha of Penrhyn Estuary. The ground cover of saltmarsh habitat ranged between 46% and 90%, depending on the area sampled. Roberts *et al*. (2006) also recorded one introduced species, *Juncus acutus*. The results from this survey largely corroborated with that done in 2003 by The Ecology Lab, although provided finer scale detail than that presented within The Ecology Lab (2003). Mapping and monitoring was again done in 2007 (Sainty *et al.* 2008) and again in 2008 (Roberts et al. 2008) prior to the rehabilitation works. The area of saltmarsh habitat mapped in 2007 was estimated to be 1.56 ha, whilst the 2008 survey yielded 1.55 ha, both estimates slightly higher than the area obtained during the 2006 mapping (Roberts *et al*. 2006). *Suaeda australis* and *Sarcocornia quinqueflora* again dominated saltmarsh assemblages during both surveys.

In other studies that have examined saltmarsh habitat within Penrhyn Estuary, The Ecology Lab (2007) undertook surveys of saltmarsh habitat as part of the monitoring program to assess the impacts on estuarine habitats of the interception and removal of groundwater entering Penrhyn Estuary (Botany Groundwater Cleanup Project). The surveys focussed on the spatial extent of the habitat, finer scale assessments (percentage cover, species composition, abundance of epifaunal invertebrates and condition of saltmarsh) along three permanent transects within four sites within inner Penrhyn Estuary and at two sites in two control locations (Woolooware Bay and Quibray Bay). Monitoring was aimed at testing the hypothesis that withdrawal of groundwater could result in conditions that would favour the dominance of *Sarcocornia quinqueflora*. No changes in saltmarsh cover were detected within the first nine months of monitoring (August 2005 to April 2006). The dominant species of saltmarsh recorded at all locations were *Sarcocornia quinqueflora, Suaeda australis* and *Sporobolus virginicus*. *Sarcocornia quinqueflora* was absent from two of the three transects on the northern bank of Springvale Drain, and at all sites on the southern bank of the Estuary. There were more *Sarcocornia quinqueflora* at control locations than in Penrhyn Estuary, and plants at the former tended to be taller than at the latter. Averaged over three surveys within nine months, the height of *Sarcocornia quinqueflora* and percentage cover of plants in good condition varied among transects within sites at Penrhyn Estuary.

2 Methods

2.1 Sampling Design

2.1.1 Study Area

The study area for the Saltmarsh Monitoring Program included the entire Penrhyn Estuary system (**Figure 2**), as well as two reference locations, with relatively undisturbed saltmarsh habitat, situated within Quibray Bay and Woolooware Bay (**Figure 5** and **6**). These references locations are the same areas used in a previous saltmarsh monitoring program undertaken within Penrhyn Estuary (The Ecology Lab 2007), and provide a basis for comparison with any changes to the saltmarsh habitat within Penrhyn Estuary. In addition to the two reference locations of Quibray Bay and Woolooware Bay, two 'treated' reference locations were also sampled at Scotts Park, Sans Souci and Salt Pan Creek, Padstow (**Figure 7** and **8**). These locations are examples within Sydney that were used as successful recipient sites for transplanted saltmarsh habitat. These 'Treated' locations provided an extra point of reference for the transplanted saltmarsh habitat within Penrhyn Estuary.

2.1.2 Mapping

The distribution and areal cover of each saltmarsh patch within Penrhyn Estuary was interpreted from recent aerial photographs and ground-truthed using a DGPS by walking around the perimeter of the saltmarsh patches within the estuary. From this, the total area (sq. m) was calculated using MapInfo Version 11.0. Comparisons of these data were made through time to assess the changes in total saltmarsh cover within the estuary (**Table 2**). Data were compared for surveys carried out prior to rehabilitation works during baseline sampling (2005 – 2008) and after construction as part of the PEHEP (2012 and 2013).

2.1.3 Fixed Transects

Fixed permanent transects were used to examine and monitor a number of key indicators that assessed the health of the saltmarsh communities within Penrhyn Estuary (**Table 2**). During each survey, the percentage cover of saltmarsh plant species (and other habitat categories such as bare surface or mangrove) were recorded along permanent transects under each 0.1 m interval, and the cover of each species/category was expressed as a percentage of the total length of a particular transect. Each transect began low on the shore (close to the water) and ran perpendicular to the shoreline, ending near the landward edge of the saltmarsh. During surveys at Woolooware Bay, where extensive saltmarsh habitat exists (~300 m wide), transects were terminated after 40 m. The locations of the fixed transects used throughout the monitoring program to date can be seen in **Figure 4 – 8**. GPS coordinates of the permanent transects are presented in **Appendix A**.

In addition to the above, the percentage cover of each saltmarsh species encountered, plant condition, number of mangrove seedlings and pneumatophores, maximum height of each species of plant and abundance of epifaunal invertebrates were also recorded within four 1 m^2 quadrats distributed randomly along each transect.

Table 2 Indicators and sampling methods for saltmarsh monitoring

Indicator	Parameter	Sampling Methodology
Saltmarsh Distribution	Area	The area of saltmarsh habitats was derived from interpretation of aerial photos and ground verification using a DGPS using MapInfo software.
Growth (success of transplantation)	Percentage Cover (%) (using fixed transect)	The cover of each species of saltmarsh was recorded along a single transect within each site and expressed as a percentage of the total transect length.
	Percentage Cover (%) (using quadrat)	The cover of each species of saltmarsh was recorded within four 1 m^2 quadrats along each transect.
Species Diversity	Number of Saltmarsh Species	The number of saltmarsh species was recorded in quadrats along each transect.
Species Abundance	Number of Individual plants	The number of individual plants of each saltmarsh species was recorded in quadrats along each transect.
Overall Condition	Plant Morphology	The condition of each plant within each 1m^2 quadrat was categorised on the following scale: ▪ Good condition – >50 % of the plant with living green bases; ▪ Poor condition - < 50 % of the plant with living green bases; and ▪ Dead/near dead – no living green bases on plant.
Growth	Height (cm)	The height of the tallest plant was recorded in quadrats along each transect.
Ecological Function	Epifaunal Invertebrates	The abundance of epifaunal invertebrates associated with saltmarsh habitat (including crabs, gastropod molluscs, etc.) was recorded in quadrats along each transect. Crab holes were used as an index of crab abundance.
Invasion by Mangroves	Number of sprouting mangrove trunks, pneumatophores, and seedlings.	The number of mangrove trunks, pneumatophores, seeds and seedlings was recorded in quadrats along each transect.

2.1.4 Experimental Design

During five baseline surveys (August 2005, November 2005, April 2006, October 2006, and March 2007), three transects were established at four separate sites within Penrhyn Estuary (**Figure 3**) and at two sites within each of the reference locations (Woolooware Bay and Quibray Bay). The data for these baseline surveys were taken as part of the Botany Groundwater Cleanup Project (The Ecology Lab 2007). It should be noted that the data collected during the baseline surveys undertaken by Roberts *et al* (2006) and Sainty *et al*., (2008) prior to the rehabilitation works were not included in the formal statistical analyses done within this report, as the sampling methodologies were slightly different to that employed for the two 'After' phase surveys (i.e. transects were randomly allocated as opposed to being based on a fixed transect design analysed using a repeated measures approach). Instead, the baseline results of Roberts *et al*. (2006), Sainty *et al*., (2008) were qualitatively assessed with the data collected during the two surveys following the rehabilitation works.

After habitat rehabilitation, two surveys were conducted in Penrhyn Estuary where four saltmarsh treatments were surveyed as part of the post-construction monitoring program (**Figure 4**). These treatments were:

1. New Saltmarsh Habitat: 13 sites with the prefix "N" are located in Penrhyn Estuary; a large rectangular area along the northern estuary boundary (N1-1 to N1-6) and fringing the southern shore, extending along the base of the new arm of the port (N2-9 to N2-13 and N2-21). New saltmarsh was also created fringing the kidney-shaped bird roost and two circular roost areas within the estuary, however the latter two habitats were not sampled to minimise the disturbance to roosting birds;

2. Transplanted Saltmarsh Habitat: three sites with prefix “TR” are located along the northern bank of Springvale Creek (TR-8, TR-17 and TR-18). These areas received saltmarsh that was previously located along the western bank of Floodvale Creek. Transplantation was done prior to removing weed and dune habitats and levelling to create the New Saltmarsh habitats mentioned above;
3. Retained, Undisturbed Saltmarsh Habitat: four sites with prefix “R”; located along the eastern bank of Floodvale Creek (R1-7 and R1-14) and south-eastern bank of Springvale Creek (R2-20 and R2-22). These areas were saltmarsh habitats prior to and during the habitat enhancement, and were undisturbed during construction and rehabilitation processes;
4. Altered Saltmarsh Habitat: three sites with prefix “A” located fringing the southern shore adjacent to Springvale Creek. These areas had weeds and mangroves (trees and pneumatophores) removed as part of habitat rehabilitation.

Figure 2 Treatments for saltmarsh habitats within Penrhyn Estuary. Annotated from Sydney Ports Corporation

Figure 3 Aerial photograph showing the position of the permanent saltmarsh transects used during baseline sampling in Penrhyn Estuary prior to rehabilitation works

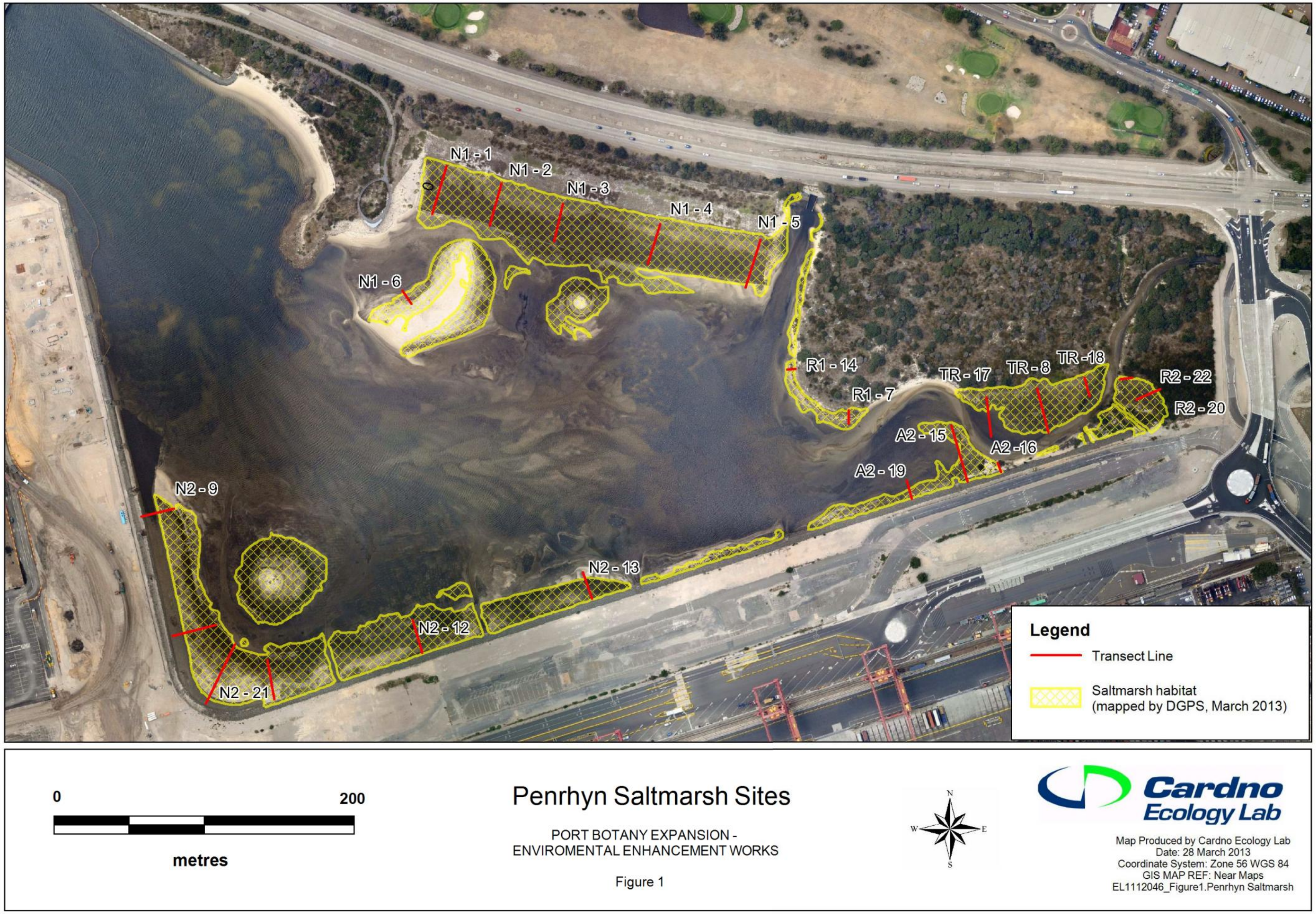

Figure 4 Position of transects within New (N), Transplanted (TR), Retained (R) and Altered Sites within Penrhyn Estuary following rehabilitation works

Figure 5 Position of transects at the Reference location at Quibray Bay

Figure 6 Position of transects at the Reference location at Woolooware Bay

Figure 7 Position of transects at the Treated Reference location at Scotts Park, Sans Souci

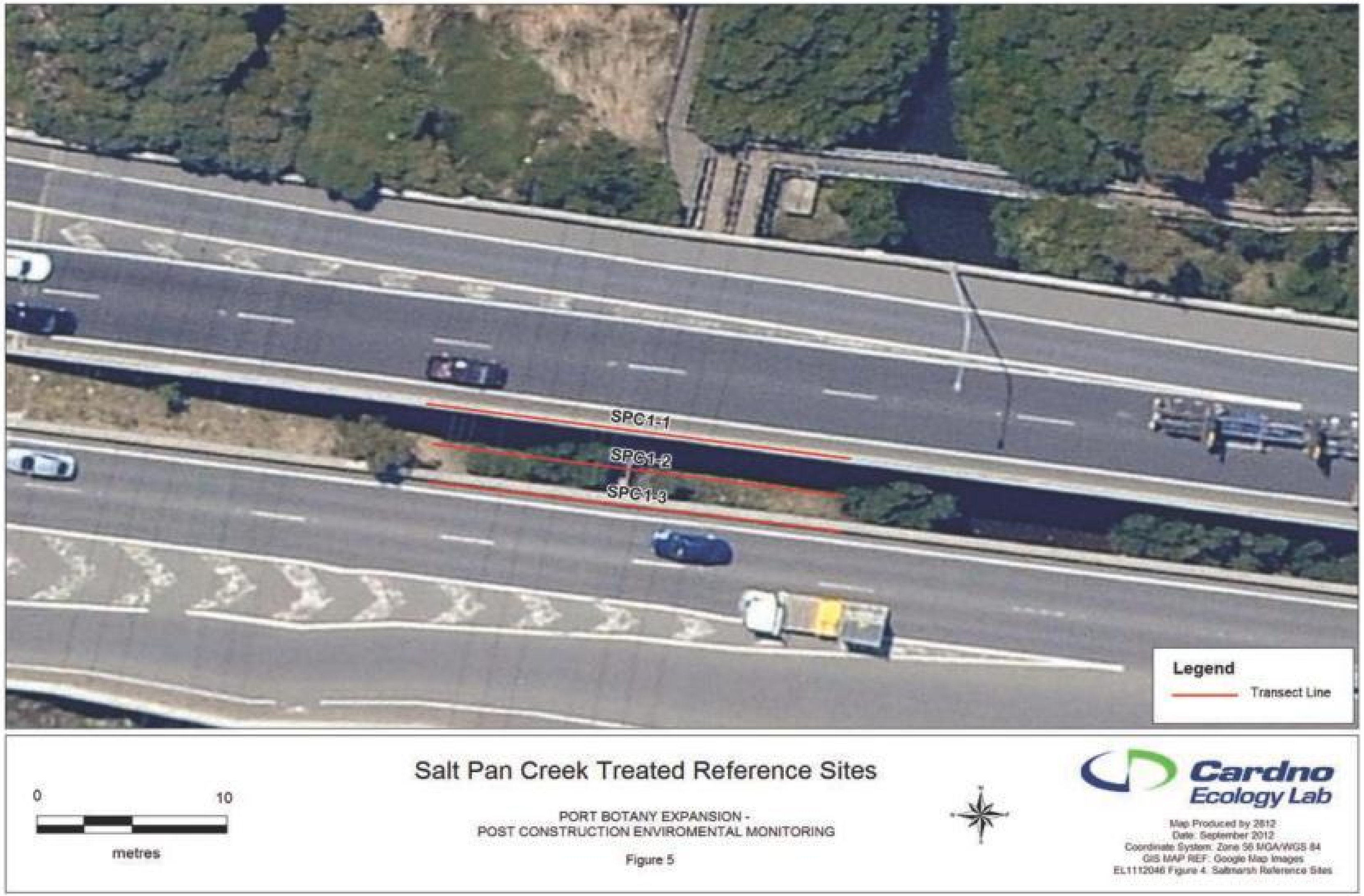

Figure 8 Position of transects at the Treated Reference location at Salt Pan Creek, Padstow

2.2 Summary of Sampling Procedures

The various saltmarsh indicators that were monitored throughout the program were sampled using a number of approaches including the use of transect and quadrat sampling methods. The methodology used for each saltmarsh indicator is shown in **Table 3**.

In order to assess the success of the rehabilitation works on the saltmarsh areas within Penrhyn Estuary, targets were set in relation to the ecological conditions before habitat rehabilitation. Because the main aims of the monitoring program were 1) to assess the changes between before and after saltmarsh rehabilitation and 2) determine whether there is any difference between Reference and all other Treatments after rehabilitation, targets for each of the saltmarsh indicators were set in relation to Baseline data and data taken from the Reference areas. **Table 3** provides a summary of the desirable targets for each indicator, which were determined *a priori*. For these targets, it was hypothesised that in the rehabilitated areas within Penrhyn Estuary, saltmarsh area, species diversity and the abundance of both saltmarsh plants and associated epifauna would increase. In addition, it was expected that mangrove cover would decline following the rehabilitation works.

Table 3 Desirable targets for the various saltmarsh indicators used throughout the monitoring program in relation to Baseline data and Reference Locations. NA = not applicable, ↑ = desirable improvement, ↓ = desirable decline. *after rehabilitation works. N = New saltmarsh, TR = Transplanted saltmarsh, RET = Retained saltmarsh and ALT = Altered saltmarsh Treatments.

Indicator	Methodology	Target							
		Compared with Baseline				Compared with Reference*			
Saltmarsh Treatment		N	TR	RET	ALT	N	TR	RET	ALT
Area	Aerial photographs	↑				NA			
Growth (plant assemblage)	Transects	NA	≠	=	≠	=	=	=	=
Species diversity in quadrats	Quadrats	NA	↑	=	↑	=	=	=	=
Species abundance:									
Sarcocornia quinqueflora	Quadrats	NA	↑	=	↑	=	=	=	=
Sporobolus virginicus	Quadrats	NA	↑	=	↑	=	=	=	=
Suaeda australis	Quadrats	NA	↑	=	↑	=	=	=	=
Juncus kraussii	Quadrats	NA	↑	=	↑	=	=	=	=
Plant health conditions	Quadrats	NA	↑	=	↑	=	=	=	=
Max height	Quadrats	NA	↑	=	↑	=	=	=	=
Ecological function (epifauna)	Quadrats	NA	↑	=	↑	=	=	=	=
Mangroves:									
Tree	Transects	NA	↓	=	↓	=	=	=	=
Seedlings	Quadrats	NA	↓	=	↓	=	=	=	=
Pneumatophores	Quadrats	NA	↓	=	↓	=	=	=	=

2.3 Sampling Dates

A summary of the key sampling dates for baseline sampling and the surveys done following the rehabilitation works within Penrhyn Estuary can be seen in **Table 4**. Baseline sampling consisted of surveys conducted by the Ecology Lab (2007) as part of the Botany Groundwater Cleanup Project and those of Roberts *et al.* (2006), Sainty *et al*. (2008) and Roberts *et al*. (2008) as part of the investigations into the port expansion and the rehabilitation of Penrhyn Estuary.

Table 4 Key sampling dates that have been utilised during the saltmarsh monitoring program to date.

Year	Phase	Designation in this report	Reference
2005 (August)	Baseline	B1	The Ecology Lab (2007)
2005 (November)	Baseline	B2	The Ecology Lab (2007)
2006 (April)	Baseline	B3	The Ecology Lab (2007)
2006 (October)	Baseline	B4	The Ecology Lab (2007)
2007 (March)	Baseline	B5	The Ecology Lab (2007)
2006 (Unknown)	Baseline	Roberts *et al.* (2006)	Roberts *et al.* (2007)
2007 (Unknown)	Baseline	Sainty *et al.* (2008)	Sainty *et al.* (2008)
2008 (March)	Baseline	Roberts *et al.* (2008)	Roberts *et al.* (2008)
2012 (March)	Post – Rehabilitation	A1	Cardno Ecology Lab (2012)
2013 (March)	Post – Rehabilitation	A2	Cardno Ecology Lab (2013)

3 Summary of Results

3.1 Overview

Table 5 presents an overview of the results for each indicator with respect to targets and in comparison to reference locations, where applicable.

Table 5 Summary of the results for each ecological indicator at the four saltmarsh treatments and comparisons with targets. *After habitat rehabilitation. N = new saltmarsh habitat, TR = existing saltmarsh that received transplants, RET = retained, undisturbed habitat, ALT= altered saltmarsh habitat where weeds, mangroves were removed. NA = not applicable, ↑ = observed improvement, ↓ = observed decline, ≠ indicates variable results, = indicates no significant difference.

Indicator	Results								Conclusion in comparison to target							
	Compared to baseline				Compared to Reference*				Compared to baseline				Compared to Reference*			
Saltmarsh vegetation	N	TR	RET	ALT	N	TR	RET	ALT	N	TR	RET	ALT	N	TR	RET	ALT
Area	↑				NA				Y				NA			
Growth (assemblage along transects)	NA	≠	=	=	=	=	=	≠	NA	Y	Y	No	Y	Y	Y	No
Species diversity in quadrats	NA	=	↑	↑	=	=	=	=	NA	No	Y	Y	Y	Y	Y	Y
Sarcocornia quinqueflora (% cover)	NA	=	=	=	=	↓	↓	↓	NA	No	Y	No	Y	No	No	No
Sporobolus virginicus (% cover)	NA	=	↑	↑	=	↑	=	=	NA	No	No	Y	Y	No	Y	Y
Suaeda australis (% cover)	NA	=	=	=	↓	=	=	↑	NA	No	Y	No	No	Y	Y	No
Juncus kraussii (% cover)	NA	↑	↑	=	=	=	=	=	NA	Y	No	No	Y	Y	Y	Y
Plant health conditions	NA	↑	↑	↑	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Max height	NA	↑	=	↑	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Ecological function (epifaunal assemblage)	NA	=	=	=	=	=	=	=	NA	No	Y	No	Y	Y	Y	Y
Mangrove																
Tree	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Seedlings	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Pneumatophores	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y

3.2 Spatial Extent of Saltmarsh Habitat

The average saltmarsh habitat area following rehabilitation was 43,860 ± 990 m^2, which corresponds approximately, to a four-fold increase in comparison to the saltmarsh area that was present prior to rehabilitation (i.e. 10,239 ± 1,490 m^2) (**Table 6; Figure 9**).

The results indicated that saltmarsh habitat at Penrhyn Estuary has undergone a slight decline between the 2012 and 2013 surveys. Loss in area can be largely attributed to the removal of saltmarsh in the south-west corner of Penrhyn Estuary as a result of the construction of a culvert/drainage system, resulting in a loss of 1,980 sq. m of saltmarsh habitat. The differences in saltmarsh areal cover between the surveys conducted by The Ecology Lab (2007) (i.e. surveys B1 – B5) and those conducted by Roberts *et al*, (2006), Sainty *et al*. (2008) and Roberts *et al*. (2008) were most likely due to different mapping interpretations.

Table 6 Summary and net change in the spatial extent of estuarine habitats in Penrhyn Estuary measured Before and After habitat rehabilitation. B1-B5 data collected by The Ecology Lab (2007), B6 data collected by Roberts *et al*. (2006), B7 data collected by Sainty *et al*. (2008), B8 data collected by Roberts *et al*. (2008).

Phase	Survey	Month and Year	Area (m^2)
Before	B1	Aug-05	6,435
	B2	Nov-05	6,558
	B3	Apr-06	6,479
	B4	Oct-06	7,846
	B5	Mar-07	8,979
	Roberts *et al*. (2006)	2006	14,500
	Sainty *et al*. (2008)	2007	15,590
	Roberts *et al*. (2008)	Mar-08	15,530
After	A1	Mar-12	44,850
	A2	Mar-13	42,870
	Mean Before		10,239 ± 1,490
	Mean After		43,860 ± 990
	Net Change		33,621

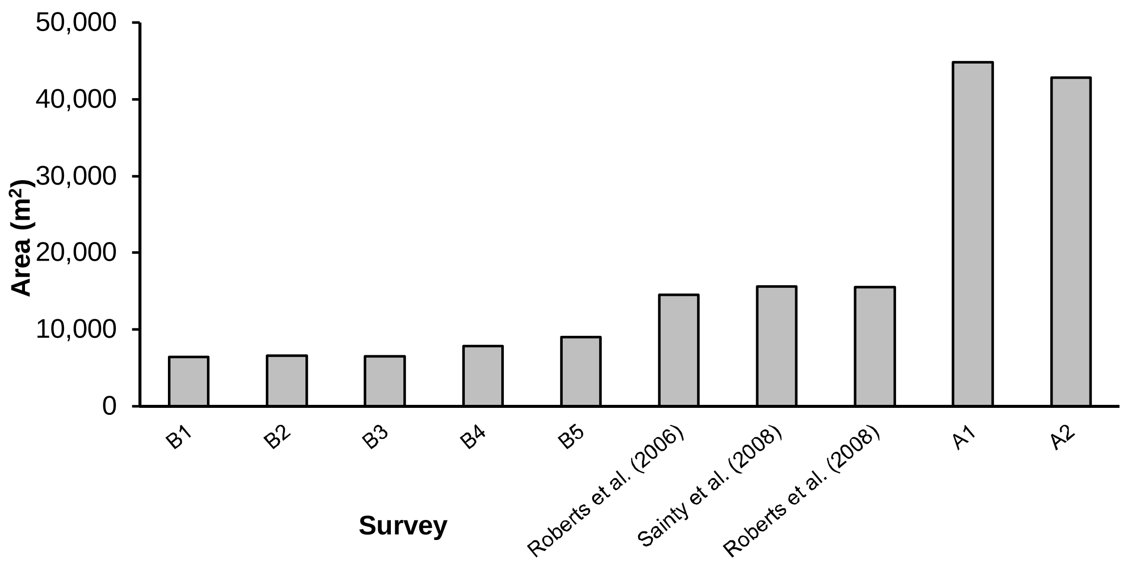

Figure 9 Spatial extent of saltmarsh habitat in Penrhyn Estuary during Before (B1 to B5) and After habitat rehabilitation surveys.

3.3 Saltmarsh Vegetation

3.3.1 Spatial Distribution of Saltmarsh Plants

After rehabilitation works within Penrhyn Estuary, the cover of bare sediment increased in Transplanted and Altered treatments, although decreased within the areas that were retained/unmodified. The new areas of saltmarsh along the northern and southern shorelines of the estuary had bare cover values comparable to those recorded within the Retained treatment. The cover of *S. quinqueflora, S. virginicus* and *J. kraussii* along transects increased markedly and consistently across all treatments after the rehabilitation works, including those at the Reference sites (**Table 7**). The cover of *S. australis*, however, was quite low within the new areas of saltmarsh and also decreased across Transplanted, Retained and Altered treatments (**Table 7**).

Table 7 Mean (±SE) percent cover of bare sediment and saltmarsh plants along transects at the six saltmarsh Treatments before and after the habitat rehabilitation works.

Treatment	Bare sediment		*S. quinqueflora*		*S. virginicus*	
	Before	After	Before	After	Before	After
New	-	19.0 ± 2.6	-	62.5 ± 3.4	-	15.4 ± 2.1
Transplanted	7.0 ± 3.5	15.2 ± 5.8	0.2 ± 0.2	7.6 ± 3.1	15.6 ± 5.2	54.4 ± 10.7
Retained	26.7 ± 3.9	21.7 ± 8.1	10.0 ± 4.8	29.7 ± 3.4	0.9 ± 0.6	9.1 ± 4.6
Altered	24.3 ± 5.7	41.0 ± 8.0	0.0 ± 0.0	4.5 ± 2.9	0.5 ± 0.5	21.8 ± 12.3
Reference	13.5 ± 1.2	11.0 ± 1.4	17.2 ± 2.7	46.6 ± 3.2	7.2 ± 1.0	18.3 ± 3.6
Treated	-	28.7 ± 6.5	-	23.9 ± 8.1	-	3.8 ± 2.6
All	16.0 ± 1.4	19.7 ± 1.9	11.3 ± 1.8	40.2 ± 2.9	6.6 ± 1.0	17.3 ± 2.2

	S. australis		*J. kraussii*	
	Before	After	Before	After
New	-	0.4 ± 0.2	-	0.5 ± 0.2
Transplanted	23.2 ± 2.7	11.4 ± 4.5	0.0 ± 0.0	8.1 ± 5.2
Retained	27.4 ± 7.6	20.1 ± 5.2	0.0 ± 0.0	10.0 ± 5.7
Altered	36.7 ± 5.8	15.1 ± 6.4	0.0 ± 0.0	0.6 ± 0.6
Reference	12.8 ± 1.5	19.3 ± 2.4	0.0 ± 0.0	0.0 ± 0.0
Treated	-	13.6 ± 5.5	-	8.7 ± 1.9
All	19.8 ± 1.8	11.9 ± 1.6	0.0 ± 0.0	3.1 ± 0.8

With the exception of a few instances (e.g. bare sediment at Retained sites and *S. australis* in Reference), the average cover of individual saltmarsh species within quadrats was in agreement with the values obtained with the transect method (**Table 7** and **Table 8**). Transect values were generally slightly higher than average percent values recorded within quadrats. The average number of plant species per quadrat within the areas that were newly planted was slightly lower to that measured within the Retained and Reference treatments after habitat rehabilitation (**Table 8**). There was an increase in the number of species across all treatments, with the largest increase occurring within the Altered sites (**Table 8**).

Table 8 Mean (±SE) percent cover of bare sediment, saltmarsh plants and number of plant species within quadrats at the six saltmarsh Treatments before and after the habitat rehabilitation works.

Treatment	Bare sediment		*S. quinqueflora*		*S. virginicus*	
	Before	After	Before	After	Before	After
New	-	44.7 ± 2.2	-	40.2 ± 2.8	-	13.4 ± 2.7
Transplanted	13.1 ± 3.6	28.0 ± 6.0	0.0 ± 0.0	4.7 ± 2.3	24.5 ± 5.1	42.3 ± 8.8
Retained	33.3 ± 3.4	37.0 ± 5.4	16.0 ± 3.3	24.8 ± 5.8	0.0 ± 0.0	7.3 ± 3.7
Altered	34.4 ± 3.6	49.3 ± 5.8	0.0 ± 0.0	2.4 ± 1.2	0.0 ± 0.0	16 ± 5.8
Reference	20.9 ± 1.4	22.0 ± 2.5	29.5 ± 2.0	46.0 ± 3.9	5.4 ± 0.9	16.5 ± 3.0
Treated	-	30.2 ± 4.0	-	23.6 ± 4.5	-	5.9 ± 2.3
All	23.5 ± 1.2	34.2 ± 1.5	19.1 ± 1.4	31.9 ± 1.9	6.6 ± 1.0	14.7 ± 1.6

	S. australis		*J. kraussii*		No. of saltmarsh species	
	Before	After	Before	After	Before	After
New	-	0.2 ± 0.1	-	0.5 ± 0.4	-	1.4 ± 0.1
Transplanted	28.0 ± 4.4	15.8 ± 4.0	0.0 ± 0.0	6.9 ± 4.5	1.2 ± 0.1	1.5 ± 0.1
Retained	34.0 ± 3.7	13.3 ± 3.8	0.0 ± 0.0	8.1 ± 4.4	1.3 ± 0.1	1.7 ± 0.1
Altered	48.7 ± 3.7	18.8 ± 5.5	0.0 ± 0.0	0.0 ± 0.0	1.0 ± 0.0	1.9 ± 0.2
Reference	15.7 ± 1.5	11.1 ± 2.2	0.0 ± 0.0	0.1 ± 0.1	1.5 ± 0.0	1.8 ± 0.1
Treated	-	12.8 ± 3.1	-	8.8 ± 2.9	-	1.6 ± 0.1
All	24.8 ± 1.4	9.3 ± 1.1	0.0 ± 0.0	3.0 ± 0.8	1.3 ± 0.0	1.6 ± 0.0

3.3.2 Plant Health Condition

There was an overall improvement in the health condition of all saltmarsh plant species following the rehabilitation works within Penrhyn Estuary, with the average cover of saltmarsh plants in poor condition or dead below 1% (**Table 9**). This value is considerably lower in comparison with pre-rehabilitation values.

Table 9 Mean (±SE) percent cover of saltmarsh plants in poor condition (i.e. < 50 % of the plant with living green bases), dead (i.e. no living green bases on plant) and sum of poor condition and dead plant cover within quadrats at the six saltmarsh Treatments before and after the habitat rehabilitation works.

Treatment	Poor condition		Dead		Poor condition + Dead	
	Before	After	Before	After	Before	After
New	-	0.0 ± 0.0	-	0.0 ± 0.0	-	0.0 ± 0.0
Transplanted	1.2 ± 0.7	0.8 ± 0.8	4.5 ± 1.5	0.0 ± 0.0	5.7 ± 1.6	0.8 ± 0.8
Retained	8.8 ± 1.8	0.0 ± 0.0	5.2 ± 1.1	0.0 ± 0.0	14.0 ± 2.1	0.0 ± 0.0
Altered	1.0 ± 0.5	0.0 ± 0.0	9.3 ± 1.7	0.0 ± 0.0	10.3 ± 1.8	0.0 ± 0.0
Reference	18.3 ± 1.5	0.0 ± 0.0	3.1 ± 0.4	0.2 ± 0.1	21.5 ± 1.6	0.2 ± 0.1
Treated	-	0.0 ± 0.0	-	0.3 ± 0.3	-	0.3 ± 0.3
All	12.0 ± 1.0	0.1 ± 0.1	4.5 ± 0.4	0.1 ± 0.1	16.6 ± 1.1	0.2 ± 0.1

3.3.3 Plant height

Despite the lack of data for some of the Treatment/Phase combinations for each saltmarsh plant species, it was possible to identify trends in plant height related to the rehabilitation works (**Table 10**). Generally, the heights of most saltmarsh species within Penrhyn Estuary following rehabilitation works were similar to those sampled within the reference areas. Interestingly, the maximum height of each species at the Treated Reference locations was generally much larger than all other treatments sampled throughout the monitoring program to date (**Table 10**). *S. virginicus* maximum height increased after rehabilitation works for all treatments, whilst *S. australis* had, on average, a similar maximum height before and after the rehabilitation works across all treatments (**Table 10**).

Table 10 Mean (±SE) height of various saltmarsh species sampled within quadrats at the six saltmarsh Treatments before and after the habitat rehabilitation works.

Treatment	*S. quinqueflora*		*S. virginicus*		*S. australis*		*J. kraussii*	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
New	-	22.0 ± 0.7	-	28.2 ± 1.6	-	-	-	-
Transplanted	-	-	25.9 ± 2.7	40.1 ± 1.8	40.3 ± 2.4	36.7 ± 3.2	-	93.7 ± 3.2
Retained	21.6 ± 1.4	21.3 ± 3.0	-	24.0 ± 4.0	32.8 ± 1.5	35.5 ± 3.5	-	97.5 ± 7.8
Altered	-	-	-	37.2 ± 3.1	42.1 ± 1.6	37.9 ± 5.3	-	-
Reference	16.3 ± 0.3	18.6 ± 0.7	18.1 ± 0.8	27.2 ± 1.7	28.9 ± 1.0	31.7 ± 1.6	-	79.5 ± 14.5
Treated	-	42.2 ± 10.0	-	-	-	46.8 ± 4.0	-	107.1 ± 14.1
All	17.0 ± 0.4	24.6 ± 1.9	19.9 ± 0.9	30.4 ± 1.1	33.9 ± 0.8	36.4 ± 1.5	-	96.5 ± 6.7

3.4 Ecological Function

The average number of epifaunal species per quadrat decreased following rehabilitation works in all treatments, with the exception of the Reference areas at Quibray Bay and Woolooware Bay (**Table 11**). The same trend was also observed for the abundance of epifauna, which decreased markedly for all treatments, including the Reference areas (**Table 11**). This pattern was the reflection of an overall decrease in the abundance of the main species of epifauna, rather than a decrease of one or a small group of species (**Table 11**). The most abundant epifaunal organisms were crabs (quantified as number of crab holes) and the gastropods *Ophicardelus ornatus, Salinator* sp., *Bembicium auratum* and *Littorina scabra*.

Table 11 Mean (±SE) number of epifauna individuals of the five most abundant species within quadrats at the six saltmarsh Treatments before and after the habitat rehabilitation works.

Treatment	Crab holes		*Ophicardelus ornatus*		*Salinator* sp.	
	Before	After	Before	After	Before	After
New	-	3.6 ± 0.9	-	0.3 ± 0.2	-	5.4 ± 1.3
Transplanted	15.3 ± 2.6	5.4 ± 1.5	12.2 ± 3.1	0.5 ± 0.2	5.2 ± 2.0	1.5 ± 0.8
Retained	5.5 ± 1.0	2.6 ± 0.7	3.0 ± 2.1	1.3 ± 0.9	4.7 ± 2.0	0.5 ± 0.3
Altered	29.9 ± 3.0	6.9 ± 1.9	1.6 ± 0.7	0.0 ± 0.0	4.5 ± 1.6	0.3 ± 0.1
Reference	15.6 ± 1.1	9.0 ± 1.3	12.8 ± 2.0	8.9 ± 2.5	5.4 ± 0.8	1.3 ± 0.3
Treated	-	3.3 ± 0.7	-	2.2 ± 1.3	-	3.8 ± 1.0
Grand Total	16.2 ± 0.9	5.3 ± 0.5	9.7 ± 1.3	3.1 ± 0.7	5.1 ± 0.6	2.8 ± 0.4

	Bembicium auratum		*Littorina scabra*		No. of Species	
	Before	After	Before	After	Before	After
New	-	0.0 ± 0.0	-	5.7 ± 2.8	-	1.1 ± 0.1
Transplanted	0.5 ± 0.3	0.0 ± 0.0	0.3 ± 0.2	0.5 ± 0.4	1.2 ± 0.2	1.0 ± 0.2
Retained	2.3 ± 0.6	0.1 ± 0.1	0.8 ± 0.3	0.0 ± 0.0	1.2 ± 0.1	0.6 ± 0.2
Altered	7.2 ± 1.5	0.2 ± 0.2	0.4 ± 0.2	0.0 ± 0.0	1.8 ± 0.1	0.9 ± 0.2
Reference	0.5 ± 0.2	0.3 ± 0.1	1.5 ± 0.5	0.0 ± 0.0	1.5 ± 0.1	1.7 ± 0.1
Treated	-	0.5 ± 0.3	-	0.0 ± 0.0	-	1.2 ± 0.1
Grand Total	1.7 ± 0.3	0.2 ± 0.1	1.1 ± 0.3	1.8 ± 0.9	1.5 ± 0.1	1.2 ± 0.1

	No. of individuals	
	Before	After
New	-	15.4 ± 3.7
Transplanted	33.5 ± 5.2	7.9 ± 1.9
Retained	16.3 ± 3.7	4.5 ± 1.4
Altered	43.6 ± 4.3	7.5 ± 2.1
Reference	35.8 ± 3.0	20 ± 3.1
Treated	-	9.9 ± 1.9
Grand Total	33.8 ± 2.1	13.4 ± 1.5

3.5 Invasion by Mangroves

Prior to the rehabilitation works, mangroves were quite common within Penrhyn Estuary with the percent cover of trees and the number of pneumatophores reaching average values of 15.6 ± 3.7% and 21.6 ± 4.3 respectively (**Table 12**). Following the habitat rehabilitation works, no mangroves were found within Penrhyn Estuary during both 'After' surveys done. Only a small percentage (1.3 ± 0.9% cover) of mangrove cover was found at both the Reference and Treated Reference locations (**Table 12**).

Table 12 Mean (±SE) percent cover of mangrove trees and the mean (±SE) number of seedlings and pneumatophores at saltmarsh Treatments before and after the habitat rehabilitation works.

Treatment	Tree (Transects)		Seedlings (quadrats)		Pneumatophores (quadrats)	
	Before	After	Before	After	Before	After
New	-	0.0 ± 0.0	-	0.0 ± 0.0	-	0.0 ± 0.0
Transplanted	7.6 ± 2.3	0.0 ± 0.0	1.4 ± 0.5	0.0 ± 0.0	21.1 ± 6.5	0.0 ± 0.0
Retained	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0
Altered	15.6 ± 3.7	0.0 ± 0.0	1.9 ± 0.3	0.0 ± 0.0	21.6 ± 4.3	0.0 ± 0.0
Reference	0.2 ± 0.1	0.6 ± 0.3	0.1 ± 0.0	0.0 ± 0.0	5.6 ± 1.0	0.0 ± 0.0
Treated	-	5.5 ± 2.3	-	0.0 ± 0.0	-	0.0 ± 0.0
All	3.4 ± 0.8	1.0 ± 0.4	0.5 ± 0.1	0.0 ± 0.0	9.3 ± 1.3	0.0 ± 0.0

4 Data Analysis

4.1 Analytical Methods

Permutational analysis of variance (PERMANOVA+ in Primer v6.0), based on a repeated measures approach due to the fixed transect sampling design, was used to test for significant differences in ecological indicators among the rehabilitated saltmarsh environment within Penrhyn Estuary and the reference locations, before and after rehabilitation, using a beyond BACI (Before-After Control-Impact) approach. Bray-Curtis dissimilarity was used for multivariate indicators (i.e. saltmarsh plant and epifaunal assemblages) and Euclidian distance for univariate indicators (e.g. percent cover, number of plant species etc.). Non-metric multidimensional scaling ordination (nMDS) was used to visualise patterns in multivariate datasets (e.g. saltmarsh and epifauna assemblage data) and to aid in the interpretation of the PERMANOVA results. Centroids, calculated for each Treatment/Survey combination (i.e. corresponding to the average assemblage across replicates at one Treatment on a given Survey), were used to create the nMDS plots due to the large number of replicates that could compromise the interpretation of the nMDS plots by increasing the stress value (Clarke and Warwick 2001). Vectors were superimposed on the nMDS plots in order to graphically represent the variables (i.e. taxa) that mostly correlated with the variability in the multivariate data. Multiple correlation was used as all other variables are taken into consideration and included in the model when calculating the correlation coefficient for each variable (Anderson *et al.* 2008). Only vectors with a multiple correlation coefficient of at least 0.35 were shown in the plot. The length and orientation of a vector show the strength and sign of the correlation between a variable and the two axes of the nMDS plot. Thus, a vector indicates a gradient in the abundance of the taxon that it represents.

Three sets of analyses were done to examine the spatial and temporal variability of the saltmarsh indicators presented in **Table 2** and assess the success of the rehabilitation works in regards to the saltmarsh habitat within Penrhyn Estuary. Analyses were separated due to the lack of baseline data for some treatments within the sampling design. Each analysis used various components of the entire sampling design and is outlined as follows:

1. New Saltmarsh vs Retained Saltmarsh vs Reference Locations

The purpose of this analysis was to compare saltmarsh areas within Penrhyn Estuary that were newly planted with the areas of saltmarsh that were retained and unaltered within the estuary, and to also compare both of these treatments with the reference locations at Quibray Bay and Woolooware Bay. As no baseline data is available for the ‘New’ treatment, only ‘After’ data was used for this analysis. The experimental design consisted of:

- Treatment (fixed factor), with three levels: New, Retained and Reference;
- Time (random factor), with two levels: After 1 (A1) and After 2 (A2);
- Location (random factor), nested in Treatment with one or two levels depending on the Treatment (i.e. Penrhyn Estuary for New and Retained, Quibray Bay and Woolooware Bay for Reference);
- Site (random factor), nested in Location with two levels within each Location;
- Transect (random factor), nested in Site with between two and six levels depending on the Site.

2. Transplanted Saltmarsh vs Retained Saltmarsh vs Treated Reference vs Reference Locations

This analysis was done to compare the area within Penrhyn Estuary that received transplanted saltmarsh to areas of saltmarsh that were retained and unmodified as par tof the rehabilitation, the ‘Treated Reference’ locations (Scotts Park and Salt Pan Creek) and the ‘Reference’ locations (Quibray Bay and Woolooware Bay) before and after the rehabilitation works within Penrhyn Estuary. It should be noted that baseline data for the Transplanted and Retained treatments were gathered from Site 3 and Site 2 (**Figure 3**), respectively, taken by The Ecology Lab (2007). No ‘Before’ data was collected from both Treated Reference locations. The experimental design consisted of:

> Treatment (fixed factor), with three levels: Transplanted, Retained, Treated Reference and Reference;
> Period (fixed factor), with two levels: Before and After rehabilitation;
> Time (random factor), nested in Period with five Before levels (B1 to B5) and two After levels (A1 and A2);
> Location (random factor), nested in Treatment with one level for Transplanted (Penrhyn), one level for Retained (Penrhyn), two levels for Treated Reference (Scotts Park and Salt Pan Creek) and two levels for Reference (Quibray Bay and Woolooware Bay);
> Site (random factor), nested in Location with one or two levels depending on the Location;
> Transect (random factor), nested in Site with two or three levels depending on the Site.

3. Altered Saltmarsh vs Retained Saltmarsh vs Reference Locations

The purpose of this analysis was to compare the area of saltmarsh habitat within Penrhyn that was cleared of mangroves (i.e. altered) to the areas within the estuary that were retained and not modified, and with the Reference Locations at Quibray Bay and Woolooware Bay before and after the rehabilitation works. All treatments within this analysis had both Before and After data available. It should be noted that baseline data for the Altered and Retained treatments were gathered from Site 4 and Site 2 (**Figure 3**), respectively, taken by The Ecology Lab (2007). The experimental design consisted of:

> Treatment (fixed factor), with three levels: Altered, Retained and Reference;
> Period (fixed factor), with two levels: Before and After rehabilitation;
> Time (random factor), nested in Period with five Before levels (B1 to B5) and two After levels (A1 and A2);
> Location (random factor), nested in Treatment with one level for Altered (Penrhyn), one level for Retained (Penrhyn), and two levels for Reference (Quibray Bay and Woolooware Bay);
> Site (random), nested in location with one or two levels depending on the Location;
> Transect (random), nested in Site with between two or three levels depending on the Site.

In addition to the above, a separate 'side' analysis (i.e. contrast) was also done to examine the differences in the saltmarsh indicators between the retained area of saltmarsh within Penrhyn Estuary and the Reference Locations (Quibray Bay and Woolooware Bay) before and after the rehabilitation works. The experimental design in this case was much the same as detailed above, with the exception of two levels for the Treatment factor (Retained and Reference) instead of three.

A summary of the Locations, Sites and Transects used in the three analyses is shown in **Table 13**. Site 2, 3 and 4 were used in the analyses as Retained, Transplanted and Altered treatments respectively in the Before phase. Differences in the replication level (i.e. number of transect) among some of the treatments are mainly the consequence of differences in the extension area of each treatment. The statistical technique used for the analyses (PERMANOVA) can be used for the analysis of unbalanced design as in this case.

Table 13 Summary of the treatments included in each of the three analyses (see section 2.1.4) and Locations/Sites/Transects used to test for differences in the indicators before and after habitat rehabilitation works at Penrhyn Estuary. n = total number of transects for each treatment.

Experimental design	Before	After
(1) New Saltmarsh Vs Retained Saltmarsh Vs Reference Locations	NA	**New saltmarsh** (n = 12) N1-1 to N1-5; N1-9 to N1-13; N1-21 **Retained** (n = 4) Penrhyn Estuary (R1-7, R1-14, R2-20, R2-22) **Reference** (n = 12) Woolooware Bay (W1-1 to W2-6) Quibray Bay (Q1-1 to Q2-6)
(2) Transplanted Saltmarsh Vs Retained Saltmarsh Vs Treated Reference Vs Reference Locations	**Site 2** Penrhyn Estuary (n = 3) **Site 3** Penrhyn Estuary (n = 3) **Reference** (n = 12) Woolooware Bay (W1-1 to W2-6), Quibray Bay (Q1-1 to Q2-6)	**Transplanted** (n = 3) Penrhyn Estuary (TR-8, TR-17, TR-18) **Retained** (n = 4) Penrhyn Estuary (R1-7, R1-14, R2-20, R2-22) **Treated** (n = 6) Sans Souci (SS1-1 to SS1-3), Salt Pan Creek (SPC1-1 to SPC1-3) **Reference** (n = 12) Woolooware Bay (W1-1 to W2-6) Quibray Bay (Q1-1 to Q2-6)
(3) Altered Saltmarsh Vs Retained Saltmarsh Vs Reference Locations Vs Retained Saltmarsh Vs Reference Locations	**Site 2** Penrhyn Estuary (n = 3) **Site 4** Penrhyn Estuary (n = 3) **Reference** (n = 12) Woolooware Bay (W1-1 to W2-6), Quibray Bay (Q1-1 to Q2-6)	**Altered** (n = 3) Penrhyn Estuary (A2-15, A2-16, A2-19) **Retained** (n = 4) Penrhyn Estuary (R1-7, R1-14, R2-20, R2-22) **Reference** (n = 12) Woolooware Bay (W1-1 to W2-6) Quibray Bay (Q1-1 to Q2-6)

4.2 Results

4.2.1 Growth

There were no significant differences in the saltmarsh plant assemblage between New, Reference or Retained locations, regardless of the phase considered but there were however, significant differences in the assemblage among locations (PERMANOVA, $p > 0.05$; **Appendix B**). Pair-wise comparisons did not detect any significant difference between location pairs (**Appendix B**).

The plant assemblage at Transplanted locations following habitat rehabilitation within Penrhyn Estuary was more similar to the Reference and Retained locations compared to before rehabilitation (pair-wise comparisons, $p > 0.05$; **Figure 10; Appendix B**). An increase in *Sarcocornia quinqueflora* and *Sporobolus virginicus,* and a decrease in debris and poor *S. quinqueflora* were the species/categories most responsible for the differences between before and after habitat rehabilitation at the Transplanted locations (**Figure 10; Appendix B**).

Retained and Reference locations had a similar saltmarsh plant assemblage across all surveys with the exception of B1 (PERMANOVA pair-wise comparisons, $p > 0.05$; **Figure 11; Appendix B**).

Altered locations had a significantly different assemblage compared to Retained and Reference locations during most of the Baseline surveys (PERMANOVA pair-wise comparisons, $p < 0.05$; **Appendix B; Figure 12**). The main drivers responsible for the observed spatial differences were a higher density of *Suaeda australis* and bare ground and a lower density of *S. quinqueflora* (**Appendix B**).

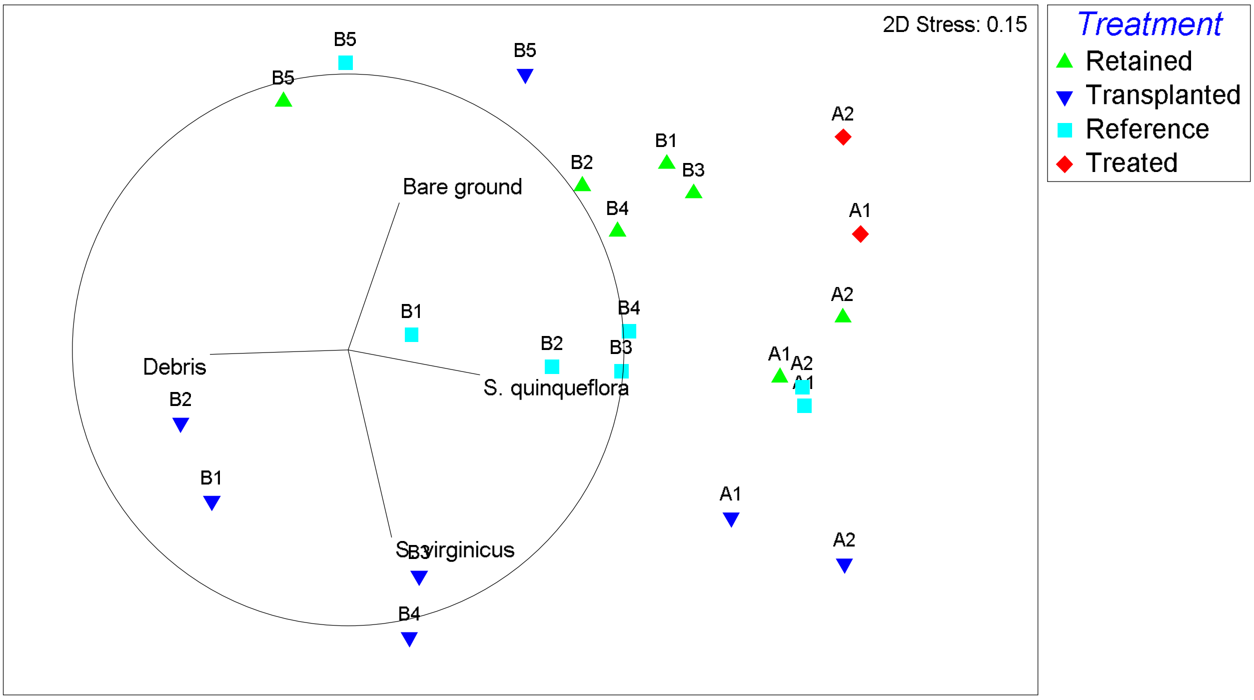

Figure 10 **nMDS plot showing centroids representing the saltmarsh plant assemblage at Retained, Transplanted, Reference and Treated locations during Baseline (B1 to B5) and after rehabilitation (A1 and A2) surveys. Vectors represent multiple correlation coefficients between the nMDS axes and the abundance of each taxon. Only taxa with a multiple correlation coefficient of at least 0.35 were shown in the plot.**

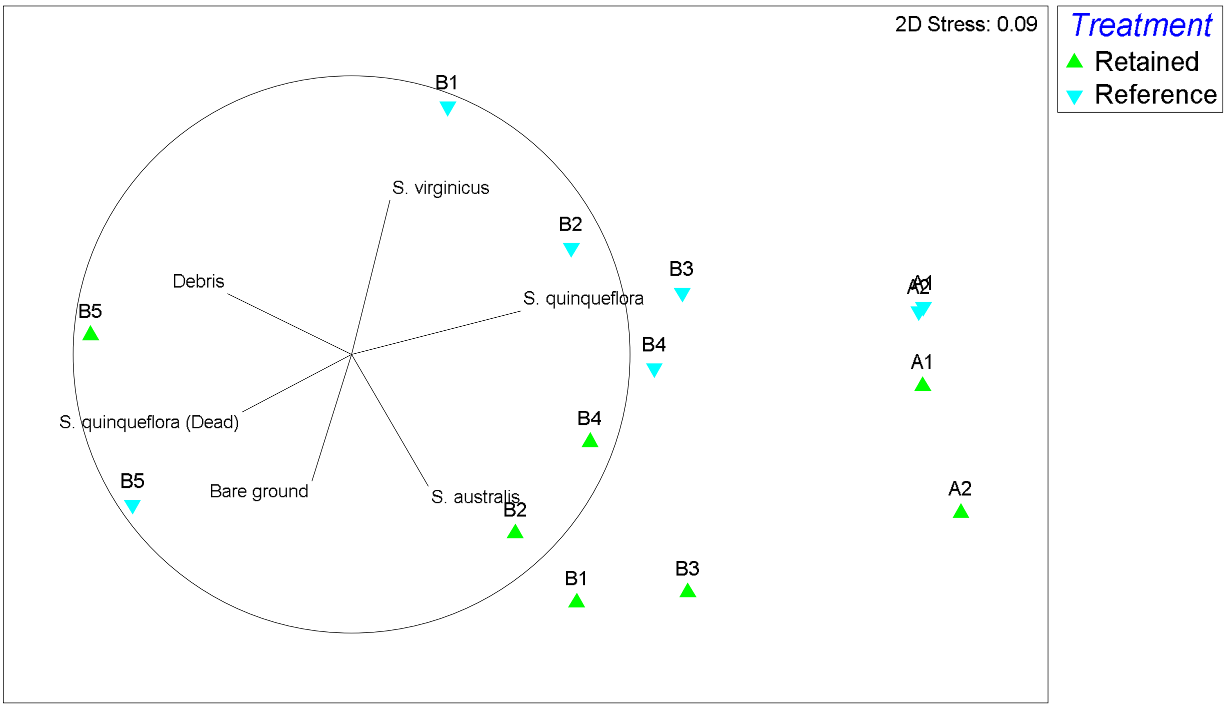

Figure 11 **nMDS plot showing centroids representing the saltmarsh plant assemblage at Retained and Reference locations during Baseline (B1 to B5) and after rehabilitation (A1 and A2) surveys. Vectors represent multiple correlation coefficients between the nMDS axes and the abundance of each taxon. Only taxa with a multiple correlation coefficient of at least 0.35 were shown in the plot.**

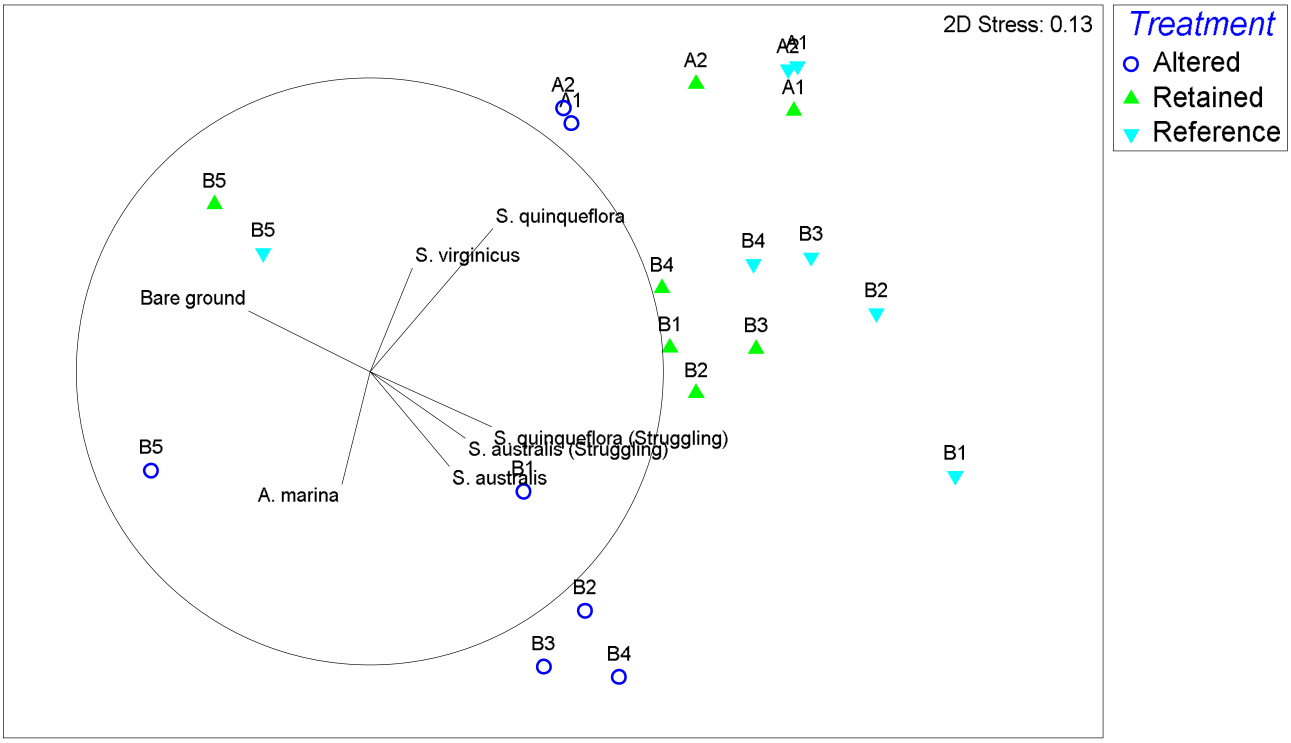

Figure 12 nMDS plot showing centroids representing the saltmarsh plant assemblage at Altered, Retained and Reference locations during Baseline (B1 to B5) and after rehabilitation (A1 and A2) surveys Altered all transects. Each point represent a transect. Vectors represent multiple correlation coefficients between the nMDS axes and the abundance of each taxon. Only taxa with a multiple correlation coefficient of at least 0.35 were shown in the plot.

4.2.2 Species Diversity

The average number of plant species at New locations was similar to the values found at Retained and Reference locations (PERMANOVA, $p > 0.05$; **Figure 13; Appendix B**).

The average number of species per quadrat at Transplanted, Retained and Reference locations was, on average, higher after compared to before habitat rehabilitation (PERMANOVA, **Appendix B; Figure 13**).

Altered locations had a significant lower number of species only before but not after rehabilitation works and all three treatments had a significantly higher number of species after rehabilitation works (pair-wise comparisons, **Appendix B; Figure 13**).

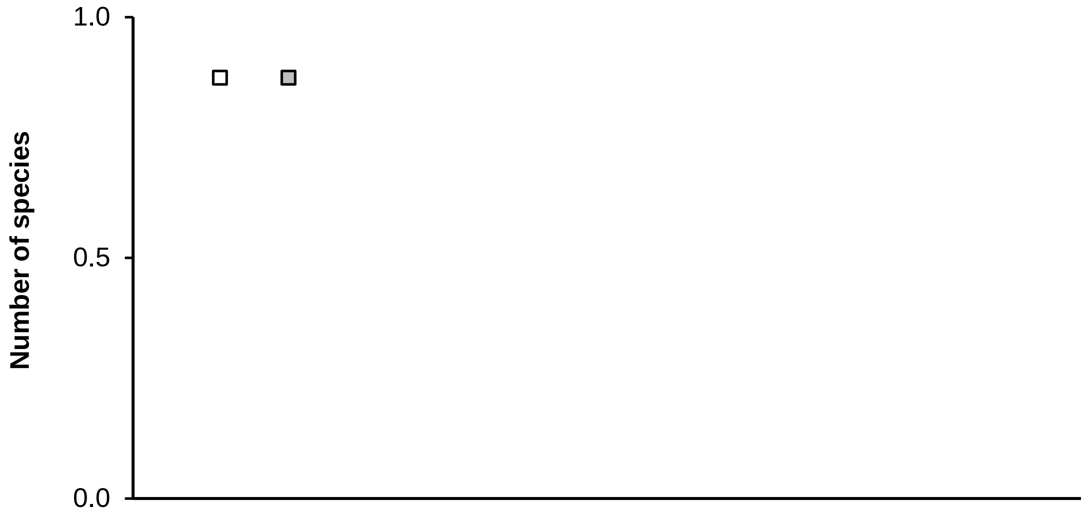

Figure 13 Mean (+SE) number of plant species per quadrat at six saltmarsh Treatments before and after habitat rehabilitation. No data for Before phase at New and Transplanted Treatment.

4.2.3 Abundance of Saltmarsh Plants

Percent cover of the saltmarsh species *S. quinqueflora* within the New locations had similar values compared to Retained and Reference locations (PERMANOVA, $p > 0.05$; **Appendix B**). There were, however, significant differences between the two latter Treatments (**Figure 14; Appendix B**). Percent cover of the saltmarsh species *S. virginicus* at the New locations was similar to the cover at Retained and Reference locations (PERMANOVA, $p > 0.05$; **Figure 15; Appendix A**). Per cent cover of the saltmarsh species *S. australis* at New locations was significantly lower compared to Retained and Reference locations (PERMANOVA, $p < 0.05$; **Appendix A; Figure 16**). Percent cover of the saltmarsh species *J. kraussii* at New locations was, on average, lower compared to Retained locations, however, this difference was not significant (PERMANOVA, $p > 0.05$; **Appendix B**).

The percent cover of *S. quinqueflora* was significantly lower at Transplanted locations compared to Retained and Reference locations, both before and after habitat rehabilitation (pair-wise comparisons, $p < 0.05$; **Appendix A; Figure 14**). At Transplanted locations, *S. virginicus* had, on average, a higher percent cover compared to Retained, Reference and Treated locations during survey B3 to B5, A1 and A2 (**Figure 15**). PERMANOVA, however detected significant differences only during survey A2 (**Appendix B**). The cover of *S. australis* at Transplanted locations did not show any relevant pattern when compared to Retained, Reference and Treated locations, with the exception of a higher cover during B5 and A2 at Transplanted locations compared to Reference locations. *J. kraussii* was not found at Transplanted, Retained and Reference locations before habitat rehabilitation (**Figure 17**). After rehabilitation, *J.* kraussii was very variable and there were no significant spatial or temporal patterns.

Retained locations had, consistently across all surveys, a lower cover of *S. quinqueflora* when compared to Reference locations (pair-wise comparisons, $p < 0.05$, **Appendix B; Figure 14**). No *S. virginicus* was found in the baseline surveys at Retained locations (**Figure 15**). After habitat rehabilitation, *S. virginicus* had similar density at Retained locations compared to Reference locations (pair-wise comparisons, $p < 0.05$, **Appendix A; Figure 15**). *S. australis* cover was, on average, higher during some of the baseline surveys at Retained locations but no significant differences were detected by PERMANOVA (pair-wise comparisons, $p < 0.05$, **Appendix A; Figure 16**). In addition, no significant differences were found between Retained and Reference locations.

The percent cover of *S. quinqueflora* was significantly lower at Altered locations compared to Retained and Reference locations, both before and after habitat rehabilitation (pair-wise comparisons, $p < 0.05$, **Appendix B; Figure 14**). *S. virginicus* was not found on any baseline surveys but only after saltmarsh rehabilitation (**Figure 15**). On A1 and A2 surveys, its cover was similar to Retained and Reference locations (pair-wise comparisons, $p > 0.05$, **Appendix A; Figure 15**). *S. australis* was significantly more abundant in Altered locations compared to Retained and Reference on B5, higher than Reference on A1, and higher than Retained on A2 survey. *J. kraussii* was not found at any of the Altered locations (**Figure 17**).

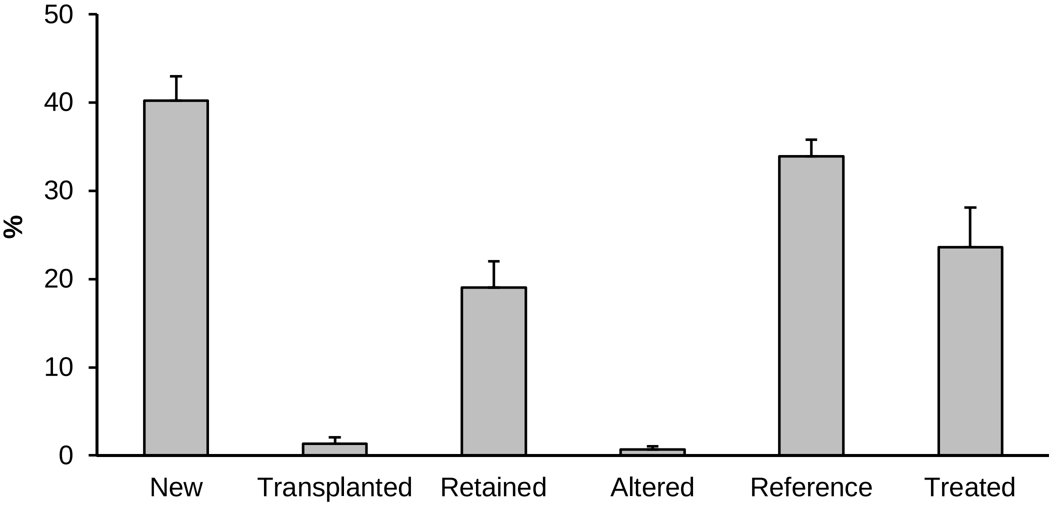

Figure 14 Mean (+SE) cover of *Sarcocornia quinqueflora* at six saltmarsh treatments during the whole sampling period (August 2005 to March 2013).

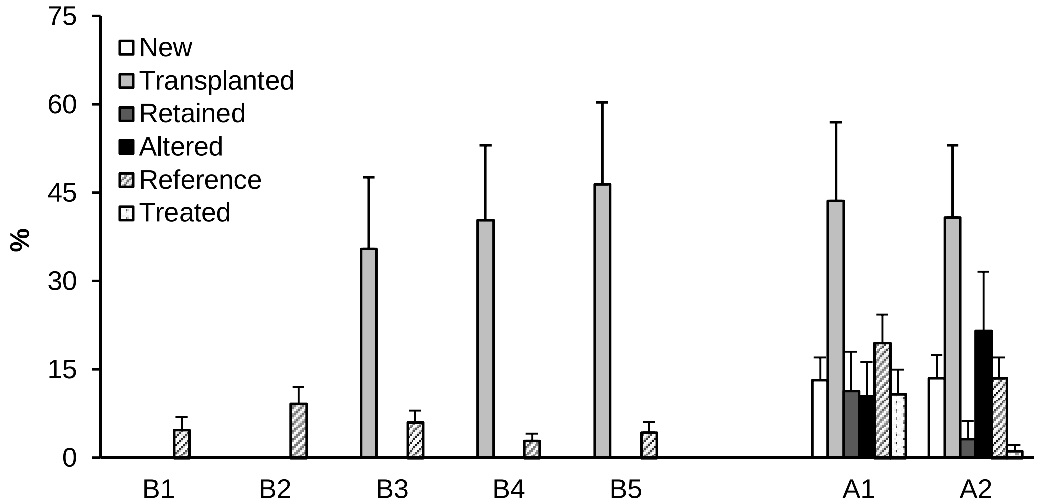

Figure 15 Mean (+SE) cover of *Sporobolus virginicus* at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

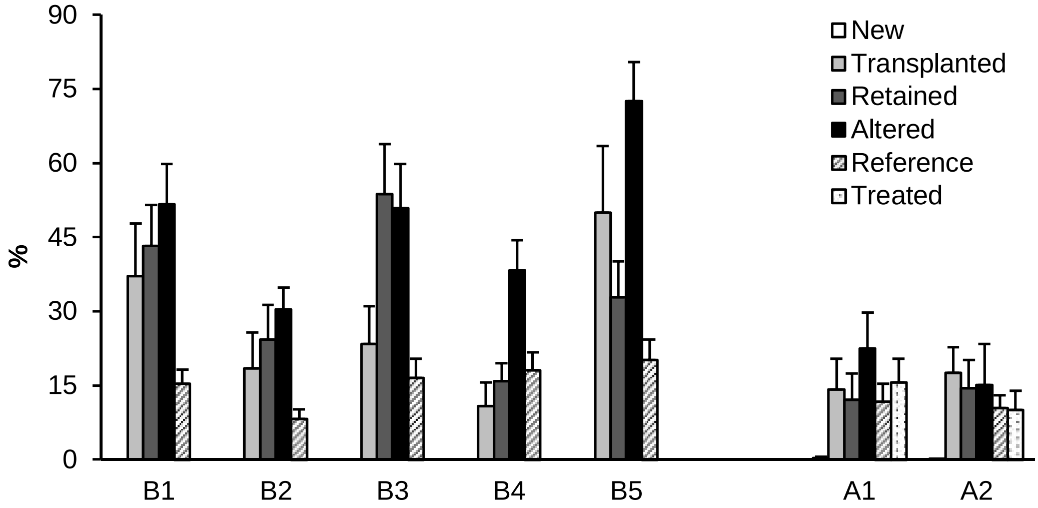

Figure 16 Mean (+SE) cover of *Suaeda australis* at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

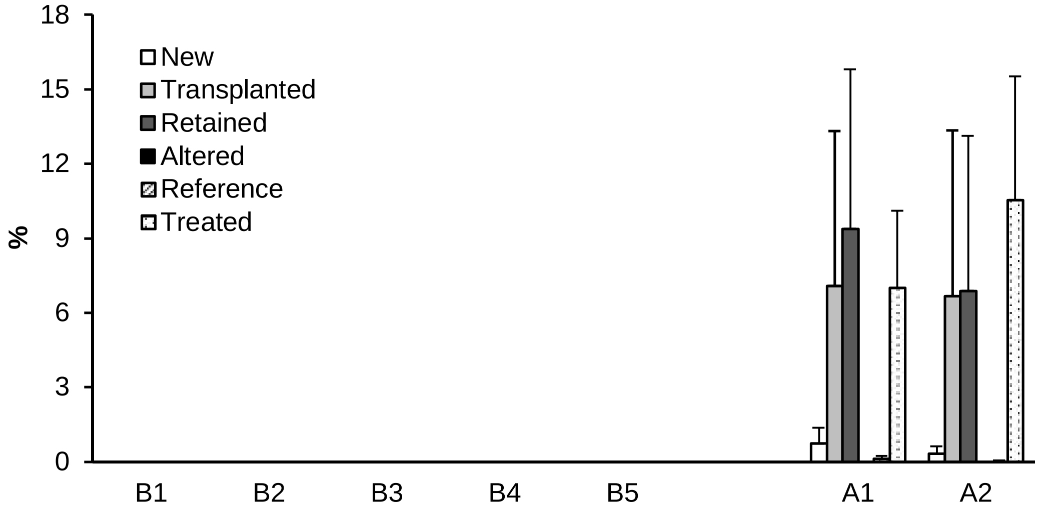

Figure 17 Mean (+SE) cover of *Juncus kraussi* at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

4.2.4 Plant Condition

Generally, the conditions of the most abundant saltmarsh plants were considered healthy, with only a small percentage of saltmarsh vegetation in poor (0.1 ± 0.1 %) or bad (0.1 ± 0.1 %) condition. This is in contrast with data from baseline surveys in which the cover of plants in poor and dead/near dead conditions was 11.6 ± 0.9 % and 4.7 ± 0.4 %, respectively.

None of the saltmarsh species was found in poor or dead conditions during surveys A1 and A2 at New, Reference and Retained locations, with the exception of dead *S. quinqueflora* which had an average cover of 0.2 ± 0.1 % at Reference locations across surveys A1 and A2 (**Figure 18; Figure 19; Figure 20; Figure 21; Figure 22**). No *J. kraussii* in poor conditions or dead was found at any survey.

There was an increase in the cover of *S. virginicus* in poor conditions at Transplanted locations following the rehabilitation (**Figure 22**). This increase was, however, not significant and the result of a few isolated patches of plant in poor conditions along one of the transects (PERMANOVA, $p > 0.05$, **Appendix A**).

Overall, there was a general trend of reduction in the cover of plants in poor conditions or dead from before to after rehabilitation at Retained, Reference and Altered locations (PERMANOVA, $p < 0.05$, **Appendix B; Figure 23**).

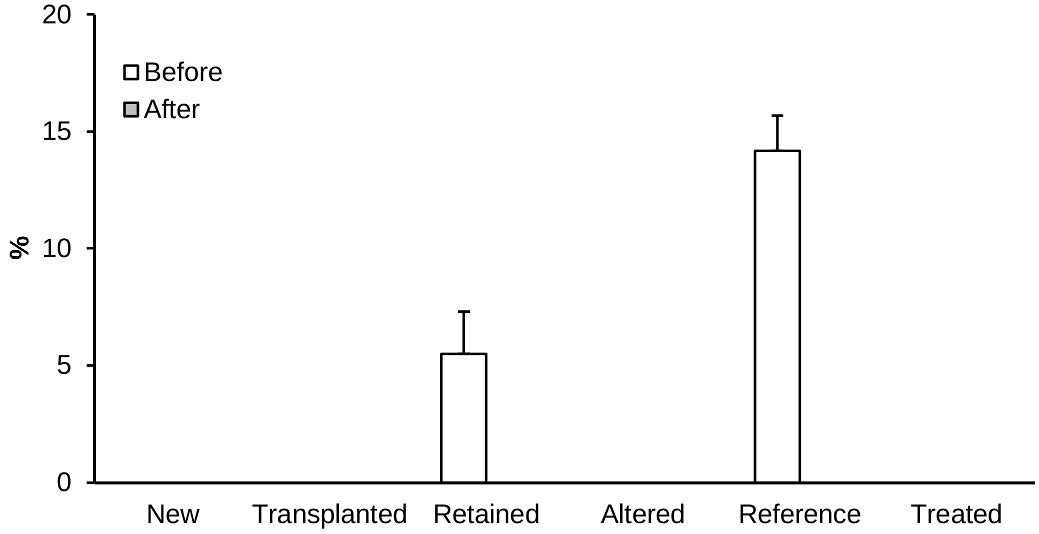

Figure 18 Mean (+SE) cover of *Sarcocornia quinqueflora* plants in poor condition at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation Phases.

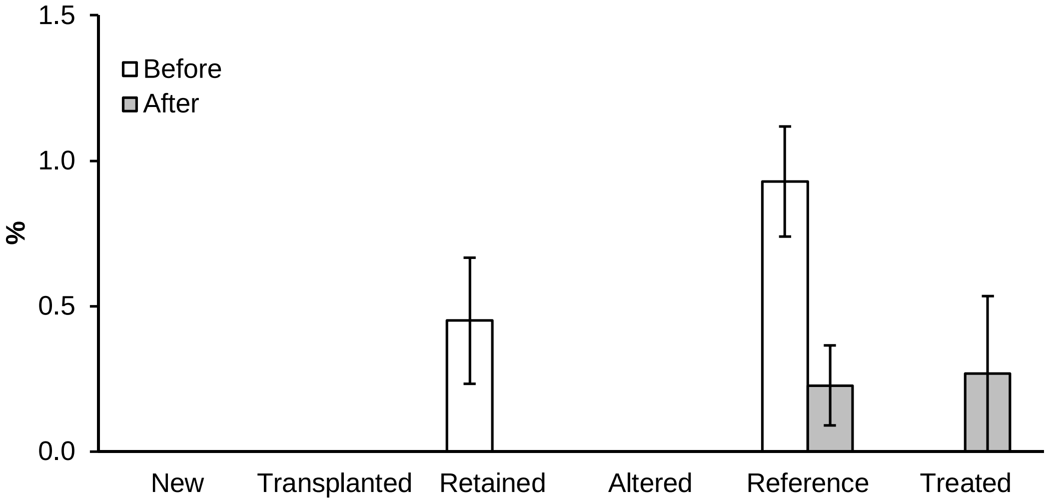

Figure 19 Mean (+SE) cover of dead *Sarcocornia quinqueflora* plants at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation Phases.

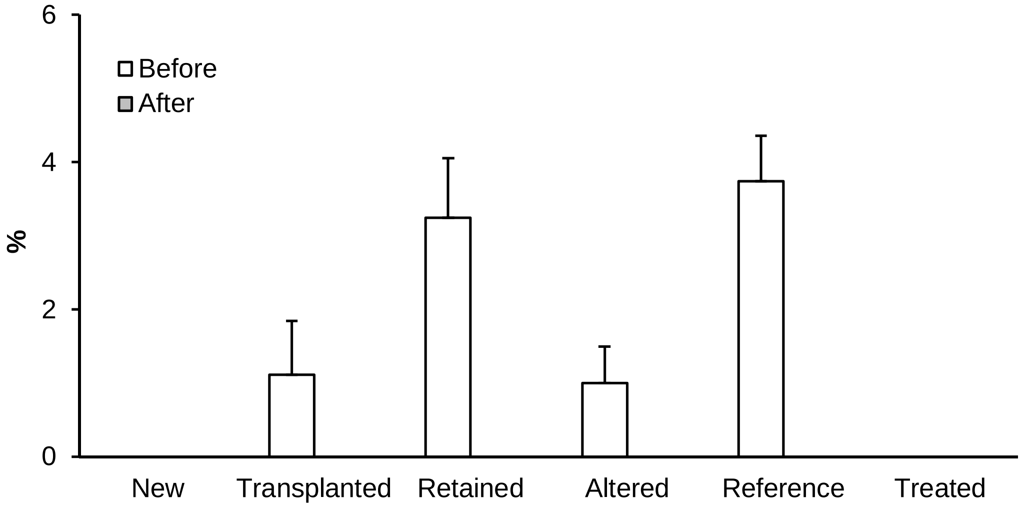

Figure 20 Mean (+SE) cover of *Suaeda australis* plants in poor condition at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation Phases.

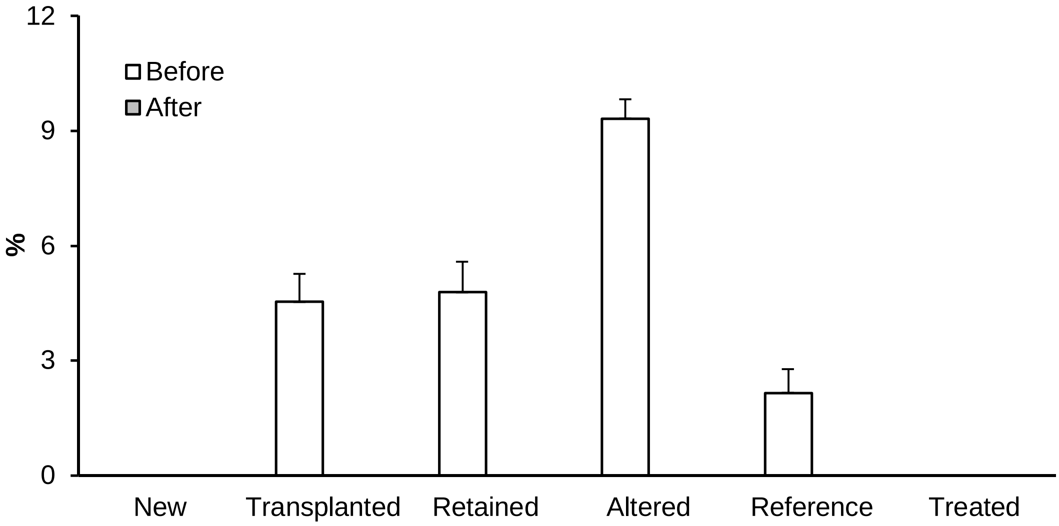

Figure 21 Mean (+SE) cover of dead *Suaeda australis* plants at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation Phases.

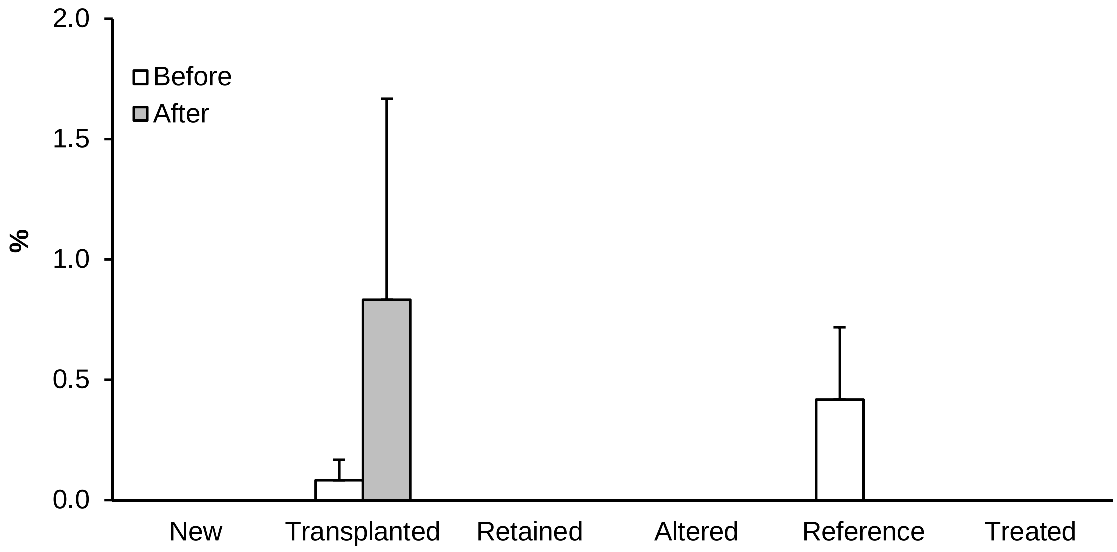

Figure 22 Mean (+SE) cover of S*porobolus virginicus* plants in poor condition at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation Phases.

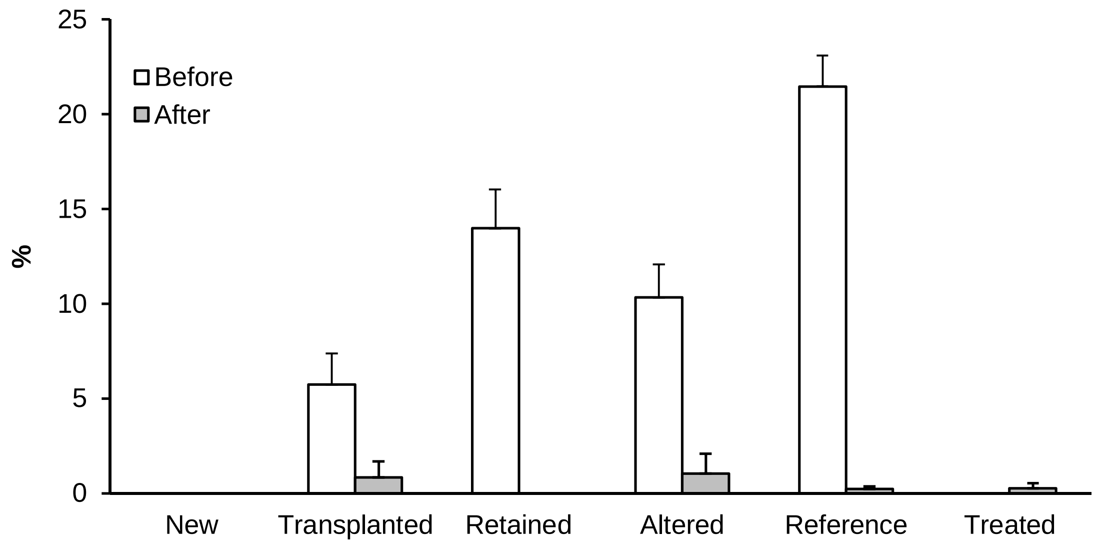

Figure 23 Mean (+SE) cover of saltmarsh plants (*Sarcocornia quinqueflora, Sporobolus virginicus, Suaeda australis* and *Isolepis nodosa)* in poor condition and dead at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation Phases.

4.2.5 Plant Height

S. quinqueflora plants were slightly, but significantly higher in New compared to Retained and Reference locations (PERMANOVA, $p < 0.05$; **Figure 24; Appendix A**). There were no differences in the maximum height of *S. virginicus*, *Suaeda australis* or *Juncus kraussii* in New locations compared to Retained and Reference locations (PERMANOVA, $p > 0.05$, **Appendix A; Figure 25; Figure 26; Figure 27**).

At Transplanted locations, *S. quinqueflora* was the tallest plant only on survey B5 when it had a similar height compared to Retained and Reference locations (**Figure 24**). At Treated locations, *S. quinqueflora* plants were taller compared to Reference locations (PERMANOVA, $p < 0.05$; **Figure 24; Appendix A**).

S. virginicus was measured on B3-B5, A1 and A2 and on these surveys it had a similar maximum height compared to Reference locations, with the exception of B5 and A2 when plants in Transplanted locations had a higher maximum height compared to Reference Locations (**Figure 25**). The height of *S. australis* and *J. kraussii* did not show any significant temporal pattern across all surveys and all treatments (PERMANOVA, $p > 0.05$; **Figure 26**).

Across all surveys, *S. quinqueflora* plants were taller at Retained locations when compared to Reference locations (PERMANOVA, $p < 0.05$, **Appendix A; Figure 24**). The height of *S. virginicus* was measured only on survey A1 and on that occasion it had a similar height to plants at Reference locations (PERMANOVA, $p < 0.05$, **Appendix A; Figure 25**).

S. quinqueflora and *S. virginicus* were the highest plants at Altered locations only in one of the survey after saltmarsh rehabilitation and there were no differences in comparison with the height of plants growing in Retained or Reference locations (**Figure 24; Figure 25**).

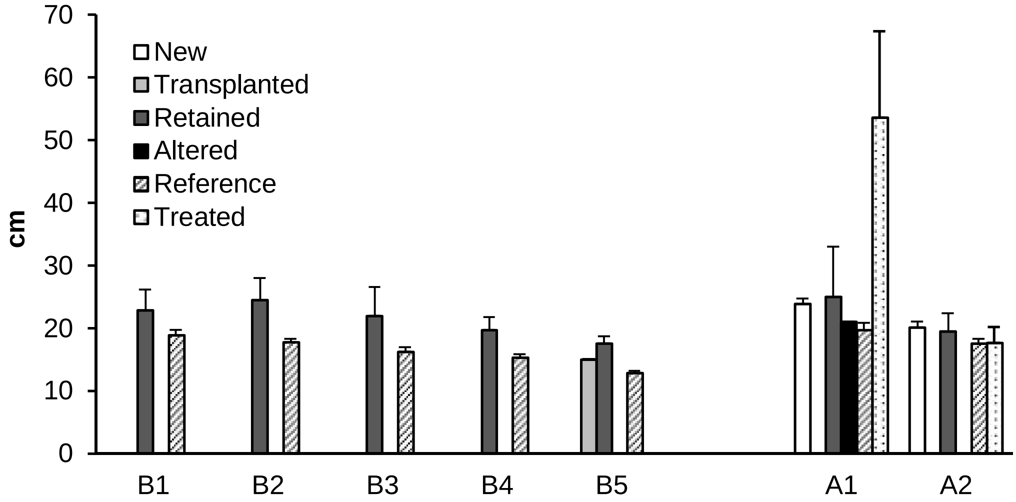

Figure 24 Mean (+SE) maximum height of *Sarcocorniaquinqueflora* at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

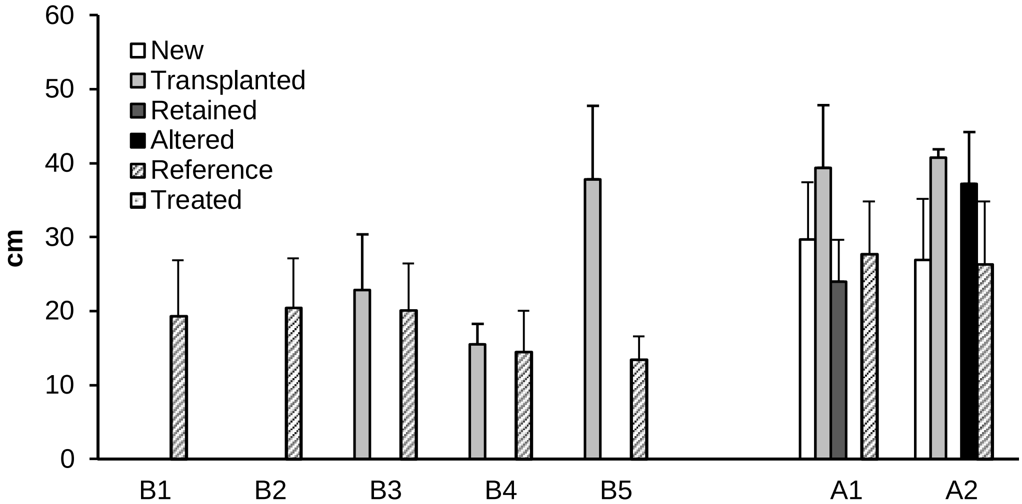

Figure 25 Mean (+SE) maximum height of *Sporobolus virginicus* at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

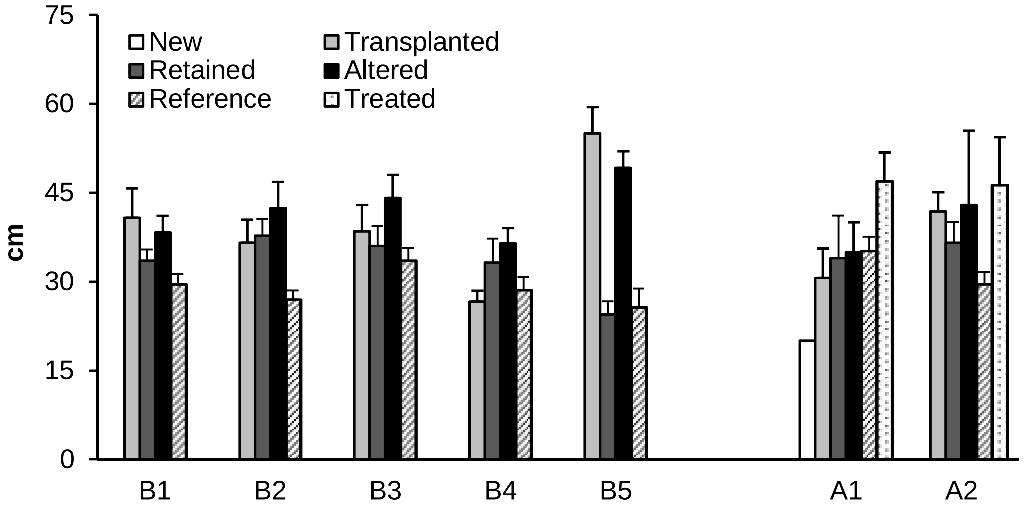

Figure 26 **Mean (+SE) maximum height of *Suaeda australis* at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.**

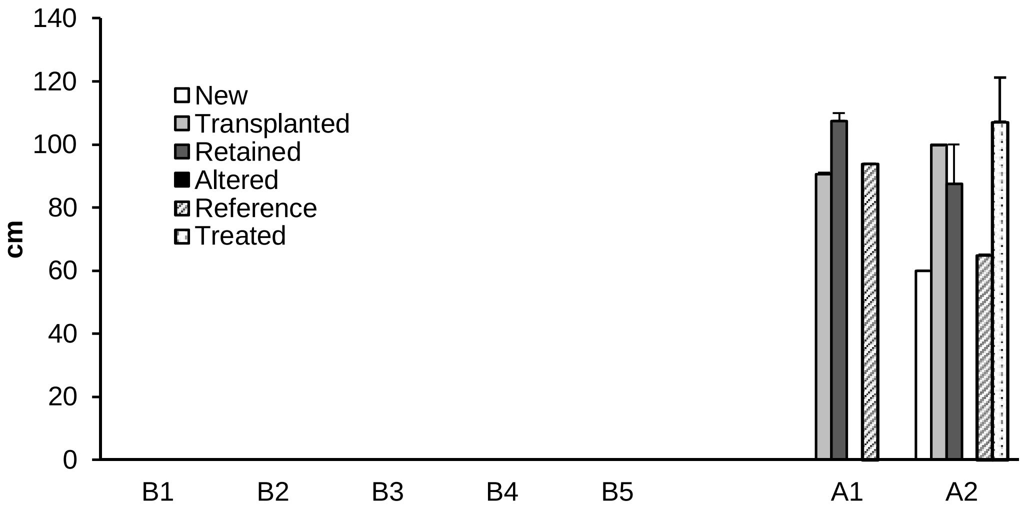

Figure 27 **Mean (+SE) maximum height of *Juncus kraussii* at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.**

4.2.6 Ecological Function

Results of multivariate analysis indicated that saltmarsh habitat at New, Retained and Reference locations supported similar epifaunal assemblages (PERMANOVA, $p > 0.05$; **Appendix B**). Similarly, there were no differences in the diversity (i.e. number of species) and abundance of epifauna.

The epifaunal assemblage did not show any difference between Transplanted, Retained, Reference and Treated treatments (PERMANOVA, $p > 0.05$; **Appendix A**). There were, however, differences among surveys that depended on the location considered (PERMANOVA, $p < 0.05$; **Appendix A**). These differences were likely to be driven by a decrease in the number of species and abundance on survey B4 (PERMANOVA, $p < 0.05$; **Appendix A; Figure 28** and **Figure 29**). There were no significant spatial or temporal patterns across these treatments in the abundance of epifauna (**Figure 29**).

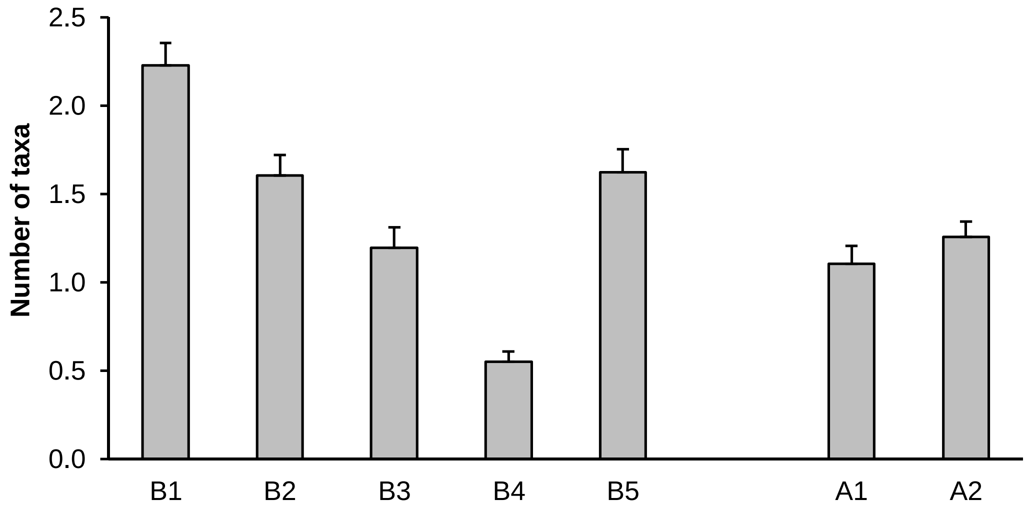

Figure 28 Mean (+SE) number of epifaunal taxa per quadrat before (B1 to B5) and after (A1 and A2) habitat rehabilitation surveys.

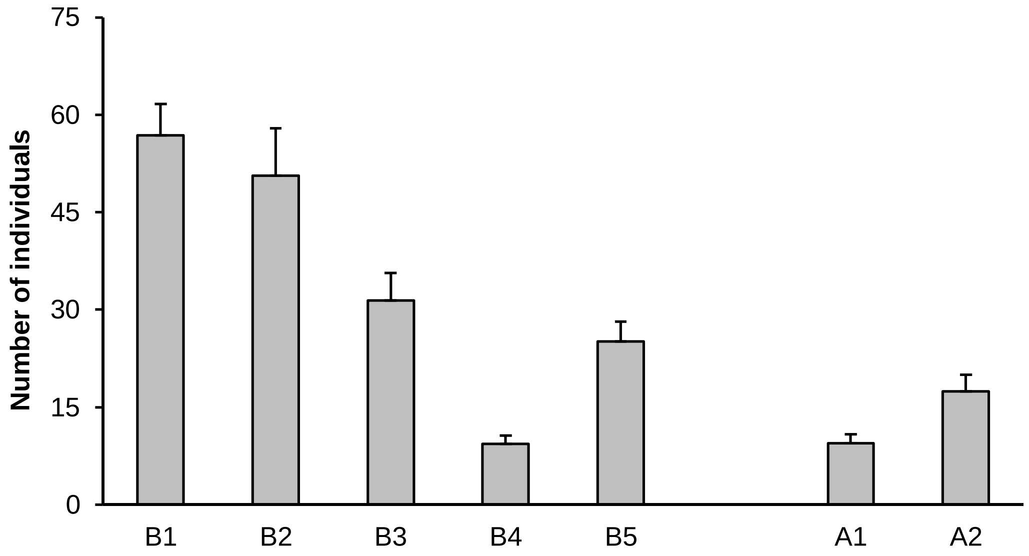

Figure 29 Mean (+SE) number of epifaunal individuals per quadrat before (B1 to B5) and after (A1 and A2) habitat rehabilitation surveys.

4.2.7 Invasion by Mangroves

With the exception of a small percent (1.3 ± 0.9 % cover) of mangrove tree cover at Reference locations, no mangroves trees, seedlings or pneumatophores were found at New, Retained and Reference locations within Penrhyn Estuary following rehabilitation work.

Mangroves were absent from most of the Transplanted, Retained, Altered, Reference and Treated locations after habitat rehabilitation and, as a result, significant lower after the rehabilitation works (PERMANOVA, $p < 0.05$, **Appendix B; Figure 30; Figure 31; Figure 32**). Only a small percentage of mangrove trees was observed at Reference (0.6 ± 0.3 % cover) and Treated (5.5 ± 2.3 % cover) locations after habitat rehabilitation within Penrhyn Estuary (i.e. survey A1 and A2).

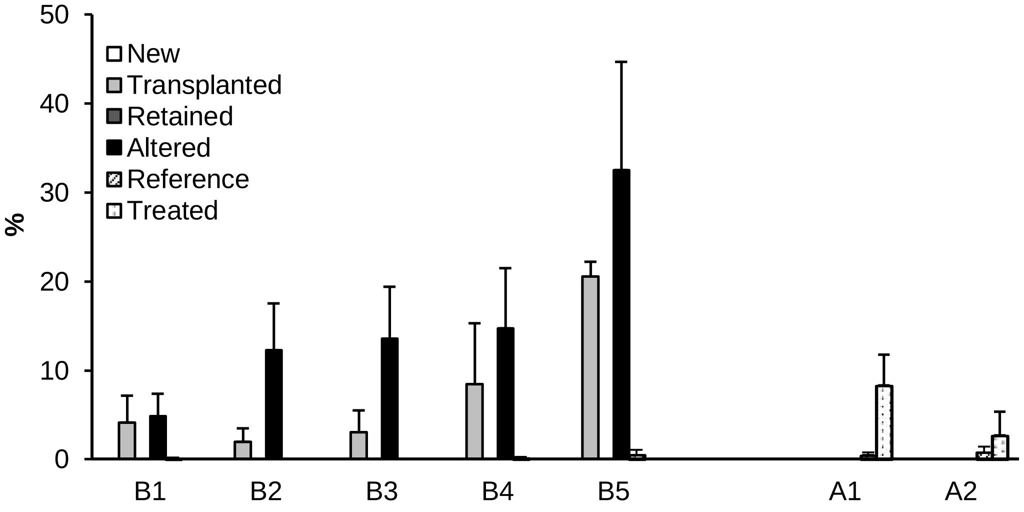

Figure 30 Mean (+SE) cover of mangrove along transects at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

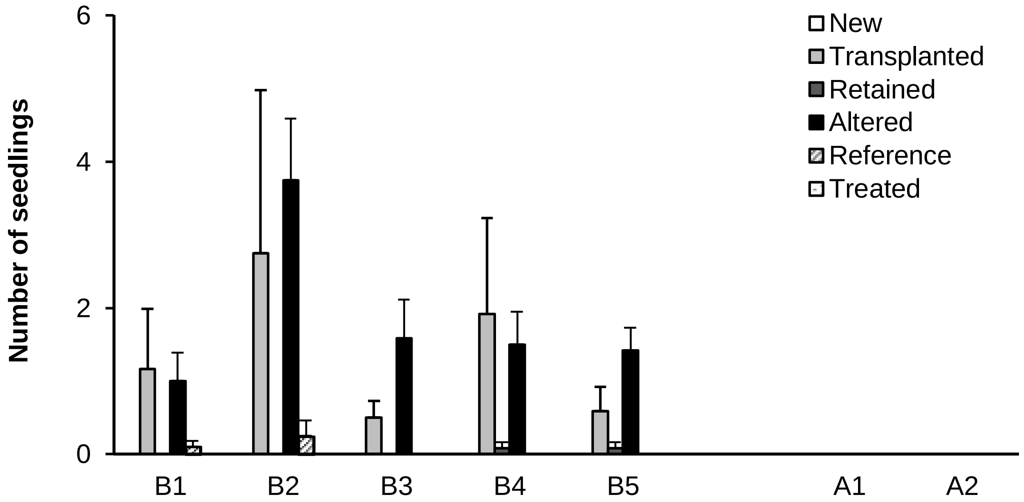

Figure 31 Mean (+SE) number of mangrove seedlings per quadrat at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

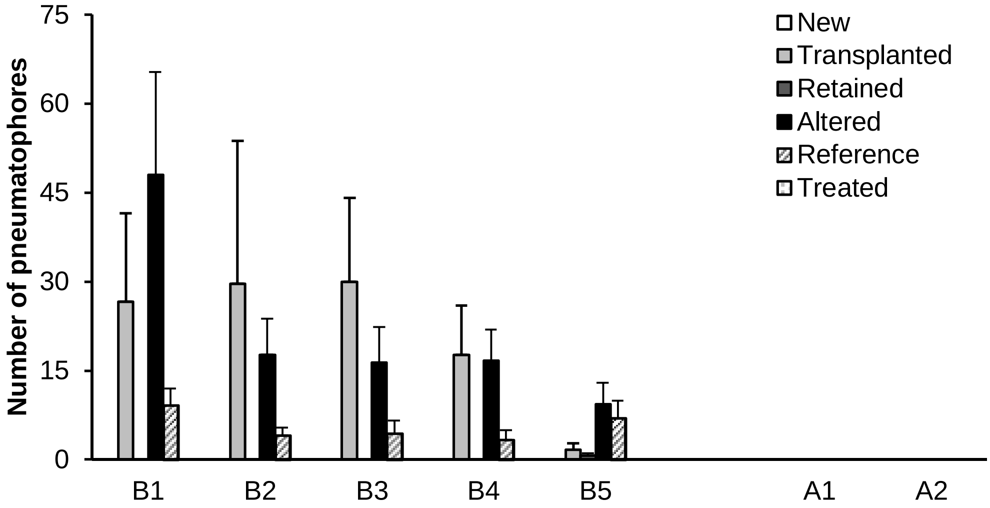

Figure 32 Mean (+SE) number of pneumatophores per quadrat at six saltmarsh treatments during Before (B1 to B5) and After (A1 and A2) habitat rehabilitation surveys.

4.3 Discussion

4.4 Saltmarsh vegetation

4.4.1 Spatial Distribution of Saltmarsh Plant

Analysis of multivariate and univariate data of the saltmarsh plant assemblage at Penrhyn Estuary suggested that, generally, habitat rehabilitation was successful in improving and maintaining the condition of the saltmarsh habitat at modified (New, Transplanted and Altered locations) and Retained locations (Table 14).

In addition, there was an overall increase in the average diversity of saltmarsh species compared to baseline, especially in Retained and Altered locations. *S. quinqueflora* cover at New locations had a similar cover compared to Reference and Retained locations but it had a very low cover at Transplanted and Altered locations. *S. virginicus* was found for the first time after rehabilitation in New, Retained and Altered locations. The cover of *S. australis* was less variable than Baseline surveys and it was found in New locations where it was absent prior to rehabilitation works. *J. kraussii* was found only following rehabilitation.

There were, however, a few instances in which targets were not met (**Table 14**). At Transplanted locations, the average species diversity and the abundance of many of the various saltmarsh species did not increase from Baseline surveys, although values were similar to reference locations (**Table 14**). At Retained and Altered locations the abundance of *S. quinqueflora* decreased compared to Baseline and to Reference locations (**Table 14**).

4.4.2 Plant Health Condition

Saltmarsh vegetation was in overall better condition compared to baseline surveys when, in some locations, plants in poor condition had a cover up to 9%. The highest cover following habitat rehabilitation of poor conditioned vegetation was observed for *S. virginicus* (0.8 ± 0.8%).within the Transplanted locations.

4.4.3 Plant Height

There were no strong patterns in the maximum height of plants and, in general, plants had a similar height compared to Baseline surveys and Reference locations (**Table 14**).

4.5 Ecological function

The ecological function of saltmarsh vegetation, evaluated by assessing the epifaunal assemblage, was similar within both newly planted areas and the Reference locations (**Table 14**). At Transplanted and Altered locations the ecological function of saltmarsh habitat did not improve substantially compared to pre-rehabilitation conditions. At these locations, however, the epifaunal assemblage was similar to that within Reference and Retained locations (**Table 14**).

4.6 Invasion by Mangroves

No mangroves were found during the two after-rehabilitation surveys (**Table 14**). This suggests that mangroves were completely eradicated from Penrhyn Estuary and have not re-appeared following the rehabilitation works.

Table 14 Summary of the results for each ecological indicator at the four saltmarsh treatments and comparisons with targets. *After habitat rehabilitation. N = new saltmarsh habitat, TR = existing saltmarsh that received transplants, RET = retained, undisturbed habitat, ALT= altered saltmarsh habitat where weeds, mangroves were removed. NA = not applicable, ↑ = observed improvement, ↓ = observed decline, ≠ indicates variable results, = indicates no significant difference.

Indicator	Results								Conclusion in comparison to target							
	Compared to baseline				Compared to Reference*				Compared to baseline				Compared to Reference*			
Saltmarsh vegetation	N	TR	RET	ALT	N	TR	RET	ALT	N	TR	RET	ALT	N	TR	RET	ALT
Area	↑				NA				Y				NA			
Growth (assemblage along transects)	NA	≠	=	=	=	=	=	≠	NA	Y	Y	No	Y	Y	Y	No
Species diversity in quadrats	NA	=	↑	↑	=	=	=	=	NA	No	Y	Y	Y	Y	Y	Y
Sarcocornia quinqueflora (% cover)	NA	=	=	=	=	↓	↓	↓	NA	No	Y	No	Y	No	No	No
Sporobolus virginicus (% cover)	NA	=	↑	↑	=	↑	=	=	NA	No	No	Y	Y	N	Y	Y
Suaeda australis (% cover)	NA	=	=	=	↓	=	=	↑	NA	No	Y	No	No	Y	Y	No
Juncus kraussii (% cover)	NA	↑	↑	=	=	=	=	=	NA	Y	No	No	Y	Y	Y	Y
Plant health conditions	NA	↑	↑	↑	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Max height	NA	↑	=	↑	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Ecological function (epifaunal assemblage)	NA	=	=	=	=	=	=	=	NA	No	Y	No	Y	Y	Y	Y
Mangrove																
Tree	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Seedlings	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y
Pneumatophores	NA	↓	=	↓	=	=	=	=	NA	Y	Y	Y	Y	Y	Y	Y

5 Conclusions

Although a number of rehabilitation targets were not met since works were completed, overall, the rehabilitation works done within Penrhyn Estuary in regards to saltmarsh habitat have been successful based on the results of the two surveys that have been done following the works. Species diversity and abundance of most species has either increased, or remained stable, from baseline studies. In addition, most species of saltmarsh vegetation showed successive improvement throughout the post-rehabilitation monitoring. The results of the monitoring to date are encouraging, given that adequate soil characteristics may not develop naturally for many years (Zedler and Callaway 1999). It is well regarded that key factors for the establishment of saltmarsh habitat are substratum composition, elevation and timing of rehabilitation. The composition of the soil is crucial in maintaining adequate growing conditions. Likewise, maintaining optimum elevation via trimming during the rehabilitation process (which eliminates pooling characteristics within the created saltmarsh) is important for a successful rehabilitation program. Timing is also an important consideration during rehabilitation and the success of the works is strongly linked to both seasonal and diel influences (Zedler 2001). It appears from the results of the post rehabilitation surveys that these factors were considered very carefully during the planning phases of the project.

Targets that were not met during the post phase of the rehabilitation program mainly came from the Transplanted and Altered treatments. On closer inspection, saltmarsh species cover and diversity within the Transplanted treatment were generally maintained when compared with baseline data and did not improve nor decrease in value to any great extent. This pattern was similar to that for the Altered treatment where mangroves and weeds were removed as part of the works. Encouragingly, the newly planted areas of saltmarsh vegetation along the northern and southern shorelines were generally comparable to other areas within the estuary in all but the cover of *S. australis*, and successively recorded greater vegetative characteristics throughout the post-rehabilitation monitoring.

Importantly, the ecological functioning of the rehabilitated saltmarsh within Penrhyn Estuary met most targets set, with all treatments comparing well to Reference areas in regards to their epifaunal assemblages. The only targets not met for the ecological function indicator were those from the Transplanted and Altered treatments when compared with their Baseline values. As for the vegetative characteristics for both of these treatments, however, their ecological functioning changed little from baseline values. These results are again encouraging and compare well with other studies that have examined the succession of macrobenthos in created or restored saltmarsh habitat (Levin *et al*. 1996).

Rehabilitation and restoration works in regards to mangrove management is proving successful, with no mangroves (% cover, seedlings or pneumatophores) recorded during the two post-rehabilitation surveys to date. This result is again encouraging, and allowed all targets to be met successfully for all treatments within the estuary when compared with both Baseline and Reference data.

6 Recommendations

It is recommended that the monitoring program that is currently underway be continued unchanged for the next round of surveys. The monitoring plan that has been established for the saltmarshes within Penrhyn Estuary has so far been able to fulfil its aims and objectives and it is important to maintain consistency when collecting data for long term monitoring programs.

7 Acknowledgements

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APPENDIX A

GPS COORDINATES OF SAMPLING SITES

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Appendix A: GPS Coordinates of Sampling Sites

A-1: GPS coordinates of sampling sites

Treatment	Area	Site (Transect)	Landward (highest) Easting	Landward (highest) Northing	Seaward (Lowest) Easting	Seaward (Lowest) Northing	General Location
New Saltmarsh 1	N1	N1-1	334443	6240661	334433	6240622	northern border of estuary
New Saltmarsh 1	N1	N1-2	334465	6240651	334458	6240614	northern border of estuary
New Saltmarsh 1	N1	N1-3	334521	6240634	334503	6240588	northern border of estuary
New Saltmarsh 1	N1	N1-4	334595	6240614	334596	6240558	northern border of estuary
New Saltmarsh 1	N1	N1-5	334669	6240604	334661	6240570	northern border of estuary
New Saltmarsh 1	N1	N1-6	334405	6240547	334399	6240560	northern border of estuary - separate to Sites 1-5
New Saltmarsh 2	N2	N2-9	334211	6240385	334229	6240396	south-eastern corner of estuary
New Saltmarsh 2	N2	N2-10	334231	6240297	334257	6240307	south-eastern corner of estuary
New Saltmarsh 2	N2	N2-11	334296	6240253	334296	6240298	south-eastern corner of estuary
New Saltmarsh 2	N2	N2-12	334400	6240317	334400	6240317	south-eastern corner of estuary
New Saltmarsh 2	N2	N2-13	334545	6240313	334535	6240346	south-eastern corner of estuary
New Saltmarsh 2	N2	N2-21	334245	6240260	334269	6240293	south-eastern corner of estuary
Transplanted Saltmarsh	TR	TR-8	334881	6240494	334886	6240457	eastern end of estuary - western portion of the southern bank of Springvale Drain (transplant recipient)
Transplanted Saltmarsh	TR	TR-17	334848	6240480	334848	6240480	eastern end of estuary - western portion of the southern bank of Springvale Drain (transplant recipient)
Transplanted Saltmarsh	TR	TR-18	334918	6240477	334918	6240477	eastern end of estuary - western portion of the southern bank of Springvale Drain (transplant recipient)
Retained Saltmarsh 1	R1	R1-7	334736	6240472	334736	6240461	along edge of north-eastern dune and along eastern side of Floodvale Drain
Retained Saltmarsh 1	R1	R1-14	334699	6240493	334690	6240493	along edge of north-eastern dune and along eastern side of Floodvale Drain
Retained Saltmarsh 2	R2	R2-20	334976	6240487	334939	6240486	very eastern end of estuary - southern bank of Springvale Drain
Retained Saltmarsh 2	R2	R2-22	334967	6240498	334948	6240498	very eastern end of estuary - southern bank of Springvale Drain
Altered Saltmarsh 2	A2	A2-15	334830	6240418	334820	6240462	eastern end of estuary - western bank of Springvale Drain
Altered Saltmarsh 2	A2	A2-16	334851	6240427	334851	6240434	eastern end of estuary - western bank of Springvale Drain
Altered Saltmarsh 2	A2	A2-19	334783	6240404	334781	6240410	eastern end of estuary - western bank of Springvale Drain
Reference Quibray Bay 1	Q1	Q1-1	333251	6235354	333248	6235333	northern side of Quibray Bay, on south side of Silver Beach boat ramp
Reference Quibray Bay 1	Q1	Q1-2	333239	6235353	333235	6235342	northern side of Quibray Bay, on south side of Silver Beach boat ramp
Reference Quibray Bay 1	Q1	Q1-3	333228	6235363	333222	6235342	northern side of Quibray Bay, on south side of Silver Beach boat ramp
Reference Quibray Bay 2	Q2	Q2-4	333104	6235367	333107	6235349	northern side of Quibray Bay, on south side of Silver Beach boat ramp
Reference Quibray Bay 2	Q2	Q2-5	333096	6235364	333096	6235349	northern side of Quibray Bay, on south side of Silver Beach boat ramp
Reference Quibray Bay 2	Q2	Q2-6	333087	6235366	333087	6235351	northern side of Quibray Bay, on south side of Silver Beach boat ramp
Reference Woolooware Bay 1	W1	W1-1	329505	6233824	329477	6233796	north-eastern side of Woolooware Bay, off walking track called Taren Point Rd
Reference Woolooware Bay 1	W1	W1-2	329495	6233836	329467	6233808	north-eastern side of Woolooware Bay, off walking track called Taren Point Rd
Reference Woolooware Bay 1	W1	W1-3	329475	6233856	329449	6233826	north-eastern side of Woolooware Bay, off walking track called Taren Point Rd
Reference Woolooware Bay 2	W2	W2-4	329438	6233898	329415	6233866	north-eastern side of Woolooware Bay, off walking track called Taren Point Rd
Reference Woolooware Bay 2	W2	W2-5	329417	6233913	329392	6233882	north-eastern side of Woolooware Bay, off walking track called Taren Point Rd
Reference Woolooware Bay 2	W2	W2-6	329398	6233924	329376	6233892	north-eastern side of Woolooware Bay, off walking track called Taren Point Rd
Treated Reference Sans Souci	SS1	SS1-1	327871	6236062	327887	6236060	northern side of Scotts Park, Sans Souci - close to observation hut
Treated Reference Sans Souci	SS1	SS1-2	327869	6236032	327890	6236023	middle of Scotts Park, Sans Souci
Treated Reference Sans Souci	SS1	SS1-3	327865	6236013	327883	6236010	southern side of Scotts Park, Sans Souci
Treated Reference Salt Pan Creek	SPC1	SPC1-1	318808	6242669	318821	6242666	between M5 bridges over Salt Pan Creek - northern side (sampled either side of boardwalk)
Treated Reference Salt Pan Creek	SPC1	SPC1-2	318803	6242677	318818	6242672	between M5 bridges over Salt Pan Creek - middle (sampled either side of boardwalk)
Treated Reference Salt Pan Creek	SPC1	SPC1-3	318793	6242598	318818	6242634	between M5 bridges over Salt Pan Creek - southern side (sampled either side of boardwalk)

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APPENDIX B

RESULTS OF STATISTICAL ANALYSIS

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Appendix B: Results of statistical analysis

B-1: Results of PERMANOVAs testing for difference in the saltmarsh plant assemblage measured along transects. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 15 New saltmarsh Sites (After habitat rehabilitation)

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	10291	5146	1.22	0.3602
Survey	1	725	725	1.53	0.3192
Location(Treatment)	**2**	**5868**	**2934**	**3.52**	**0.0011**
TreatmentxSurvey	2	810	405	0.82	0.6088
Site(Location(Treatment))	3	1584	528	0.98	0.5259
SurveyxLocation(Treatment)	2	835	418	1.55	0.2750
Transect(Site(Location(Treatment)))	20	8617	431	2.15	
SurveyxSite(Location(Treatment))	3	934	311	1.56	0.0891
Res	20	4005	200		
Total	55	33531			

PAIR-WISE TESTS				
Term 'Location(Treatment)'				
Within level 'Retained' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
Floodvale Creek, Springvale Creek	2.02	0.3303	3	0.0605
Within level 'Reference' of factor 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
Quibray Bay, Woolooware Bay	1.51	0.1366	151	0.1312

Table 16 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	28211	9404	1.66	RED
Phase	1	31679	31679	3.86	RED
Survey(Phase)	5	22409	4482	5.44	RED
TreatmentxPhase	2	7813	3906	0.74	0.8071
Location(PhasexTreatment)	4	20758	5190	3.04	RED
TreatmentxSurvey(Phase)	**11**	**23522**	**2138**	**2.56**	**0.0209**
Site(Location(PhasexTreatment))	4	5095	1274	1.12	0.2933
Location(PhasexTreatment)xSurvey(Phase)	**7**	**6845**	**978**	**1.92**	**0.0367**
Transect(Site(Location(PhasexTreatment)))	28	25621	915		
Survey(Phase)xSite(Location(PhasexTreatment))	10	5172	517	1.38	0.0809
Res	64	24036	376		
Total	139	245790			

PAIR-WISE TESTS				
Term 'Treatment x Survey(Ph)' for pairs of levels of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**2.58**	**0.1045**	**10**	**0.0192**
Retained, Reference	**2.46**	**0.1305**	**15**	**0.0348**
Transplanted, Reference	**2.96**	**0.1320**	**15**	**0.0142**
Within level 'Before' of factor 'Phase'				
Within level 'B2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**2.50**	**0.0987**	**10**	**0.0232**
Retained, Reference	0.87	0.5422	15	0.5837
Transplanted, Reference	1.67	0.1961	15	0.1732
Within level 'Before' of factor 'Phase'				
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**2.89**	**0.1057**	**10**	**0.0091**
Retained, Reference	1.26	0.1965	15	0.2952
Transplanted, Reference	1.84	0.2055	15	0.1043
Within level 'Before' of factor 'Phase'				
Within level 'B4' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**2.78**	**0.1011**	**10**	**0.0237**
Retained, Reference	0.92	0.6719	15	0.5229
Transplanted, Reference	**3.03**	**0.2039**	**15**	**0.0155**
Within level 'Before' of factor 'Phase'				
Within level 'B5' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**2.19**	**0.0971**	**10**	**0.0375**
Retained, Reference	1.73	0.1274	15	0.1010
Transplanted, Reference	**3.18**	**0.1290**	**15**	**0.0073**

PAIR-WISE TESTS				
Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.02	0.3358	3	0.4962
Retained, Reference	0.77	0.6877	27	0.7106
Retained, Treated	0.68	1.0000	6	0.7124
Transplanted, Reference	1.44	0.1997	15	0.2092
Transplanted, Treated	0.63	1.0000	3	0.7540
Reference, Treated	1.09	0.3338	27	0.3795
Within level 'After' of factor 'Phase'				
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	0.97	0.3260	3	0.5209
Retained, Reference	1.02	0.4260	27	0.4432
Retained, Treated	0.76	1.0000	6	0.6404
Transplanted, Reference	2.21	0.2017	15	0.0809
Transplanted, Treated	1.17	0.3442	3	0.3985

Table 17 Altered and Retained sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	19390	9695	2.45	RED
RET	1	4596	4596	1.36	0.2161
Phase	**1**	**25251**	**25251**	**3.18**	**0.0129**
Survey(Phase)	5	27459	5492	8.10	RED
TreatmentxPhase	2	8399	4199	1.15	0.3167
RETxPhase	1	1198	1198	0.49	0.9202
Location(PhasexTreatment)	**3**	**9558**	**3186**	**2.04**	**0.0144**
Location(PhasexRET)	**3**	**9558**	**3186**	**2.05**	**0.0154**
Treatment x Survey(Phase)	**10**	**17280**	**1728**	**2.52**	**0.0157**
RETxSurvey(Phase)	5	6704	1341	1.97	0.0903
Site(Location(PhasexTreatment))	4	5095	1274	1.10	0.3148
Site(Location(PhasexRET))	4	5095	1274	1.24	0.1622
Location(PhasexTreatment)xSurvey(Phase)	6	4638	773	1.52	0.1340
Location(PhasexRET)xSurvey(Phase)	6	4638	773	1.52	0.1254
Transect(Site(Location(PhasexTreatment)))	**24**	**23578**	**982**	**2.58**	**0.0001**
Transect(Site(Location(PhasexRET)))	**20**	**16088**	**804**	**2.20**	**0.0003**
Survey(Phase)xSite(Location(PhasexTreatment))	10	5172	517	1.36	0.0938
Survey(Phase)xSite(Location(PhasexRET))	10	5172	517	1.42	0.0718
Res	60	22881	381		

Total	127	207520

PAIR-WISE TESTS

Term 'TreatmentxSurvey(Phase)' for pairs of levels of factor 'Treatment'

Within level 'Before' of factor 'Phase'

Within level 'B1' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	1.29	0.2931	10	0.2373
Retained, Reference	**2.46**	**0.1328**	**15**	**0.0374**
Altered, Reference	**3.37**	**0.1341**	**15**	**0.0092**

Within level 'Before' of factor 'Phase'

Within level 'B2' of factor 'Survey'

PAIR-WISE TESTS (continued)

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	1.87	0.0969	10	0.0793
Retained, Reference	0.87	0.5352	15	0.5872
Altered, Reference	1.60	0.2016	15	0.2042

Within level 'Before' of factor 'Phase'

Within level 'B3' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**2.32**	**0.1027**	**10**	**0.0250**
Retained, Reference	1.26	0.1913	15	0.3015
Altered, Reference	2.01	0.2046	15	0.0828

Within level 'Before' of factor 'Phase'

Within level 'B4' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	1.96	0.1020	10	0.0692
Retained, Reference	0.92	0.6700	15	0.5304
Altered, Reference	**3.11**	**0.1957**	**15**	**0.0119**

Within level 'Before' of factor 'Phase'

Within level 'B5' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	1.80	0.0994	10	0.0833

Retained, Reference	1.73	0.1360	15	0.1046
Altered, Reference	**3.47**	**0.1302**	**15**	**0.0023**
Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	1.14	0.3704	101	
Retained, Reference	0.77	0.7311	9944	
Altered, Reference	1.74	0.1976	15	0.1255
Within level 'After' of factor 'Phase'				
Within level 'A2' of factor 'Survey'				

PAIR-WISE TESTS (Continued)				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	0.79	0.7582	101	
Retained, Reference	1.02	0.4277	9952	
Altered, Reference	2.32	0.1978	15	0.0678
Term 'Location(PhasexTreatment)'				
Within level 'Retained' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Floodvale Creek, Springvale Creek	2.02	0.3346	3	0.0577
Within level 'Reference' of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	
Woolooware Bay, Quibray Bay	1.19	0.2436	9944	
Within level 'Reference' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	
Woolooware Bay, Quibray Bay	1.51	0.1355	151	

B-2: Results of SIMPER analysis for Retained and Altered treatments to identify the taxa that mostly contributed to differences in the saltmarsh assemblage.

Table 18 Retained vs. Altered. Average dissimilarity = 61.8

	Group Retained	Group Altered				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Suaeda australis	24.9	30.5	8.66	1.28	14.0	14.0
Sarcocornia quinqueflora	16.9	1.3	7.67	1.23	12.4	26.4
Bare ground	25.0	29.1	6.21	1.30	10.0	36.5
Avicennia marina tree	0.0	6.4	4.68	1.13	7.6	44.0
Debris	6.4	3.0	4.46	0.89	7.2	51.3
Sporobolus virginicus	3.8	6.6	4.34	0.68	7.0	58.3
A. marina pneumatophores	1.1	6.4	4.02	0.79	6.5	64.8
Struggling *S. quinqueflora*	16.9	1.3	3.72	0.59	6.0	70.8
Dead *Suaeda australis*	1.7	3.7	3.46	1.10	5.6	76.4
Struggling *Suaeda australis*	3.1	1.7	2.69	0.66	4.4	80.7
Juncus kraussii	3.5	0.2	1.71	0.41	2.8	83.5
Dead *Sarcocornia quinqueflora*	3.6	0.0	1.50	0.31	2.4	85.9
Isolepis nodosa	0.0	3.6	1.47	0.32	2.4	88.3
A. marina with *S. australis*	0.0	1.6	1.39	0.54	2.2	90.6

Table 19 Retained vs. Reference. Average dissimilarity = 55.2

	Group Retained	Group Reference				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Sarcocornia quinqueflora	16.9	25.6	8.10	1.31	14.7	14.7
Suaeda australis	24.9	14.7	7.05	1.45	12.8	27.4
Struggling *S. quinqueflora*	7.6	12.0	6.14	0.96	11.1	38.6
Sporobolus virginicus	3.8	10.4	6.01	1.35	10.9	49.5
Bare ground	25.0	12.8	5.44	1.43	9.9	59.3
Debris	6.4	6.5	5.16	1.11	9.4	68.7
Struggling *S. australis*	24.9	14.7	4.31	1.00	7.8	76.5
Dead *S. quinqueflora*	3.6	6.6	3.68	0.56	6.7	83.1
Dead *S. australis*	24.9	14.7	2.49	0.94	4.5	87.6
A. marina pneumatophores	1.1	1.9	1.94	0.58	3.5	91.1

Table 20 Altered vs. Reference. Average dissimilarity = 64.1

	Group Altered	Group Reference				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Sarcocornia quinqueflora	1.3	25.6	9.42	1.34	14.7	14.7
Suaeda australis	30.5	14.7	7.30	1.66	11.4	26.1
Sporobolus virginicus	6.6	10.4	6.45	1.31	10.1	36.2
Bare ground	29.1	12.8	5.98	1.31	9.3	45.5
Struggling *S. quinqueflora*	1.3	25.6	4.80	0.77	7.5	53.0
Avicennia marina tree	6.4	0.2	4.33	1.14	6.8	59.8

Debris	3.0	6.5	4.25	1.16	6.6	66.4
Struggling *Suaeda australis*	30.5	14.7	3.95	0.97	6.2	72.6
A. marina pneumatophores	6.4	1.9	3.87	0.85	6.1	78.6
Dead *Suaeda australis*	3.7	1.8	3.21	1.14	5.0	83.6
Dead *Sarcocornia quinqueflora*	0.0	6.6	2.65	0.46	4.1	87.8
Isolepis nodosa	3.6	0.0	1.40	0.33	2.2	90.0
Aegiceras corniculatum	3.0	0.0	1.32	0.34	2.1	92.0

B-3: Results of PERMANOVAs testing for difference in the number of saltmarsh plant species per quadrat. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 21 New saltmarsh Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	6.0	3.0	2.20	0.1732
Survey	1	0.0	0.0	0.13	0.9345
Location(Treatment)	2	2.4	1.2	1.54	0.2954
TreatmentxSurvey	2	0.1	0.0	0.22	0.9452
Site(Location(Treatment))	3	0.3	0.1	0.26	0.9878
SurveyxLocation(Treatment)	2	1.5	0.8	1.29	0.3280
Transect(Site(Location(Treatment)))	**19**	**16.5**	**0.9**	**2.57**	**0.0231**
SurveyxSite(Location(Treatment))	3	2.3	0.8	2.25	0.1147
SurveyxTransect(Site(Location(Treatment)))	19	6.4	0.3	0.58	0.9175
Res	162	94.3	0.6		
Total	215	130.3			

Table 22 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	4.6	1.5	1.03	0.4427
Phase	**1**	**9.4**	**9.4**	**3.49**	**0.0398**
Survey(Phase)	5	1.7	0.3	0.28	0.9307
TreatmentxPhase	2	0.5	0.3	0.52	0.8496
Location(PhasexTreatment)	5	15.6	3.1	2.33	0.0703
TreatmentxSurvey(Phase)	11	3.6	0.3	0.27	0.9860
Site(Location(PhasexTreatment))	4	0.4	0.1	0.25	0.9998
Location(PhasexTreatment)xSurvey(Phase)	**8**	**12.6**	**1.6**	**3.66**	**0.0188**
Transect(Site(Location(PhasexTreatment)))	**27**	**35.0**	**1.3**	**3.89**	**0.0001**
Survey(Phase)xSite(Location(PhasexTreatment))	10	4.4	0.4	1.32	0.2322
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	63	21.0	0.3	0.72	0.9441
Res	420	193.3	0.5		
Total	559	305.9			

Table 23 Retained and Altered Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	1.8	0.9	1.57	RED
RET	1	0.8	0.8	1.49	0.2448
Phase	1	24.2	24.2	19.04	RED
Survey(Phase)	5	1.3	0.3	0.21	0.9574
TreatmentxPhase	**2**	**6.3**	**3.1**	**3.18**	**0.0297**
RETxPhase	1	0.5	0.5	1.31	0.2969
Location(PhasexTreatment)	3	5.0	1.7	1.20	0.3766
Location(PhasexRET)	3	5.0	1.7	1.20	0.3733
TreatmentxSurvey(Phase)	10	2.6	0.3	0.20	0.9888
RETxSurvey(Phase)	5	1.3	0.3	0.19	0.9559
Site(Location(PhasexTreatment))	4	0.4	0.1	0.26	0.9995
Site(Location(PhasexRET))	4	0.4	0.1	0.26	0.9990
Location(PhasexTreatment)xSurvey(Phase)	**6**	**10.5**	**1.7**	**4.01**	**0.0205**
Location(PhasexRET)xSurvey(Phase)	**6**	**10.5**	**1.7**	**4.02**	**0.0221**
Transect(Site(Location(PhasexTreatment)))	**23**	**29.2**	**1.3**	**3.72**	**0.0001**
Transect(Site(Location(PhasexRET)))	**19**	**21.5**	**1.1**	**3.70**	**0.0001**
Survey(Phase)xSite(Location(PhasexTreatment))	10	4.4	0.4	1.29	0.2634
Survey(Phase)xSite(Location(PhasexRET))	10	4.4	0.4	1.44	0.1913
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	59	20.2	0.3	0.80	0.8434
Survey(Phase)xTransect(Site(Location(PhasexRET)))	49	15.0	0.3	0.64	0.9713
Res	378	161.0	0.4		
Total	503	267.2			

PAIR-WISE TESTS			
Term 'Treatment x Phase' for pairs of levels of factor 'Treatment'			
Within level 'Before' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Retained, Altered	**4.14**	**0.0011**	**4332**
Retained, Reference	1.35	0.2325	9883
Altered, Reference	**2.87**	**0.0112**	**9922**
Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Retained, Altered	1.47	0.2743	9788
Retained, Reference	0.80	0.6540	9976
Altered, Reference	0.59	0.8285	9969
Term 'TreatmentxPhase' for pairs of levels of factor 'Phase'			
Within level 'Retained' of factor 'Treatment'			

Groups	t	P(perm)	Unique perms
Before, After	3.01	0.0156	9820

Within level 'Altered' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Before, After	2.95	0.0047	8353

Within level 'Reference' of factor 'Treatment'			
Groups	t	P(perm)	Unique perms
Before, After	1.77	0.0990	9966

B-4: Results of PERMANOVAs testing for difference in the abundance of *Sarcocornia quinqueflora* per quadrat. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 24 New Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	**2**	**10386**	**5193**	**5.42**	**0.0194**
Survey	1	4	4	0.11	0.9566
Location(Treatment)	2	1118	559	0.52	0.8087
TreatmentxSurvey	2	419	209	0.34	0.8761
Site(Location(Treatment))	3	1853	618	0.84	0.6188
SurveyxLocation(Treatment)	2	1530	765	3.17	0.0898
Transect(Site(Location(Treatment)))	**19**	**19799**	**1042**	**2.72**	**0.0167**
SurveyxSite(Location(Treatment))	3	457	152	0.40	0.7564
SurveyxTransect(Site(Location(Treatment)))	19	7269	383	0.33	0.9955
Residual	162	187530	1158		
Total	215	230830			

PAIR-WISE TESTS				
Term 'Treatment'				
Groups	t	P(perm)	Unique perms	P(MC)
New, Retained	2.25	0.0508	9965	0.2216
New, Reference	1.68	0.1753	9970	0.2523
Retained, Reference	**3.32**	**0.0169**	**9970**	**0.0227**

Table 25 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	**3**	**77485**	**25828**	**4.88**	**0.0006**
Phase	1	7323	7323	1.31	0.2793

Survey(Ph)	5	5899	1180	0.65	RED
TreatmentxPhase**	2	2286	1143	0.48	0.8864
Location(PhxTre)	5	28975	5795	1.49	RED
TreatmentxSurvey(Ph)	11	6491	590	0.32	0.9773
Site(Lo(PhxTre))	4	14251	3563	1.72	0.0966
Location(PhxTre)xSu(Ph)	**8**	**17518**	**2190**	**2.76**	**0.0458**
Transect(Si(Lo(PhxTre)))	**27**	**38878**	**1440**	**3.35**	**0.0002**
Survey(Ph)xSite(Lo(PhxTre))	10	8379	838	1.95	0.0510
Survey(Ph)xTransect(Si(Lo(PhxTre)))	63	27102	430	0.55	0.9981
Residual	420	328970	783		
Total	559	586280			

PAIR-WISE TESTS			
Term 'Treatmet'			
Groups	t	P(perm)	Unique perms
Retained, Transplanted	**3.03**	**0.0123**	**9957**
Retained, Reference	**3.00**	**0.0024**	**9949**
Retained, Treated	0.18	0.9980	9957
Transplanted, Reference	**4.81**	**0.0001**	**9950**
Transplanted, Treated	0.66	0.7696	9968
Reference, Treated	1.78	0.1291	9953

Table 26 Retained and Altered Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	**2**	**77754**	**38877**	**16.11**	**0.0001**
RET	**1**	**18816**	**18816**	**8.99**	**0.0027**
Phase	1	6259	6259	2.60	0.0846
Survey(Phase)	5	5845	1169	0.56	0.7439
TreatmentxPhase	2	2992	1496	1.41	0.2648
RETxPhase	1	906	906	1.36	0.2870
Location(PhasexTreatment)	3	4118	1373	0.37	0.9250
Location(PhasexRET)	3	4118	1373	0.36	0.9306
TreatmentxSurvey(Phase)	10	6090	609	0.28	0.9782
RETxSurvey(Phase)	5	2157	431	0.20	0.9579
Site(Location(PhasexTreatment))	4	14251	3563	1.64	0.1223
Site(Location(PhasexRET))	4	14251	3563	1.48	0.1815
Location(PhasexTreatment)xSurvey(Phase)	**6**	**17207**	**2868**	**3.51**	**0.0298**
Location(PhasexRET)xSurvey(Phase)	**6**	**17207**	**2868**	**3.49**	**0.0306**
Transect(Site(Location(PhasexTreatment)))	**23**	**38109**	**1657**	**3.66**	**0.0001**
Transect(Site(Location(PhasexRET)))	**19**	**37857**	**1993**	**3.65**	**0.0005**
Survey(Phase)xSite(Location(PhasexTreatment))	10	8379	838	1.85	0.0698

Survey(Phase)xSite(Location(PhasexRET))	10	8379	838	1.54	0.1548
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	59	26744	453	0.59	0.9928
Survey(Phase)xTransect(Site(Location(PhasexRET)))	49	26734	546	0.59	0.9871
Res	378	292320	773		
Total	503	525100			
PAIR-WISE TESTS					
Term 'Treatment'					
Groups	t	P(perm)	Unique perms		
Retained, Altered	**3.28**	**0.0105**	**9961**		
Retained, Reference	**3.00**	**0.0017**	**9936**		
Altered, Reference	**4.95**	**0.0004**	**9949**		

B-5: Results of PERMANOVAs testing for difference in the abundance of *Sporobolus virginicus* per quadrat. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 27 New Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	1711	856	0.27	0.9496
Survey	1	802	802	1.52	0.3988
Location(Treatment)	**2**	**8388**	**4194**	**5.04**	**0.0157**
TreatmentxSurvey	2	591	296	0.67	0.7094
Site(Location(Treatment))	3	804	268	0.81	0.6352
SurveyxLocation(Treatment)	2	934	467	1.93	0.1941
Transect(Site(Location(Treatment)))	19	12265	646	1.70	0.1295
SurveyxSite(Location(Treatment))	3	468	156	0.41	0.7470
SurveyxTransect(Site(Location(Treatment)))	19	7196	379	0.52	0.9510
Residual	162	118020	729		
Total	215	151770			

Table 28 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	42475	14158	3.47	RED
Phase	1	10292	10292	2.48	0.0828
Survey(Ph)	5	10978	2196	5.30	RED
TreatmentxPhase**	2	1103	552	0.23	0.9937
Location(PhxTre)	**5**	**12524**	**2505**	**4.62**	**0.0055**
TreatmentxSurvey(Ph)	**11**	**23203**	**2109**	**5.08**	**0.0038**
Site(Lo(PhxTre))	4	607	152	0.25	0.9997
Location(PhxTre)xSu(Ph)	8	3641	455	1.79	0.1752
Transect(Si(Lo(PhxTre)))	**27**	**29974**	**1110**	**5.58**	**0.0001**
Survey(Ph)xSite(Lo(PhxTre))	10	2609	261	1.31	0.2423

Survey(Ph)xTransect(Si(Lo(PhxTre)))	63	12534	199	0.44	1.0000
Residual	420	191750	457		
Total	559	335820			

PAIR-WISE TESTS				
Term 'Location(PhasexTreatment)'				
Within level 'Retained' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Springvale Creek, Floodvale Creek	1.67	0.2358	19	0.2965
Within level 'Reference' of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	**2.68**	**0.0235**	**9966**	**0.0437**
Within level 'Reference' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	3.15	0.0471	9968	0.0638
Within level 'Treated' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Sans Souci	Den. is 0			
Woolooware Bay, Salt Pan Creek	1.02	0.4458	143	0.4382
Sans Souci, Salt Pan Creek	1.15	0.3368	158	0.4190
Term 'TrexSu(Ph)' for pairs of levels of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	Den. is 0			
Retained, Reference	0.62	0.7350	9	0.6325
Transplanted, Reference	0.62	0.7407	9	0.6276
Within level 'Before' of factor 'Phase'				
Within level 'B2' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	Den. is 0			
Retained, Reference	1.90	0.1911	15	0.1572
Transplanted, Reference	1.90	0.2056	15	0.1613

Within level 'Before' of factor 'Phase'				
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**4.80**	**0.1063**	**4**	**0.0102**
Retained, Reference	0.65	0.5363	15	0.6142
Transplanted, Reference	3.20	0.2080	15	0.1525
Within level 'Before' of factor 'Phase'				
Within level 'B4' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**7.89**	**0.1043**	**4**	**0.0014**
Retained, Reference	0.56	0.4004	15	0.6373
Transplanted, Reference	**7.28**	**0.2011**	**15**	**0.0195**

Within level 'Before' of factor 'Phase'				
Within level 'B5' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**10.15**	**0.1031**	**4**	**0.0006**
Retained, Reference	1.20	0.6061	9	0.3485
Transplanted, Reference	**11.84**	**0.1347**	**15**	**0.0036**

Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.72	0.4083	65	0.3536
Retained, Reference	0.44	0.6843	9819	0.7023
Retained, Treated	0.21	0.8395	504	0.8493
Transplanted, Reference	1.34	0.2923	9929	0.4101
Transplanted, Treated	1.97	0.2457	883	0.1917
Reference, Treated	0.69	0.5339	9929	0.5364

Within level 'After' of factor 'Phase'				
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	7.12	0.0853	31	0.0894
Retained, Reference	1.16	0.3094	9864	0.3529
Retained, Treated	0.85	0.5937	10	0.4484
Transplanted, Reference	2.26	0.1360	9937	0.2353

Transplanted, Treated	**22.08**	**0.0064**	**95**	**0.0018**
Reference, Treated	1.87	0.1321	9922	0.1548

Table 29 Retained and Altered Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	3107	1553	0.78	0.6214
RET	1	3061	3061	1.47	0.2632
Phase	**1**	**9260**	**9260**	**4.50**	**0.0256**
Survey(Phase)	5	135	27	0.11	0.9920
TreatmentxPhase	2	727	364	0.28	0.9767
RETxPhase	1	158	158	0.21	0.9835
Location(PhasexTreatment)	**3**	**9915**	**3305**	**8.06**	**0.0014**
Location(PhasexRET)	**3**	**9915**	**3305**	**8.10**	**0.0017**
TreatmentxSurvey(Phase)	10	1868	187	0.63	0.7408
RETxSurvey(Phase)	5	268	54	0.18	0.9565
Site(Location(PhasexTreatment))	4	607	152	0.34	0.9953
Site(Location(PhasexRET))	4	607	152	0.36	0.9912
Location(PhasexTreatment)xSurvey(Phase)	6	1893	315	1.23	0.3428
Location(PhasexRET)xSurvey(Phase)	6	1893	315	1.23	0.3560
Transect(Site(Location(PhasexTreatment)))	**23**	**16473**	**716**	**3.92**	**0.0001**
Transect(Site(Location(PhasexRET)))	**19**	**13143**	**692**	**3.51**	**0.0011**
Survey(Phase)xSite(Location(PhasexTreatment))	10	2609	261	1.43	0.1921
Survey(Phase)xSite(Location(PhasexRET))	10	2609	261	1.32	0.2359
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	59	10766	182	0.66	0.9800
Survey(Phase)xTransect(Site(Location(PhasexRET)))	49	9662	197	0.68	0.9553
Res	378	105260	278		
Total	503	167280			

PAIR-WISE TESTS				
Term 'Location(PhasexTreatment)'				
Within level 'Retained' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Floodvale Creek, Springvale Creek	1.67	0.2419	19	0.3051
Within level 'Reference' of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	**2.68**	**0.0220**	**9949**	**0.0448**

Within level 'Reference' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	3.15	0.0476	9966	0.0667

B-6: Results of PERMANOVAs testing for difference in the abundance of *Suaeda australis* per quadrat. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 30 New Saltmarsh

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	**2**	**7695**	**3847**	**4.26**	**0.0352**
Survey	1	13	13	0.30	0.8233
Location(Treatment)	2	1115	557	1.37	0.3285
TreatmentxSurvey	2	51	25	0.48	0.8020
Site(Location(Treatment))	3	874	291	1.00	0.5027
SurveyxLocation(Treatment)	2	417	208	1.13	0.3659
Transect(Site(Location(Treatment)))	19	7627	401	1.60	0.1461
SurveyxSite(Location(Treatment))	3	426	142	0.57	0.6517
SurveyxTransect(Site(Location(Treatment)))	19	4760	251	1.11	0.3402
Residual	162	36429	225		
Total	215	58539			

Table 31 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	10928	3643	1.12	RED
Phase	1	11002	11002	2.12	0.1273
Survey(Ph)	5	16114	3223	6.99	RED
TreatmentxPhase**	2	4690	2345	0.74	0.6637
Location(PhxTre)	**5**	**12860**	**2572**	**3.50**	**0.0144**
TreatmentxSurvey(Ph)	**11**	**16709**	**1519**	**3.28**	**0.0212**
Site(Lo(PhxTre))	4	1296	324	0.43	0.9788
Location(PhxTre)xSu(Ph)	8	4250	531	2.05	0.1220
Transect(Si(Lo(PhxTre)))	**27**	**37662**	**1395**	**3.48**	**0.0001**
Survey(Ph)xSite(Lo(PhxTre))	10	2411	241	0.60	0.8019
Survey(Ph)xTransect(Si(Lo(PhxTre)))	63	25247	401	0.74	0.9334
Residual	420	227990	543		
Total	559	367510			

PAIR-WISE TESTS
Term 'Location(PhasexTreatment)'

Within level 'Retained' of factor 'Treatment'			
Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Springvale Creek, Floodvale Creek	0.44	0.8501	1249

Within level 'Reference' of factor 'Treatment'			
Within level 'Before' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Woolooware Bay, Quibray Bay	0.49	0.9349	9957

Within level 'Reference' of factor 'Treatment'			
Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Woolooware Bay, Quibray Bay	1.29	0.3152	9953

Within level 'Treated' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Sans Souci	5.99	0.0349	31	0.0955
Woolooware Bay, Salt Pan Creek	**4.27**	**0.0253**	**3153**	
Sans Souci, Salt Pan Creek	2.43	0.0733	4396	

Term 'TreatmentxSurvey(Phase)' for pairs of levels of factor 'Treatment'.

Within level 'Before' of factor 'Phase'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	0.31	0.9020	10	0.7828
Retained, Reference	3.28	0.1950	15	0.1358
Transplanted, Reference	2.56	0.2006	15	0.1714

Within level 'Before' of factor 'Phase'				
Within level 'B2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	0.39	0.7982	10	0.7194
Retained, Reference	**5.45**	**0.1996**	**15**	**0.0468**
Transplanted, Reference	3.49	0.2098	15	0.0928

Within level 'Before' of factor 'Phase'				
Within level 'B3' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.37	0.3052	7	0.2468
Retained, Reference	3.32	0.2080	15	0.1712
Transplanted, Reference	0.60	0.7982	15	0.6362

Within level 'Before' of factor 'Phase'				
Within level 'B4' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	0.98	0.4074	7	0.3676
Retained, Reference	0.40	0.8046	15	0.7082
Transplanted, Reference	1.28	0.4042	15	0.2840

Within level 'Before' of factor 'Phase'				
Within level 'B5' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.25	0.3184	9	0.2674
Retained, Reference	2.71	0.1312	15	0.0768
Transplanted, Reference	**6.33**	**0.1316**	**15**	**0.0070**

Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.03	0.5948	62	0.6226
Retained, Reference	0.02	0.9848	4955	
Retained, Treated	0.68	0.5520	3104	
Transplanted, Reference	0.96	0.4554	4941	
Transplanted, Treated	0.38	0.9214	858	
Reference, Treated	0.86	0.4526	4981	

Within level 'After' of factor 'Phase'				
Within level 'A2' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**29.31**	**0.0448**	**65**	**0.0264**
Retained, Reference	0.39	0.7502	4960	

Retained, Treated	0.14	0.9226	2359
Transplanted, Reference	0.60	0.6114	4975
Transplanted, Treated	0.18	0.9968	1741
Reference, Treated	0.42	0.7370	4981

Table 32 Retained and Altered Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	23668	11834	6.42	RED
RET	1	6144	6144	2.86	RED
Phase	1	24296	24296	6.04	RED
Survey(Phase)	5	17892	3578	7.32	RED
TreatmentxPhase	**2**	**11288**	**5644**	**3.19**	**0.0285**
RETxPhase	1	4451	4451	2.14	0.1268
Location(PhasexTreatment)	3	1117	372	0.60	0.7606
Location(PhasexRET)	3	1117	372	0.60	0.7619
TreatmentxSurvey(Phase)	**10**	**15165**	**1517**	**3.05**	**0.0340**
RETxSurvey(Phase)	**5**	**8749**	**1750**	**3.51**	**0.0387**
Site(Location(PhasexTreatment))	4	1296	324	0.38	0.9870
Site(Location(PhasexRET))	4	1296	324	0.36	0.9925
Location(PhasexTreatment)xSurvey(Phase)	6	3782	630	2.49	0.0947
Location(PhasexRET)xSurvey(Phase)	6	3782	630	2.52	0.0893
Transect(Site(Location(PhasexTreatment)))	**23**	**40255**	**1750**	**3.90**	**0.0001**
Transect(Site(Location(PhasexRET)))	**19**	**34421**	**1812**	**4.40**	**0.0001**
Survey(Phase)xSite(Location(PhasexTreatment))	10	2411	241	0.54	0.8519
Survey(Phase)xSite(Location(PhasexRET))	10	2411	241	0.59	0.8188
Survey(Phase)xTransect(Site(Location(PhxTreat)))	59	26505	449	0.88	0.7279
Survey(Phase)xTransect(Site(Location(PhxRET)))	49	20187	412	0.84	0.7695
Res	378	193630	512		
Total	503	369840			

PAIR-WISE TESTS

Term 'TreatmentxSurvey(Phase)' for pairs of levels of factor 'Treatment'.

Within level 'Before' of factor 'Phase'

Within level 'B1' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	0.44	0.7030	10	0.6833
Retained, Reference	3.28	0.1989	15	0.1356
Altered, Reference	4.27	0.1991	15	0.0871

Within level 'Before' of factor 'Phase'				
Within level 'B2' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	0.43	0.7998	10	0.6937
Retained, Reference	**5.45**	**0.1994**	**15**	**0.0490**
Altered, Reference	**7.53**	**0.1895**	**15**	**0.0282**

Within level 'Before' of factor 'Phase'				
Within level 'B3' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	0.13	1.0000	10	0.9048
Retained, Reference	3.32	0.2007	15	0.1743
Altered, Reference	3.06	0.1922	15	0.1866

Within level 'Before' of factor 'Phase'				
Within level 'B4' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	2.70	0.1061	9	0.0583
Retained, Reference	0.40	0.7960	15	0.7098
Altered, Reference	**3.58**	**0.1238**	**15**	**0.0387**

Within level 'Before' of factor 'Phase'				
Within level 'B5' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**2.82**	**0.1021**	**10**	**0.0472**
Retained, Reference	2.71	0.1306	15	0.0811
Altered, Reference	**11.10**	**0.1330**	**15**	**0.0015**

Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	2.10	0.3247	62	0.3198
Retained, Reference	0.02	0.9861	9864	0.9849
Altered, Reference	3.70	0.0360	9879	0.1241

Within level 'After' of factor 'Phase'				
Within level 'A2' of factor 'Survey'				

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**38.82**	**0.0383**	**66**	**0.0189**
Retained, Reference	0.39	0.7440	9879	0.7100
Altered, Reference	0.45	0.8637	9938	0.8994

PAIR-WISE TESTS

Term 'TreatmentxPhase' for pairs of levels of factor 'Treatment'.

Within level 'Before' of factor 'Phase'

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	0.99	0.4541	9952	0.3740
Retained, Reference	2.72	0.0120	9952	0.0512
Altered, Reference	**5.60**	**0.0004**	**9949**	**0.0029**

Within level 'After' of factor 'Phase'

Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	1.44	0.2929	9968	0.3041
Retained, Reference	0.68	0.7602	9954	0.7847
Altered, Reference	1.06	0.4502	9962	0.4417

B-7: Results of PERMANOVAs testing for difference in the per cent cover of saltmarsh plants in poor conditions or dead per quadrat. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 33 New Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	1673	836	0.59	0.9016
Survey	1	42	42	1.41	0.4785
Location(Treatment)	**2**	**2113**	**1056**	**9.33**	**0.0082**
TreatmentxSurvey	2	35	18	0.59	0.8154
Site(Location(Treatment))	3	2	1	0.05	1.0000
SurveyxLocation(Treatment)	2	50	25	3.28	0.1280
Transect(Site(Location(Treatment)))	**19**	**4363**	**230**	**21.23**	**0.0148**
SurveyxSite(Location(Treatment))	3	17	6	0.52	0.7350
SurveyxTransect(Site(Location(Treatment)))	19	206	11	0.13	0.9994
Res	162	13632	84		
Total	215	22114			

Table 34 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	1677.5	559.2	1.37	0.2444
Phase	**1**	**1857.6**	**1857.6**	**3.62**	**0.0335**
Survey(Ph)	5	0.1	0.0	0.01	RED
TreatmentxPhase**	2	1347.4	673.7	1.39	0.2474
Location(PhxTre)	5	3177.0	635.4	3.90	RED
TreatmentxSurvey(Ph)	11	132.2	12.0	0.10	0.9960
Site(Lo(PhxTre))	4	0.6	0.2	0.04	1.0000
Location(PhxTre)xSu(Ph)	**8**	**1289.3**	**161.2**	**108.18**	**0.0001**
Transect(Si(Lo(PhxTre)))	**27**	**9314.4**	**345.0**	**25.69**	**0.0001**
Survey(Ph)xSite(Lo(PhxTre))	10	0.3	0.0	0.00	1.0000
Survey(Ph)xTransect(Si(Lo(PhxTre)))	63	846.1	13.4	0.14	1.0000
Residual	420	41761.0	99.4		
Total	559	62650.0			

PAIR-WISE TESTS				
Term 'Location(PhasexTreatment)'				
Within level 'Retained' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Springvale Creek, Floodvale Creek	1.00	0.7114	3	0.4241
Within level 'Reference' of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	Denominator is 0			
Within level 'Reference' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	1.02	0.1868	14	0.4388
Within level 'Treated' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Sans Souci	0.98	0.5137	559	0.4563
Woolooware Bay, Salt Pan Creek	1.02	0.4770	143	0.4623
Sans Souci, Salt Pan Creek	0.53	0.8726	9791	0.7965

Table 35 Altered and Retained

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	1079.8	539.9	1.19	0.3505
RET	1	1018.8	1018.8	2.13	0.1526
Phase	1	548.9	548.9	1.26	0.2594
Survey(Phase)	5	19.7	3.9	0.76	RED
TreatmentxPhase	2	1079.8	539.9	1.19	0.3061
RETxPhase	1	1018.8	1018.8	2.13	0.1507
Location(PhasexTreatment)	3	2112.8	704.3	38.26	RED
Location(PhasexRET)	3	2112.8	704.3	34.01	RED
TreatmentxSurvey(Phase)	10	36.7	3.7	0.68	0.5101
RETxSurvey(Phase)	5	34.0	6.8	1.23	0.2815
Site(Location(PhasexTreatment))	4	0.6	0.2	0.01	0.9993
Site(Location(PhasexRET))	4	0.6	0.2	0.01	0.9993
Location(PhasexTreatment)xSurvey(Phase)	**6**	**50.1**	**8.4**	**69.67**	**0.0025**
Location(PhasexRET)xSurvey(Phase)	**6**	**50.1**	**8.4**	**60.00**	**0.0022**
Transect(Site(Location(PhasexTreatment)))	**23**	**4228.0**	**183.8**	**107.03**	**0.0004**
Transect(Site(Location(PhasexRET)))	**19**	**4228.0**	**222.5**	**107.60**	**0.0006**
Survey(Phase)xSite(Location(PhasexTreatment))	10	0.3	0.0	0.02	0.8787
Survey(Phase)xSite(Location(PhasexRET))	10	0.3	0.0	0.01	0.9547
Survey(Phase)xTransect(Site(Location(PhxTreat)))	59	101.3	1.7	0.05	0.9999
Survey(Phase)xTransect(Site(Location(PhxRET)))	49	101.3	2.1	0.05	0.9997
Res	378	12769.0	33.8		
Total	503	21286.0			
PAIR-WISE TESTS					
Term 'Location(PhasexTreatment)'					
Within level 'Retained' of factor 'Treatment'					
Within level 'After' of factor 'Phase'					
Groups	t	P(perm)	Unique perms		
Floodvale Creek, Springvale Creek	1.00	0.7127	3		
Within level 'Reference' of factor 'Treatment'					
Within level 'Before' of factor 'Phase'					
Groups	t	P(perm)	Unique perms		
Woolooware Bay, Quibray Bay	Den. is 0				

Within level 'Reference' of factor 'Treatment'
Within level 'After' of factor 'Phase'

Groups	t	P(perm)	Unique perms
Woolooware Bay, Quibray Bay	1.02	0.1893	14

B-8: Results of PERMANOVAs testing for difference in the abundance of epifaunal individuals. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 36 New Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	6472	3236	1.33	0.3536
Survey	1	1881	1881	2.47	0.2824
Location(Treatment)	2	3427	1713	1.22	0.3860
TreatmentxSurvey	2	901	451	1.02	0.5732
Site(Location(Treatment))	3	5695	1898	1.47	0.2468
SurveyxLocation(Treatment)	2	1407	703	0.65	0.5447
Transect(Site(Location(Treatment)))	19	21324	1122	0.92	0.5509
SurveyxSite(Location(Treatment))	3	3009	1003	0.82	0.4957
SurveyxTransect(Site(Location(Treatment)))	19	23233	1223	1.43	0.1097
Res	162	138740	856		
Total	215	206500			

Table 37 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Tre	3	21273	7091	0.96	0.4938
Ph	1	22356	22356	1.09	0.3662
Su(Ph)	5	62430	12486	3.00	RED
TrexPh**	2	2057	1029	0.39	0.9412
Lo(PhxTre)	5	60234	12047	1.53	RED
TrexSu(Ph)	11	14465	1315	0.32	0.9730
Si(Lo(PhxTre))	4	27822	6956	2.22	RED
Lo(PhxTre)xSu(Ph)	**8**	**39299**	**4912**	**2.82**	**0.0492**
Tra(Si(Lo(PhxTre)))	27	42546	1576	2.20	0.0063
Su(Ph)xSi(Lo(PhxTre))	**10**	**18681**	**1868**	**2.60**	**0.0113**
Su(Ph)xTra(Si(Lo(PhxTre)))	63	45223	718	0.71	0.9510
Res	420	422140	1005		
Total	559	825060			

Table 38 Altered and Retained

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	20499	10250	0.88	0.5344

RET	1	20350	20350	1.53	0.2362
Phase	1	32184	32184	1.35	0.2811
Survey(Phase)	5	60734	12147	2.65	RED
TreatmentxPhase	2	7069	3535	0.48	0.8624
RETxPhase	1	129	129	0.31	0.9340
Location(PhasexTreatment)	3	58998	19666	1.93	RED
Location(PhasexRET)	3	58998	19666	1.93	RED
TreatmentxSurvey(Phase)	10	19632	1963	0.42	0.9131
RETxSurvey(Phase)	5	8039	1608	0.34	0.8687
Site(Location(PhasexTreatment))	4	27822	6956	2.40	RED
Site(Location(PhasexRET))	4	27822	6956	2.34	RED
Location(PhasexTreatment)xSurvey(Phase)	**6**	**36967**	**6161**	**3.42**	**0.0354**
Location(PhasexRET)xSurvey(Phase)	**6**	**36967**	**6161**	**3.41**	**0.0365**
Transect(Site(Location(PhasexTreatment)))	**23**	**31403**	**1365**	**2.10**	**0.0121**
Transect(Site(Location(PhasexRET)))	**19**	**28120**	**1480**	**2.07**	**0.0214**
Survey(Phase)xSite(Location(PhasexTreatment))	**10**	**18681**	**1868**	**2.87**	**0.0069**
Survey(Phase)xSite(Location(PhasexRET))	**10**	**18681**	**1868**	**2.61**	**0.0148**
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	59	38360	650	0.61	0.9899
Survey(Phase)xTransect(Site(Location(PhasexRET)))	49	35065	716	0.61	0.9845
Res	378	400290	1059		
Total	503	781320			

B-9: Results of PERMANOVAs testing for difference in the abundance of epifaunal taxa. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 39 New Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Tre	2	36.7	18.3	1.23	0.4002
Su	1	1.2	1.2	0.99	0.4992
Lo(Tre)	2	20.8	10.4	2.58	0.1137
TrexSu	2	0.3	0.1	0.55	0.7557
Si(Lo(Tre))	3	14.4	4.8	1.98	0.1220
SuxLo(Tre)	2	2.6	1.3	0.70	0.5268
Tra(Si(Lo(Tre)))	19	24.5	1.3	0.77	0.7034
SuxSi(Lo(Tre))	3	5.9	2.0	1.19	0.3433
SuxTra(Si(Lo(Tre)))	19	31.7	1.7	1.17	0.2903
Res	162	231.8	1.4		
Total	215	361.0			

Table 40 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	37.7	12.6	1.12	0.3809

Phase	1	2.2	2.2	0.19	0.9926
Survey(Ph)	5	76.7	15.3	4.38	RED
TreatmentxPhase**	2	10.6	5.3	0.54	0.8349
Location(PhxTre)	5	61.0	12.2	1.01	0.4794
TreatmentxSurvey(Ph)	11	23.6	2.1	0.62	0.8068
Site(Lo(PhxTre))	4	62.0	15.5	4.12	RED
Location(PhxTre)xSu(Ph)	8	30.8	3.9	1.92	0.1365
Transect(Si(Lo(PhxTre)))	27	47.5	1.8	2.36	0.0021
Survey(Ph)xSite(Lo(PhxTre))	**10**	**21.6**	**2.2**	**2.90**	**0.0050**
Survey(Ph)xTransect(Si(Lo(PhxTre)))	63	46.9	0.7	0.77	0.8970
Residual	420	403.5	1.0		
Total	559	839.1			

Table 41 Altered and Retained

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	33.1	16.6	1.00	0.4620
RET	1	32.3	32.3	1.83	0.1744
Phase	1	12.1	12.1	0.50	0.7936
Survey(Phase)	5	62.7	12.5	4.62	RED
TreatmentxPhase	2	22.2	11.1	0.71	0.6650
RETxPhase	1	9.9	9.9	0.66	0.6482
Location(PhasexTreatment)	3	56.8	18.9	1.37	0.3021
Location(PhasexRET)	3	56.8	18.9	1.37	0.3062
TreatmentxSurvey(Phase)	10	24.7	2.5	0.91	0.5665
RETxSurvey(Phase)	5	13.1	2.6	0.97	0.4766
Site(Location(PhasexTreatment))	4	62.0	15.5	3.81	RED
Site(Location(PhasexRET))	4	62.0	15.5	4.17	RED
Location(PhasexTreatment)xSurvey(Phase)	6	17.8	3.0	1.42	0.2830
Location(PhasexRET)xSurvey(Phase)	6	17.8	3.0	1.42	0.2925
Transect(Site(Location(PhasexTreatment)))	**23**	**50.4**	**2.2**	**3.15**	**0.0002**
Transect(Site(Location(PhasexRET)))	**19**	**35.0**	**1.8**	**2.28**	**0.0109**
Survey(Phase)xSite(Location(PhasexTreatment))	**10**	**21.6**	**2.2**	**3.11**	**0.0032**
Survey(Phase)xSite(Location(PhasexRET))	**10**	**21.6**	**2.2**	**2.68**	**0.0110**
Survey(Phase)xTransect(Site(Location(PhxTreat)))	59	41.0	0.7	0.78	0.8717
Survey(Phase)xTransect(Site(Location(PhxRET)))	49	39.5	0.8	0.84	0.7765
Res	378	334.8	0.9		
Total	503	744.1			
PAIR-WISE TESTS					
Term 'Survey(Phase)'					
Within level 'Before' of factor 'Phase'					
Groups	t	P(perm)	Unique perms	P(MC)	

B1, B2	2.69	0.0722	9304	0.1240
B1, B3	1.65	0.1989	9434	0.2538
B1, B4	**4.76**	**0.0191**	**9580**	**0.0389**
B1, B5	**6.20**	**0.0082**	**9338**	**0.0235**
B2, B3	0.73	0.5251	9278	0.5223
B2, B4	1.77	0.1772	9141	0.2735
B2, B5	0.27	0.8157	9175	0.8180
B3, B4	1.62	0.2134	9182	0.3402
B3, B5	0.08	0.9424	9376	0.9505
B4, B5	2.62	0.0794	9424	0.1132

Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	0.41	0.793	9946	0.8672

B-10: Results of PERMANOVAs testing for difference in the epifaunal assemblage. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 42 New Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	49359	24679	2.17	0.0933
Survey	1	4724	4724	1.78	0.2360
Location(Treatment)	2	13713	6856	1.75	0.1430
TreatmentxSurvey	2	3724	1862	0.79	0.6713
Site(Location(Treatment))	3	9766	3255	1.18	0.3183
SurveyxLocation(Treatment)	2	4556	2278	1.17	0.3413
Transect(Site(Location(Treatment)))	19	37467	1972	1.21	0.2252
SurveyxSite(Location(Treatment))	3	6459	2153	1.32	0.2367
SurveyxTransect(Site(Location(Treatment)))	19	31013	1632	1.21	0.1763
Res	162	218630	1350		
Total	215	376530			

Table 43 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	37978	12659	0.97	0.5040
Phase	1	11372	11372	0.55	0.8962
Survey(Phase)	5	64947	12989	3.44	RED
TreatmentxPhase**	2	9536	4768	0.46	0.9863
Location(PhasexTreatment)	5	73770	14754	1.55	RED
TreatmentxSurvey(Phase)	11	41747	3795	1.00	0.4928
Site(Location(PhasexTreatment))	4	38853	9713	2.84	RED

Location(PhasexTreatment)xSurvey(Phase)	**8**	**36257**	**4532**	**3.00**	**0.0012**
Transect(Site(Location(PhasexTreatment)))	27	58188	2155	2.13	0.0001
Survey(Phase)xSite(Location(PhasexTreatment))	**10**	**15696**	**1570**	**1.55**	**0.0470**
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	63	63675	1011	0.81	0.9489
Res	420	521550	1242		
Total	559	999560			

Table 44 Altered and Retained

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	43447	21723	1.21	0.2893
RET	1	32607	32607	1.67	0.1426
Phase	1	30973	30973	1.26	0.2706
Survey(Phase)	5	50957	10191	3.45	RED
TreatmentxPhase	2	20195	10098	0.64	0.8651
RETxPhase	1	6312	6312	0.44	0.9638
Location(PhasexTreatment)	3	63362	21121	2.01	RED
Location(PhasexRET)	3	63362	21121	2.01	RED
TreatmentxSurvey(Phase)	10	38304	3830	1.27	0.2349
RETxSurvey(Phase)	5	22828	4566	1.52	0.1466
Site(Location(PhasexTreatment))	**4**	**38853**	**9713**	**2.58**	**0.0021**
Site(Location(PhasexRET))	**4**	**38853**	**9713**	**2.88**	**0.0013**
Location(PhasexTreatment)xSurvey(Phase)	**6**	**22417**	**3736**	**2.43**	**0.0130**
Location(PhasexRET)xSurvey(Phase)	**6**	**22417**	**3736**	**2.42**	**0.0109**
Transect(Site(Location(PhasexTreatment)))	23	61716	2683	2.57	0.0001
Transect(Site(Location(PhasexRET)))	19	43231	2275	2.03	0.0003
Survey(Phase)xSite(Location(PhasexTreatment))	10	15696	1570	1.50	0.0599
Survey(Phase)xSite(Location(PhasexRET))	10	15696	1570	1.40	0.1035
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	59	61657	1045	0.91	0.7459
Survey(Phase)xTransect(Site(Location(PhasexRET)))	49	55033	1123	0.93	0.6789
Res	378	431880	1143		
Total	503	891360			

B-11: Results of PERMANOVA testing for difference in mangrove tree cover along transects. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 45 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	506.7	168.9	1.54	0.1936
Phase	1	106.0	106.0	0.94	0.4669
Survey(Phase)	**5**	**345.2**	**69.0**	**10.32**	**0.0499**
TreatmentxPhase**	2	231.3	115.7	1.07	0.3981
Location(PhasexTreatment)	**4**	**294.1**	**73.5**	**8.44**	**0.0018**
TreatmentxSurvey(Phase)	11	635.0	57.7	8.34	0.0542
Site(Location(PhasexTreatment))	4	2.4	0.6	0.56	0.9278
Location(PhasexTreatment)xSurvey(Phase)	7	64.7	9.2	4.51	0.0821
Transect(Site(Location(PhasexTreatment)))	28	307.0	11.0	1.69	0.0661
Survey(Phase)xSite(Location(PhasexTreatment))	10	18.3	1.8	0.28	0.9702
Res	64	416.0	6.5		
Total	139	2845.4			

Pair Wise Tests				
Term ‘Location(PhasexTreatment)’				
Within level ‘Retained of factor ‘Treatment’				
Within level ‘After’ of factor ‘Phase’				
Groups	t	P(perm)	Unique perms	P(MC)
Springvale Creek, Floodvale Creek	Denominator is 0			
Within level ‘Reference’ of factor ‘Treatment’				
Within level ‘Before’ of factor ‘Phase’				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	1.08	0.3858	31	0.4216
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	2.21	0.0575	103	0.1355
Within level 'Treated' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Sans Souci, Salt Pan Creek	1.84	0.1013	7	0.1993
Term 'Survey(Phase)'				
Within level 'Before' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
B1, B2	**6.08**	**0.0469**	**66.0**	**0.0169**
B1, B3	3.17	0.0475	66.0	0.0668
B1, B4	**6.11**	**0.0833**	**444.0**	**0.0318**
B1, B5	**10.67**	**0.0904**	**442.0**	**0.0018**
B2, B3	Denominator is 0			

B2, B4	**15.04**	**0.0519**	**66.0**	**0.0019**
B2, B5	**12.10**	**0.1704**	**78.0**	**0.0024**
B3, B4	**12.59**	**0.0506**	**66.0**	**0.0026**
B3, B5	**11.42**	**0.0722**	**66.0**	**0.0038**
B4, B5	**6.74**	**0.0845**	**444.0**	**0.0202**
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
A1, A2	0.97	0.3511	9875.0	0.3949

Table 46 Altered and Retained

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	811.8	405.9	3.77	RED
RET	1	2.5	2.5	3.99	0.0307
Phase	1	473.8	473.8	3.86	RED
Survey(Phase)	5	575.8	115.2	101.87	RED
TreatmentxPhase	**2**	**919.1**	**459.5**	**4.26**	**0.0153**
RETxPhase	1	0.9	0.9	2.25	0.1166
Location(PhasexTreatment)	3	2.5	0.8	1.73	0.1682
Location(PhasexRET)	3	2.5	0.8	1.89	0.1280
TreatmentxSurvey(Phase)	**10**	**1012.8**	**101.3**	**92.51**	**0.0029**
RETxSurvey(Phase)	5	0.6	0.1	0.11	0.9392
Site(Location(PhasexTreatment))	**4**	**2.4**	**0.6**	**5.12**	**0.0004**
Site(Location(PhasexRET))	4	2.4	0.6	0.47	0.9724
Location(PhasexTreatment)xSurvey(Phase)	6	4.0	0.7	0.21	0.9820
Location(PhasexRET)xSurvey(Phase)	6	4.0	0.7	0.37	0.9171
Transect(Site(Location(PhasexTreatment)))	24	82.0	3.4	0.13	1.0000
Transect(Site(Location(PhasexRET)))	20	31.0	1.5	1.58	0.1317
Survey(Phase)xSite(Location(PhasexTreatment))	10	18.3	1.8	0.07	0.9976
Survey(Phase)xSite(Location(PhasexRET))	10	18.3	1.8	1.86	0.0542
Res	60	1574.7	26.2		
Total	127	6079.6			

Pair Wise Tests				
Term 'Treatment x Survey(Phase)' for pairs of levels of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	1.95	0.3993	2	0.1241
Retained, Reference	0.45	1.0000	1	0.6931
Altered, Reference	**17.39**	**0.1991**	**4**	**0.0021**
Within level 'B2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)

Retained, Altered	2.33	0.0992	4	0.0788
Retained, Reference	Denominator is 0			
Altered, Reference	Denominator is 0			
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	2.32	0.1006	4	0.0773
Retained, Reference	Denominator is 0			
Altered, Reference	Denominator is 0			
Within level 'B4' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	2.18	0.0981	4	0.1000
Retained, Reference	0.45	1.0000	1	0.6906
Altered, Reference	**44.82**	**0.1952**	**4**	**0.0001**
Within level 'B5' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	2.67	0.0983	4	0.0540
Retained, Reference	0.45	1.0000	1	0.6982
Altered, Reference	**27.19**	**0.1892**	**4**	**0.0011**
Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	Denominator is 0			
Retained, Reference	1.45	0.1719	28	0.1978
Altered, Reference	0.93	0.6058	4	0.4264
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	Denominator is 0			
Retained, Reference	0.95	0.5545	7	0.3850
Altered, Reference	0.65	0.5886	4	0.5638

B-12: Results of PERMANOVA testing for difference in the number of mangrove pneumatophores. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 47 Transplanted

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	4609	1536	1.43	0.2319
Phase	**1**	**5888**	**5888**	**5.13**	**0.0131**
Survey(Phase)	5	2810	562	2.83	0.1109
TreatmentxPhase**	2	4540	2270	1.98	0.1092
Location(PhasexTreatment)	**5**	**3682**	**736**	**3.14**	**0.0273**
TreatmentxSurvey(Phase)	11	6500	591	2.96	0.0890
Site(Location(PhasexTreatment))	4	115	29	0.38	0.9898

Location(PhasexTreatment)xSurvey(Phase)	8	1751	219	1.44	0.2789
Transect(Site(Location(PhasexTreatment)))	27	17758	658	2.36	0.0144
Survey(Phase)xSite(Location(PhasexTreatment))	10	1369	137	0.49	0.8371
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	63	17594	279	0.73	0.9280
Res	420	161060	383		
Total	559	233360			

Pair-Wise Tests			
Term 'Location(PhasexTreatment)'			
Within level 'Retained' of factor 'Treatment'			
Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Springvale Creek, Floodvale Creek	Denominator is 0		
Within level 'Reference' of factor 'Treatment'			
Within level 'Before' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Woolooware Bay, Quibray Bay	**2.79**	**0.0198**	**9955**
Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Woolooware Bay, Quibray Bay	Denominator is 0		
Within level 'Treated' of factor 'Treatment'			
Within level 'After' of factor 'Phase'			
Groups	t	P(perm)	Unique perms
Woolooware Bay, Sans Souci	Denominator is 0		
Woolooware Bay, Salt Pan Creek	Denominator is 0		
Sans Souci, Salt Pan Creek	Denominator is 0		

Table 48 Altered and Retained

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	2	4768	2384	1.60	RED
RET	1	460	460	0.82	0.5361
Phase	1	6095	6095	3.11	0.0592
Survey(Phase)	5	5989	1198	5.06	RED
TreatmentxPhase	2	4768	2384	1.60	0.1921
RETxPhase	1	460	460	0.82	0.5605
Location(PhasexTreatment)	**3**	**3682**	**1227**	**4.68**	**0.0128**
Location(PhasexRET)	**3**	**3682**	**1227**	**4.64**	**0.0130**
TreatmentxSurvey(Phase)	**10**	**7944**	**794**	**3.30**	**0.0482**
RETxSurvey(Phase)	5	206	41	0.17	0.9439
Site(Location(PhasexTreatment))	4	115	29	0.48	0.9619
Site(Location(PhasexRET))	4	115	29	0.40	0.9855
Location(PhasexTreatment)xSurvey(Phase)	6	1751	292	2.14	0.1230

Location(PhasexRET)xSurvey(Phase)	6	1751	292	2.14	0.1336
Transect(Site(Location(PhasexTreatment)))	23	4410	192	1.46	0.1354
Transect(Site(Location(PhasexRET)))	19	4404	232	1.89	0.0541
Survey(Phase)xSite(Location(PhasexTreatment))	10	1369	137	1.04	0.4100
Survey(Phase)xSite(Location(PhasexRET))	10	1369	137	1.12	0.3642
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	59	7734	131	0.51	0.9987
Survey(Phase)xTransect(Site(Location(PhasexRET)))	49	6018	123	0.87	0.7164
Res	378	97612	258		
Total	503	150360			

Pair-Wise Tests				
Term 'TreatmentxSurvey(Phase)' for pairs of levels of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**7.89**	**0.1017**	**4**	**0.0013**
Retained, Reference	0.72	0.5269	15	0.5937
Altered, Reference	3.08	0.2014	15	0.1782
Within level 'B2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**5.22**	**0.1039**	**4**	**0.0071**
Retained, Reference	1.20	0.4098	15	0.4354
Altered, Reference	4.00	0.2015	15	0.1358
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**6.27**	**0.1022**	**4**	**0.0039**
Retained, Reference	0.62	0.9342	9	0.6478
Altered, Reference	1.73	0.2006	15	0.3215
Within level 'B4' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**5.85**	**0.0995**	**4**	**0.0037**
Retained, Reference	1.21	0.3286	9	0.3504
Altered, Reference	**4.85**	**0.0674**	**15**	**0.0427**
Within level 'B5' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	**2.96**	**0.0977**	**7**	**0.0404**
Retained, Reference	0.52	0.8006	9	0.6822
Altered, Reference	0.20	0.8066	15	0.8710
Within level 'After' of factor 'Phase'				
Within level 'A1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	Denominator is 0			

Retained, Reference	Denominator is 0			
Altered, Reference	Denominator is 0			
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Altered	Denominator is 0			
Retained, Reference	Denominator is 0			
Altered, Reference	Denominator is 0			
Term 'Location(PhasexTreatment)'				
Within level 'Retained' of factor 'Treatment'				
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Floodvale Creek, Springvale Creek	Denominator is 0			
Within level 'Reference' of factor 'Treatment'				
Within level 'Before' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	2.79	0.0211	9948	0.0353
Within level 'After' of factor 'Phase'				
Groups	t	P(perm)	Unique perms	P(MC)
Woolooware Bay, Quibray Bay	Denominator is 0			

B-13: Results of PERMANOVA testing for difference in counts of mangrove seedlings. Monte Carlo (MC) simulations were used to calculate p-values for tests where possible permutations were < 100.

Table 49 Transplanted Sites

Source	df	SS	MS	Pseudo-F	P(perm)
Treatment	3	25.7	8.6	2.58	RED
Phase	1	18.1	18.1	4.02	RED
Survey(Phase)	5	22.6	4.5	19.63	RED
TreatmentxPhase	**2**	**24.9**	**12.4**	**4.08**	**0.0180**
Location(PhasexTreatment)	5	0.5	0.1	0.53	0.8854
TreatmentxSurvey(Phase)	**11**	**32.2**	**2.9**	**13.09**	**0.0237**
Site(Location(PhasexTreatment))	4	1.2	0.3	1.10	0.3651
Location(PhasexTreatment)xSurvey(Phase)	8	1.6	0.2	0.42	0.8658
Transect(Site(Location(PhasexTreatment)))	27	51.5	1.9	0.88	0.5538
Survey(Phase)xSite(Location(PhasexTreatment))	10	2.8	0.3	0.13	0.9566
Survey(Phase)xTransect(Site(Location(PhasexTreatment)))	63	136.0	2.2	0.99	0.5567
Res	420	916.5	2.2		
Total	559	1253.4			

Pair Wise Tests				
Term 'TreatmentxSurvey(Phase)				
Within level 'Before' of factor 'Phase'				
Within level 'B1' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.27	0.0944	3	0.2709
Retained, Reference	0.93	0.6012	4	0.4418
Transplanted, Reference	**9.47**	**0.1277**	**9**	**0.0054**
Within level 'B2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.36	0.0992	4	0.2490
Retained, Reference	0.56	0.6023	6	0.6364
Transplanted, Reference	**5.57**	**0.2000**	**9**	**0.0261**
Within level 'B3' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	**3.46**	**0.0990**	**4**	**0.0273**
Retained, Reference	Denominator is 0			
Transplanted, Reference	Denominator is 0			
Within level 'B4' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.29	0.0993	5	0.2685
Retained, Reference	Denominator is 0			
Transplanted, Reference	Denominator is 0			
Within level'B5' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	2.12	0.2000	4	0.0958
Retained, Reference	Denominator is 0			
Transplanted, Reference	Denominator is 0			
Within level 'A1' of factor 'Survey				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	Denominator is 0			
Retained, Reference	Denominator is 0			
Retained, Treated	Denominator is 0			
Transplanted, Reference	Denominator is 0			
Transplanted, Treated	Denominator is 0			
Reference, Treated	Denominator is 0			

Pair Wise Tests				
Within level 'A2' of factor 'Survey'				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	Denominator is 0			
Retained, Reference	Denominator is 0			
Retained, Treated	Denominator is 0			
Transplanted, Reference	Denominator is 0			
Transplanted, Treated	Denominator is 0			
Reference, Treated	Denominator is 0			

Term 'TreatmentxPhase' for pairs of levels of factor 'Treatment				
Within level 'Before' of factor 'Phase				
Groups	t	P(perm)	Unique perms	P(MC)
Retained, Transplanted	1.88	0.0411	9923	
Retained, Reference	0.78	0.8606	8232	
Transplanted, Reference	3.26	0.0009	9952	

Within level 'After of factor 'Phase	
Groups	
Retained, Transplanted	Denominator is 0
Retained, Reference	Denominator is 0
Retained, Treated	Denominator is 0
Transplanted, Reference	Denominator is 0
Transplanted, Treated	Denominator is 0
Reference, Treated	Denominator is 0

Saltmarsh Annual Report 2013

APPENDIX C

RAW DATA 2012

Cardno
Shaping the Future

C-1: The cover of each species of saltmarsh recorded along the length of a single transect at each site from Penrhyn Estuary and Reference Sites (sampled 5 - 7 March 2012) and Treated Reference Sites (sampled 3 September 2012). Data are expressed as a percentage of the total transect length.

		Treatment	New Saltmarsh 1						New Saltmarsh 2					
		Transect	N1-1	N1-2	N1-3	N1-4	N1-5	N1-6	N2-9	N2-10	N2-11	N2-12	N2-13	N2-21
Species Name	Common Name	Transect length (m)	43.1	39.0	52.2	57.0	39.9	17.2	26.1	41.2	41.0	33.9	16.4	51.0
Bare	bare ground		6.7	4.1	22.8	31.2	13.8	26.7	24.5	17.5	37.1	42.5	1.2	21.8
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atriplex australasica	Green Saltbush		2.3	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove tree		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove seedling		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Hydrocotyle sp.	Pennywort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		0.0	4.4	0.0	1.6	4.8	0.0	0.0	0.0	3.4	0.0	0.0	0.0
Juncus kraussii	Sea Rush		0.5	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Pennisetum clandestinum	Kikuya Grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcocornia quinqueflora	Beaded Glasswort		78.0	71.5	57.3	52.5	68.7	18.0	63.6	65.5	51.5	50.1	86.0	49.0
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinifex sericeus	Hairy Spinifex grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sporobolus virginicus	Salt Couch		9.3	20.0	16.3	7.5	12.8	50.6	11.9	17.0	8.0	7.4	12.8	18.4
Stenotaphrum secundatum	Buffalo Grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		1.2	0.0	0.6	0.4	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.2
Suaeda australis (Dead)	Dead Seablite		2.1	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Westringia fruticosa	Native Rosemary		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush (dead)	dead unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified herb	unidentified herb		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued…

C-1: continued

		Treatment	Transplanted Saltmarsh			Retained Saltmarsh 1		Retained Saltmarsh 2		Altered Saltmarsh 2		
		Transect	TR-8	TR-17	TR-18	R1-7	R1-14	R2-20	R2-22	A2-15	A2-16	A2-19
Species Name	Common Name	Transect length (m)	34.1	18.5	20.1	11.7	7.4	38.2	30.2	35.0	5.7	7.3
Bare	bare ground		15.5	36.2	0.0	12.0	47.3	1.3	0.7	64.3	26.3	30.1
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.0
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atriplex australasica	Green Saltbush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove tree		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove seedling		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0
Hydrocotyle sp.	Pennywort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.9	0.0
Juncus kraussii	Sea Rush		22.9	0.0	0.0	0.0	0.0	36.6	0.0	0.0	3.5	0.0
Pennisetum clandestinum	Kikuya Grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcocornia quinqueflora	Beaded Glasswort		3.8	0.0	7.5	28.2	44.6	35.1	21.5	1.1	0.0	17.8
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinifex sericeus	Hairy Spinifex grass		0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	7.0	0.0
Sporobolus virginicus	Salt Couch		30.5	36.2	83.6	0.0	0.0	13.9	37.7	6.6	0.0	37.0
Stenotaphrum secundatum	Buffalo Grass		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		27.3	15.1	7.0	34.2	8.1	13.1	37.1	28.0	0.0	15.1
Suaeda australis (Dead)	Dead Seablite		0.0	12.4	0.0	10.3	0.0	0.0	3.0	0.0	0.0	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Westringia fruticosa	Native Rosemary		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush (dead)	dead unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified herb	unidentified herb		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued…

C-1: continued

		Treatment	Reference Quibray Bay 1			Reference Quibray Bay 2			Reference Woolooware Bay 1			Reference Woolooware Bay 2		
		Transect	Q1-1	Q1-2	Q1-3	Q2-4	Q2-5	Q2-6	W1-1	W1-2	W1-3	W2-4	W2-5	W2-6
Species Name	Common Name	Transect length (m)	25.4	29.3	38.0	26.4	28.9	27.6	40.0	39.5	39.4	40.0	40.2	41.6
Bare	bare ground		4.7	6.5	9.7	7.2	2.1	9.1	12.0	7.1	6.3	9.3	8.5	18.0
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Atriplex australasica	Green Saltbush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove tree		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove seedling		0.0	0.0	0.0	3.4	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrocotyle sp.	Pennywort		0.4	2.7	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Juncus kraussii	Sea Rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennisetum clandestinum	Kikuya Grass		0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcocornia quinqueflora	Beaded Glasswort		51.6	49.8	30.5	24.2	38.4	8.3	53.8	66.1	51.5	64.0	35.8	57.0
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	0.0
Spinifex sericeus	Hairy Spinifex grass		0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sporobolus virginicus	Salt Couch		30.3	29.4	25.5	47.7	0.0	70.3	9.8	3.8	6.6	6.5	7.2	7.5
Stenotaphrum secundatum	Buffalo Grass		0.0	0.0	0.0	1.1	40.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		6.3	8.9	27.1	10.6	10.7	9.4	24.5	22.0	34.3	20.3	31.1	17.5
Suaeda australis (Dead)	Dead Seablite		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	0.5	1.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Westringia fruticosa	Native Rosemary		3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush (dead)	dead unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified herb	unidentified herb		0.0	0.0	0.0	4.2	1.4	1.1	0.0	0.0	0.0	0.0	0.0	0.0

continued…

C-1: continued

		Treatment	Treated Reference Sans Souci			Treated Reference Salt Pan Creek		
		Transect	SS1-1	SS1-2	SS1-3	SPC1-1	SPC1-2	SPC1-3
Species Name	Common Name	Transect length (m)	20.7	21.1	17.9	21.5	23.7	23.8
Bare	bare ground		64.3	34.6	24.0	0.0	0.0	2.9
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0
Atriplex australasica	Green Saltbush		0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove tree		0.0	1.9	0.0	9.8	16.5	20.2
Avicennia marina	Grey Mangrove seedling		0.0	1.4	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	0.0	0.0	0.0	0.0
Hydrocotyle sp.	Pennywort		0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		0.0	0.0	0.0	0.0	0.0	0.0
Juncus kraussii	Sea Rush		12.1	4.7	7.3	14.0	1.7	10.9
Pennisetum clandestinum	Kikuya Grass		0.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	0.0	0.0	0.0
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	35.8	7.2	0.0
Sarcocornia quinqueflora	Beaded Glasswort		23.7	57.3	68.7	0.0	0.0	0.0
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0
Spinifex sericeus	Hairy Spinifex grass		0.0	0.0	0.0	0.0	0.0	0.0
Sporobolus virginicus	Salt Couch		0.0	0.0	0.0	0.0	30.8	8.0
Stenotaphrum secundatum	Buffalo Grass		0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		0.0	0.0	0.0	40.5	27.0	44.5
Suaeda australis (Dead)	Dead Seablite		0.0	0.0	0.0	0.0	8.4	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	0.0	0.0	0.0	0.0
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	3.0	0.0
Westringia fruticosa	Native Rosemary		0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	8.4
unidentified rush (dead)	dead unidentified rush		0.0	0.0	0.0	0.0	5.5	5.0
unidentified herb	unidentified herb		0.0	0.0	0.0	0.0	0.0	0.0

C-2: The percent cover of each species of saltmarsh recorded within four random quadrats (1m^2) along the transect at each site from Penrhyn Estuary and Reference Sites (sampled 5 - 7 March 2012) and Treated Reference Sites (sampled 3 September 2012). Data are presented as means and standard errors for four quadrats.

	Treatment	New Saltmarsh 1											
	Transect	N1-1		N1-2		N1-3		N1-4		N1-5		N1-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	42.00	9.95	29.50	9.80	45.25	15.36	50.00	7.36	32.25	5.17	57.50	10.90
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	2.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	7.50	7.50	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	52.50	13.31	47.50	14.79	35.50	14.73	38.75	13.44	51.50	17.60	18.75	13.90
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	1.25	1.25	22.50	22.50	18.75	18.75	0.00	0.00	16.25	16.25	21.25	12.64
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	1.25	1.25	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	2.50	1.44
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	2.50	2.50	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-2: continued

Treatment		New Saltmarsh 2											
Transect		N2-9		N2-10		N2-11		N2-12		N2-13		N2-21	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	12.60	52.50	38.00	10.16	51.25	9.87	57.50	12.50	43.75	6.57	30.00	9.79
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	5.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	8.14	46.25	43.75	18.86	30.00	14.29	28.75	9.66	46.25	13.60	47.50	17.38
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	3.16	1.25	18.25	15.70	12.50	12.50	13.75	13.75	10.00	10.00	22.50	22.50
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-2: continued

	Treatment / Transect	Transplanted Saltmarsh TR-8		TR-17		TR-18		Retained Saltmarsh 1 R1-7		R1-14	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	40.00	12.42	48.75	19.83	9.00	3.49	54.50	13.82	58.25	14.94
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	21.25	18.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	0.00	0.00	0.00	0.00	4.50	2.63	20.00	20.00	32.50	14.51
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	1.75	1.75	7.50	7.50	3.75	2.39
Sporobolus virginicus	Salt Couch	21.25	21.25	25.00	25.00	84.75	4.80	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	17.50	10.31	25.00	14.86	0.00	0.00	11.75	3.84	5.50	4.86
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	1.25	1.25	0.00	0.00	5.00	5.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-2: continued

Treatment		Retained Saltmarsh 2				Altered Saltmarsh 2					
Transect		R2-20		R2-22		A2-15		A2-16		A2-19	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	13.75	6.88	16.25	6.25	62.50	10.10	27.00	1.78	38.00	13.41
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	31.75	10.19	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	22.00	2.86	0.00	0.00
Juncus kraussii	Sea Rush	37.50	21.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	26.25	16.75	28.25	19.57	0.00	0.00	0.00	0.00	8.25	5.68
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	1.25	1.25	0.00	0.00	11.75	5.22	0.00	0.00
Sporobolus virginicus	Salt Couch	22.50	14.36	23.00	22.34	0.00	0.00	7.50	7.50	23.75	14.77
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	31.25	18.07	37.50	10.10	0.00	0.00	30.00	14.72
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-2: continued

	Treatment	Reference Quibray Bay 1						Reference Quibray Bay 2					
	Transect	Q1-1		Q1-2		Q1-3		Q2-4		Q2-5		Q2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	15.00	8.66	17.00	7.84	20.50	17.18	13.75	4.73	11.25	9.66	3.00	2.38
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	5.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	1.25	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	40.00	19.58	52.50	21.46	29.75	22.86	32.50	19.74	55.00	25.08	17.50	12.99
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	6.25	4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	45.00	20.62	9.25	8.60	25.00	17.68	37.50	15.34	0.00	0.00	59.75	24.16
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	3.75	3.75	27.50	22.78	0.75	0.75
Suaeda australis	Seablite	0.00	0.00	13.75	13.75	19.00	19.00	6.25	4.73	5.00	5.00	19.00	18.67
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	6.25	6.25	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00

continued…

C-2: continued

	Treatment	Reference Woolooware Bay 1						Reference Woolooware Bay 2					
	Transect	W1-1		W1-2		W1-3		W2-1		W2-2		W2-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	32.50	14.36	20.50	6.89	17.50	1.44	17.50	6.29	36.00	20.25	10.50	3.07
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.75	8.75	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	6.25	6.25	0.00	0.00	0.00	0.00	7.75	4.84	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	47.50	20.67	50.00	23.45	31.25	18.53	75.00	8.42	33.75	17.49	46.25	21.35
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	8.75	3.15	3.75	3.75	0.00	0.00	0.00	0.00	0.00	0.00	25.75	22.54
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	11.25	11.25	19.00	18.67	51.25	19.83	6.25	6.25	12.50	12.50	17.50	15.88
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-2: continued

	Treatment	Treated Reference Sans Souci						Treated Reference Salt Pan Creek					
	Transect	SS1-1		SS1-2		SS1-3		SPC1-1		SPC1-2		SPC1-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	50.00	16.75	41.25	21.25	40.00	12.75	10.50	4.99	2.50	2.50	7.50	7.50
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.75	0.75	0.00	0.00	0.00	0.00	3.50	2.87	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	5.00	5.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	1.25	1.25	0.00	0.00	16.25	14.63	14.75	11.77	15.50	11.08	1.25	1.25
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	30.75	14.24	16.50	16.17	2.50	2.50
Sarcocornia quinqueflora	Beaded Glasswort	48.00	16.55	58.75	21.25	43.75	12.48	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	10.50	9.84	36.00	15.82	28.75	18.07
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	20.00	8.90	17.00	6.70	21.25	14.20
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	2.50	2.50	0.00	0.00	6.25	6.25
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	11.90
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	5.00	12.50	12.50
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	7.50	5.95	6.25	4.73	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

C-3: Abundance of indivuduals of each saltmarsh, mangrove and epifaunal invertebrate species recorded within four random quadrats (1m^2) along the transect at each site from Penrhyn Estuary and Reference Sites (sampled 5 - 7 March 2012) and Treated Reference Sites (sampled 3 September 2012). Data are presented as means and standard errors for four quadrats.

	Treatme	New Saltmarsh 1											
	Transect	N1-1		N1-2		N1-3		N1-4		N1-5		N1-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.50	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	8.75	2.43	8.75	1.70	7.75	2.78	7.25	2.95	11.25	3.40	5.75	2.29
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.75	0.75	13.75	13.75	6.25	6.25	0.00	0.00	3.25	3.25	22.75	13.26
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.25	0.25	0.00	0.00	1.00	1.00	0.25	0.25	0.00	0.00	0.50	0.29
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.50	0.50	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.48	0.25	0.25	0.00	0.00
crab hole	crab hole	4.25	4.25	1.50	1.50	2.00	2.00	1.25	1.25	0.00	0.00	2.50	2.50
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.50	0.50	0.25	0.25	0.00	0.00	0.75	0.75	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	4.00	4.00
Ophicardelus ornatus	Mangrove air-breather	1.25	1.25	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	2.25	2.25	3.50	3.50	0.00	0.00	6.75	6.75	0.75	0.75	1.75	1.75
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.50	0.50	1.25	1.25
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-3: continued

	Treatme Transect	New Saltmarsh 2 N2-9		N2-10		N2-11		N2-12		N2-13		N2-21	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	32.25	21.93	8.00	3.39	6.25	2.17	6.00	1.41	7.50	1.32	9.25	3.15
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.50	0.50	3.50	2.60	2.75	2.75	11.00	11.00	10.75	10.75	52.50	52.50
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	2.25	1.65	2.00	2.00	2.25	2.25	18.25	9.47	0.25	0.25	16.25	9.87
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	0.50	0.50	0.00	0.00	0.00	0.00	4.75	4.75	0.50	0.50	22.00	13.02
Calthalotia fragum	Top shell	0.50	0.50	0.00	0.00	0.00	0.00	0.75	0.48	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.29	0.00	0.00	0.00	0.00

continued…

C-3: continued

Treatme Transect		Transplanted Saltmarsh TR-8		TR-17		TR-18		Retained Saltmarsh 1 R1-7		R1-14	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	3.00	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	0.00	0.00	0.00	0.00	1.25	0.75	3.00	3.00	4.25	1.80
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.50	0.50	1.50	1.50	2.00	1.41
Sporobolus virginicus	Salt Couch	3.75	3.75	30.00	30.00	25.75	3.68	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	1.50	0.87	1.00	0.41	0.00	0.00	4.00	1.08	1.00	0.71
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	8.50	4.73	7.25	4.57	1.50	1.19	6.50	2.22	0.00	0.00
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	1.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued...

C-3: continued

	Treatme	Retained Saltmarsh 2				Altered Saltmarsh 2					
	Transect	R2-20		R2-22		A2-15		A2-16		A2-19	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.25	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	7.25	0.85	0.00	0.00
Juncus kraussii	Sea Rush	6.25	3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	9.00	5.93	11.75	9.56	0.00	0.00	0.00	0.00	0.75	0.25
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.50	0.50	0.00	0.00	1.50	0.29	0.00	0.00
Sporobolus virginicus	Salt Couch	13.75	9.44	6.50	6.17	0.00	0.00	2.00	2.00	11.75	7.33
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	3.25	1.89	3.50	1.55	0.00	0.00	2.50	1.55
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	1.50	0.96	4.25	2.53	11.00	2.08	0.00	0.00	4.00	1.87
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	0.00	0.00	0.25	0.25	0.50	0.50	0.00	0.00	0.25	0.25
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.48
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-3: continued

	Treatme	Reference Quibray Bay 1						Reference Quibray Bay 2					
	Transect	Q1-1		Q1-2		Q1-3		Q2-4		Q2-5		Q2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	1.75	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	15.75	6.45	7.25	3.33	4.25	2.72	6.25	3.66	1.27	0.00	3.50	3.18
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	18.75	7.65	4.25	3.61	6.25	4.48	19.25	6.70	1.68	0.00	15.75	5.45
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	2.25	2.25	4.59	0.00	0.25	0.25
Suaeda australis	Seablite	0.00	0.00	2.00	2.00	1.00	1.00	2.25	1.65	1.42	0.00	2.25	1.93
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	10.25	10.25	2.56	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	3.50	1.76	4.50	2.10	0.75	0.75	3.00	2.68	4.34	0.00	2.25	2.25
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	0.00	0.00	1.50	1.19	0.75	0.75	0.00	0.00	9.44	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	2.00	1.68	0.00	0.00	0.50	0.50	0.00	0.00	3.75	0.00	0.00	0.00
Calthalotia fragum	Top shell	1.25	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-3: continued

	Treatme Transect	Reference Woolooware Bay 1						Reference Woolooware Bay 2					
		W1-1		W1-2		W1-3		W2-1		W2-2		W2-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.50	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	35.50	35.50	19.50	18.17	1.75	0.75	2.00	2.00	34.25	29.46	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	20.00	6.61	4.50	1.55	4.00	2.48	18.25	2.78	4.75	2.25	6.00	2.68
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	12.00	4.92	2.75	2.75	0.00	0.00	0.00	0.00	0.00	0.00	6.25	5.01
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	3.50	3.50	1.25	0.95	3.50	1.32	0.75	0.75	1.00	1.00	1.75	1.44
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.75	0.48	1.75	0.85	0.00	0.00	1.50	1.50	0.25	0.25	0.00	0.00
crab hole	crab hole	10.25	2.39	39.75	16.94	4.50	1.04	7.25	3.61	21.50	6.51	1.50	1.19
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	3.50	1.26	16.00	8.38	0.75	0.48	15.25	11.60	3.25	2.36	0.00	0.00
Salinator fragilis	Fragile air-breather	1.25	0.95	2.50	2.50	0.50	0.50	1.75	1.44	0.00	0.00	0.50	0.29
Calthalotia fragum	Top shell	0.00	0.00	3.50	2.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-3: continued

	Treatme	Treated Reference Sans Souci						Treated Reference Salt Pan Creek					
	Transect	SS1-1		SS1-2		SS1-3		SPC1-1		SPC1-2		SPC1-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.50	0.29	0.00	0.00	0.00	0.00	0.50	0.29	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.75	11.75	35.00	35.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.25	0.25	0.00	0.00	1.50	1.19	1.75	1.15	2.75	1.89	0.25	0.25
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	12.00	5.10	3.25	2.93	1.75	1.75
Sarcocornia quinqueflora	Beaded Glasswort	15.75	4.77	16.50	6.40	11.75	4.31	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	3.00	2.38	9.00	3.89	8.75	5.91
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	2.75	1.18	2.00	0.71	2.25	1.31
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25	1.93
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75	1.75	1.50	1.50
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.75	0.75	0.48	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	4.25	2.72	2.00	1.22	5.00	2.86	1.50	1.50	0.00	0.00	1.00	1.00
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	3.75	3.42	1.00	1.00	2.25	2.25	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	6.75	5.22	0.00	0.00	2.75	1.89	0.25	0.25	0.75	0.75	0.00	0.00
Calthalotia fragum	Top shell	0.25	0.25	0.50	0.50	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

C-4: Height (cm) of the tallest plant species recorded within four random quadrats (1m^2) along the transect at each site from Penrhyn Estuary and Reference Sites (sampled 5 - 7 March 2012) and Treated Reference Sites (sampled 3 September 2012). Data are presented as means and standard errors for four quadrats.

	Treatment	New Saltmarsh 1											
	Transect	N1-1		N1-2		N1-3		N1-4		N1-5		N1-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	14.75	5.92	19.00	6.62	15.25	5.09	27.25	0.25	17.75	6.33	9.00	5.45
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	10.75	10.75	7.75	7.75	0.00	0.00	7.75	7.75	11.25	6.87
Suaeda australis	Seablite	5.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

	Treatment	New Saltmarsh 2											
	Transect	N2-9		N2-10		N2-11		N2-12		N2-13		N2-21	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	11.75	11.75	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	23.50	1.55	14.25	8.25	14.50	8.41	14.00	5.49	21.00	7.15	18.50	6.56
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	14.50	8.41	7.00	7.00	9.50	9.50	8.75	8.75	4.50	4.50
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-4: continued

	Treatment	Transplanted Saltmarsh						Retained Saltmarsh 1			
	Transect	TR-8		TR-17		TR-18		R1-7		R1-14	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	45.25	26.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.25	8.25
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	12.50	12.50	13.75	7.96
Sporobolus virginicus	Salt Couch	0.00	0.00	11.25	11.25	38.00	4.53	5.00	5.00	0.00	0.00
Suaeda australis	Seablite	15.00	8.66	23.25	10.06	0.00	0.00	10.25	5.92	7.25	7.25
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

	Treatment	Retained Saltmarsh 2				Altered Saltmarsh 2					
	Transect	R2-20		R2-22		A2-15		A2-16		A2-19	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	41.25	27.26	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	28.75	17.37	0.00	0.00
Juncus kraussii	Sea Rush	53.75	31.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	0.00	0.00	4.25	4.25	0.00	0.00	0.00	0.00	5.25	5.25
Spinifex sericeus	Hairy Spinifex grass	10.50	6.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	25.00	14.80	36.75	6.07	0.00	0.00	24.50	10.72
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-4: continued

	Treatment	Reference Quibray Bay 1						Reference Quibray Bay 2					
	Transect	Q1-1		Q1-2		Q1-3		Q2-4		Q2-5		Q2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	11.25	6.75	11.50	6.64	6.00	6.00	4.00	4.00	12.50	7.22	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	13.50	7.80	7.75	7.75	18.75	11.37	5.50	5.50	0.00	0.00	20.00	6.93
Suaeda australis	Seablite	0.00	0.00	8.00	8.00	10.75	10.75	7.25	7.25	5.50	5.50	10.75	10.75
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	4.25	4.25	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.75	8.75	0.00	0.00

continued…

	Treatment	Reference Woolooware Bay 1						Reference Woolooware Bay 2					
	Transect	W1-1		W1-2		W1-3		W2-1		W2-2		W2-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.75	13.75	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	11.25	11.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	23.50	23.50	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	4.75	4.75	7.50	4.33	5.00	5.00	8.25	4.87	7.50	4.79	5.50	5.50
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	9.25	5.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.25	8.81
Suaeda australis	Seablite	8.00	8.00	11.25	11.25	27.50	9.67	9.75	9.75	7.50	7.50	9.25	9.25
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

C-4: continued

	Treatment	Treated Reference Sans Souci						Treated Reference Salt Pan Creek					
	Transect	SS1-1		SS1-2		SS1-3		SPC1-1		SPC1-2		SPC1-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	13.50	4.56	16.25	5.60	61.25	41.26	48.75	28.16	56.25	33.25	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	20.00	20.00	0.00	0.00	0.00	0.00	22.25	12.85	22.25	12.93	13.75	13.75
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.00	24.88
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Saltmarsh Annual
Report 2013

APPENDIX D
RAW DATA 2013

Cardno
Shaping the Future

D-1: The cover of each species of saltmarsh recorded along the length of a single transect at each site from Penrhyn Estuary, Reference Sites and Treated Reference Sites (sampled 5 - 6 March 2013). Data are expressed as a percentage of the total transect length.

		Treatment	New Saltmarsh 1						New Saltmarsh 2					
		Transect	N1-1	N1-2	N1-3	N1-4	N1-5	N1-6	N2-9	N2-10	N2-11	N2-12	N2-13	N2-21
Species Name	Common Name	Transect length (m)	41.8	39.5	50.0	55.5	39.5	15.5	20.1	29.2	41.0	31.8	16.8	42.3
Bare	bare ground		10.3	7.8	9.8	31.4	18.7	16.1	12.9	6.5	27.1	46.5	0.0	18.7
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atriplex australasica	Green Saltbush		0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove tree		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove seedling		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0
Hydrocotyle sp.	Pennywort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		0.0	1.8	0.0	0.7	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.7
Juncus kraussii	Sea Rush		0.0	3.3	0.0	1.1	0.0	0.0	0.0	0.0	3.4	0.0	0.0	3.3
Pennisetum clandestinum	Kikuya Grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcocornia quinqueflora	Beaded Glasswort		70.3	63.3	68.8	53.3	61.5	43.2	87.1	86.6	57.1	42.5	86.9	68.6
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinifex sericeus	Hairy Spinifex grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Sporobolus virginicus	Salt Couch		19.4	23.3	19.8	13.5	19.7	34.2	0.0	6.8	9.0	11.0	13.1	7.6
Stenotaphrum secundatum	Buffalo Grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Suaeda australis (Dead)	Dead Seablite		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Westringia fruticosa	Native Rosemary		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush (dead)	Dead unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified herb	unidentified herb		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued…

D-1: continued

		Treatment	Transplanted Saltmarsh			Retained Saltmarsh 1		Retained Saltmarsh 2		Altered Saltmarsh 2		
		Transect	TR-8	TR-17	TR-18	R1-7	R1-14	R2-20	R2-22	A2-15	A2-16	A2-19
Species Name	Common Name	Transect length (m)	39.2	11.0	21.1	11.2	9.5	38.7	25.9	42.5	6.9	5.6
Bare	bare ground		14.3	25.5	0.0	36.6	58.9	2.3	14.3	49.6	59.4	16.1
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atriplex australasica	Green Saltbush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove tree		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove seedling		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	0.0	0.0	0.0	5.7	17.4	0.0	0.0	0.0
Hydrocotyle sp.	Pennywort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.6	0.0
Juncus kraussii	Sea Rush		26.0	0.0	0.0	0.0	0.0	34.4	8.9	0.0	0.0	0.0
Pennisetum clandestinum	Kikuya Grass		0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcocornia quinqueflora	Beaded Glasswort		2.8	20.9	10.4	12.5	30.5	32.3	33.2	0.7	0.0	7.1
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinifex sericeus	Hairy Spinifex grass		1.0	0.0	0.0	0.0	10.5	0.0	0.0	0.0	7.2	0.0
Sporobolus virginicus	Salt Couch		33.2	53.6	89.6	0.0	0.0	14.0	7.3	10.6	0.0	76.8
Stenotaphrum secundatum	Buffalo Grass		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		19.1	0.0	0.0	38.4	0.0	11.4	18.9	39.1	8.7	0.0
Suaeda australis (Dead)	Dead Seablite		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Westringia fruticosa	Native Rosemary		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush (dead)	Dead unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified herb	unidentified herb		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued…

D-1: continued

		Treatment	Reference Quibray Bay 1			Reference Quibray Bay 2			Reference Woolooware Bay 1			Reference Woolooware Bay 2		
		Transect	Q1-1	Q1-2	Q1-3	Q2-4	Q2-5	Q2-6	W1-1	W1-2	W1-3	W2-4	W2-5	W2-6
Species Name	Common Name	Transect length (m)	19.7	19.5	22.2	19.4	16.6	17.9	34.5	39.8	39.4	39.2	40.2	39.7
Bare	bare ground		4.1	5.1	3.2	25.3	19.9	13.4	5.8	11.8	17.5	15.3	26.6	15.6
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Atriplex australasica	Green Saltbush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove tree		7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove seedling		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrocotyle sp.	Pennywort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Juncus kraussii	Sea Rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennisetum clandestinum	Kikuya Grass		0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcocornia quinqueflora	Beaded Glasswort		50.8	67.7	55.0	34.0	65.1	36.9	26.7	60.3	33.5	55.4	42.0	61.0
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinifex sericeus	Hairy Spinifex grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sporobolus virginicus	Salt Couch		34.5	12.3	19.8	21.1	12.7	47.5	20.3	6.3	3.8	5.9	4.5	6.5
Stenotaphrum secundatum	Buffalo Grass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		3.0	14.9	20.3	19.6	2.4	2.2	45.2	21.6	45.2	23.5	24.9	16.9
Suaeda australis (Dead)	Dead Seablite		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Westringia fruticosa	Native Rosemary		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush (dead)	Dead unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified herb	unidentified herb		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued…

D-1: continued

		Treatment	Treated Reference Sans Souci			Treated Reference Salt Pan Creek		
		Transect	SS1-1	SS1-2	SS1-3	SPC1-1	SPC1-2	SPC1-3
Species Name	Common Name	Transect length (m)	24.0	23.2	21.0	21.5	25.5	20.2
Bare	bare ground		53.8	41.4	17.6	38.6	11.8	55.0
Acacia sp.	unidentified Wattle		0.0	0.0	0.0	0.0	0.0	0.0
Aegiceras corniculatum	River Mangrove		0.0	0.0	0.0	0.0	0.0	0.0
Atriplex australasica	Green Saltbush		0.0	0.0	0.0	0.0	15.3	0.0
Avicennia marina	Grey Mangrove tree		0.0	0.0	0.0	0.0	16.1	0.0
Avicennia marina	Grey Mangrove seedling		0.0	0.0	0.0	0.0	0.0	0.0
Avicennia marina	Grey Mangrove pneumatophores		0.0	0.0	0.0	0.0	0.0	0.0
Bidens pilosa	Farmers Friend		0.0	0.0	0.0	0.0	0.0	0.0
Carpobrotus sp.	Pigface		0.0	0.0	0.0	0.0	0.0	0.0
Hydrocotyle sp.	Pennywort		0.0	0.0	0.0	0.0	0.0	0.0
Isolepis nodosa	Knobby Club-rush		0.0	0.0	0.0	0.0	0.0	0.0
Juncus kraussii	Sea Rush		19.2	8.2	19.5	0.0	7.1	0.0
Pennisetum clandestinum	Kikuya Grass		0.0	0.0	0.0	0.0	0.0	0.0
Plantago coronopus	Plantain		0.0	0.0	0.0	0.0	0.0	0.0
Samolus repens	Creeping Brookweed		0.0	0.0	0.0	57.2	0.0	45.0
Sarcocornia quinqueflora	Beaded Glasswort		27.1	46.6	62.9	0.0	0.0	0.0
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort		0.0	0.0	0.0	0.0	0.0	0.0
Spinifex sericeus	Hairy Spinifex grass		0.0	0.0	0.0	0.0	0.0	0.0
Sporobolus virginicus	Salt Couch		0.0	0.0	0.0	0.0	6.7	0.0
Stenotaphrum secundatum	Buffalo Grass		0.0	0.0	0.0	0.0	0.0	0.0
Suaeda australis	Seablite		0.0	3.9	0.0	4.2	43.1	0.0
Suaeda australis (Dead)	Dead Seablite		0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia tetragonioides	New Zealand Spinach		0.0	0.0	0.0	0.0	0.0	0.0
Triglochin striata	Streaked Arrowgrass		0.0	0.0	0.0	0.0	0.0	0.0
Westringia fruticosa	Native Rosemary		0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush	unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0
unidentified rush (dead)	Dead unidentified rush		0.0	0.0	0.0	0.0	0.0	0.0
unidentified herb	unidentified herb		0.0	0.0	0.0	0.0	0.0	0.0

D-2: The percent cover of each species of saltmarsh recorded within four random quadrats (1m^2) along the transect at each site from Penrhyn Estuary, Reference Sites and Treated Reference Sites (sampled 5 - 6 March 2013). Data are presented as means and standard errors for four quadrats.

	Treatment	New Saltmarsh 1											
	Transect	N1-1		N1-2		N1-3		N1-4		N1-5		N1-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	50.00	7.36	36.25	6.25	23.50	8.35	48.75	13.29	41.25	13.90	58.50	15.16
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.75	3.75
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Dead Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	46.25	8.26	45.00	13.69	55.25	19.67	30.00	12.25	38.75	17.60	24.00	15.60
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	3.75	3.75	18.75	18.75	21.25	21.25	21.25	21.25	20.00	20.00	13.75	4.73
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus (Dead)	Dead Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-2: continued

	Treatment	New Saltmarsh 2											
	Transect	N2-9		N2-10		N2-11		N2-12		N2-13		N2-21	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	46.25	14.34	45.00	2.89	64.25	12.29	56.25	14.34	34.50	6.41	38.25	11.64
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00	0.00	0.00	7.50	7.50
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Dead Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	3.75	3.75	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	53.75	14.34	51.25	5.91	23.00	14.25	28.75	12.97	46.50	16.01	35.25	19.96
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	3.75	3.75	7.50	7.50	15.00	15.00	18.75	18.75	18.75	18.75
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus (Dead)	Dead Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.25	0.25	0.25	0.25
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-2: continued

	Treatment	Transplanted Saltmarsh						Retained Saltmarsh 1			
	Transect	TR-8		TR-17		TR-18		R1-7		R1-14	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	28.75	17.60	35.00	16.20	6.25	4.73	57.00	12.31	65.00	16.71
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Dead Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	20.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	10.00	10.00	0.00	0.00	13.75	8.98	3.75	3.75	26.25	20.14
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	8.75	5.15
Sporobolus virginicus	Salt Couch	16.25	16.25	37.50	22.50	68.75	20.25	0.00	0.00	0.00	0.00
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	5.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus (Dead)	Dead Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	8.75	8.75	0.00	0.00
Suaeda australis	Seablite	25.00	7.91	16.25	8.98	11.25	11.25	29.25	15.96	0.00	0.00
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (dead)	Dead Seablite	0.00	0.00	6.25	6.25	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-2: continued

	Treatment	Retained Saltmarsh 2				Altered Saltmarsh 2					
	Transect	R2-20		R2-22		A2-15		A2-16		A2-19	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	13.75	12.14	17.50	8.54	33.75	18.53	80.75	2.53	54.00	14.87
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	23.75	23.75	15.00	9.57	0.00	0.00	0.50	0.50	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	3.75	3.75	0.00	0.00
Isolepis nodosa (dead)	Dead Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	2.50	2.50	0.00	0.00
Juncus kraussii	Sea Rush	27.50	24.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	31.25	21.93	30.00	20.10	0.50	0.50	0.00	0.00	5.75	3.20
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	6.25	3.75	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	12.50	12.50	24.50	24.50	0.00	0.00	40.00	15.81
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus (Dead)	Dead Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	3.75	3.75	25.00	12.42	41.25	20.14	3.75	3.75	0.25	0.25
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-2: continued

	Treatment	Reference Quibray Bay 1						Reference Quibray Bay 2					
	Transect	Q1-1		Q1-2		Q1-3		Q2-4		Q2-5		Q2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	15.75	6.10	21.25	4.27	19.50	10.22	28.50	11.02	30.25	22.69	23.75	14.63
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	6.25	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Dead Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	61.25	17.84	60.00	15.14	48.75	19.08	21.50	13.16	51.25	20.65	50.00	20.41
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	1.25	1.25	0.00	0.00	0.00	0.00	0.00	0.00	2.50	2.50	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	15.50	11.70	13.75	13.75	20.50	18.20	36.25	17.25	13.75	8.00	20.00	11.37
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus (Dead)	Dead Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	5.00	5.00	0.00	0.00	13.75	4.27	1.25	1.25	6.25	3.75
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	11.25	8.26	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-2: continued

	Treatment	Reference Woolooware Bay 1						Reference Woolooware Bay 2					
	Transect	W1-1		W1-2		W1-3		W2-4		W2-5		W2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	32.25	4.09	13.75	2.39	33.75	9.87	27.00	12.86	44.75	23.79	30.00	16.20
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.50	7.50	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Dead Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	17.50	6.29	65.00	21.79	28.75	22.58	61.75	11.75	47.50	27.50	47.50	16.14
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.25	0.25	21.25	21.25	0.00	0.00	10.50	9.84	0.00	0.00	6.25	6.25
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus (Dead)	Dead Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	37.50	13.15	0.50	0.29	0.25	0.25	16.25	8.51
Suaeda australis (poor)	Seablite	50.00	8.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-2: continued

	Treatment	Treated Reference Sans Souci						Treated Reference Salt Pan Creek					
	Transect	SS1-1		SS1-2		SS1-3		SPC1-1		SPC1-2		SPC1-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bare	bare ground	42.00	23.80	48.75	17.37	22.50	16.52	27.50	17.02	11.25	6.57	50.00	15.68
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	35.00	21.79	23.75	12.14	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.75	3.75
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Dead Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	26.25	24.61	2.50	2.50	31.25	23.66	0.00	0.00	13.75	6.25	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	33.75	10.28	0.00	0.00	46.25	15.73
Sarcocornia quinqueflora	Beaded Glasswort	31.75	22.17	46.25	16.25	42.50	20.46	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (Dead)	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	3.75	3.75	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.50	7.50	0.00	0.00
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus (Dead)	Dead Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	3.75	3.75	26.25	18.19	0.00	0.00
Suaeda australis (poor)	Seablite	0.00	0.00	2.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

D-3: Abundance of individuals of each saltmarsh, mangrove and epifaunal invertebrate species recorded within four random quadrats (1m^2) along the transect at each site from Penrhyn Estuary, Reference Sites and Treated Reference Sites (sampled 5 - 6 March 2013). Data are presented as means and standard errors for four quadrats.

	Treatme	New Saltmarsh 1											
	Transect	N1-1		N1-2		N1-3		N1-4		N1-5		N1-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.50
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	15.25	2.02	10.75	3.35	11.75	3.79	8.50	2.90	9.00	4.14	6.75	3.75
Sarcocornia quinqueflora(poo	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (De	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	2.00	2.00	7.50	7.50	7.75	7.75	5.00	5.00	4.00	4.00	15.25	6.39
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	Dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	2.75	2.75	1.75	1.75	14.00	2.12	2.75	2.75	1.75	1.75	0.25	0.25
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	1.00	1.00	0.25	0.25	0.25	0.35	0.00	0.00	0.25	0.25	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	0.00	0.00	0.00	0.00	4.50	6.36	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	10.00	10.00	2.00	2.00	8.75	0.35	10.50	7.31	3.75	3.12	0.00	0.00
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-3: continued

	Treatme	New Saltmarsh 2											
	Transect	N2-9		N2-10		N2-11		N2-12		N2-13		N2-21	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	2.00	2.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	20.50	3.38	17.50	3.84	10.75	5.17	12.50	4.97	17.00	5.49	12.25	4.33
Sarcocornia quinqueflora(poo	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (De	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	3.00	3.00	4.50	4.50	13.00	13.00	7.50	7.50	15.00	15.00
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.50	0.50	0.50	0.50
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	Dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	0.00	0.00	7.50	6.51	1.00	1.00	0.75	0.25	0.50	0.50	0.75	0.75
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.50	0.50	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	63.50	47.03	4.75	4.75	1.00	1.00	0.00	0.00	58.00	40.99	3.00	3.00
Ophicardelus ornatus	Mangrove air-breather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	1.50	1.50	5.00	4.02	2.25	2.25	10.75	8.86	17.50	12.20	15.75	15.09
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-3: continued

	Treatme Transect	Transplanted Saltmarsh TR-8		TR-17		TR-18		Retained Saltmarsh 1 R1-7		R1-14	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	2.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	2.00	2.00	0.00	0.00	3.00	1.47	1.00	1.00	4.50	3.57
Sarcocornia quinqueflora(poo	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (De	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	2.50	1.50
Sporobolus virginicus	Salt Couch	10.00	10.00	22.50	14.36	41.50	12.74	0.00	0.00	0.00	0.00
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	2.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
Suaeda australis	Seablite	2.00	0.00	1.50	0.87	2.25	2.25	3.50	1.04	0.00	0.00
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	Dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	4.75	4.75	7.25	4.75	3.00	2.38	2.25	1.65	0.00	0.00
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50
Littorina scabra	Rough periwinkle	3.00	2.38	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	1.50	1.19	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	5.25	3.35	0.00	0.00	2.75	2.75	0.00	0.00	0.00	0.00
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-3: continued

	Treatme	Retained Saltmarsh 2				Altered Saltmarsh 2					
	Transect	R2-20		R2-22		A2-15		A2-16		A2-19	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	11.25	11.25	2.00	1.68	0.00	0.00	0.50	0.50	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.00	0.00
Isolepis nodosa (dead)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.87	0.00	0.00
Juncus kraussii	Sea Rush	0.75	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	8.25	5.27	7.25	4.75	1.50	1.50	0.00	0.00	3.50	1.26
Sarcocornia quinqueflora(poo	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (De	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	3.00	1.78	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	3.25	3.25	6.25	6.25	0.00	0.00	16.50	4.17
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	4.00	3.67	5.25	1.03	3.25	1.38	0.75	0.75	0.50	0.50
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	Dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	5.75	3.61	0.50	0.50	14.25	6.97	0.00	0.00	12.25	6.84
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	10.75	5.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	3.50	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.48
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-3: continued

Treatme Transect		Reference Quibray Bay 1 Q1-1		Q1-2		Q1-3		Reference Quibray Bay 2 Q2-4		Q2-5		Q2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	14.25	8.78	0.00	0.00	0.00	0.00	3.00	3.00	0.75	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	14.75	3.66	13.50	2.90	14.25	4.31	6.00	3.19	4.93	0.00	12.50	5.33
Sarcocornia quinqueflora(poo	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (De	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	8.50	4.48	2.25	2.25	10.00	6.88	13.75	7.03	9.81	0.00	8.75	6.37
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	1.25	1.25	1.75	1.18	2.75	1.03	0.48	0.00	1.25	0.95
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	Dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	9.25	3.73	21.25	3.94	5.75	2.84	4.00	2.35	6.58	0.00	7.75	3.59
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.50	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	14.25	10.35	0.25	0.25	3.25	1.89	0.00	0.00	40.75	0.00	1.75	1.75
Salinator fragilis	Fragile air-breather	4.50	2.40	0.00	0.00	1.00	0.71	0.00	0.00	0.25	0.00	0.00	0.00
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-3: continued

	Treatme Transect	Reference Woolooware Bay 1						Reference Woolooware Bay 2					
		W1-1		W1-2		W1-3		W2-4		W2-5		W2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75	1.75	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	21.00	8.42	0.00	0.00	27.00	25.04	13.50	9.43
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	4.00	1.63	8.50	2.90	3.75	2.39	2.25	2.25	5.75	3.38	11.25	3.28
Sarcocornia quinqueflora(poo	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (De	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	1.25	0.95	6.25	6.25	0.00	0.00	0.50	0.50	0.00	0.00	1.50	1.50
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	6.25	1.18	0.00	0.00	4.25	1.55	4.25	3.33	0.25	0.25	2.75	2.10
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	Dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	7.25	3.82	6.25	1.89	5.50	3.40	5.00	1.78	12.25	1.70	6.75	4.31
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	3.25	2.14	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	1.50	1.50
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	8.00	4.69	21.50	8.73	29.50	14.08	3.25	2.36	10.00	6.44	35.75	25.95
Salinator fragilis	Fragile air-breather	0.00	0.00	3.50	1.19	1.50	1.50	0.00	0.00	4.00	1.87	2.25	1.31
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

D-3: continued

Treatme		Treated Reference Sans Souci						Treated Reference Salt Pan Creek					
Transect		SS1-1		SS1-2		SS1-3		SPC1-1		SPC1-2		SPC1-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.25	2.39	0.00	0.00
Avicennia marina	Grey Mangrove tree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75
Avicennia marina	Grey Mangrove seedling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove pneumatophores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carpobrotus sp.	Pigface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle sp.	Pennywort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (dead)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	10.25	9.92	0.50	0.50	1.25	0.75	0.00	0.00	1.25	0.63	0.00	0.00
Plantago coronopus	Plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Creeping Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	9.75	2.95	0.00	0.00	6.00	3.12
Sarcocornia quinqueflora	Beaded Glasswort	8.75	5.04	11.75	4.17	8.25	3.94	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora(poo	Beaded Glasswort	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora (De	Dead Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.00	0.00	0.00
Sporobolus virginicus (poor)	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.75	0.75	0.00	0.00	0.75	0.75	9.25	1.55	0.00	0.00
Suaeda australis (poor)	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis (Dead)	Dead Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetragonia tetragonioides	New Zealand Spinach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush (dead)	Dead unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapsidae crab	unidentified grapsid crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
crab hole	crab hole	2.25	2.25	0.50	0.50	2.50	1.50	14.25	4.71	0.00	0.00	3.25	2.02
Amphipoda	unidentified amphipod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onchidium damelli	Air breathing sea slug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bembicium auratum	Estuarine periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littorina scabra	Rough periwinkle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ophicardelus ornatus	Mangrove air-breather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salinator fragilis	Fragile air-breather	8.25	6.69	0.50	0.50	0.50	0.29	17.00	6.12	6.75	2.75	7.25	2.50
Calthalotia fragum	Top shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batillariidae	unidentified whelk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilidae	unidentified mussel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

D-4: Height (cm) of the tallest plant species recorded within four random quadrats (1m^2) along the transect at each site from Penrhyn Estuary, Reference Sites and Treated Reference Sites (sampled 5 -6 March 2013). Data are presented as means and standard errors for four quadrats.

	Treatment	New Saltmarsh 1											
	Transect	N1-1		N1-2		N1-3		N1-4		N1-5		N1-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	11.75	4.73	10.50	3.86	17.50	6.18	16.75	5.88	14.75	5.02	2.00	2.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	5.00	5.00	7.50	7.50	7.25	7.25	5.00	5.00	9.00	9.00	13.25	5.39
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

continued…

	Treatment	New Saltmarsh 2											
	Transect	N2-9		N2-10		N2-11		N2-12		N2-13		N2-21	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.75	13.75
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	15.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	21.25	0.95	18.50	6.51	9.75	5.66	16.75	7.23	15.75	5.27	10.75	6.21
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	7.00	7.00	7.00	7.00	8.50	8.50	10.00	10.00	8.00	8.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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D-4: continued

	Treatment	Transplanted Saltmarsh						Retained Saltmarsh 1			
	Transect	TR-8		TR-17		TR-18		R1-7		R1-14	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	25.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.50	4.50
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.50	8.96
Sporobolus virginicus	Salt Couch	0.00	0.00	20.50	11.84	30.50	10.19	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	18.75	18.75	0.00	0.00
Suaeda australis	Seablite	34.25	12.13	19.50	11.32	9.00	9.00	25.50	8.77	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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	Treatment	Retained Saltmarsh 2				Altered Saltmarsh 2					
	Transect	R2-20		R2-22		A2-15		A2-16		A2-19	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	33.75	19.51	0.00	0.00
Juncus kraussii	Sea Rush	43.75	25.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	6.25	6.25	5.75	5.75	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	10.00	10.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	10.00	10.00	0.00	0.00	36.50	3.93
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	7.25	7.25	31.25	11.61	36.75	16.45	6.25	6.25	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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D-4: continued

	Treatment	Reference Quibray Bay 1						Reference Quibray Bay 2					
	Transect	Q1-1		Q1-2		Q1-3		Q2-4		Q2-5		Q2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex australasica	Green Saltbush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	13.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Samolus repens	Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	14.75	5.44	13.50	4.52	8.50	4.97	0.00	0.00	4.75	4.75	3.75	3.75
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	6.00	6.00	5.00	5.00	18.50	10.87	9.50	5.50
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	6.50	6.50	6.75	6.75	19.00	6.36	0.00	0.00	5.00	5.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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	Treatment	Reference Woolooware Bay 1						Reference Woolooware Bay 2					
	Transect	W1-1		W1-2		W1-3		W2-4		W2-5		W2-6	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.00	13.00	0.00	0.00
Atriplex		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	0.00	0.00	0.00	0.00	0.00	0.00	16.25	16.25	0.00	0.00	0.00	0.00
Samolus repens	Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarcocornia quinqueflora	Beaded Glasswort	0.00	0.00	14.25	4.77	3.00	3.00	0.00	0.00	7.75	4.48	3.00	3.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	35.00	3.58	0.00	0.00	32.50	13.27	24.50	8.23	1.75	1.75	27.25	9.32
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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D-4: continued

	Treatment	Treated Reference Sans Souci						Treated Reference Salt Pan Creek					
	Transect	SS1-1		SS1-2		SS1-3		SPC1-1		SPC1-2		SPC1-3	
Species Name	Common Name	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acacia sp.	unidentified Wattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegiceras corniculatum	River Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.25	21.25	0.00	0.00
Avicennia marina	Grey Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	20.00
Isolepis nodosa	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolepis nodosa (poor)	Knobby Club-rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juncus kraussii	Sea Rush	58.75	35.14	10.00	10.00	70.00	40.41	0.00	0.00	48.75	28.60	0.00	0.00
Samolus repens	Brookweed	0.00	0.00	0.00	0.00	0.00	0.00	18.75	1.31	0.00	0.00	10.25	3.47
Sarcocornia quinqueflora	Beaded Glasswort	6.25	4.73	11.00	6.43	10.75	6.21	0.00	0.00	0.00	0.00	0.00	0.00
Spinifex sericeus	Hairy Spinifex grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus virginicus	Salt Couch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenotaphrum secundatum	Buffalo Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suaeda australis	Seablite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.75	13.75	0.00	0.00
unidentified rush	unidentified rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified herb	unidentified herb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified plant	unidentified plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Port Botany Post Construction Monitoring
Annual Report 2013

APPENDIX D

SEAGRASS ANNUAL MONITORING REPORT 2013

Cardno
Shaping the Future

Port Botany Post Construction Environmental Monitoring

Seagrass Annual Report 2013

EL1112046

Prepared for Sydney Ports Corporation

September 2013

Cardno
Shaping the Future

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Document Control

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Executive Summary

This report summarises the findings of the Seagrass Monitoring Program from March 2012 to March 2013. It also incorporates data from earlier investigations carried out as part of the Port Botany Expansion baseline and pre-construction monitoring.

As part of the Port Botany Expansion Project, extensive dredging and modifications have altered seagrass habitat in Penrhyn Estuary and parts of Foreshore Beach in Botany Bay. Prior to construction, monitoring works carried out in May 2008 (Roberts *et al*. 2008) indicated that approximately 317 sq. m of seagrass (including *Zostera capricorni*, *Halophila* spp. and *Posidonia australis*) would be lost through land reclamation, boat ramp construction and dredging works associated with the port expansion. The remaining seagrass beds were monitored during the construction phase and are now being monitored post-construction in accordance with the PEHEP by measuring changes in distribution and condition. Beds of *P. australis* located within the dredging footprint were also removed and transplanted to Quibray Bay as part of the PEHEP. The Seagrass Monitoring Plan will also investigate the success of this transplantation over time.

The key objective of the PEHEP Seagrass Monitoring Program is to determine if seagrass habitat has been affected by port construction and if mitigation efforts and habitat creation have been successful. This will be assessed by:

- Mapping of the distribution and measuring ecological characteristics of seagrass along Foreshore Beach and in the Rehabilitation Area; and
- Measuring the success of transplanting *P. australis* in Quibray Bay.

Several different sampling methods and indicators were used to capture the distribution, composition and condition of seagrasses at Foreshore Beach, the rehabilitated section of Penrhyn Estuary (the Rehabilitation Area) and at Planting Areas and Experimental Sites within Quibray Bay where seagrass from Foreshore Beach was transplanted.

Results of pre- and post-construction monitoring over the past 11 years has identified that seagrass distribution and species composition within Foreshore Beach and the Penrhyn Estuary Rehabilitation Area is highly variable. This is evident from a major decline in seagrass area from approximately 65,821 sq. m in 2002 to 698 sq. m in February 2007, prior to construction works commencing. Impacts to seagrasses as a result of the Port Botany Expansion are therefore relatively minor in relation to the variability (natural or otherwise) observed over the six year period prior to any construction works taking place. Monitoring carried out during the construction works indicated that seagrass condition and distribution remained relatively stable during this period.

Initial findings of the post–construction monitoring (March 2012 to March 2013) at Foreshore Beach and the Rehabilitation Area are positive and suggest early signs of recovery for *Halophila* spp. and *Z. capricorni* following the pre-construction decline, but not for *P. australis*. The majority of seagrass present within these areas was, however, sparse and patchily distributed. These initial findings are consistent with results of water quality monitoring, which suggest that water quality parameter are within the requirements for seagrass growth.

Within Penrhyn Estuary, no intertidal seagrasses were observed in searches in March 2012, but sparse patches of *Z. capricorni* and *Halophila* spp. were observed in November 2012 near the enhanced saltmarsh habitat on the northern side of the estuary and along the western boundary adjacent to the new terminal structure. Sparse patches of *Halophila* spp. were observed in the inner estuary near the confluence of Floodvale and Springdale creeks in March 2013. The observations of sparse, ephemeral seagrass since late 2012 indicates that inner estuary habitats have stabilised to the stage where they support seasonal patches of sparse seagrass in a manner similar to that observed prior to habitat enhancement.

Indicators of seagrass condition at Foreshore Beach showed significant improvements in post-construction surveys carried out from March 2012 to March 2013. The condition of the small areas of *Halophila* spp. sampled within the Rehabilitation Area was variable in terms of shoot densities and had relatively short leaves indicating that it was either newly established or may be a response to environmental stress.

The level of epiphytic growth observed on seagrasses ranged from none to high, but was generally recorded within the light to medium range which would be expected for a developed urban estuary within a major population centre. The invasive alga *Caulerpa taxifolia* was not observed at any location the March 2012 and March 2013 surveys.

Overall, water quality data (PAR and TSS) indicated that seagrass growth within the estuary is unlikely to be limited by light attenuation in the long term and should therefore be conducive to growth and recovery. TSS levels recorded within Penrhyn Estuary and at reference sites before and after construction did not appear to be significantly different. No clear spatial relationship between mean TSS and PAR levels with the distribution of seagrasses was evident. While some water quality indicators have varied from pre-construction averages, overall water quality outcomes in Penrhyn Estuary are suitable to support the habitats enhanced by the PEHEP, with no indication of potential for the formation of eutrophic conditions to date.

The transplantation of *P. australis* from Foreshore Beach to Quibray Bay appears to have been highly successful and will have helped offset direct losses of seagrass as a result of dredging and reclamation at Foreshore Beach.

Investigations into the various methods of transplantation treatments against control treatments have shown that all methods (whole, trimmed and rhizomes) showed positive results. As the growth and establishment of *P. australis* can be slow, continued monitoring of these treatments over the course of the project will be important in determining whether one or more methods were more successful than others.

This study was limited by the amount of raw data available from past investigations and as such, statistical analyses were not possible for some aspects of the investigation. Results of the 2012 to 2017 surveys will therefore be important in assessing the success of the PEHEP by providing a complete data set collected in a consistent and quality controlled manner.

A summary of key results is provided below:

Seagrass Indicator	Result	Comment
Distribution along Foreshore Beach	Decreased significantly prior to habitat enhancement	Negative but not associated with Port Expansion project
Distribution in Rehabilitation Area (Channel and outer estuary)	Early signs of recovery for *Halophila* and *Zostera*, but not *Posidonia*	Positive trend
Condition along Foreshore Beach	*Halophila* with short sparse leaves with medium load of epiphytes	Positive trend
Distribution on intertidal/subtidal areas within Penrhyn Estuary	Observation of sparse, ephemeral patches of *Zostera*	Positive result, similar to pre-enhancement
Condition of *Posidonia* transplanted to Quibray Bay	Successful, generally not distinguishable from surrounding seagrass but variable among sites	Positive result

There are no recommendations to alter the current sampling program at this stage.

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Appendices

1 Introduction

1.1 Background

As part of the Port Botany Expansion Project, Sydney Ports has rehabilitated Penrhyn Estuary, located adjacent to the port expansion (**Figure 1**). Penrhyn Estuary is a small waterway of approximately 80 ha located to the north of Brotherson Dock which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978. Since its creation, it has been utilised by a diverse group of migratory birds. The purpose of the rehabilitation works was to enhance the existing intertidal habitat and to expand the estuary as a long term habitat for migratory shorebirds. This involved the removal of mangroves, weeds and introduced species, the enhancement of existing saltmarsh and the creation of new saltmarsh habitat. An extensive area of foredune was also levelled to create an intertidal feeding and roosting habitat for key species of migratory shorebirds that currently use the estuary, and to potentially attract a greater number of shorebirds upon completion. The design, methodology and ongoing maintenance for the estuary are outlined within the Penrhyn Estuary Habitat Enhancement Plan (PEHEP).

As part of the Port Botany Expansion Project, extensive dredging and modifications have altered seagrass habitat in Penrhyn Estuary and along nearby Foreshore Beach in Botany Bay (**Table 1**). Prior to construction, monitoring works carried out in May 2008 (Roberts *et al*. 2008) indicated that approximately 317 sq. m of seagrass (including *Zostera capricorni*, *Halophila* spp. and *Posidonia australis*) would be lost through land reclamation, boat ramp construction and dredging works associated with the port expansion. The remaining seagrass beds were monitored during the construction phase and are now being monitored post-construction in accordance with the PEHEP by measuring changes in distribution and condition.

Table 1 Timeframe for seagrass surveys and major habitat enhancement events in Penrhyn Estuary to April 2013

Activity	Date	Comments
Before Construction Survey 1	Unknown period 1995	*(Source: Watford and Williams 1998)*
Before Construction Survey 2	April 2002	*(Source: The Ecology Lab 2003)*
Before Construction Survey 3	July 2002	*(Source: Roberts et al. 2006)*
Before Construction Survey 4	February 2007	*(Source: Roberts et al. 2007)*
Before Construction Survey 5	November 2007	*(Source: Roberts et al. 2008)*
Before Construction Survey 6	May 2008	*(Source: Roberts et al. 2008)*
Construction	January – July 2008	Removal and relocation of sand dunes Construction of temporary roosting island
Construction	August 2008 – end March 2009	Mangrove removal by hand, weed clearing Saltmarsh transplanting within Penrhyn Estuary No machine work in inner estuary (peak bird season) CSD dredging in Botany Bay from September
Construction	End March - July 2009	Central estuary filled, sand augmented with mud and seagrass wrack Filamentous algal bloom (until September 2009) Sand stockpiled for later filling outer estuary (80,000 m^3) Dredging in Botany Bay complete April
Construction	August 2009 – March 2010	Saltmarsh area augmented (Nov) and planted (Dec) New boat ramp opened (Nov) Filling of outer estuary begins, less seagrass wrack than in inner estuary Tidal flow maintained throughout

Activity	Date	Comments
		filling/contouring
Construction	April 2010 – July 2011	Further saltmarsh planting Flushing channel contoured using small dredger Filling outer estuary complete by end Dec 2010
After Construction Survey 1	14 March – 4 April 2012, July 2012	
After Construction Survey 2	26 March – 9 April 2013	

The population of *P. australis* within Botany Bay is listed under the *Fisheries Management Act 1994* (FM Act) as endangered and as such, beds of *P. australis* located within the dredging footprint were removed and transplanted to Quibray Bay as part of the PEHEP. The Seagrass Monitoring Plan will therefore investigate the success of this transplantation over time.

The Seagrass Monitoring Plan also relates to the Water Quality Monitoring Plan which has partly focused on providing adequate flushing of the rehabilitated area in the channel of Penrhyn Estuary to support seagrass rehabilitation.

1.2 Aims

The key objective of the PEHEP seagrass monitoring program is to determine if seagrass habitat has been affected by port construction and if mitigation efforts and habitat creation have been successful. This will be assessed by:

> Mapping of the distribution and measuring ecological characteristics of seagrass along Foreshore Beach and in the Rehabilitation Area (**Figure 2)**; and

> Measuring the success of transplanting *P. australis* in Quibray Bay.

Specific tasks of the monitoring program are to:

> Map the extent of seagrass habitat along Foreshore Beach and the Rehabilitation Area and record distribution and abundance of species present, density, morphology and presence of epiphytes;

> Undertake statistical analyses to determine changes in areal extent of habitat density and condition of seagrass along Foreshore Beach and the Rehabilitation Area;

> Assess density and condition of transplanted *P. australis* in Quibray Bay;

> Undertake statistical analyses to determine changes recorded in transplanted *P. australis;* and

> Identify any changes required to the Seagrass Monitoring Plan and implementation due to differences between anticipated and actual seagrass extent and seagrass transplanted.

The PEHEP seagrass monitoring program is scheduled to run from March 2012 until March 2017. This annual report documents the results of seagrass monitoring undertaken between March 2012 and March 2013 and is the first of five annual reports.

1.3 Review of Existing Information

1.3.1 Ecological Function of Seagrasses

Seagrass is a functional grouping of marine flowering plants mostly found in soft sediment nearshore and estuarine environments (Butler and Jernakoff 1999). The ecological functions of seagrasses include a significant contribution to the productivity of the ecosystem, stabilising sediments and providing food and habitat for fish and invertebrates, including juveniles of recreational and commercial importance (Smith and Pollard 1999). Seagrasses also baffle water currents, causing them to release their sediment loads, thus maintaining water quality (Smith and Pollard 1999) and help prevent erosion by stabilising sediments and assisting in the cycling of nutrients (Smith *et al*.1997). Loss of seagrass can result in the destabilisation of sediments, removal of potential nursery habitats for fish and invertebrates and a decrease in primary productivity of estuaries. Many organisms also benefit from the organic matter released by the slow bacterial and fungal breakdown of seagrass detritus.

A number of fish and invertebrate species important to commercial and recreational fisheries have been recorded from seagrass beds in the northern section of Botany Bay, including sand whiting (*Sillago ciliata*), yellowfin bream (*Acanthopagrus australis*), tarwhine (*Rhabdosargus sarba*), luderick (*Girella tricuspidata*), sand mullet (*Myxus elongatus*), yellow-finned leatherjacket (*Meuschenia trachylepis*), king prawns (*Melicertus plebijus*), blue swimmer (*Portunus pelagicus*) and other crabs, octopi, cuttlefish, squid and shrimp. Overall, the seagrass beds off Foreshore Beach have shown consistently greater abundances of commercially important species, but fewer species than other sites in the bay (The Ecology Lab 2003).

1.3.2 Seagrasses in Botany Bay

Three types of seagrass, *Halophila* spp. *Z. capricorni*, and *P. australis*, have been recorded at Foreshore Beach and Penrhyn Estuary. *Halophila* spp. (also known as 'paddleweed'), is a member of the family Hydrocharitaceae and has small thin ovate leaves with stalk like petioles. *Halophila* species can establish and grow rapidly, with high rhizome turn-over and are generally considered pioneering species prior to the colonisation of *Z. capricorni* followed by *P. australis*.

Z. capricorni (also known as 'eelgrass') is the most common species of the family Zosteraceae found in NSW. It generally has narrow, slender leaves with a blunt apex, although leaf length and width may vary considerably depending on conditions. *Z. capricorni* exhibits fast leaf growth during spring and summer months and generally has a dieback period during winter when leaf growth is slow (West 2000).

P. australis (also known as 'strapweed') is one of eight species of the family Posidoniaceae that occur in Australia. *P. australis* is the largest of the NSW seagrasses and has tough, strap-like leaves that can reach up to 60 cm in length and are typically between 10 - 20 mm wide. New leaves are often bright green and more mature leaves may be brown in colour and commonly covered in epiphytes (small algae which attach themselves to the leaf surface). Leaves are produced throughout the year, but growth is slower during winter months.

1.3.3 Factors Affecting the Growth and Distribution of Seagrasses

A range of physical factors affect the distribution and abundance of seagrass, including light, turbidity, sedimentation, nutrient levels, temperature, salinity, current and wave action and water depth (Connell and Gillanders 2007). Light availability is considered one of the most important environmental variables controlling the distribution and abundance of seagrass, although light requirements vary among species. The main factors affecting light availability are increases in suspended sediments and turbidity and nutrient inputs which in turn may result in increased growth of phytoplankton macroalgae and epiphytes, leading to shading. Inputs of suspended sediment loads and nutrients are often related to seasonal episodic pulses of rainfall and would enter Penrhyn Estuary via Floodvale and Springvale Creeks.

Seagrass responses to disturbances and environmental conditions can lead to considerable variability in growth forms for any one particular seagrass species. For example, short stunted growth can occur in most seagrasses subjected to environmental stress (Butler and Jernakoff 1999). Smaller seagrasses (e.g. *Halophila* spp. have smaller rhizomes which persist for weeks to months while larger seagrasses such as *P. australis* have deeper rooted rhizomes which persist for months to years. Depending on the species of seagrass, recovery of beds from disturbances can be slow. Seedlings of *P. australis* take 2–3 years before producing rhizomes (which help anchor plants) and are thought to be vulnerable to physical disturbance and smothering during this time.

Intact stands of *P. australis* have the ability to grow quite rapidly, however, if the growing tips of the rhizomes are damaged, the plants cease to establish lateral rhizome runners and may be very slow to recover. For example, it may take up to 50 years to close a gap of 1 m following damage to these tips (NSW DPI 2012). For this reason and due to substantial reductions in its abundance, the population of *P. australis* occurring in Port Botany was listed as endangered under the FM Act. Studies within Botany Bay have also indicated that *Z. capricorni* may take several years to recolonise following its loss (Larkum and West 1980).

1.3.4 Seagrass Studies Relating to the Port Botany Expansion

A number of studies documenting seagrass distribution and condition have been carried out in the northern part of Botany Bay including Foreshore Beach and Penrhyn Estuary. Historically, the earliest estimates of seagrass distribution in the northern part of Botany Bay (including Cooks River to Frenchman's Bay) were based on aerial photographs from the 1930's up until the late 1970's. During this period, considerable changes in the extent of the seagrass beds along the entire northern shore of the bay were observed. This was largely attributed to two expansions of the airport and the development of port facilities although differences between 1930 and 1961 indicate that natural variability in the area was high prior to any significant development (The Ecology Lab 2003).

A summary of seagrass studies undertaken at Foreshore Beach and Penrhyn Estuary in relation to the Port Botany Expansion from 2002 to date are presented in **Table 2**. The first of these investigations was carried out by The Ecology Lab in April/July 2002 as part of baseline investigations for the Port of Botany Expansion Environmental Impact Statement (The Ecology Lab 2003). This study also made comparisons to NSW Fisheries seagrass mapping based on 1995 aerial imagery (Watford and Williams 1998) for the same area. Results showed an increase in total seagrass cover from 74,752 sq. m in 1995 (Watford and Williams 1998) to 96,715 sq. m in 2002 (The Ecology Lab). In addition to an actual increase in seagrass cover, these changes were also attributed to possible differences in the quality and scale of the NSW Fisheries aerial photographs. Very sparse areas of seagrasses occurring along the eastern edge of the parallel runway were also not included in the Watford and Williams (1998) mapping (estimated to be 2000 sq. m.). Overall, the 2002 mapping showed that *Z. capricorni* was the most abundant species of seagrass present which varied from sparse to dense patches and was also mixed with *Halophila* spp. and *Caulerpa* spp. in places. *P. australis* was found in small clumps at the seaward edge of the main bed of *Z. capricorni* but was not recorded in the earlier 1995 study.

Prior to dredging and construction activities commencing, Roberts *et al.* (2006, 2007 and 2008) carried out further mapping of Foreshore Beach to provide a baseline for future monitoring and help inform proposed transplant experiments. The survey method involved the placement of 200 m long fixed transects (14 in total) along the length of Foreshore Beach. The total area covered by seagrasses in 2006 was calculated to be 47,100 sq. m and was comprised predominantly of *Z. capricorni*, mixed *Z. capricorni* and *Halophila* spp. and small patches of *P. australis* (approximately 14 sq. m). Within Penrhyn Estuary variable amounts of short *Z. capricorni* were recorded on mud flats and among mangrove pneumatophores during five surveys from July 2005 to June 2007 (The Ecology Lab 2007).

The total area of seagrass cover along Foreshore Beach in February 2007 was calculated to be only 698 sq. m, comprised predominantly of mixed beds of *Z. capricorni* and *Halophila* spp. (423 sq. m), followed by *Z. capricorni* (192 sq. m), *P. australis* (45 sq. m), *Halophila* spp. (27 sq. m) and mixed patches of all three species (11 sq. m). This extensive reduction in seagrass cover between 2006 and February 2007 was attributed to burial by sand from erosion along Foreshore Beach, although the cause of increased erosion was not speculated upon. The total area of seagrass cover reported in November 2007 was 365 sq. m comprised of mixed beds of *Z. capricorni* and *Halophila* spp. (217 sq. m), *Z. capricorni* (93 sq. m), *P. australis* (43 sq. m), mixed patches of *Z. capricorni* and *P. australis* (8 sq. m) and mixed patches of all three species (approximately 4 sq. m). The total area of seagrass cover reported in May 2008 was 352 sq. m comprised of mixed beds of *Z. capricorni* and *Halophila* spp. (221 sq. m), *Z. capricorni* (86 sq. m), *P. australis* (36 sq. m), mixed patches of *Z. capricorni* and *P. australis* (5 sq. m) and mixed patches of all three species (approximately 4 sq. m). Following the final pre-construction survey in May 2008, the total area of seagrass estimated to be directly impacted by the dredging and reclamation works was 317 sq. m. This included mixed beds of *Z. capricorni*, *Halophila* spp. and *P. australis* (207 sq. m), *Z. capricorni* (84 sq. m), *P. australis* (26 sq. m).

During construction works, NGH Environmental on behalf of Baulderstone Jan De Nul and SPC undertook weekly monitoring of seagrass at 10 Sites along Foreshore Beach using an underwater viewing tube from a boat. Monthly surveys were also carried out on SCUBA. Monitoring locations were selected on the basis of earlier studies. Results of 2009 sampling indicated that the area of seagrass cover at most of the sites was generally stable and/or increasing initially for *Z. capricorni* and *Halophila* spp. By the end of 2011, seagrass cover remained stable or was in decline although no physical disturbance to the retained seagrass patches was observed. Epiphytic growth was apparent at all sampling sites over the course of the sampling program which was attributed to high nutrient levels within Port Botany.

Post-enhancement monitoring of Foreshore Beach and rehabilitated area of Penrhyn Estuary has been carried out by Cardno Ecology Lab in March/April 2012 and 2013 and is the subject of this annual report.

Table 2 Summary of seagrass studies of Foreshore Beach and Penrhyn Estuary, Port Botany

Year	Project Phase	Approximate Area of Seagrass (sq. m)	Reference
1995	Pre-Enhancement	74,752	Watford and Williams (1998)
2003	Pre-Enhancement	94,715	The Ecology Lab (2003)
2006	Pre-Enhancement	47,100	Roberts *et al.* (2006)
2007 (February)	Pre-Enhancement	698	Roberts *et al.* (2007)
2007 (November)	Pre-Enhancement	365	Roberts *et al.* (2008)
2008	Pre-Enhancement	352	Roberts *et al.* (2008)
2009	During Construction	Not comparable	SPC (2009)
2010	During Construction	Not comparable	SPC (2010)
2011	During Construction	Not comparable	SPC (2011)
2012	Post Enhancement	26,000	Cardno Ecology Lab (2012)
2013	Post Enhancement	10,323	Cardno Ecology Lab (2013)

1.3.5 Transplantation Experiments

Seagrass mapping carried out prior to enhancement works indicated that approximately 26 sq. m of *P. australis* would be directly impacted by works associated with the Port Botany Expansion (Roberts *et al.* 2008). Given its conservation value and slow recovery rate of *P. australis*, it was identified within the PEHEP that this area of seagrass would be relocated and transplanted to Quibray Bay.

Past seagrass transplantation experiments within Botany Bay have, however, had limited success. One of the greatest causes of failure has been attributed to poor decisions regarding the location of recipient sites (Sainty and Roberts 2004). Recipient sites at Quibray Bay were therefore carefully selected in consultation with NSW DPI and where conditions were considered to be optimal for transplantation success. Quibray Bay (at the southern end of Botany Bay) contains significant beds of *P. australis*, is sheltered from wave action and receives sufficient sunlight. Sites were selected where there was either bare substratum adjacent to existing beds of *P. australis* or large bare patches within the existing beds.

The timing of transplantation was considered to be optimal when water temperatures were low and water clarity (light penetration) was good. This was based on the assumption that less energy would be expended on growth and/or reproduction and could be conserved for repairing any damage and stress caused during transplantation (Roberts and Murray 2009).

The seagrass in the impact area was removed by excavating the sediment down to the roots (below 1 m) using a hand held water pump. As excavations took place, a greater area of seagrass was exposed from beneath the sand, resulting in a total area of 132 sq. m being transplanted, although a number of plants were lost in the transplantation. Overall, a total of 1771 individual plants were harvested and transplanted to Quibray Bay over a period of 18 days in July 2008.

Two areas (Planting Area 1 and Planting Area 2) were chosen to receive the bulk of the transplanted seagrasses. Planting Area 1 covered an area of approximately 16 sq. m and Planting Area 2 covered an area of approximately 90 sq. m. Densities at the time of planting were 10 and 15 plants per sq. m in Planting Areas 1 and 2 respectively. Three additional sites (Experimental Sites 1 – 3) were also established to test and evaluate different transplanting methods. The experimental treatments included:

1. Whole (rhizomes + whole shoots);

2. Trimmed (rhizomes + shoots trimmed to 2 cm);
3. Rhizomes (rhizomes – no shoots);
4. Seagrass Control (existing *P. australis* at recipient site);
5. Bare Control (bare sediment).

Locations and sampling methodology are outlined in further detail in **Section 2.1.3**.

Initial results indicated that 14 months following transplantation, the seagrasses within the Planting Areas had successfully established, with average shoot densities of approximately 9 and 14 plants per sq. m in Planting Areas 1 and 2 respectively. Over two years on from transplantation (October 2010), average shoot densities had increased substantially with estimated densities of 37 and 43 shoots per sq. m recorded in Planting Areas 1 and 2 respectively.

Within the experimental plots, the 'whole' treatments recorded the greatest increase in shoot density and 'trimmed' treatments had the greatest increase in leaf length. In October 2010, there had been an increase in the leaf length of plants within all treatments compared to that recorded in the previous survey (September 2009).

2 Methods

2.1 Sampling Design

2.1.1 Foreshore Beach

2.1.1.1 Study Area

The extent of Foreshore Beach sampling included the area between the new boat ramp west to the mouth of the Mill Stream (**Figure 1**). It is noted that the methods used to monitor seagrass at Foreshore Beach were modified from that originally specified in the PEHE Seagrass Monitoring Plan due to a significant reduction in seagrass cover between 2006 and 2008 surveys carried out by Roberts *et al.* (2006, 2007 and 2008). The methodology outlined in this report is therefore consistent with these earlier pre-enhancement surveys.

2.1.1.2 Mapping

The distribution and areal cover of each seagrass patch in existing seagrass beds at Foreshore Beach was mapped by divers and the total area (sq. m) and species composition of each seagrass patch calculated in MapInfo Version 11.0. Comparisons were made through time to assess the changes in total seagrass cover. Data was compared for surveys carried out before construction (2003 – 2008) and after construction as part of the PEHEP (2012 and 2013). The total percent cover for different species groups was also compared for years 2012 and 2013. The following species classifications were used:

> Patchy Sparse *Z. capricorni;*

> Patchy Sparse *Halophila* spp.;

> Patchy Sparse *P. australis;* and

> Continuous Sparse *Halophila* spp. and *Z. capricorni*

2.1.1.3 Transects

Distribution and percent cover of seagrass at Foreshore Beach was mapped by divers along 11 transects spaced 50 m apart extending up to 200 m perpendicular to Foreshore Beach. Locations of transects at Foreshore Beach are indicated in **Figure 1**.

Roberts *et al*. (2006, 2007 and 2008) measured percent cover of seagrass along six of these transects prior to construction, however, data were not available to allow statistical comparison with post-construction 2012 and 2013 surveys, therefore only data from 2012 and 2013 surveys were presented.

2.1.1.4 Fixed Points

In addition to mapping and transects, percent cover was estimated by divers at five fixed point locations numbered 1, 2, 3, 5 and 6 (**Figure 1**). These sites were consistent with locations surveyed during pre-construction surveys. Initially a total of 44 fixed locations were surveyed from the 2007 pre-construction survey, however, only these five fixed points contained seagrass during the 2012 and 2013 surveys. Percentage cover was compared at fixed points for times before and after construction.

2.1.1.5 Patches

As a measure of seagrass condition, seagrass morphology was measured in the two largest patches of *Z. capricorni* and *Halophila* spp. at Foreshore Beach in March 2012 and 2013. In each patch, five 0.25 sq. m quadrats were placed randomly at two randomly selected sites. Sites were labelled P1A, P2A, P1B and P2B (**Figure 1**). The following indicators were measured by divers at each site:

> Shoot Density - The total number of shoots within each of the five quadrats was recorded to provide a measure of seagrass density.

> Leaf Length - The length of 10 randomly selected leaves within each of the five quadrats was recorded to provide an indicator of growth which can vary widely depending on the habitat in which seagrass grows.

> Epiphyte Load - Epiphyte load was recorded by divers on 10 randomly selected leaves within each of the five quadrats using a four-point classification scale:

- L= Low;
- M=Medium;
- H=High;
- N=None.

The amount of epiphytic growth on the leaves is considered an indicator of seagrass health. Excessive epiphytic growth can reduce the amount of light available for growth and high epiphytic load may be indicative of high nutrient levels within the water column.

> The invasive alga *Caulerpa taxifolia* was noted if present.

2.1.1.6 Data Analysis

> Total areas of seagrass at Foreshore Beach were presented in tables and maps through time for the years 2003 – 2013.

> Percent cover of total seagrass and seagrass species along transects and fixed points were presented as means and standard errors for each transect/site in tables and compared graphically and statistically through time for the years 2006 – 2013. Data for epiphyte load were not analysed statistically. The statistical design to investigate percentage cover along transects and fixed points was as follows:

- Period (fixed, orthogonal) – before and after construction;
- Time (random, nested in Period) – (“Before”: June 2006, February 2007, August 2008; “After”: March 2012 and March 2013); and
- Transect/Site (fixed, orthogonal to Period and Time). Note that this was a ‘repeated measures’ sampling design.

> Indicators of seagrass condition within patches (shoot density and leaf length) for each seagrass species were presented as means and standard errors in tables and compared graphically and statistically through time for the years 2012-2013 for each site. Data for epiphyte load were not analysed statistically. The experimental design to investigate seagrass shoot density was as follows:

- Time (random, orthogonal) –(March 2012 and March 2013); and
- Site (random, orthogonal to Time) – (Patch 1A, Patch 1B, Patch A2, Patch 2B; see **Figure 1**)

Quadrats (1-5) were used as replicates.

The experimental design to investigate seagrass leaf length was as follows:

- Time (random, orthogonal) –(March 2012 and March 2013);
- Site (random, orthogonal to Time);

Data from quadrats were used as replicates.

Percent cover of total seagrass and seagrass species along transects and shoot density and leaf length in patches were investigated using permutational analyses of variance (PERMANOVA+). After calculating a Euclidean distance matrix of all possible pairs of samples of the variable of interest, the underlying distribution of the data was determined by repeated randomisation of the samples in the matrix, enabling exact tests for all levels of the experimental design (Anderson *et al*. 2008).

To examine the relationship between water quality and seagrass % cover, a sub-program within the PRIMER package called Distance Based Linear Models (DIST-LM) was used. DIST-LM models the relationship between biological data and one or more predictor variables that were measured from the same set of samples. P-values for testing the null hypothesis of no relationship are obtained using permutation methods rather than traditional tables.

2.1.2 Rehabilitation Area

2.1.2.1 Study Area

The Penrhyn Estuary Rehabilitation Area is located to the east the boat ramp and incorporates the estuary channel and main Estuary as far as Springvale Creek (**Figure 2**).

2.1.2.2 Mapping

The channel to Penrhyn Estuary was surveyed by divers within the Rehabilitation Area in March 2012 and March 2013, however, only data for the 2013 sampling period has been mapped as seagrass was not found in the 2012 survey. The distribution and areal cover of each seagrass patch was mapped by divers and the total area (sq. m) and species composition of each seagrass calculated in MapInfo Version 11.0.

Comparison of seagrass maps of the Rehabilitation Area with earlier (pre-construction) maps was based on the area between the footprint of the new boat ramp, west to the end of Penrhyn Estuary. Total seagrass area for the April 2002 survey (The Ecology Lab 2003) was derived from MapInfo files. Areas of seagrass mapped by Roberts *et al*. (2006, 2007 and 2008) within the Rehabilitation Area were extrapolated from data included in reports.

2.1.2.3 Transects

Distribution and percent cover of seagrasses within the Rehabilitation Area was mapped by divers along 12 transects spaced 50 m apart extending up to 200 m perpendicular from the shore. All 12 transects were established as part of the post-construction monitoring and were not comparable to pre-construction transects located in a similar area due to modifications associated with the port expansion. Locations of transects sampled within the Rehabilitation Area are indicated in **Figure 2**.

2.1.2.4 Fixed Points

Fixed Points were not sampled within the Rehabilitation Area as comparable sites had not been established prior to construction.

2.1.2.5 Patches

Seagrass was not recorded within the Rehabilitation Area during the March 2012 survey, therefore no patch data are available for this sampling time. Seagrass was, however, observed within the Rehabilitation Area during the March 2013 survey, therefore patch monitoring sites were established to measure seagrass condition. Seagrass condition (shoot density, leaf length and epiphyte growth) was measured in four sites (P3A, P3B, P3C, P3D) within one patch of *Halophila* spp. only as *Z. capricorni* was not present (**Figure 2**). Within each of the four sites, five 0.25 sq. m quadrats were placed randomly and indicators of seagrass condition measured as described in **Section 2.1.1.5**.

2.1.2.6 Inner Penrhyn Estuary

As part of the collection of intertidal sediment samples the PEHEP Benthos Monitoring Program, intertidal sand flat within Penrhyn Estuary were searched on foot at low tide for seagrass. If observed, photographs were taken, GPS co-ordinates were recorded and seagrass mapped. Observations were made on:

- 5-7 March, 2012;
- 12-14 November, 2012; and
- 8 – 12 March 2013

2.1.2.7 Data Analysis

- Percent cover of seagrass along transects and fixed points was presented as means and standard errors for each transect/site in tables and compared graphically and statistically using PERMANOVA+ (see **Section 2.1.1.6**) for the years 2012 – 2013. The statistical design to investigate percentage cover along transects and fixed points was as follows:
  - Time (random, orthogonal) –(March 2012 and March 2013);
  - Transect/Site (random, orthogonal to Time).

Indicators of seagrass condition (shoot density, leaf length and epiphyte load) in patches were presented as means and standard errors in tables for 2013 only, but will be statistically analysed in future surveys where comparable data are available.

2.1.3 Quibray Bay Planting Areas

2.1.3.1 Study Area

Quibray Bay is located on the southern side of Botany Bay. *P. australis* to be impacted by the Port Botany Expansion was transplanted to Quibray Bay in July 2008 (Bio-Analysis 2009). As described in **Section 1.3.5** there were two main Planting Areas within Quibray Bay and two Control Sites. The Control Sites used were the same controls set up for the experimental sites 1 and 2 (**Figure 3**):

> Planting Area 1;

> Planting Area 2;

> Control Site1; and

> Control Site 2.

Consistent with previous transplant monitoring surveys (Bio-Analysis 2008 - 2010), divers sampled shoot density in nine 0.25 sq. m quadrats in Planting Areas 1 and 2 (Quibray Bay) and nine quadrats in two Control Sites adjacent to the Planting Areas.

Measurements of leaf length and epiphyte load were also recorded by divers from 10 randomly selected leaves in each of the nine 0.25 sq. m quadrats in Planting Areas 1 and 2 and Controls 1 and 2. Data for leaf lengths and epiphyte load were not, however, available for years 2008 -2010 and therefore only data from the March 2012 survey are presented here.

2.1.3.2 Data Analysis

> Shoot density and leaf length were presented as means and standard errors for each Planting Area/Control Site in tables and compared graphically and statistically using PERMANOVA+ (see **Section 2.1.1.6**) for the years 2008 – 2012.

The experimental design for analysis of shoot density (March 2012 survey only) was as follows:

- Treatment (fixed, orthogonal) – ('transplant' and 'control'); and
- Sites (random, nested within treatment) – (Planting Area 1, Planting Area 2, Control Site1, Control Site 2).

Data from quadrats were used as replicates.
Raw data for the years 2008 – 2010 were not available, therefore the factor 'Time' was not included as a factor in this analyses.

Epiphyte load was not analysed statistically but presented as percentages of total observations categorised in the high, medium and low ranges or none if no epiphytes were observed.

2.1.4 Quibray Bay Experimental Sites

2.1.4.1 Study Area

Experimental Sites (1-3) were also established within Quibray Bay to investigate the relative success of different planting techniques (**Figure 3**). The planting techniques (or treatment) applied within each of the three Experimental Sites were:

1. Whole (rhizomes + entire shoots);
2. Trimmed (rhizomes + shoots trimmed to 2 cm);
3. Rhizomes (rhizomes – no shoots);
4. Seagrass Control (existing *P. australis* at recipient site);
5. Bare Control (bare sediment).

At each of the three sites, shoot density, leaf length and epiphytic growth were recorded for each experimental treatment within three fixed 0.25 sq. m quadrats (i.e. 15 quadrats per site with 45 quadrats in total).

2.1.4.2 Data Analysis

Shoot density and leaf length were presented as means and standard errors for each Experimental Site in tables and compared graphically and statistically using PERMANOVA+ (see **Section 2.1.1.6**) for the years 2008 – 2012. The experimental design was as follows:

> Time (random, orthogonal) – (July 2008, October 2008, September 2008, October 2010 and March 2013);

> Treatment (fixed, orthogonal) - (Entire, Trimmed, Rhizomes, Seagrass Control, Bare Control); and

> Sites (random, orthogonal) – (Site 1, Site 2, Site 3).

Data from quadrats will serve as replicate measures as described above. In addition, as the same plots were measured at each time, this design is a repeated measures design with the factor site being the repeated measures term. The factor site was not however, considered within the interpretation of the results. A total of six replicates were analysed for leaf length as per the data provided by BioAnalysis.

Epiphyte load was not analysed statistically but presented as percentages of total observations categorised in the high, medium, low ranges or as none if no epiphytes were observed.

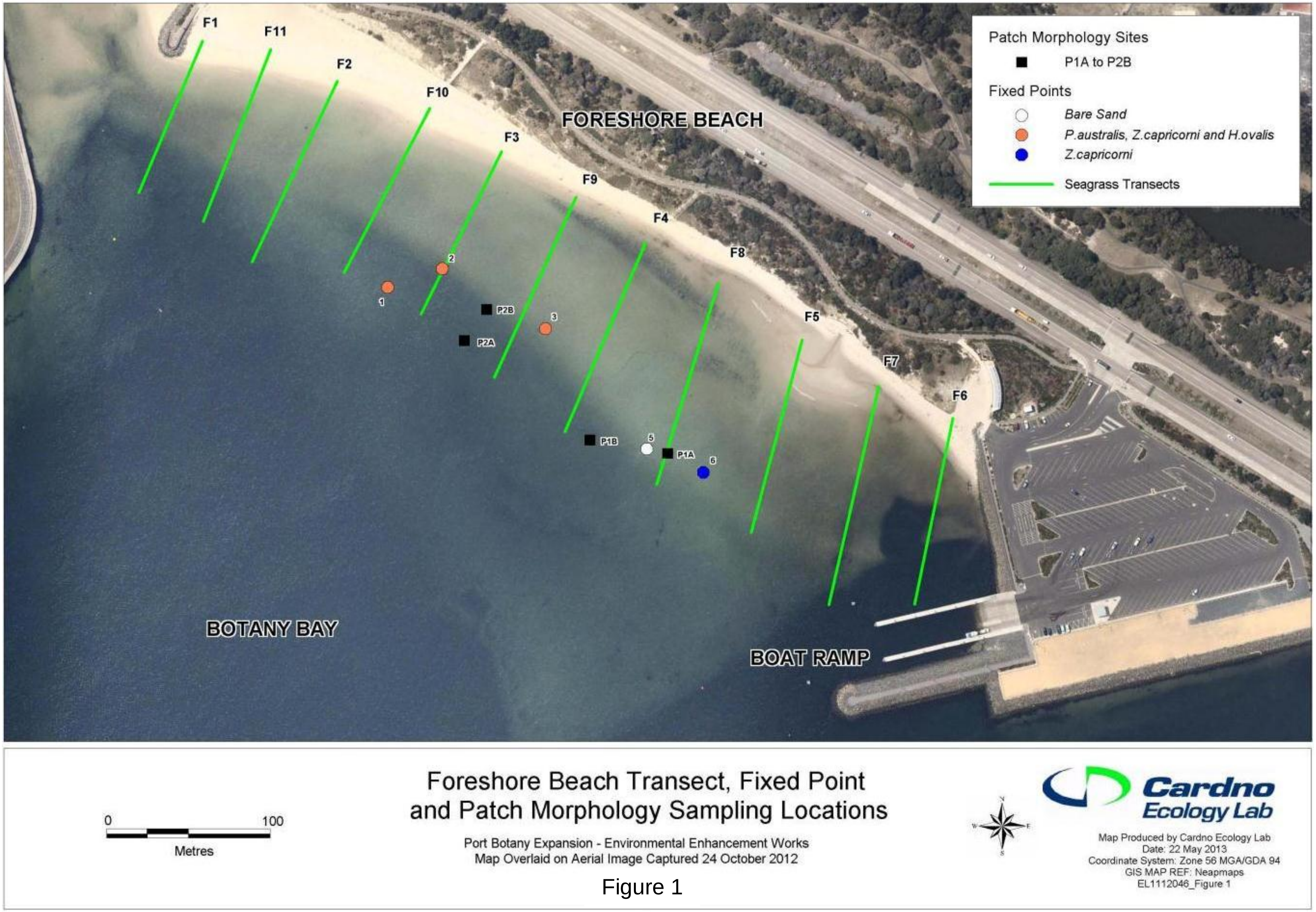

Figure 1 Foreshore Beach transect, fixed point and patch morphology sampling locations

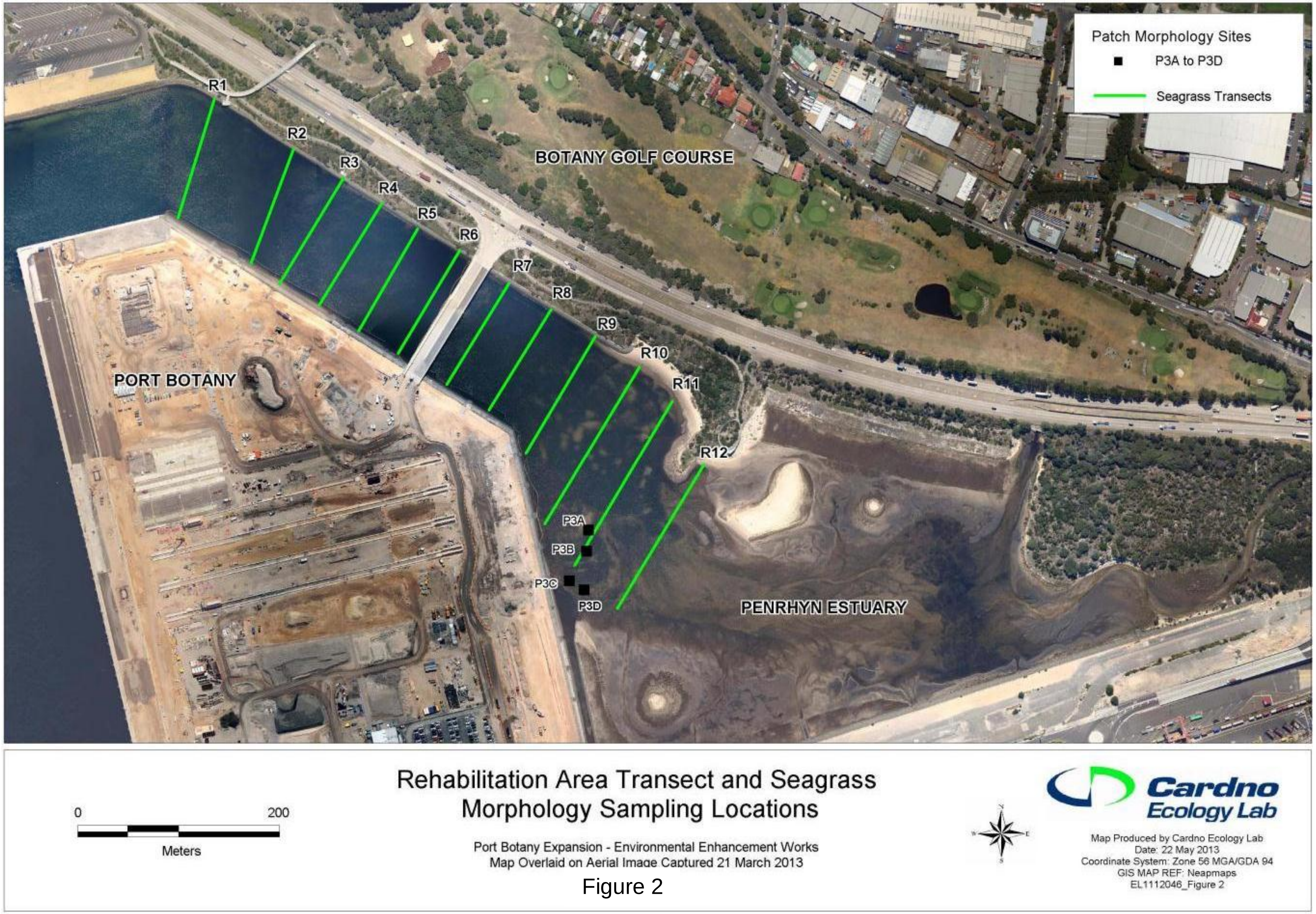

Figure 2 Rehabilitation Area transect and seagrass morphology sampling locations

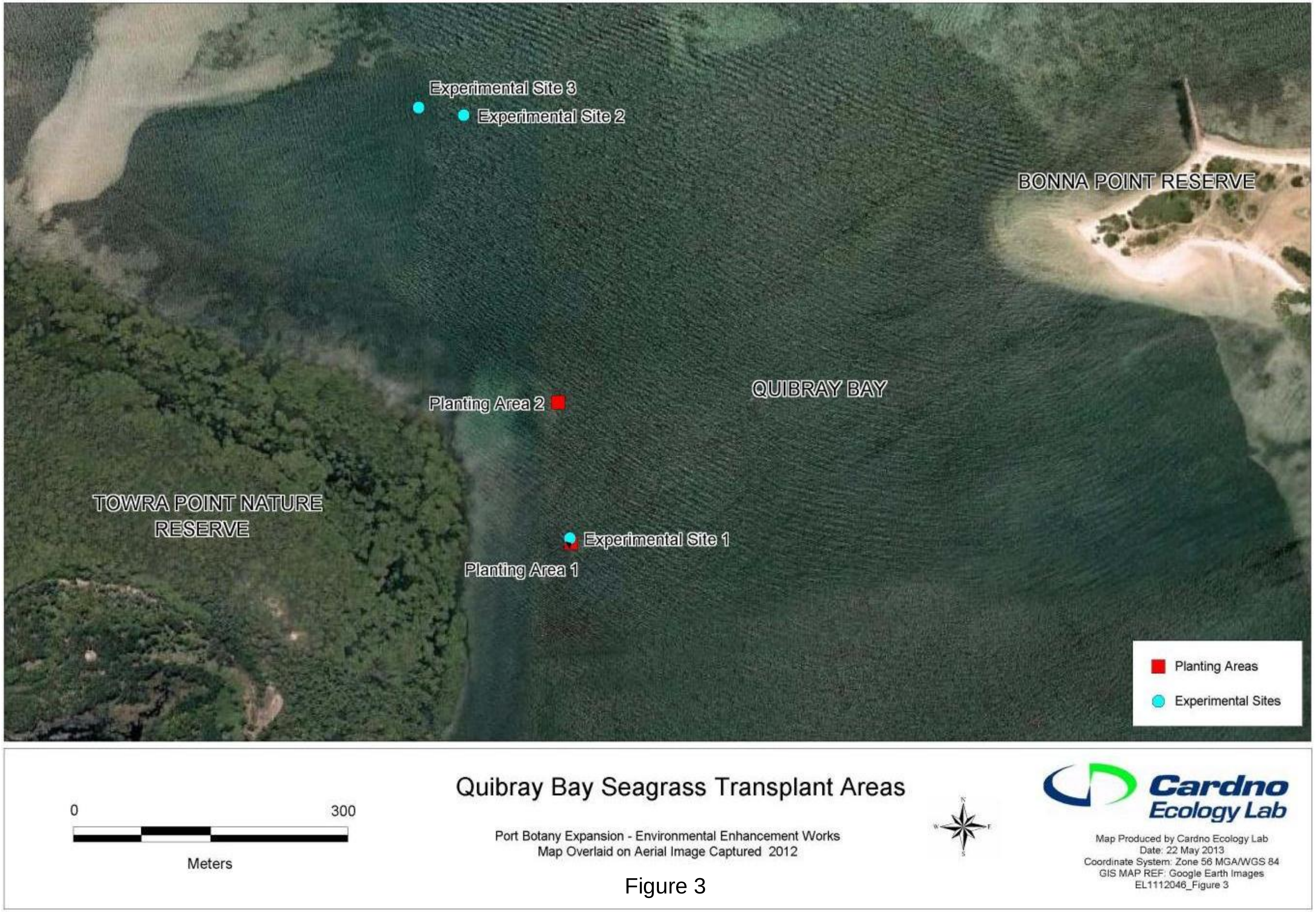

Figure 3 Quibray Bay seagrass transplant areas

2.2 Summary of Sampling

Table 3 Summary of seagrass sampling methods, indicators and period/year of data analysed

Location	Sampling Method	Indicator	Period/Years
Foreshore Beach	Diver mapping (entire area)	Seagrass species % cover (Maps available for 2002, 2012 and 2013 only)	Before: 2002, 2006, 2007, 2008 After: 2012, 2013
	Diver transects survey x11 transects Visual estimates recorded every metre along transect	Seagrass species % cover	Before: Data not available After: 2012, 2013
	Diver fixed point survey x5 Sites, x5 quadrats per site	Seagrass species % cover	Before: 2007, 2008 After: 2012, 2013
	Diver patch survey x4 patches, x5 quadrats per patch	Shoot density Leaf length (x10 reps) Epiphyte load	After: 2012, 2013
Rehabilitation Area	Diver mapping (whole area)	Seagrass species % cover (Maps available for 2002, 2012 and 2013 only)	Before: 2002, 2006, 2007, 2008 After: 2012, 2013
	Diver transects survey x12 transects Visual estimates recorded every metre along transect	Seagrass species % cover	Before: Data not available After: 2012, 2013
	Diver patch survey x4 patches, x5 quadrats per patch	Shoot density Leaf length (x10 reps) Epiphyte load	After: 2013
Quibray Bay (Planting Areas)	Diver survey x2 Planting Areas, x9 quadrats per area x2 Control Areas, x9 quadrats per area	Shoot density of *P. australis* Leaf length (x10 reps) Epiphyte load	After: 2008, 2009, 2010, 2012 2012 Data available only
Quibray Bay (Experimental Sites)	x3 Experimental Sites, x5 treatments, x3 quadrats per treatment	Shoot density of *P. australis* Leaf length (x10 reps) Epiphyte load	After: 2008, 2009, 2010, 2012 Data available only

2.3 Sampling Dates

Dates of seagrass sampling carried out by Cardno Ecology Lab to date are listed in **Table 4** below.

Table 4 Dates and locations of seagrass sampling carried out to date by Cardno Ecology Lab during 2012 – 2013.

Date	Location	Details
14.03.2012 to 04.04.2012, 31.07.2012	Foreshore Beach Quibray Bay	Mapping/transects/fixed points Transplant site quadrat surveys
26.03.2013 to 09.04.2013	Foreshore Beach	Mapping/transects/fixed points

Searches of intertidal seagrass made during collection of intertidal sediment as part of the Benthos Monitoring Program within Penrhyn Estuary were made on:

> 5 - 7 March, 2012

> 12 - 14 November, 2012

> 8 - 12 March 2013.

3 Summary of Results

3.1 Foreshore Beach

No *Caulerpa taxifolia* was observed in the seagrass monitoring areas at Foreshore Beach, the rehabilitation area at Penrhyn Estuary or Quibray Bay during the March 2012 and March 2013 surveys.

3.1.1 Mapping

> Prior to the Port Botany Expansion, seagrass mapping showed a major decline in total seagrass area from approximately 65,821 sq. m in 2002 to 698 sq. m in February 2007 (**Table 5**).

> Post-construction monitoring shows signs of recovery are evident in years 2012 and 2013, however, the seagrass cover in these post-construction surveys was sparse and patchy in distribution.

> Species composition between 2002 and 2013 has also changed from an assemblage comprised predominantly of *Z. capricorni* between 2002 and 2006 to one composed mainly of *Halophila* spp. or mixed beds of sparse, patchy *Z. capricorni* and *Halophila* spp. following the significant loss of all species between 2007 and 2012 (**Figure 4**).

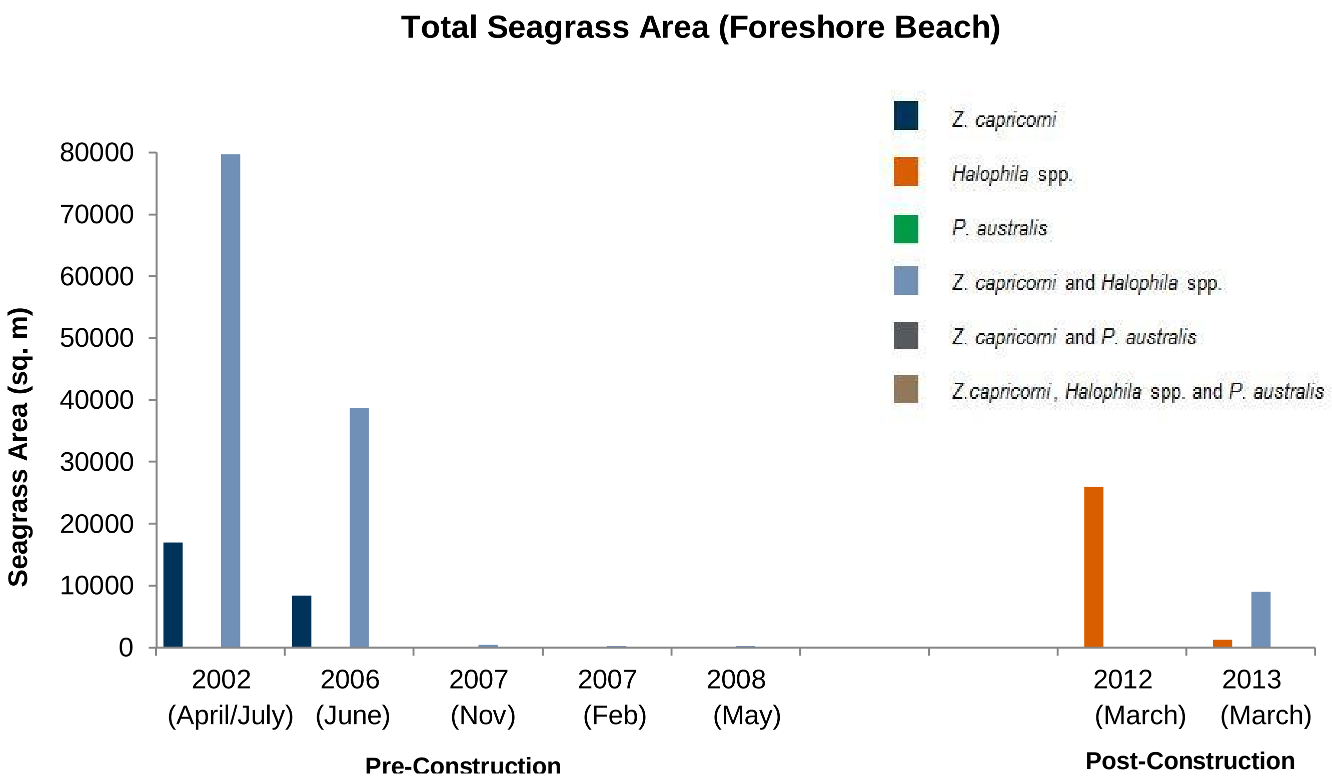

Figure 4 Total area of seagrasses at Foreshore Beach between 2002 and 2013

3.1.2 Transects

> Total percent cover of seagrasses along transects was relatively small but has increased from the first post-construction monitoring survey in March 2012 to March 2013.

> Species composition along transects has also changed from the first post-construction survey in 2012 to one composed of both *Z. capricorni and Halophila* spp in 2013.

3.1.3 Fixed Points

> Seagrass area surveyed at fixed points increased overall by 16.2 sq. m between 2007 – 2013.

> Percent cover of Z. capricorni increased while the percent cover of Halophila spp. and P. australis appears to have decreased.

3.1.4 Patches

> Indicators of seagrass condition within patches has shown significant improvements in post-construction surveys carried out from March 2012 to March 2013, although this was not the case for all species at all sites.

> Mean shoot density and leaf length of *Z. capricorni* and *Halophila* spp. has increased overall, whereas *P. australis* was no longer recorded at the one site where it had been observed previously.

> Epiphytes were not observed on any plants sampled within patches during the 2012 survey, but were recorded on *Z. capricorni* and *Halophila* spp. in the March 2013 survey in mostly low to medium density.

3.2 Rehabilitation Area

3.2.1 Mapping

> Prior to any construction works or land reclamation taking place, pre-construction seagrass mapping showed a major reduction in total seagrass area from approximately 28,894 sq. m in 2002 to 299 sq. m in May 2008 (**Figure 5**).

> In the first year of post-construction monitoring (March 2012), seagrass was not recorded within the Rehabilitation Area but appears to have established in the most recent (March 2013) survey, although this was very sparse and patchy in distribution.

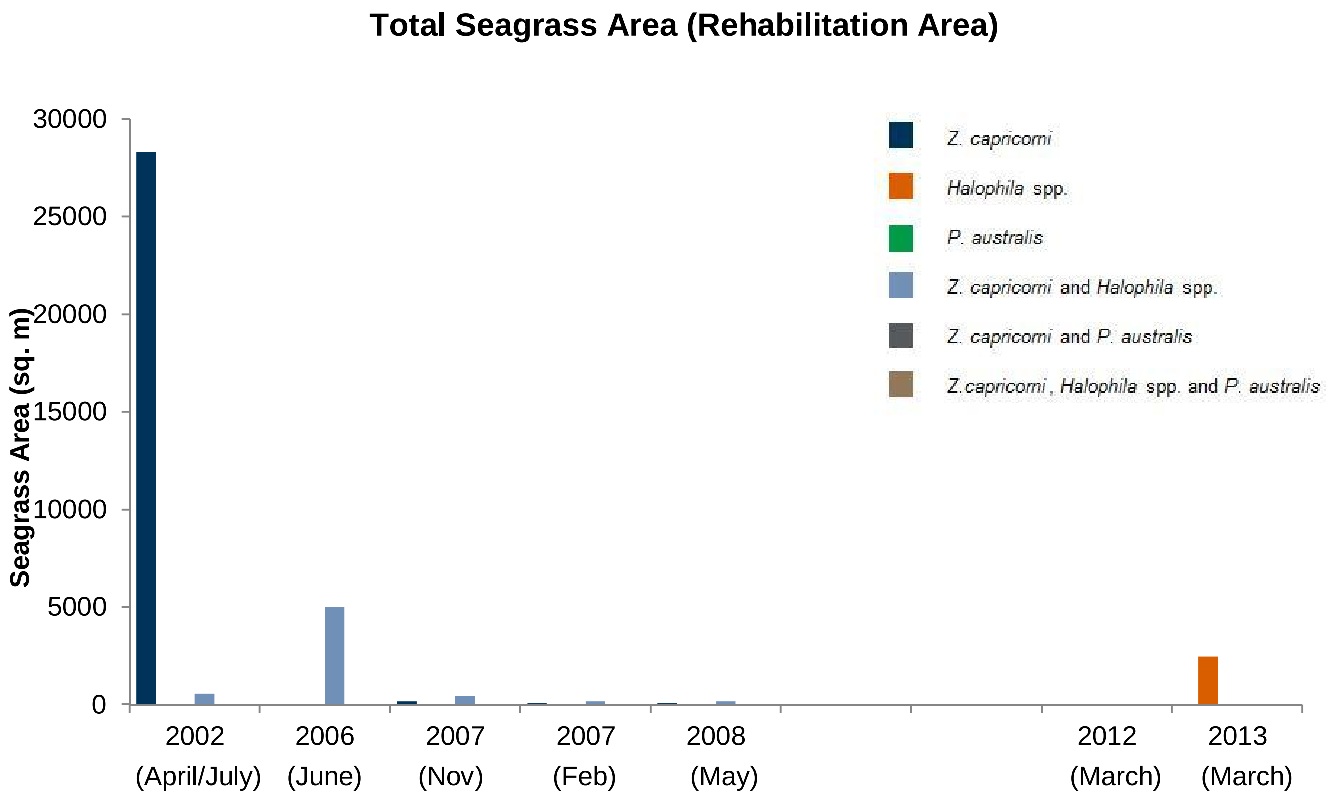

Figure 5 Total area of seagrasses within the Rehabilitation Area between 2002 and 2013

3.2.2 Transects

> Seagrass was not recorded in transects surveyed in March 2012 but small areas were observed in the 2013 survey.

> *Halophila* spp. was the most abundant species recorded followed by a small amount of *Z. capricorni*. *P. australis* was not recorded along any transects during the March 2013 survey.

3.2.3 Patches

> Seagrass was not recorded within the Rehabilitation Area during the March 2012 survey and therefore no patch data was recorded for this survey.

> Distinct patches of sparse *Halophila* spp. were observed during the March 2013 survey and therefore new patch sites P3A, P3B, P3C and P3D were established within the main bed.

> The condition of the *Halophila* spp. in the newly established patches appeared to be moderate, with mean shoot density ranging between 16 and 48 shoots per 0.25 sq. m, but with relatively short leaves. No epiphytes were recorded on *Halophila* spp. leaves.

3.2.4 Penrhyn Estuary

No intertidal seagrasses were observed in searches in March 2012.

Sparse patches of *Z. capricorni* and *Halophila* spp. were observed in November 2012 near the enhanced saltmarsh habitat on the northern side of the estuary and along the western boundary adjacent to the new terminal structure (**Figure 22**).

Sparse patches of *Halophila* spp. were observed in the inner estuary near the confluence of Floodvale and Springdale creeks in March 2013 (**Figure 23**).

3.3 Quibray Bay Planting Areas

> Mean shoot density of transplanted seagrass at Quibray Bay has increased overall since the initial translocation in July 2008 (**Figure 6**).

> Mean shoot density and leaf lengths of *P. australis* recorded in Planting Areas during the March 2012 survey was similar to that of the adjacent control sites.

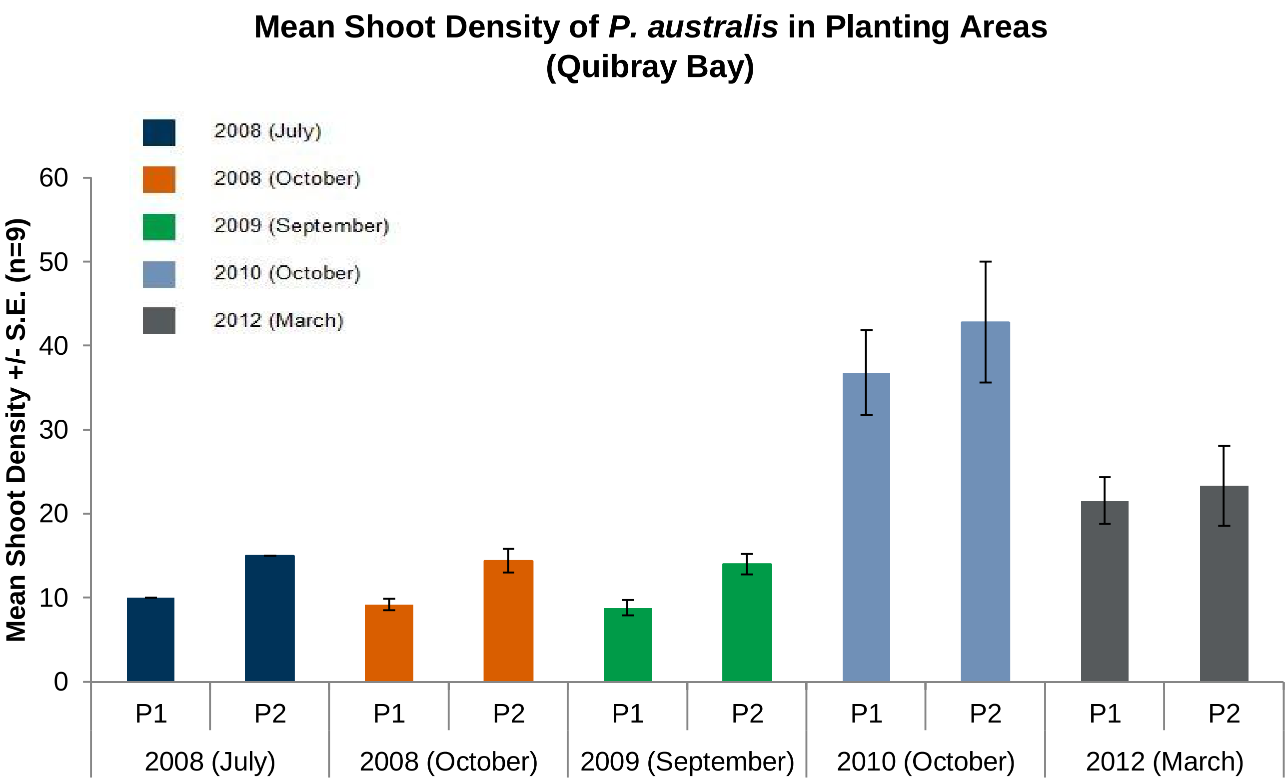

Figure 6 Mean shoot density (shoots per sq. m) of *P. australis* transplanted into Planting Areas 1 and 2 in Quibray Bay between July 2008 and March 2012

3.4 Quibray Bay Experimental Sites

> Mean shoot density of transplanted *P. australis* appears to have increased for all non-control transplant treatments i.e. whole, trimmed and rhizomes, between July 2008 when they were first translocated and the latest transplant survey in March 2012 (**Figure 7**).

> Overall, the ‘trimmed’ treatment has increased the most out of the three transplant treatments in terms of mean shoot density and leaf length.

> While transplanted *P. australis* appears to have increased in mean shoot density, the mean shoot density of the control seagrass has marginally declined from the September 2009 survey but remains higher overall than that of any of the transplanted seagrass.

> Mean leaf length increased for transplanted *P. australis* which had been trimmed or had rhizomes only transplanted, but decreased slightly for the ‘whole’ seagrass treatment.

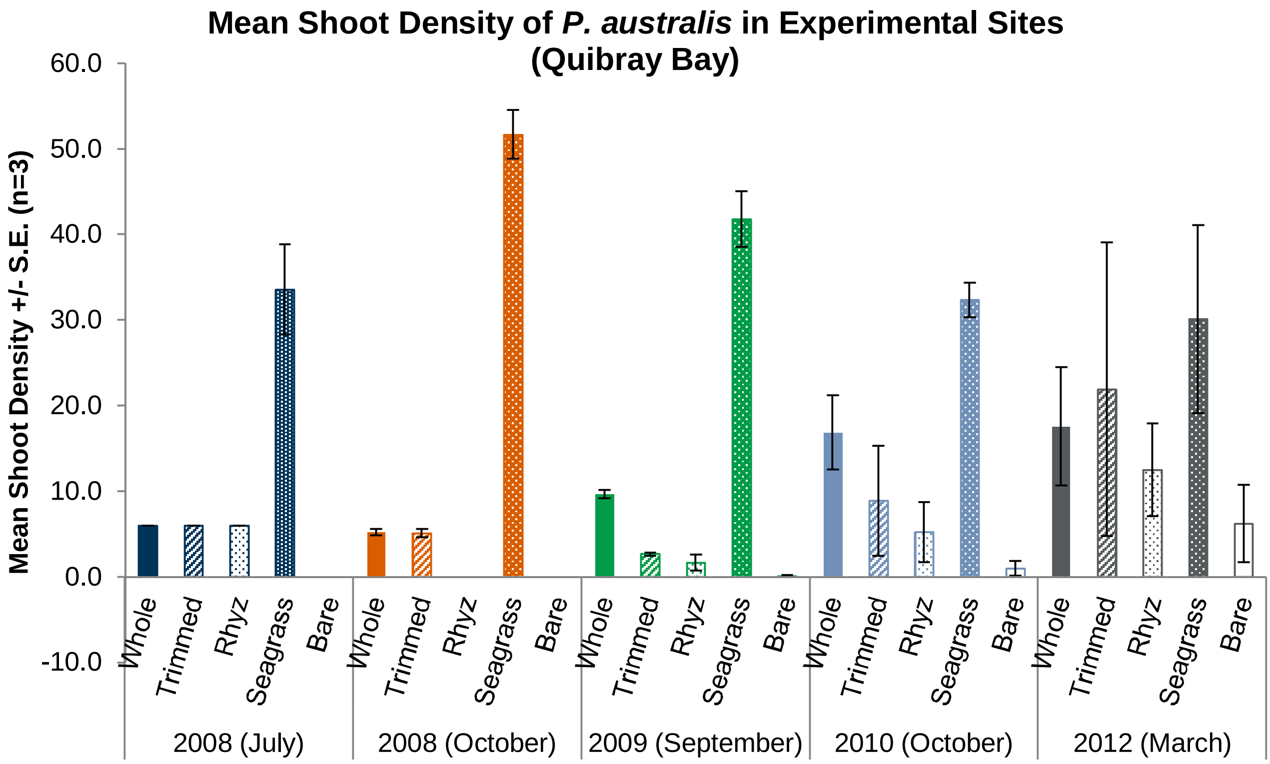

Figure 7 **Mean shoot density for treatments surveyed within experimental sites between July 2008 and March 201**

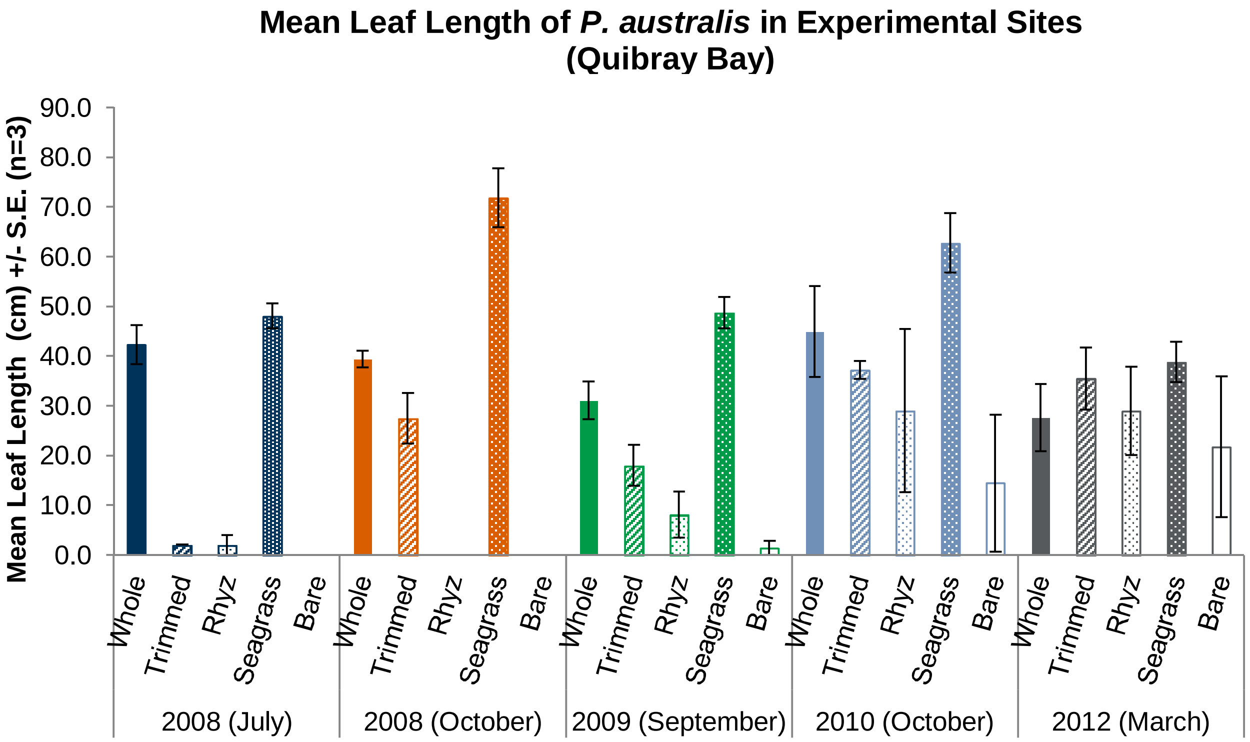

Figure 8 **Mean leaf length for treatments surveyed within experimental sites between July 2008 and March 2012**

4 Data Analysis

4.1.1 Foreshore Beach

4.1.1.1 Mapping

Total cover of seagrass (sq. m) at Foreshore Beach has declined in the pre-construction period between 2002 and 2008 with a major (order of magnitude) reduction between 2006 (42,100 sq. m) and 2007 (698 sq. m) **Table 5** and **Figure 10**. Signs of recovery were evident in the post-construction period (years 2012 and 2013), however, the seagrass cover in these post-construction surveys appeared very sparse and patchy.

Species composition between 2002 and 2013 has also changed from an assemblage comprised predominantly of *Z. capricorni* between 2002 and 2006 to one composed mainly of *Halophila* spp. or mixed beds of sparse, patchy *Z. capricorni* and *Halophila* spp. following the major reduction in cover of all species between 2007 and 2012 (**Figure 10**).

Mapping carried out as part of the EIS and PEHEP (**Figure 11 – 13**) showed that the total cover of seagrass decreased from 65,821 sq. m in April/July 2002 to 10,323 in March 2013. Species composition also changed from predominantly *Z. capricorni* in 2002 to *Halophila* spp. in March 2012 and mixed *Halophila* spp. and *Z. capricorni* in March 2013.

Table 5 Total seagrass area (sq. m) at Foreshore beach between 2002 and 2013

Year	Phase	Approximate Area of Seagrass (sq. m)	Reference
2002 (April/July)	Pre-Construction	65,821 (94,715)*	The Ecology Lab (2003)
2006 (June)	Pre-Construction	42,100 (47,100)*	Roberts *et al.* (2006)
2007 (February)	Pre-Construction	698	Roberts *et al.* (2007)
2007 (November)	Pre-Construction	365	Roberts *et al.* (2008)
2008 (May)	Pre-Construction	352	Roberts *et al.* (2008)
2012 (March)	Post-Construction	26,000 (Sparse coverage)	Cardno Ecology Lab (2012)
2013 (March)	Post- Construction	10,323 (Sparse coverage)	Cardno Ecology Lab (2013)

*Figures in parentheses include the areas of Foreshore Beach within the construction footprint and Penrhyn Estuary.

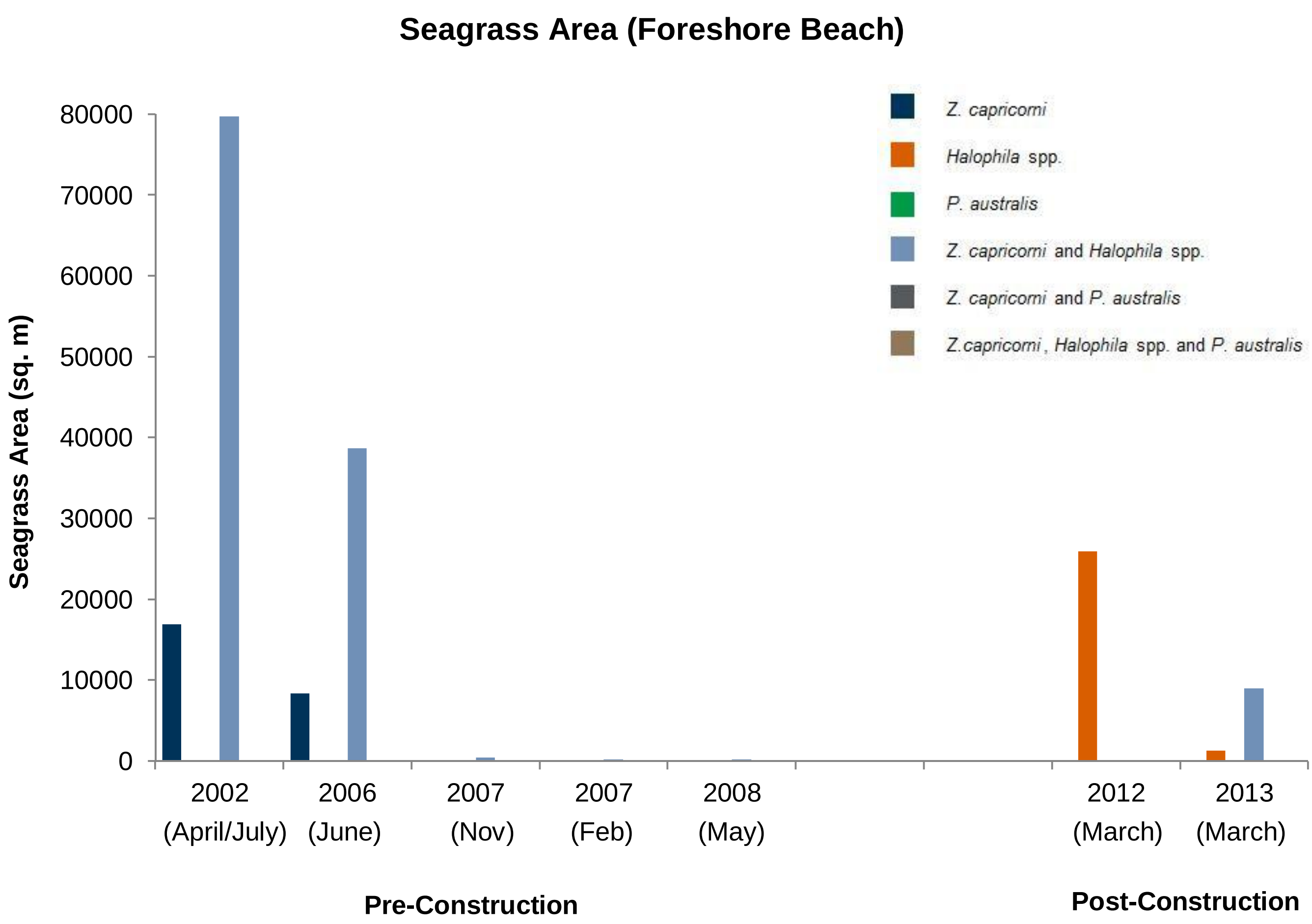

Figure 10 Area of seagrasses at Foreshore Beach between 2002 and 2013

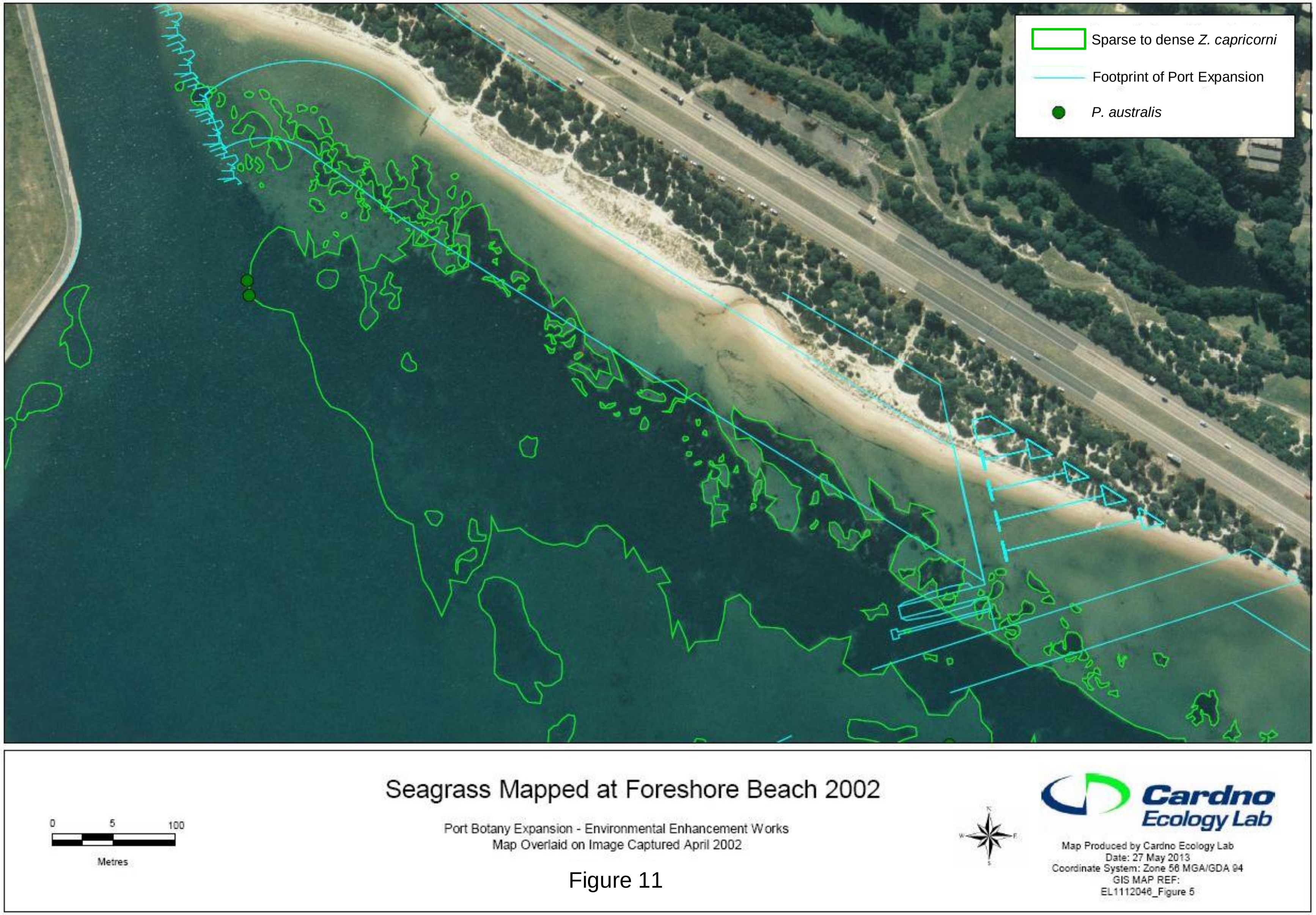

Figure 11 Seagrass mapped at Foreshore Beach, April 2002

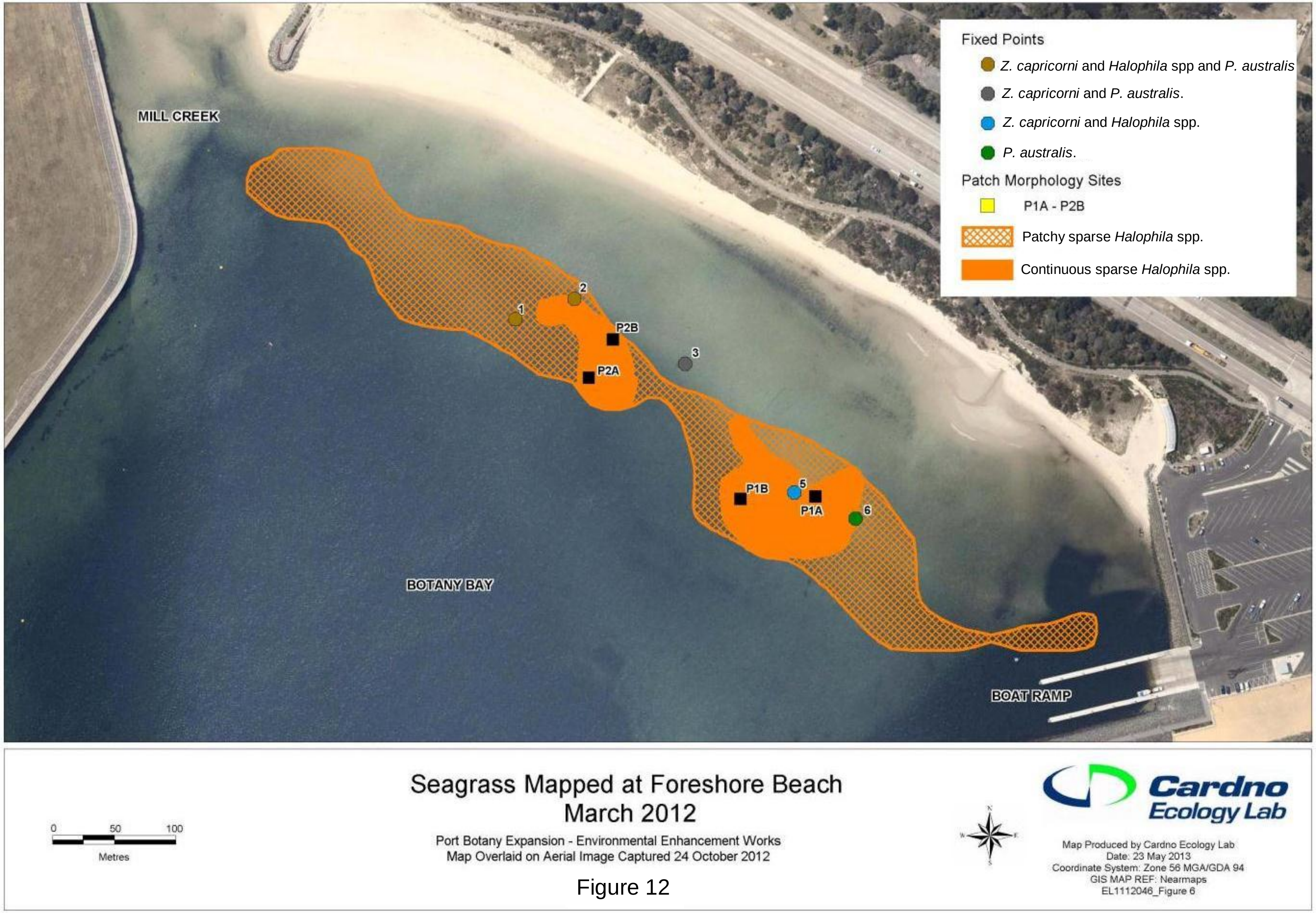

Figure 12 Seagrass mapped at Foreshore Beach, March 2012

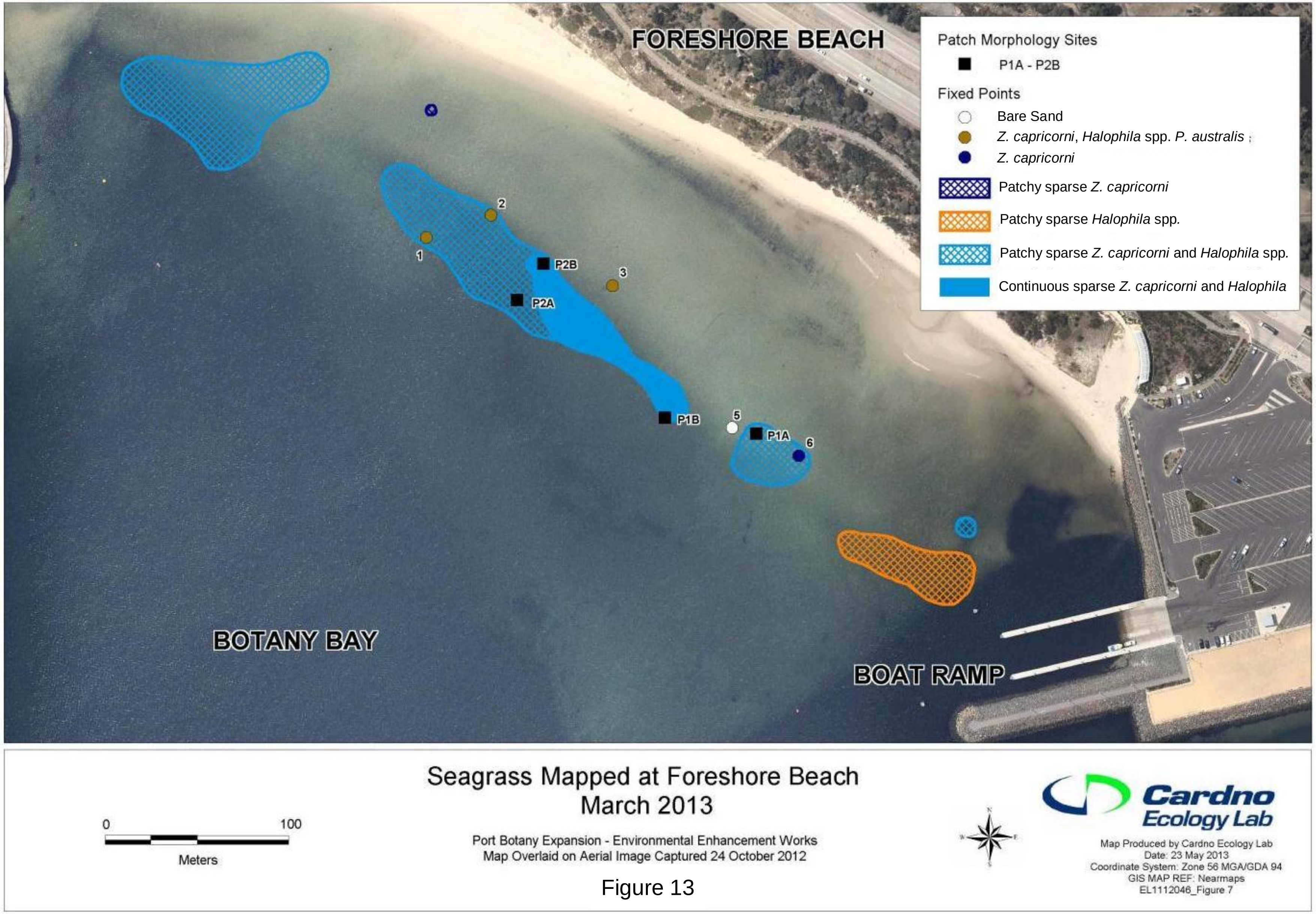

Figure 13 Seagrass mapped at Foreshore Beach, March 2013

4.1.1.2 Transects

Total percent cover of seagrasses along transects 1 – 11 was on average 2.84% in March 2012 and increased to 3.45% in March 2013. This change was not, however, significantly different between the two years (*P*=0.61) (Appendix C). The percent cover of *Z. capricorni* increased from an average 0.12% in March 2012 to 1.79% in March 2012, while the average percent cover of *Halophila* spp. decreased marginally from 2.72% in March 2012 to 1.66% in March 2013. *P. australis* was not recorded in any transects in during the March 2012 and 2013 surveys (**Figure 14**).

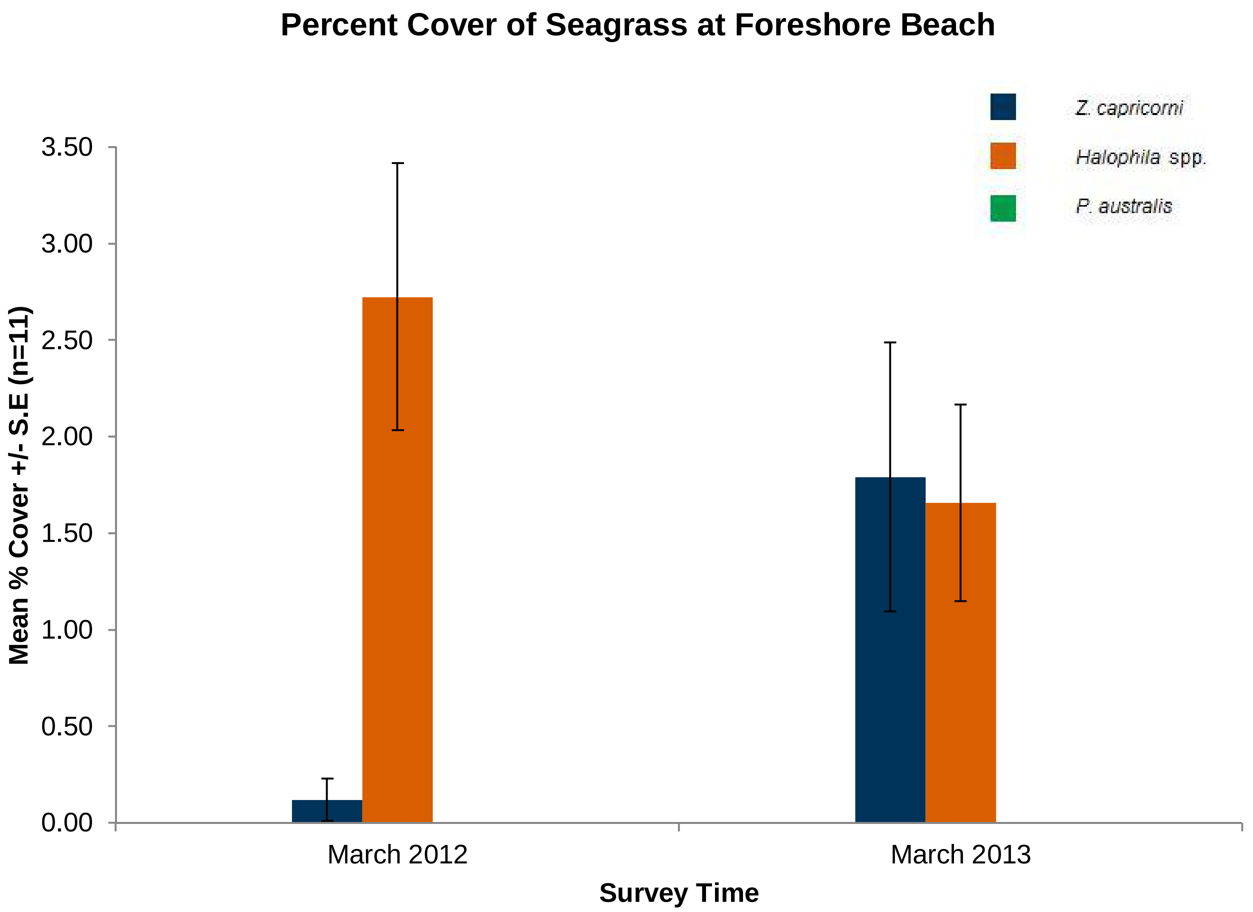

Figure 14 Percent cover of seagrasses recorded along transects at Foreshore Beach in March 2012 and 2013

4.1.1.3 Fixed Points

Percent cover of seagrasses at fixed points at Foreshore Beach between years 2007 and 2013 are shown in **Figure 15**. Overall, the total estimated area of *Z. capricorni* has increased from 8% in 2007 to 50% in 2013, although this increase was not consistent at all fixed point sites. While *Z. capricorni* remained present and increased at some fixed points over time, it disappeared completely from others and also colonised new sites where it had not previously occurred. The total estimated area of *Halophila* spp. has decreased slightly from 5% in 2007 to 2% in 2013. The distribution of *Halophila* spp. appeared to vary among sites through time. The total estimated area of *P. australis* has decreased overall from 65% cover in 2007 to 23% in 2013. *P. australis* was recorded at fixed points 1 to 3 in all years surveyed and also at fixed point 6, but only in years 2008 and 2012.

The total estimated area (sq. m) of seagrass at fixed point sampling locations increased from 11 sq. m in 2007 to 48.5 sq. m in 2012 and then decreased to 27.5 sq. m in 2013.

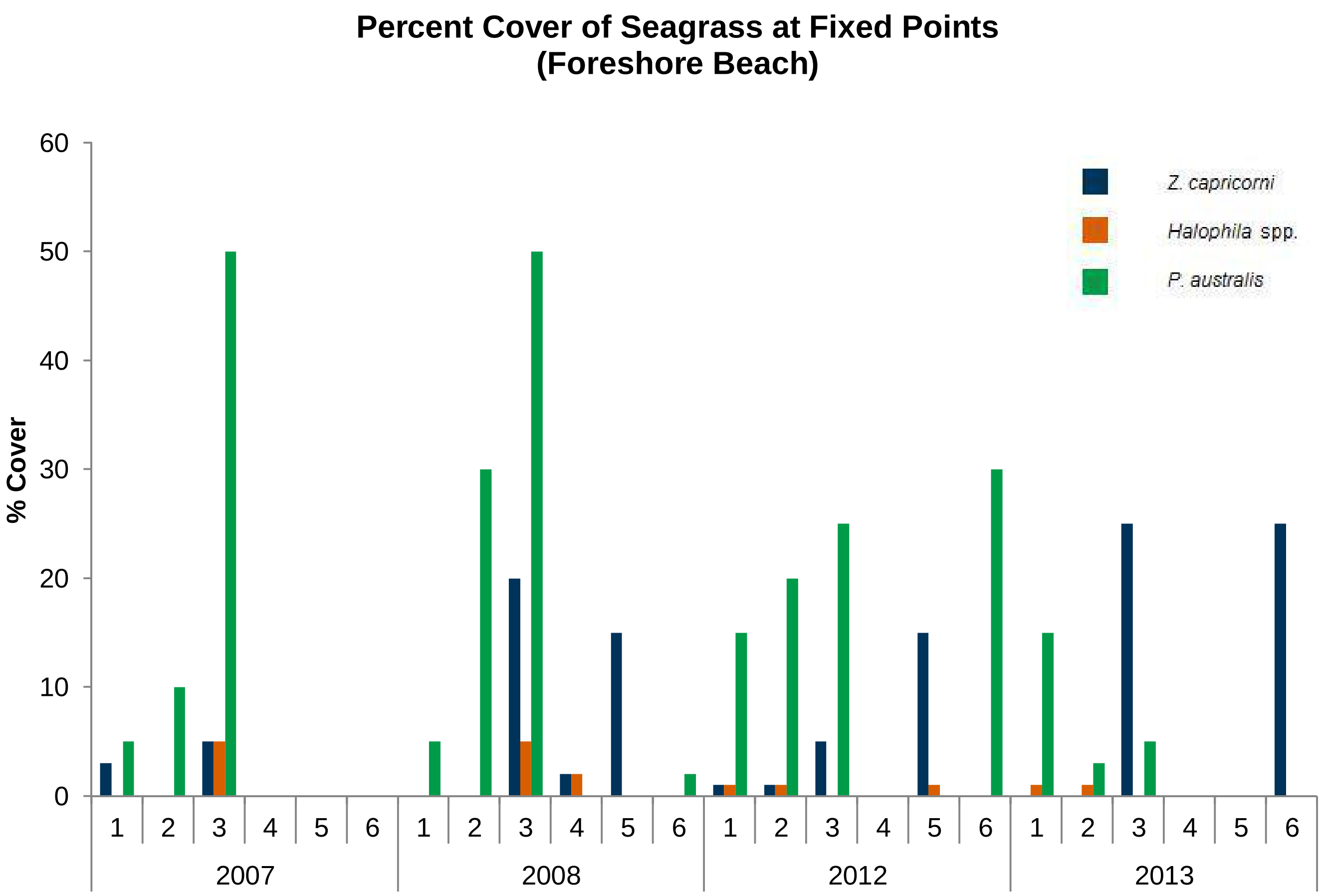

Figure 15 **Percent cover of seagrass occurring at fixed points 1 – 6 during years 2007, 2008, 2012 and 2013**

4.1.1.4 Patches

Shoot Density

Overall, mean shoot density was significantly different between years 2012 and 2013, although this was dependent on the patch site (*P*=<0.0058) (Appendix C). Pair-wise tests indicate that the difference in mean shoot density between March 2012 and March 2013 was mainly due to an increase at P1A (*P*= 0.0067). Mean shoot density at P2B also appears to have increased substantially between March 2012 and 2013, although there was greater variability among quadrats within the patch and this was not statistically significant (*P*=0.072). Mean shoot density decreased slightly at P1B and P2A (**Table 6; Figure 16**). *Halophila* spp. was the most widely distributed seagrass taxa occurring in all patches in both years apart from P2A in 2013. Mean shoot density of *Halophila* spp. appears to have increased substantially at P1A and P2B but decreased slightly at P1B and P2A (Figure 17). *Z. capricorni* was only recorded within P2B in 2012 and P1A in 2013 (**Figure 17**), but overall, mean shoot density increased from 0.8 shoots per quadrat in 2012 to 7.0 shoots per 0.25 sq. m quadrat in 2013. *P. australis* was recorded only within P1B in the 2012 survey. Mean shoot density was 2.0 shoots per 0.25 sq. m quadrat and no shoots were recorded in any of the survey patches during the 2013 survey.

Table 6 Mean shoot densities (n=5) of seagrasses sampled within patches at Foreshore Beach during March 2012 and 2013

	2012				2013			
Patch Code	**P1A**	**P1B**	**P2A**	**P2B**	**P1A**	**P1B**	**P2A**	**P2B**
Z. capricorni	0.0	0.0	0.0	0.8	7.0	0.0	0.0	0.0
Halophila spp.	4.2	6.2	1.2	6.2	37.8	5.4	0.4	76.0
P. australis	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**4.2**	**8.2**	**1.2**	**7.0**	**44.8**	**5.4**	**0.4**	**76.0**

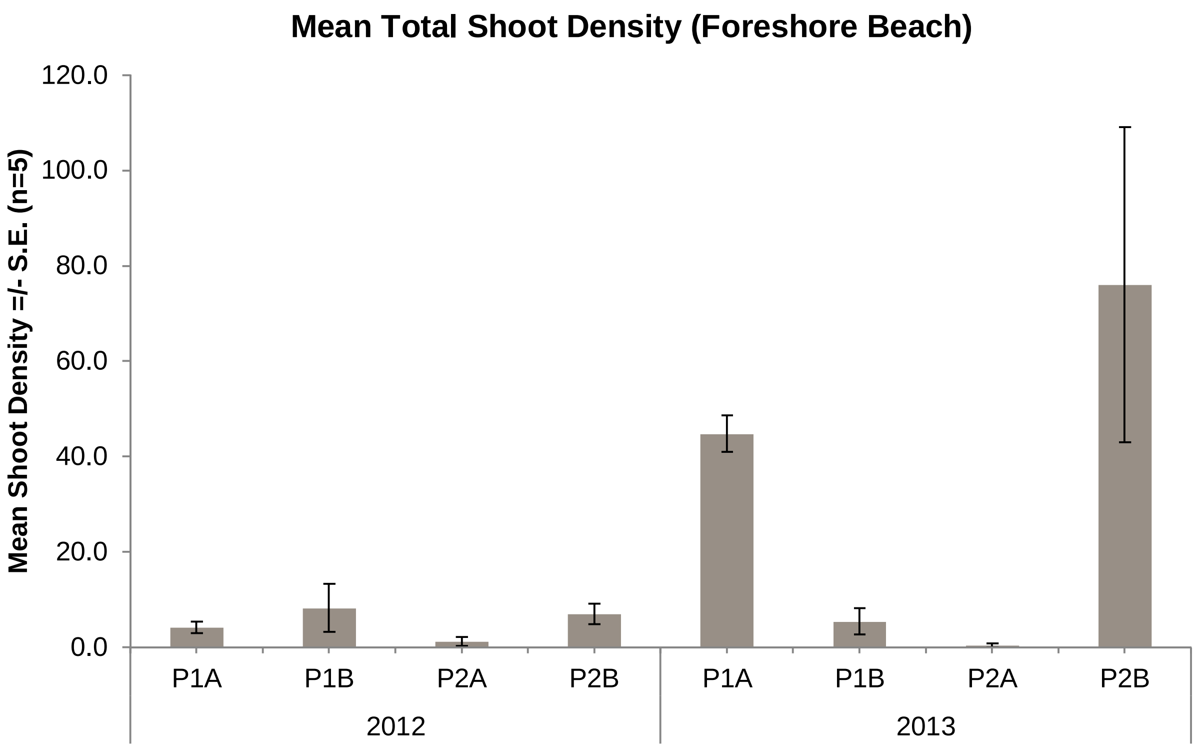

Figure 16 Mean shoot densities (n=5) of seagrasses sampled within patches at Foreshore Beach during March 2012 and 2013

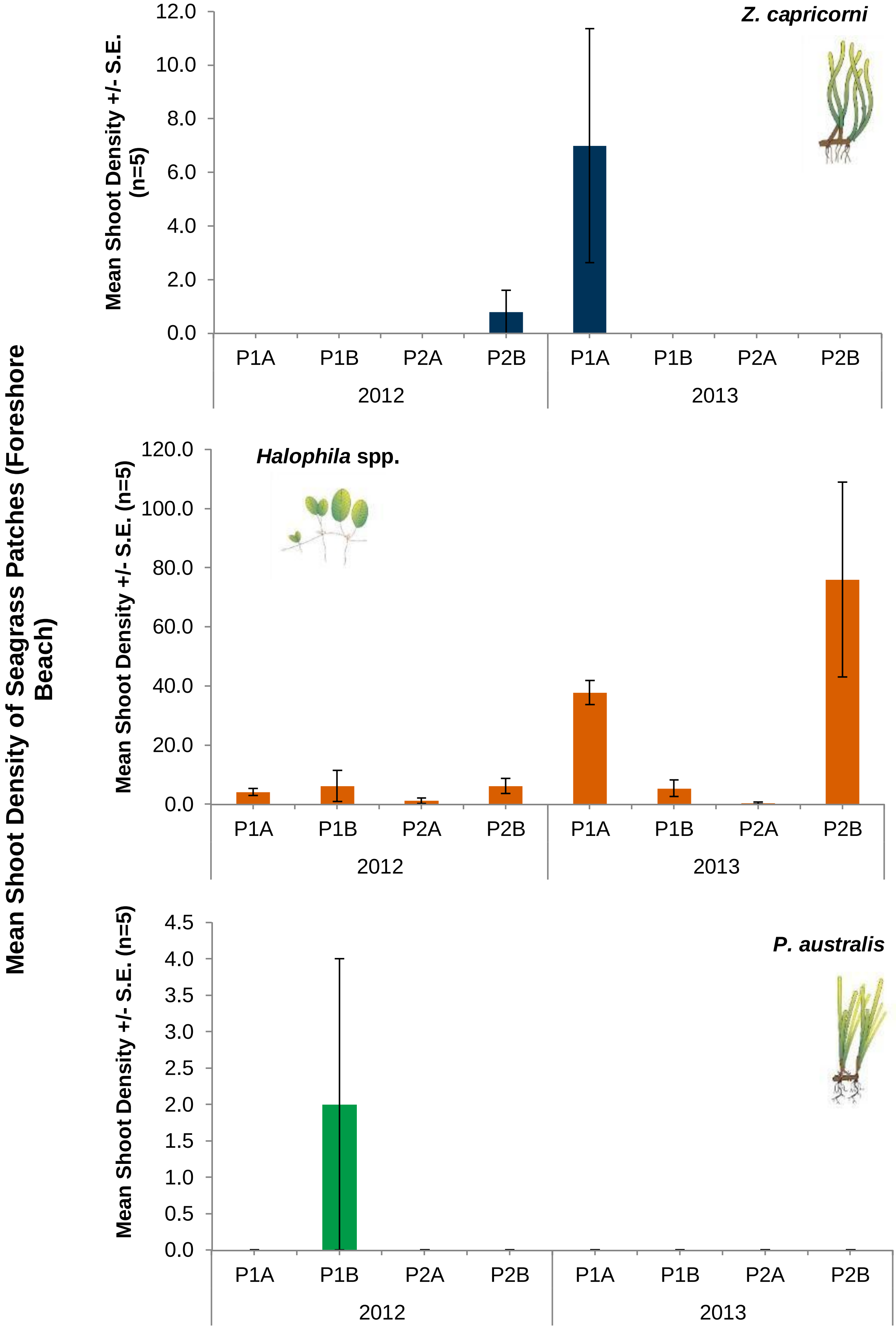

Figure 17 Mean shoot densities (n=5) of seagrasses sampled within patches at Foreshore Beach during March 2012 and 2013

Leaf Length

Mean leaf length increased at P1A, P1B and P2B but decreased marginally at P2A (**Table 7; Figure 18**). Overall, differences in mean leaf length between years 2012 and 2013 was significantly different, but was dependent on the patch site (*P*=0.0006). Pair-wise tests indicate that the difference in mean leaf length between March 2012 and March 2013 was mainly due to an increase at P1A (*P*= 0.0065). Mean leaf length at P1B and P2B also appears to have increased slightly between March 2012 and 2013, although this was not statistically significant (**Table 7; Figure 18**). *Z. capricorni* was recorded in P2B in 2012 but not in 2013 and similarly did not occur in P1A in 2012 but did in 2013. On this basis it is not possible to make direct comparisons in mean length however, it is notable that the leaf length at P1A in 2013 was greater than in P2B in 2012, but also highly variable (**Figure 19**). The mean leaf length of *Halophila* spp. increased at all sites apart from P2A where leaf length remained similar (**Figure 19**). Mean leaf length of *P. australis* was only recorded at P1B in 2012 and this seagrass was not recorded within any patch sampled in 2013.

Table 7 Mean Total leaf length (cm) n=5 of seagrasses sampled within patches at Foreshore Beach during March 2012 and 2013

	2012				2013			
Patch Code	**P1A**	**P1B**	**P2A**	**P2B**	**P1A**	**P1B**	**P2A**	**P2B**
Z. capricorni	0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.0
Halophila spp.	0.4	0.6	0.1	1.2	3.2	1.4	0.1	1.8
P. australis	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.4**	**1.0**	**0.1**	**1.5**	**3.6**	**1.4**	**0.1**	**1.8**

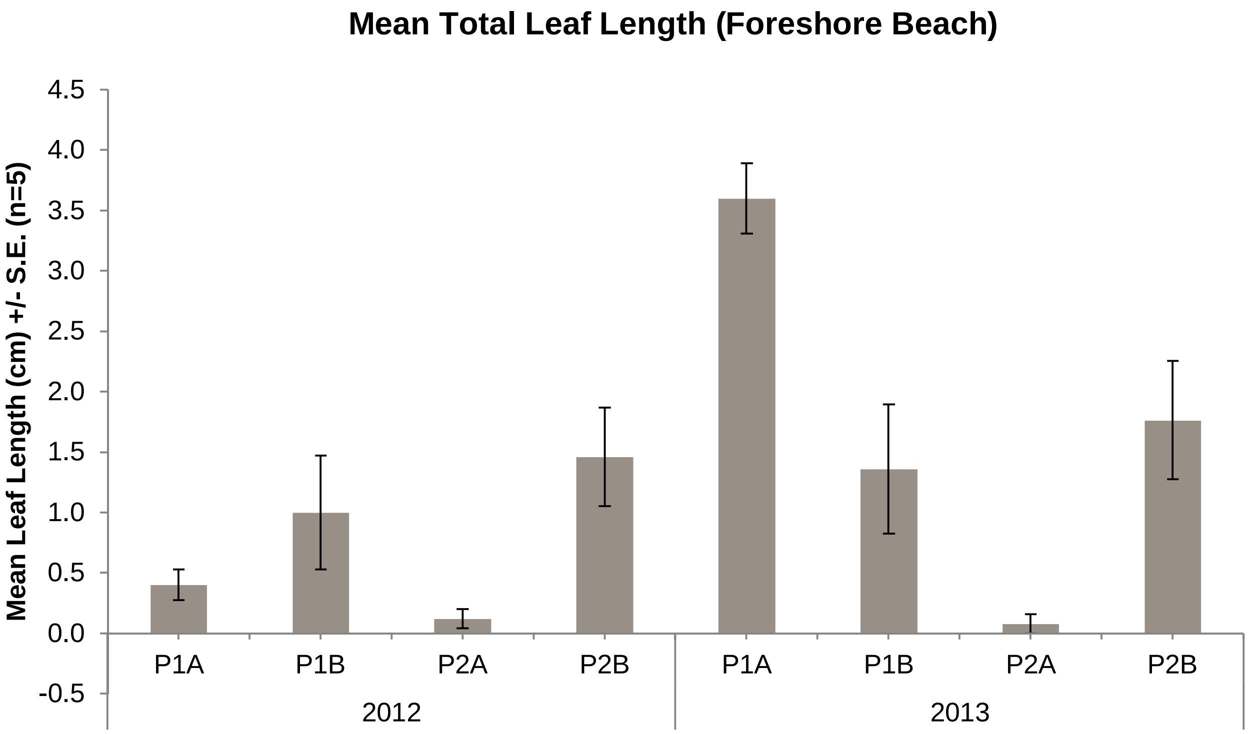

Figure 18 Mean leaf length (n=5) of seagrasses sampled within patches at Foreshore Beach during March 2012 and 2013

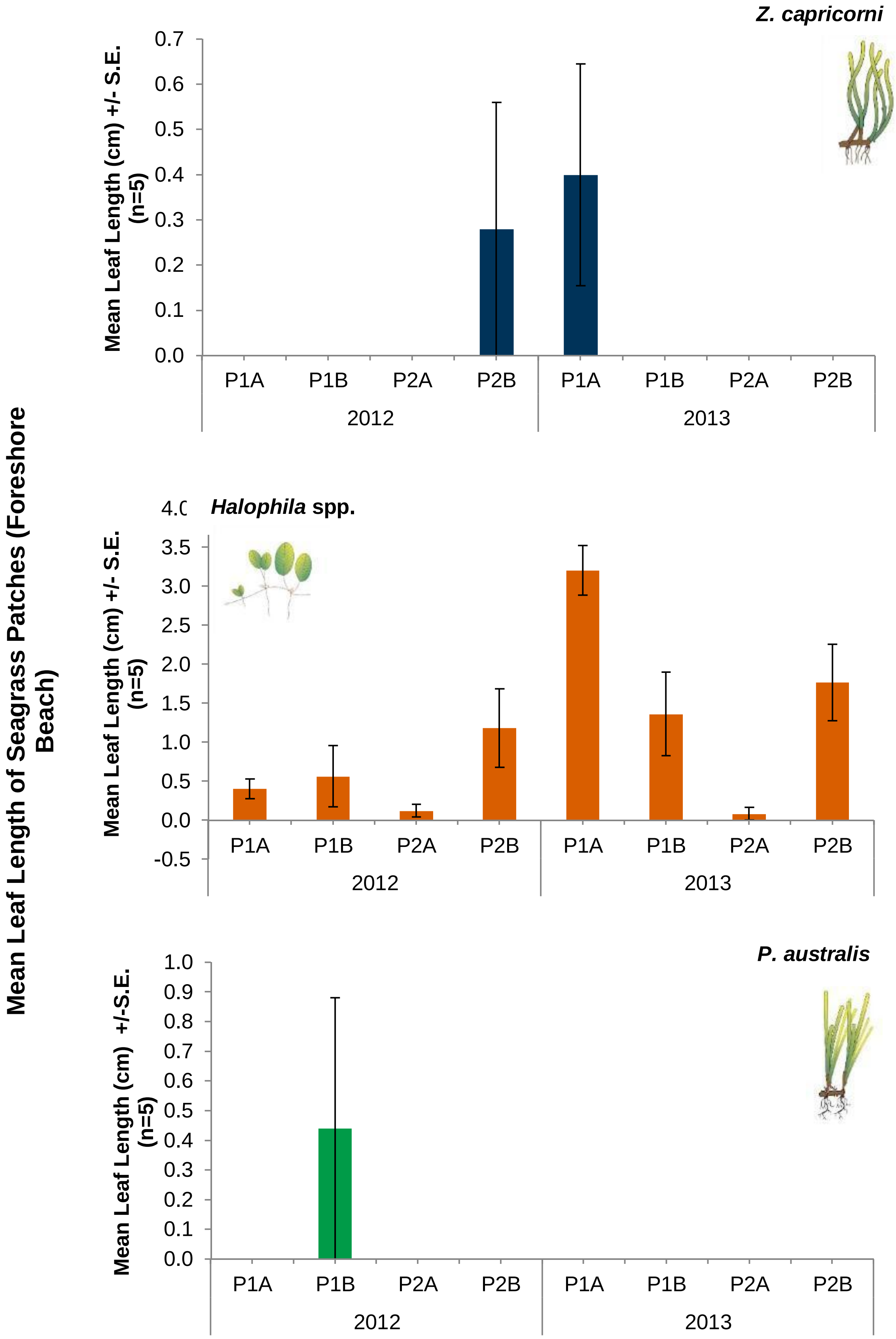

Figure 19 Mean leaf length (n=5) of seagrasses sampled within patches at Foreshore Beach during March 2012 and 2013

Epiphytes

Epiphytes were not observed on any plants sampled within patches during the 2012 survey. In the 2013 survey, epiphyte cover recorded on leaves of *Z. capricorni* was light, epiphytes observed on *Halophila* spp. was light to medium at P1A, medium to high at P1B and medium at P2A and P2B. *P. australis* was not recorded within patches sampled during the 2013 survey and therefore not epiphyte observations were recorded.

4.1.2 Rehabilitation Area

4.1.2.1 Mapping

Prior to construction, there was a major reduction in seagrass area in the Rehabilitation Area, from approximately 28,894 sq. m in 2002 to 299 sq. m in May 2008 (**Table 8; Figure 21**). In the first year of post-construction monitoring (March 2012), seagrass was not recorded within the Rehabilitation Area but has reappeared in the most recent (March 2013) survey, although this was very sparse and patchy.

Species composition within the Rehabilitation Area has changed substantially over the survey period (**Figure 21**). The pre-construction assemblage mapped in April 2002 was comprised predominantly of sparse to dense *Z. capricorni* with small isolated patches of *Halophila* spp. located opposite the old boat ramp within Penrhyn Estuary. A continuous mixed bed of *Z. capricorni* and *Halophila* spp. was recorded at the western extent of the Rehabilitation Area which is now part of the estuary entrance channel. Small isolated patches of *Z. capricorni* and *Halophila* spp. and *P. australis* were also recorded within the area which now forms the estuary entrance channel. Between February 2007 and May 2008 seagrass cover was substantially reduced to isolated patches of *Z. capricorni* and *P. australis* and occasional mixed beds located throughout what is now the estuary entrance channel. Seagrass recorded within the Rehabilitation Area in March 2013 consisted of small isolated patches of sparse *Halophila* spp. with the occasional patch of *Z. capricorni*. Note that individual shoots or clumps less than 5 sq. m were not included in the data presented in **Figure 20**.

Table 8 Total seagrass area (sq. m) within the Penrhyn Estuary Rehabilitation Area between 2002 and 2013

Year	Phase	Approximate Area of Seagrass (sq. m)	Reference
2002 (April/July)	Pre-Construction	28,894	The Ecology Lab (2003)
2006 (June)	Pre-Construction	5000	Roberts *et al*. (2006)
2007 (February)	Pre-Construction	677	Roberts *et al*. (2007)
2007 (November)	Pre-Construction	315	Roberts *et al*. (2008)
2008 (May)	Pre-Construction	299	Roberts *et al*. (2008)
2012 (March)	Post-Construction	0	Cardno Ecology Lab (2012)
2013 (March)	Post- Construction	2466	Cardno Ecology Lab (2013)

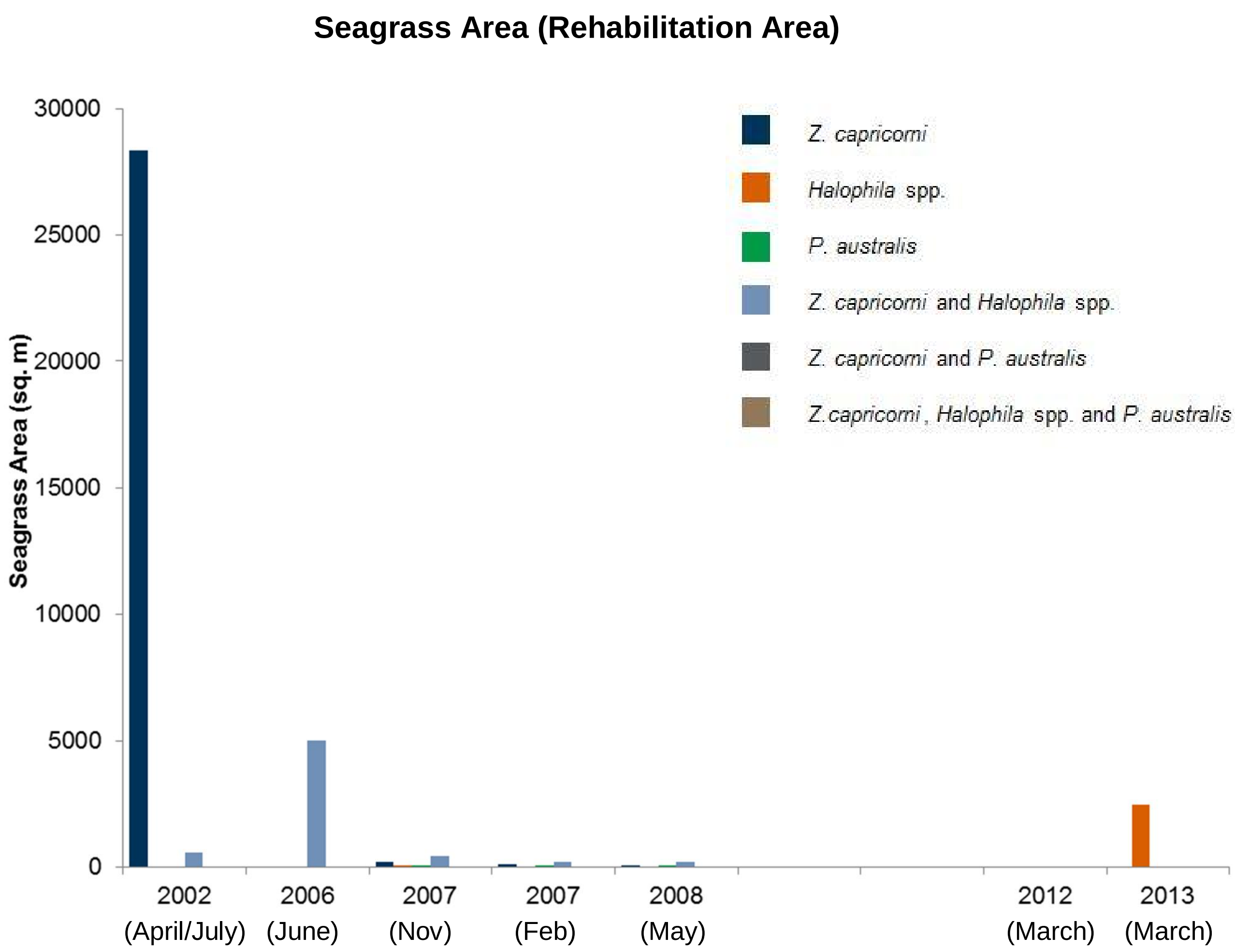

Figure 20 Area of seagrasses within the Rehabilitation Area between 2002 and 2013

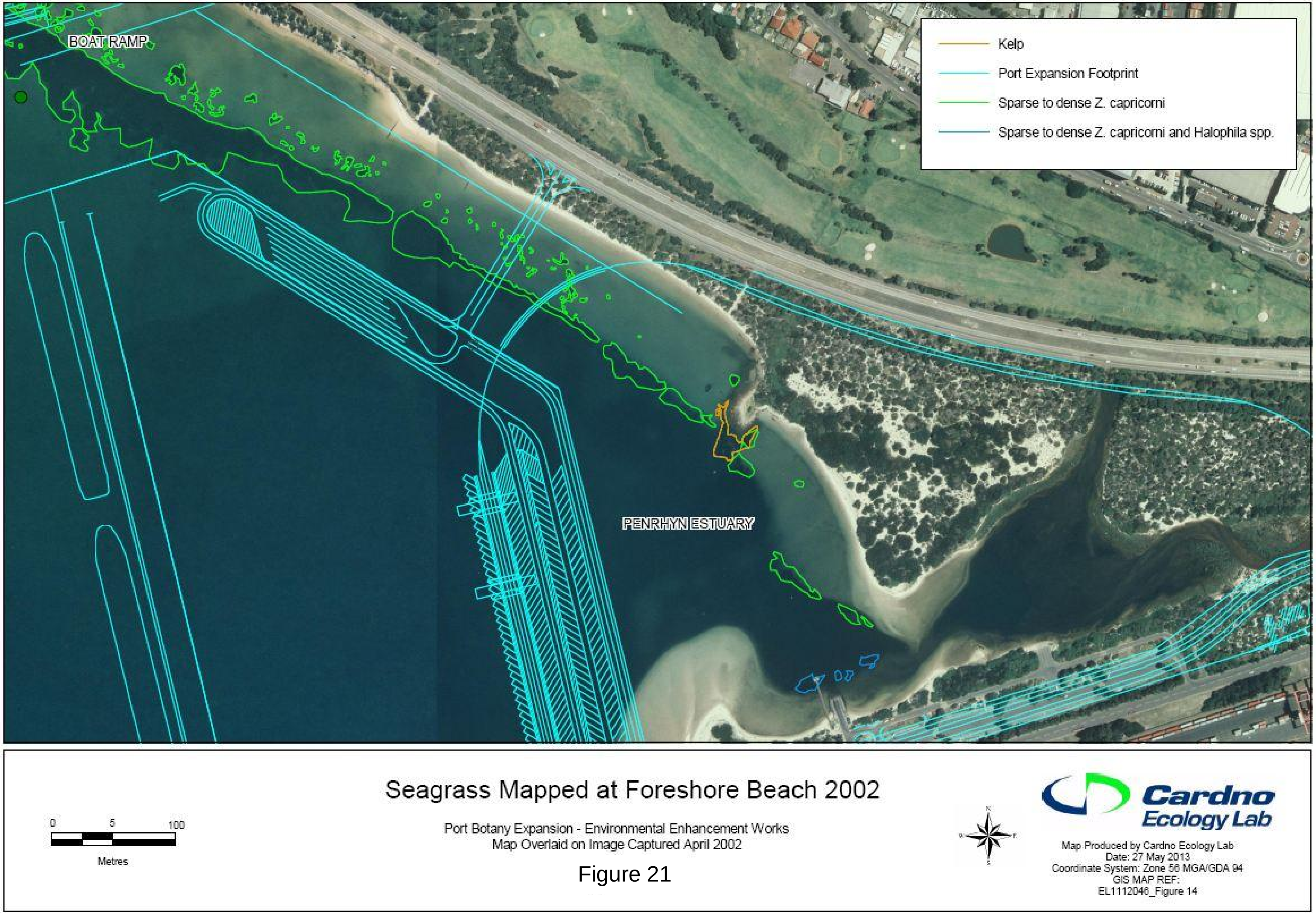

Figure 21 Seagrass mapped at Penrhyn Estuary prior to rehabilitation, April 2002

Figure 22 Seagrass observed in intertidal habitats in Penrhyn Estuary November 2012

Figure 23 Seagrass mapped at Penrhyn Estuary Rehabilitation Area, March 2013

4.1.2.2 Transects

Seagrass was not recorded along any of the 12 transects surveyed in the Rehabilitation Area in March 2012. The mean percent cover of seagrass recorded along transects sampled in 2013 was 0.34% for *Z. capricorni* and 4.3% for *Halophila* spp. *P. australis* was not recorded along any transects during the March 2013 survey.

4.1.2.3 Patches

Shoot Density

Seagrass was not recorded within the Rehabilitation Area during the March 2012 survey. Distinct patches of sparse *Halophila* spp. were observed during the March 2013 survey and new patch sites P3A, P3B, P3C and P3D were established within these beds. Mean shoot density of *Halophila* spp. at the four patches sampled is presented in (**Figure 24**).

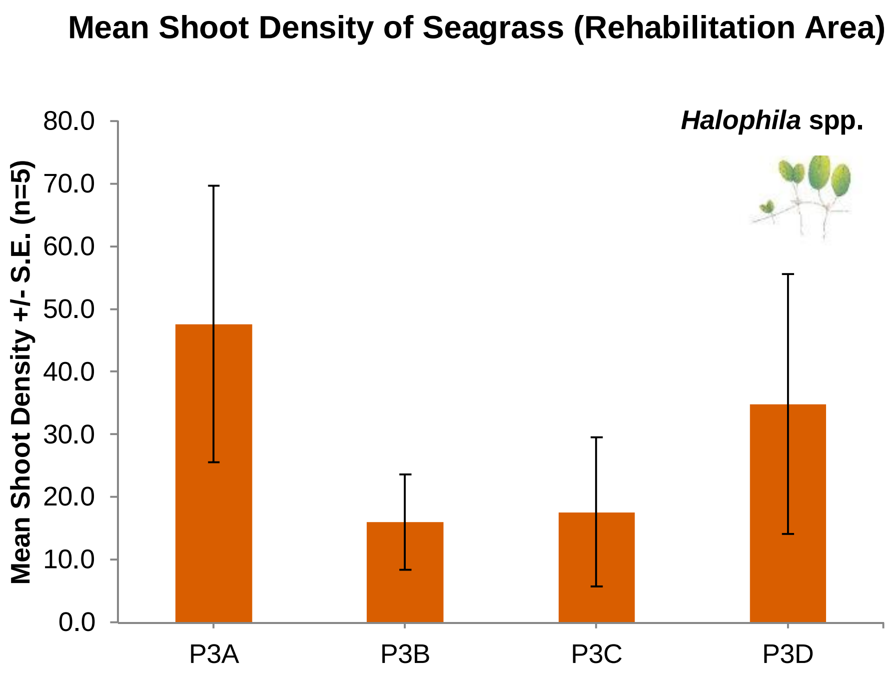

Figure 24 Mean shoot densities (n=5) of *Halophila* spp. sampled within patches at the Rehabilitation Area during March 2013

Leaf Length

Mean leaf length recorded in patches of *Halophila* spp. during the 2013 survey varied between 0.3 cm in P3C to 1.2 cm at P3B (**Figure 25**).

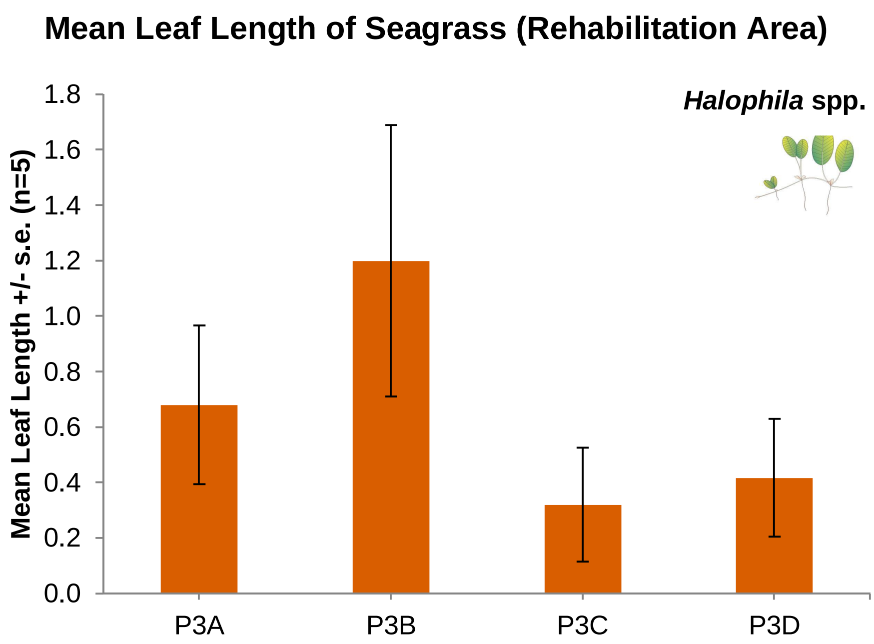

Figure 25 Mean leaf length (n=5) of *Halophila* spp. sampled within patches at the Rehabilitation Area during March 2013

Epiphytes

Epiphytes were not observed on seagrass leaves sampled within patches during the 2013 survey.

4.1.3 Quibray Bay Planting Areas

4.1.3.1 Shoot Density

Overall, mean shoot density of *P. australis* at Planting Area 1 increased from 10 shoots per quadrat after the initial transplant in July 2008 to 21.6 shoots per quadrat in March 2012, although there was a decrease from the previous survey carried out in October 2010. Mean shoot density at Planting Area 2 was generally higher than at Planting Area 1, but followed a similar pattern, with an overall increase in shoot density from 15 shoots per quadrat in July 2008 to 23.3 shoots per quadrat in March 2012 (**Table 9; Figure 26**). Data for corresponding control locations was not available for all the years surveyed, but was recorded for the 2012 survey (**Figure 27**). Statistical analyses showed that shoot densities of *P. australis* recorded in March 2012 did not differ between control and transplant treatments but was significantly different among sites (P=0.027). Pair wise tests indicated that this was due to differences between Control Site 1 and Control Site 2 (P=0.0001) (**Figure 27**).

Table 9 Mean shoot density (shoots per sq. m) of *P. australis* transplanted into Planting Areas 1 and 2 in Quibray Bay between July 2008 and March 2012

	2008 (July)		2008 (October)		2009 (September)		2010 (October)		2012 (March)	
	P1	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
Mean	10	15	9.2	14.4	8.8	14	36.8	42.8	21.6	23.3
S.E.	No Data	No Data	0.7	1.4	0.9	1.2	5.1	7.2	2.8	4.7

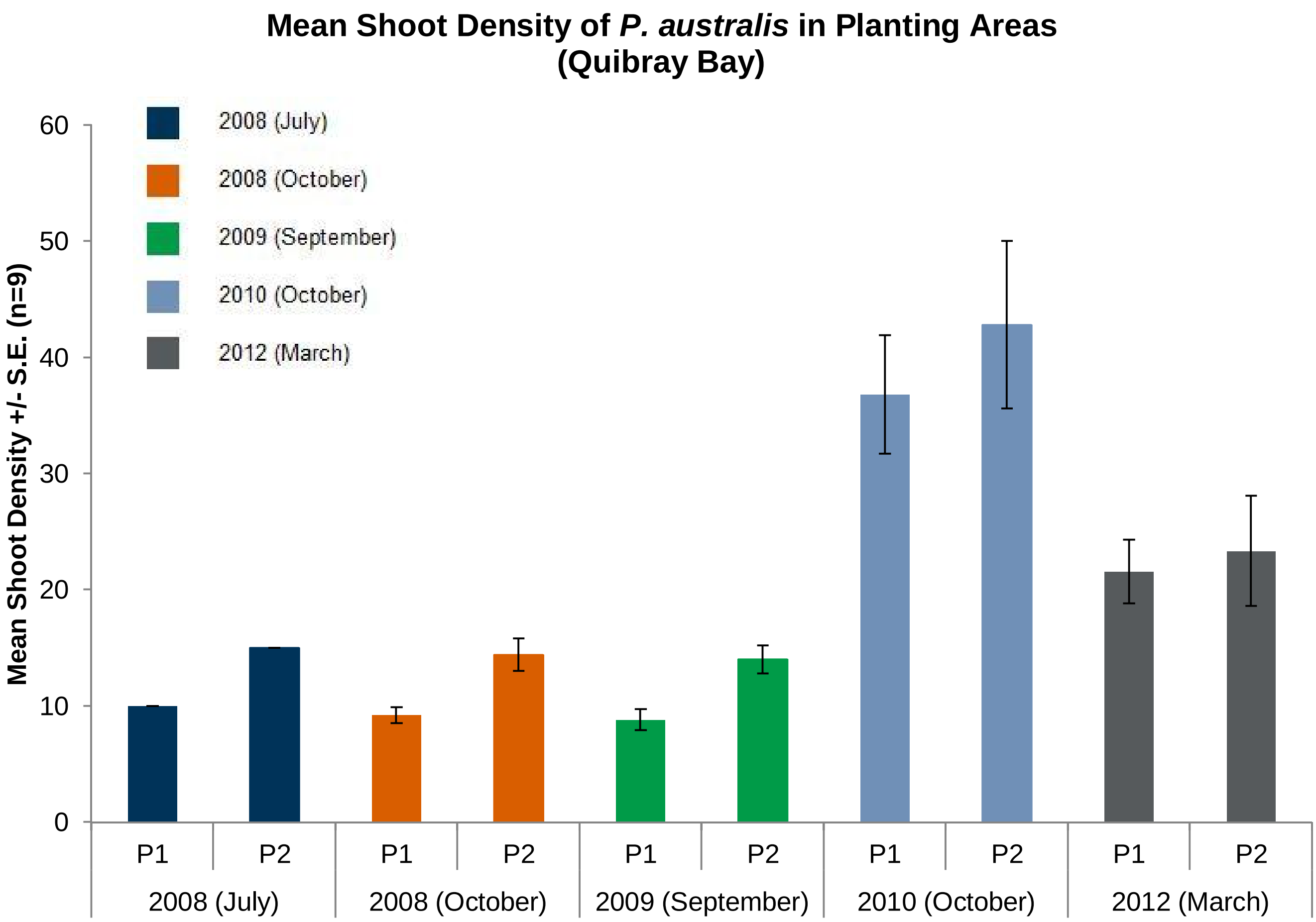

Figure 26 Mean shoot density (shoots per sq. m) of *P. australis* transplanted into Planting Areas 1 and 2 in Quibray Bay between July 2008 and March 2012. Note that standard errors were not available for July 2008 data

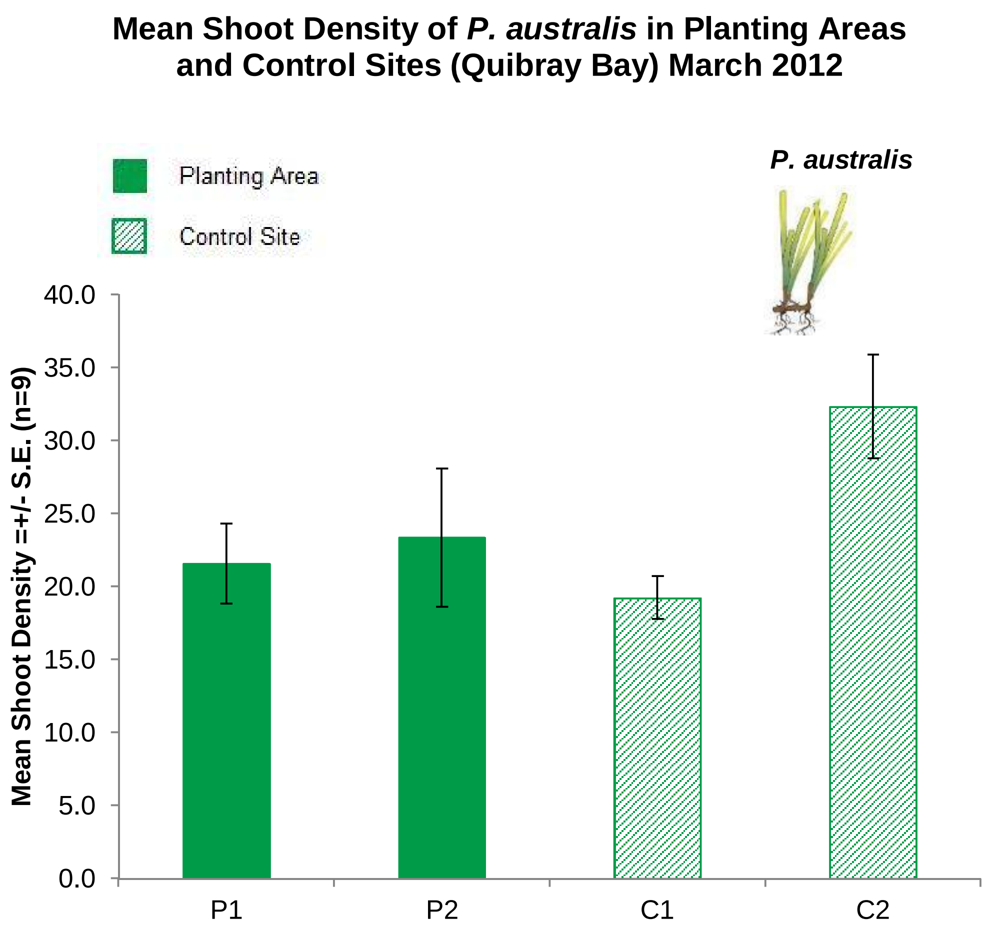

Figure 27 **Mean shoot density (shoots per sq. m) of *P. australis* transplanted into Planting Areas 1 and 2 and at Control Sites in Quibray Bay (March 2012)**

4.1.3.2 Leaf Length

Leaf length of *P. australis* within Quibray Bay was generally longer at the Control Sites than at the Planting Areas although this difference was not statistically significant (*P*=0.669). Differences among sites were significantly different (P=< 0.0001) which pair wise tests indicated were due to the differences between Planting Area 1 and Planting Area 2 (**Figure 28**).

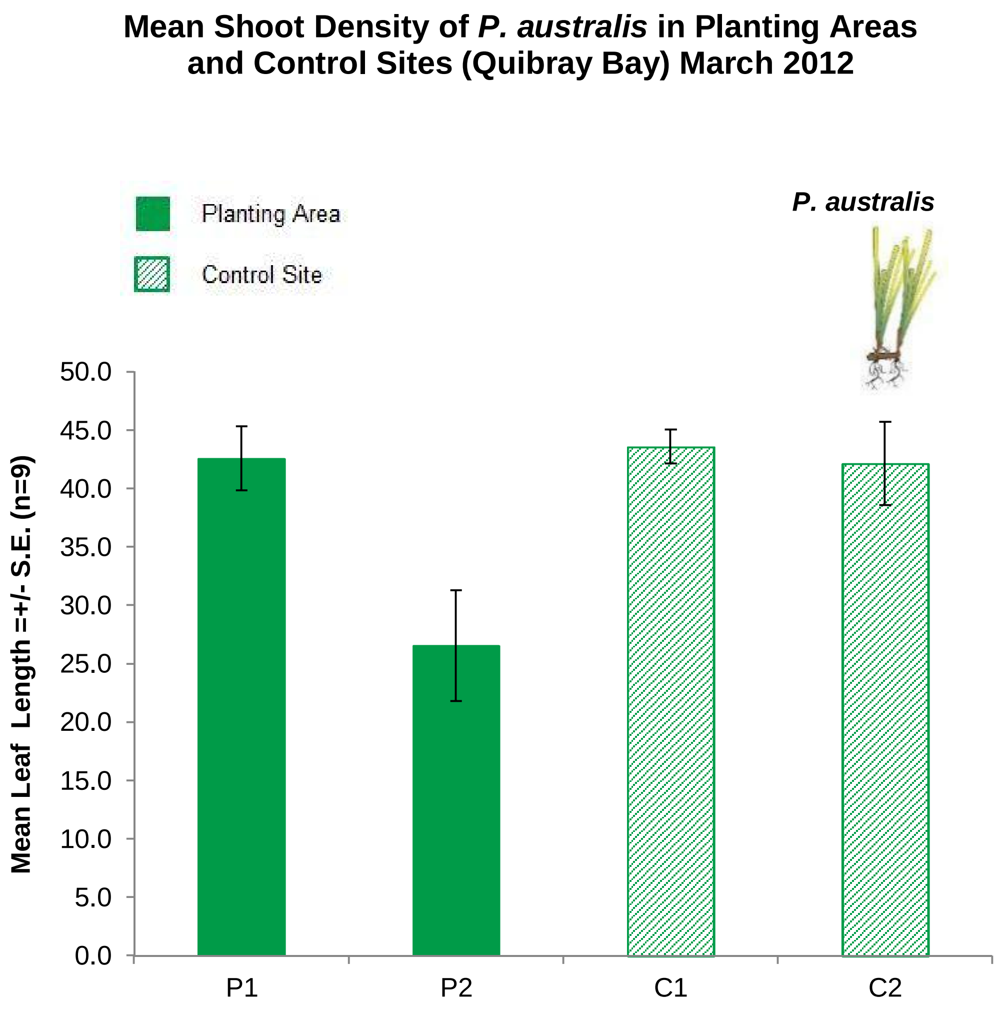

Figure 28 Mean leaf length of *P. australis* transplanted into Planting Areas 1 and 2 and at Control Sites in Quibray Bay (March 2012)

4.1.3.3 Epiphytes

A similar pattern of epiphyte growth was observed at both Planting Areas and Control Sites with the largest proportion of epiphyte load observed in the medium density category and ranging between 40% and 78% of all observations per site. Observations in the high density category ranged between 12% and 31% of all observations per site and observations in low density category ranged between 6% and 20% per site. Very few leaves observed across the survey had no epiphytes with the exception of Planting Area 2 (**Figure 29**).

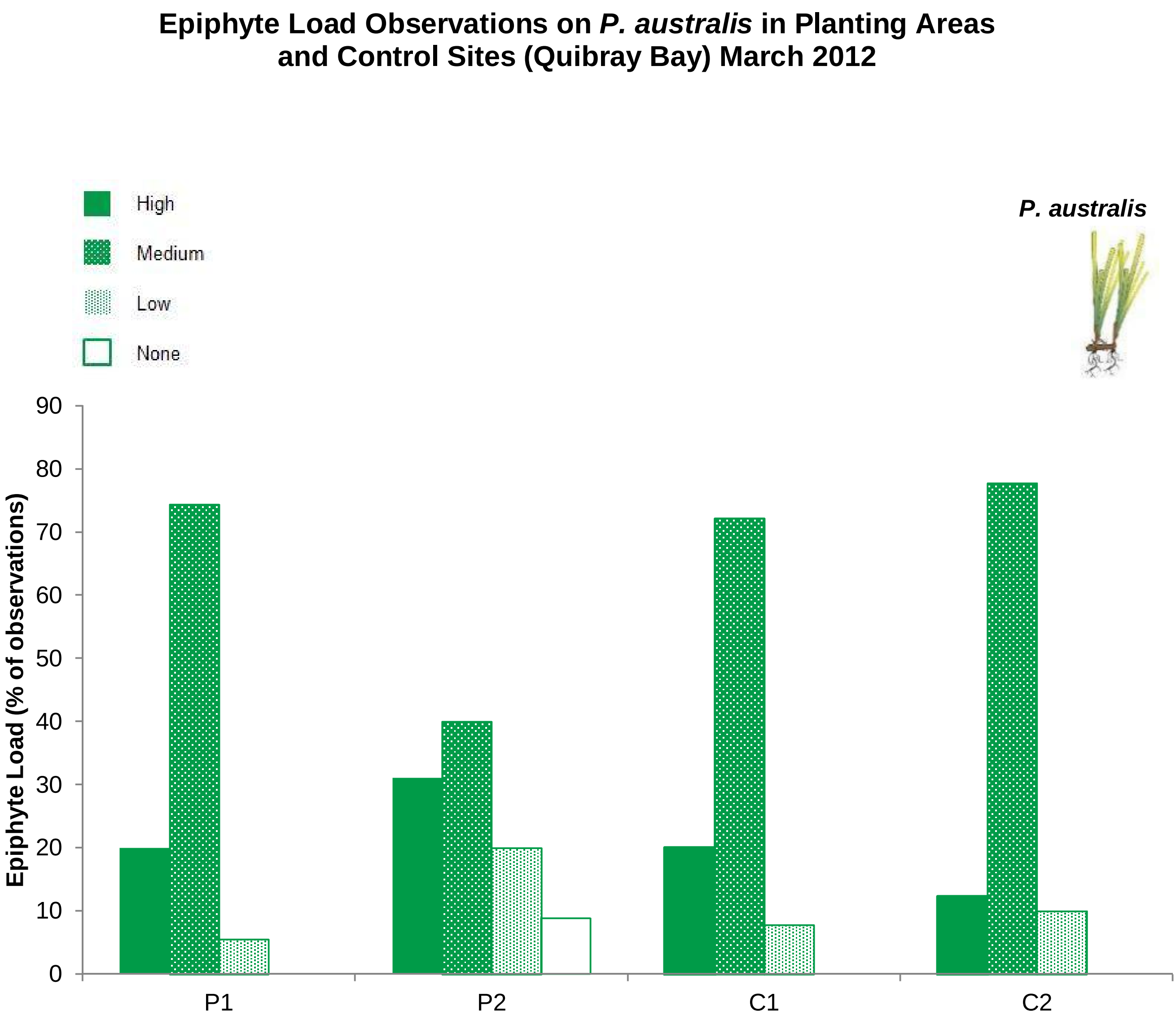

Figure 29 Observations of epiphytes observed on *P. australis* in Planting Areas and Control Sites (Quibray Bay) March 2012

4.1.4 Quibray Bay Experimental Sites

4.1.4.1 Shoot Density

Mean shoot density of *P. australis* in the 'whole' transplanted seagrass treatment has increased from 6 shoots per quadrat in July 2008 to 17.6 shoots per quadrat in March 2012. Mean shoot density for the 'seagrass' treatment (which serves as a control for the transplanted 'whole' treatment varied between 30.1 shoots per 0.25 sq. m quadrat in March 2012 and 51.7 in October 2008. Mean shoot density within the 'trimmed' treatment was initially as low as 2.7 but by March 2012 had increased to 21.9 shoots per quadrat. Similarly, mean shoot density within the rhizome treatment increased overall from no shoots in October 2008 to 12.5 shoots in March 2012. *P. australis* also appears to have established in bare patches from around September 2009 with a mean shoot density of 6.2 shoots per quadrat recorded by March 2012 (**Figure 30**). Statistical analyses showed that shoot density was significantly different among times but that this was dependent on treatment (*P*=0.0001).

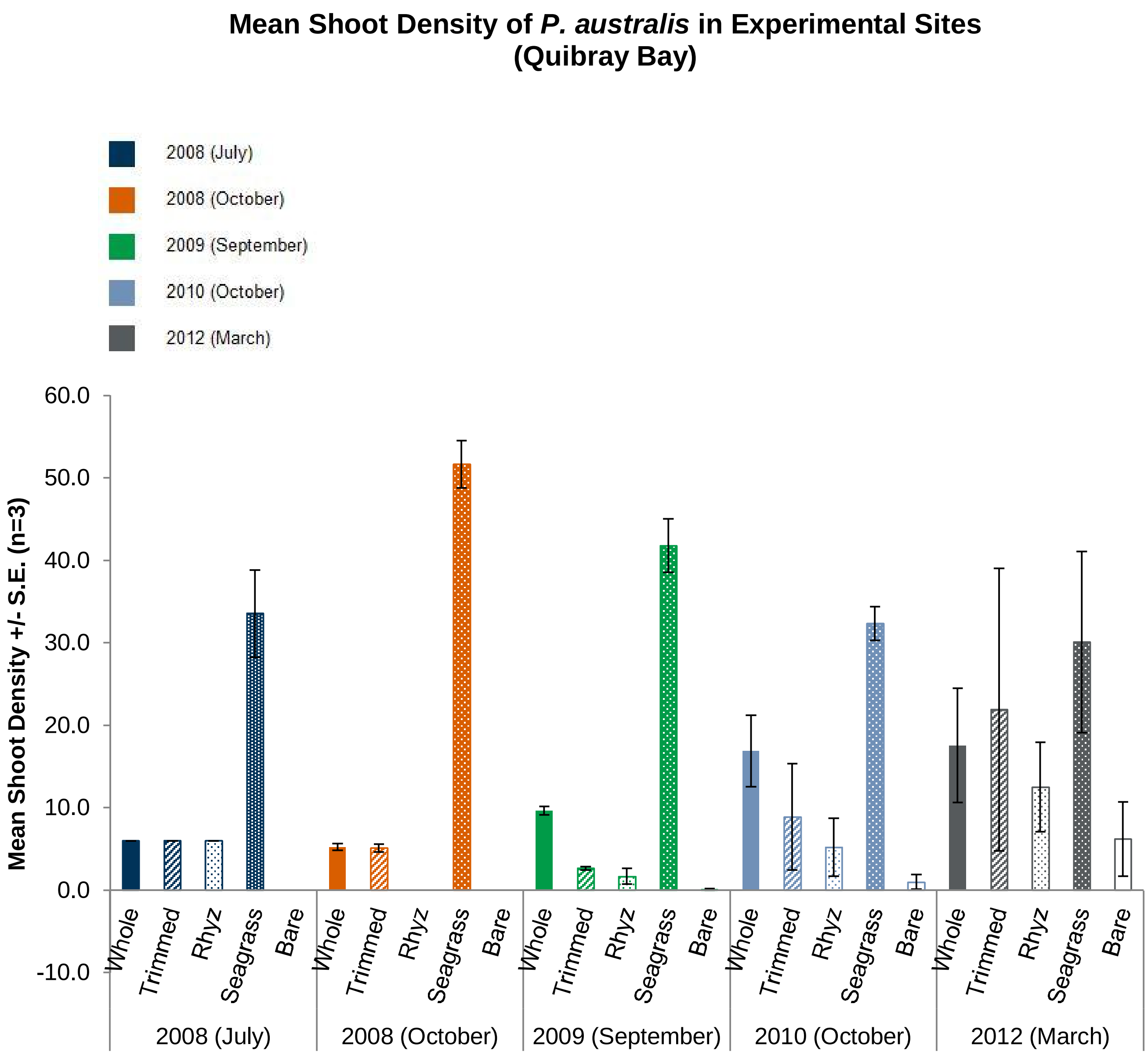

Figure 30 Mean shoot density for treatments surveyed within experimental sites between July 2008 and March 2012

4.1.4.2 Leaf Length

Mean leaf length of *P. australis* within the transplanted 'whole' treatment has decreased overall from 42.3 cm in July 2008 to 27.6 cm in March 2012. Mean leaf length within the seagrass control also decreased overall over this time. Trimmed seagrasses appeared to have grown from a mean of 2 cm in July 2008 to 35.5 cm in March 2012. Seagrasses within the Rhizome treatment also appeared to have grown since surveys carried out in 2008 where leaf length was 0 – 2 cm up to 29 cm in March 2012 (**Figure 31**). Statistical analyses indicated that mean leaf length was significantly different among times, but that this was dependent on the treatment (*P*=0.0001).

Mean Leaf Length of *P. australis* in Experimental Sites (Quibray Bay)

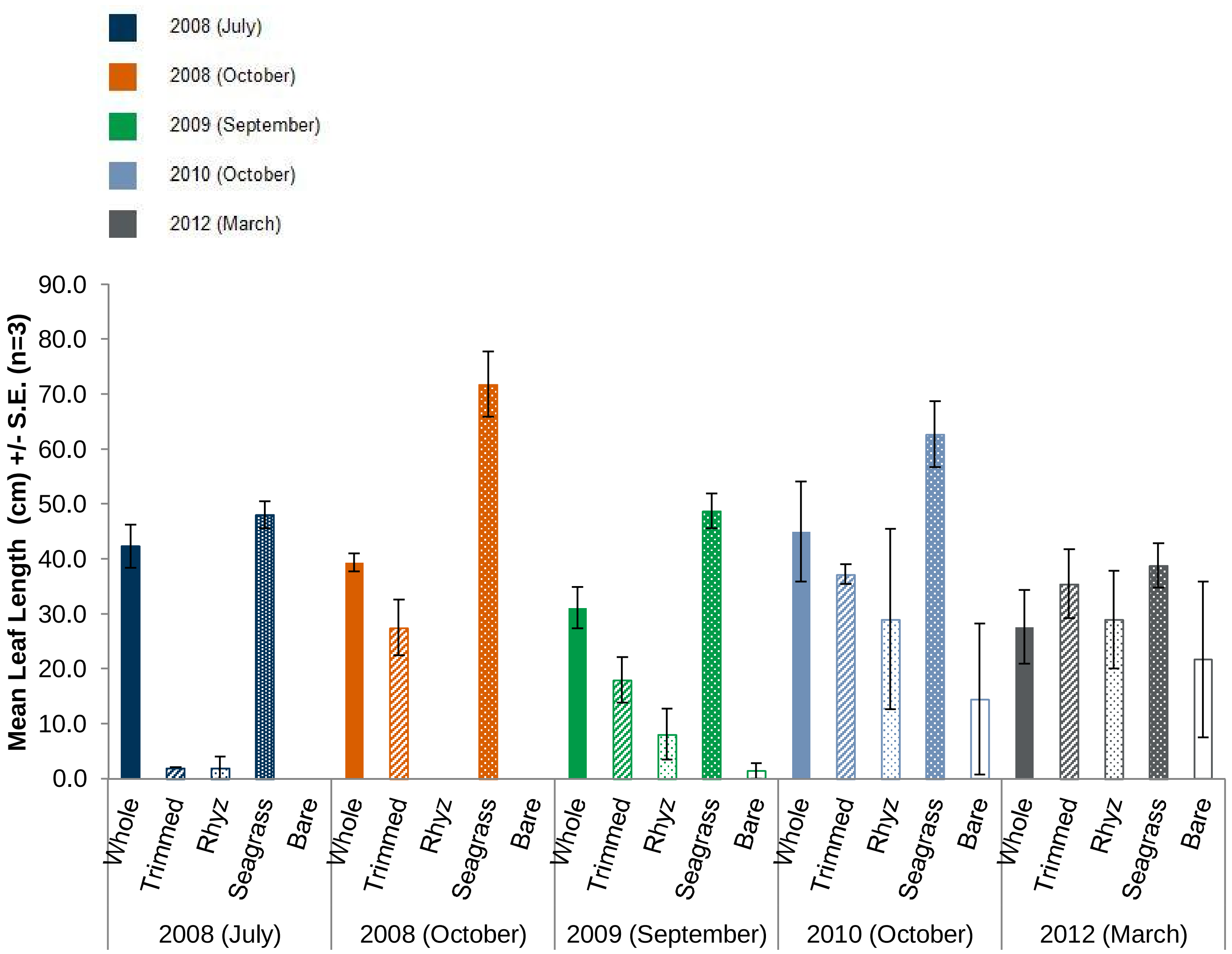

Figure 31 Mean leaf length for treatments surveyed within experimental sites between July 2008 and March 2012

5 Interpretation

5.1 Foreshore Beach

The distribution and areal coverage of seagrass at Foreshore Beach declined substantially between 2002 and 2007, prior to any dredging, land reclamation or construction works associated with the Port Botany Expansion. Roberts *et al.* (2008) suggest this may have been a result of erosion at Foreshore Beach and consequent sedimentation/smothering of seagrass located seaward of the Beach. The cause of the increased erosion is not speculated upon, but may have been due to a natural storm event or other engineering works within Botany Bay which may have altered nearshore coastal processes. During the removal of *P. australis* for transplantation to Quibray Bay, Roberts *et al*. (2009) also noted that in several areas, *P. australis* was buried beneath a layer of sand. Erosion and sedimentation along Foreshore Beach is potentially a limiting factor in the recovery of seagrasses in this area.

Given the large amount of variation shown in pre-construction monitoring and the stability of retained beds throughout the construction monitoring, it does not appear that the construction works have had any notable impact on the seagrass beds at Foreshore Beach other than the predicted loss of seagrass within the footprint of the reclaimed land and boat ramp (estimated to be approximately 317 sq. m). Post-construction, monitoring of Foreshore Beach using mapping, transect and fixed point sampling methods indicated that seagrass may be recovering following the pre-construction decline, although the distribution remains sparse and patchy. Although there was a decrease in area observed between March 2012 and March 2013 potentially due to known natural variation and the ephemeral nature of *Halophila* spp. and *Z. capricorni*, the area of seagrass in the post-construction period is an order of magnitude greater than what it had been at the end of the pre-construction period. Further, *Halophila* spp. initially the most widely distributed taxa recorded in the post-construction period, has been followed by the establishment of *Z. capricorni* in the 2013 survey. This pattern of succession might be expected on the basis that *Halophila* spp. is considered to be a pioneer and is often followed by *Zostera* spp. Only small isolated patches of *P. australis* have been recorded in recent surveys and recovery of this species is likely to take a longer period of time to re-establish particularly if sediment mobility continues to be an issue at Foreshore Beach. Results of fixed point sampling (2007 – 2013) confirms that the occurrence of *Z. capricorni* and *Halophila* spp. is more variable through time than *P. australis* which occurred at the same sites through time, although percentage cover varied..

At the sites where seagrass has become established, growth and condition is generally improving for *Halophila* spp. and *Z. capricorni*. Leaf length for *Halophila* spp. was within the range expected for healthy plants, however, despite the increase in leaf length, *Z. capricorni* was very stunted, indicating these plants may be experiencing environmental stress. Epiphyte load on *Z. capricorni* was light, while epiphytes on *Halophila* spp. was mostly light to medium and occasionally high. This does not suggest excessive nutrient levels but would be considered typical of a highly urbanised and developed estuary.

The occurrence of *P. australis* in only one patch during the 2012 survey and its absence in the 2013 survey suggests that post-construction conditions have not been favourable for this species at Foreshore Beach. Plants sampled during the 2012 survey were also very stunted.

5.2 Rehabilitation Area

Prior to construction and enhancement activities, a similar decline in seagrass distribution to that at Foreshore Beach was evident at the eastern end of Foreshore Beach. Any seagrass that had remained following the pre-construction decline (approximately 299 sq. m) appears to have died as none was observed within the rehabilitation area in the first post-construction monitoring survey in March 2012. Although some *P. australis* was removed for transplantation, the majority was directly lost from land reclamation and construction of the boat ramp, or indirectly though changes to environmental conditions. The establishment of *Halophila* spp. and the occasional patch of *Z. capricorni* in the latest 2013 survey are indicative signs of recovery, although the patches were isolated and sparse in cover. Leaf length of *Halophila* spp. within the Rehabilitation Area, was short. This was potentially due to environmental stress but more likely because these beds are newly established and have not yet had a chance to develop. Data from future monitoring surveys will be important in determining this.

Following enhancement activities, seagrasses within Penrhyn Estuary showed similar patterns previously documented on the intertidal sand flats. These include ephemeral patches of low density *Halophila* spp. and *Z. capricorni*, the latter with short, narrow blades. Their absence in March 2012 and presence in November 2012 and March 2013 indicates that the enhanced estuary substratum had likely stabilised. While the enhanced substratum is appropriate for seagrass growth, seagrass within the estuary is likely to continue to be sparse, have short leaf length (*Z. capricorni*) and ephemeral in nature, as was previously recorded in this habitat.

As discussed in Section 1.3.3, light is considered to be the primary environmental variable that affects the spatial distribution of seagrass. As such, the amount of photosynthetically active radiation (PAR) and total suspended solids (TSS) were measured at sites within Penrhyn Estuary, Foreshore Beach and reference sites as part of the PEHEP Water Quality monitoring program. The methodology and results of these investigations are described within the Water Quality Annual Report 2013 (Cardno Ecology Lab 2013). Overall, PAR measurements for 2012 and 2013 showed that levels within the estuary were greater than at reference sites located approximately 1.5 and 2.5 km offshore of Foreshore Beach. This indicates that seagrass growth within the estuary is unlikely to be limited by light attenuation in the long term and, given other water quality parameters are suitable, conditions should therefore be conducive to seagrass growth and recovery. PAR recorded at the western end of Foreshore Beach was on average, slightly lower than that recorded at the reference sites. This may be due to inputs of suspended sediments from the Engine Pond and Mill Creek catchments, although 2012 and 2013 maps do not suggest that seagrass recovery at this end of Foreshore Beach is impeded.

Mean TSS was variable across the six sampling sites for years 2012 and 2013, but was generally lower at reference site 6 (the furthest offshore), which would be expected given the proximity to the entrance of Botany Bay and the influence of ocean conditions. There was otherwise no clear difference between Foreshore Beach and Penrhyn Estuary sites with reference sites. The median value for all sites was 10mg/L or less which is within the suggested light requirements for *Zostera* spp., which is 15 mg/L (Kemp *et al*. 2004). This is also likely to be within the light requirements for *Halophila* spp. which is generally more tolerant to reduced water clarity than *Z. capricorni*.

TSS levels were recorded before and after construction within Penrhyn Estuary and at reference sites, and no significant differences between times or treatments were detected, nor any clear relationship with seagrass distribution was observed.

5.3 Quibray Bay Planting Areas

The transplantation of *P. australis* into Planting Areas within Quibray Bay appears to have been largely successful, with an overall increase in mean shoot density since their initial translocation in July 2008. The similarity in mean shoot density and leaf length between *P. australis* sampled in Control and Planting Areas in the latest March 2012 survey also indicates that the translocated plants have become well established and do not appear to have sustained any long term damage as a result of the transplantation process.

5.4 Quibray Bay Experimental Sites

Shoot density in all three transplanted *P. australis* treatments (whole, trimmed and rhizomes) has increased gradually since transplanting. Increases to shoot densities in the rhizome and trimmed treatments took longer to occur than for the whole treatment but by March 2012 shoot densities in all three treatments were similar. Despite increasing, shoot densities in the whole, trimmed and rhizome treatments were still less than for natural seagrasses in the area. It appears that densities are still increasing highlighting the need for ongoing monitoring. Leaf length of *P. australis* in the whole, trimmed and rhizome treatments followed a similar pattern but a similar length to natural seagrass in the area by March 2012.

6 Conclusions

Results of pre and post construction monitoring over the past 11 years have been important in identifying the highly variable nature of seagrass distribution and species composition within Foreshore Beach and the Penrhyn Estuary Rehabilitation Area. Impacts on seagrasses as a result of the Port Botany Expansion are relatively minor in relation to the variability (natural or otherwise) observed over the six year period prior to construction works. Initial findings of post–construction monitoring at Foreshore Beach are positive and suggest early signs of recovery for *Halophila* spp. and *Z. capricorni*, following the pre-construction decline. The remaining patches of *P. australis* appear to be in decline but it is not clear whether this is related to construction or due to other impacts

There are signs that seagrass is colonising the Rehabilitated Area with large patches of the early colonising species, *Halophila* spp. appearing in the eastern end of the channel.

The invasive alga *Caulerpa taxifolia,* has been recorded previously in areas surveyed, however, it was not observed in the March 2012 and 2013 surveys. As the presence of *Caulerpa taxifolia* may vary temporally (NSW DPI 2011), it still may be recorded in future surveys.

Overall, water quality data (PAR and TSS) indicates that seagrass growth within the estuary is unlikely to be limited by light attenuation in the long term and should therefore be conducive to growth and recovery. TSS levels recorded within Penrhyn Estuary and at reference sites before and after construction did not appear to be significantly different. No clear spatial relationship between mean TSS and PAR levels with the distribution of seagrasses was evident.

The transplantation of *P. australis* from Foreshore Beach to Quibray Bay appears to have been successful and will have helped offset direct losses of seagrass within the footprint of the reclaimed land and boat ramp at Foreshore Beach.

Investigations into the various methods of transplantation treatments against control treatments have shown that all methods (whole, trimmed and rhizomes) showed positive results. As the growth and establishment of *P. australis* can be slow, continued monitoring of these treatments over the course of the project will be important in determining whether one or more methods were more successful than others.

This study was limited by the amount of raw data available from past investigations and as such, statistical analyses were not possible for some aspects of the investigation. Results of the 2012 to 2017 surveys will therefore be important in assessing the success of the PEHEP by providing a complete data set collected in a consistent and quality controlled manner.

7 Acknowledgements

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APPENDIX A
2012 SEAGRASS DATA

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Appendix A: 2012 Seagrass Data

A-1: Summary of transect data for Foreshore Beach (transects 1 - 11) and the rehabilitated area of Penrhyn Estuary (transects R1 - R12)

Seagrass species	Transect	Mean % cover	Standard error	Range (min - max)	Occurrence %
***Halophila* spp.**	F1	0.02	0.01	0 - 1	1.59
	F2	0.60	0.16	0 - 10	18.94
	F3	0.51	0.10	0 - 10	19.51
	F4	0.44	0.11	0 - 5	12.75
	F5	0.42	0.08	0 - 5	15.00
	F6	0.05	0.03	0 - 4	2.58
	F7	0.01	0.01	0 - 1	0.79
	F8	0.34	0.08	0 - 5	11.50
	F9	0.12	0.04	0 - 4	5.81
	F10	0.19	0.06	0 - 4	7.14
	F11	0.05	0.02	0 - 2	3.79
	R1	0.00	0.00	0.00	0.00
	R2	0.00	0.00	0.00	0.00
	R3	0.00	0.00	0.00	0.00
	R4	0.00	0.00	0.00	0.00
	R5	0.00	0.00	0.00	0.00
	R6	0.00	0.00	0.00	0.00
	R7	0.00	0.00	0.00	0.00
	R8	0.00	0.00	0.00	0.00
	R9	0.00	0.00	0.00	0.00
	R10	0.00	0.00	0.00	0.00
	R11	0.00	0.00	0.00	0.00
	R12	0.00	0.00	0.00	0.00

Seagrass species	Transect	Mean % cover	Standard error	Range (min - max)	Occurrence %
P. australis	F1	0.00	0.00	0.00	0.00
	F2	0.00	0.00	0.00	0.00
	F3	0.00	0.00	0.00	0.00
	F4	0.00	0.00	0.00	0.00
	F5	0.00	0.00	0.00	0.00
	F6	0.00	0.00	0.00	0.00
	F7	0.00	0.00	0.00	0.00
	F8	0.00	0.00	0.00	0.00
	F9	0.00	0.00	0.00	0.00
	F10	0.00	0.00	0.00	0.00
	F11	0.00	0.00	0.00	0.00
	R1	0.00	0.00	0.00	0.00
	R2	0.00	0.00	0.00	0.00
	R3	0.00	0.00	0.00	0.00
	R4	0.00	0.00	0.00	0.00
	R5	0.00	0.00	0.00	0.00
	R6	0.00	0.00	0.00	0.00
	R7	0.00	0.00	0.00	0.00
	R8	0.00	0.00	0.00	0.00
	R9	0.00	0.00	0.00	0.00
	R10	0.00	0.00	0.00	0.00
	R11	0.00	0.00	0.00	0.00
	R12	0.00	0.00	0.00	0.00
Z. capricorni	F1	0.00	0.00	0.00	0.00
	F2	0.02	0.01	0 - 1	1.52
	F3	0.00	0.00	0.00	0.00

Seagrass species	Transect	Mean % cover	Standard error	Range (min - max)	Occurrence %
	F4	0.03	0.03	0 - 4	0.67
	F5	0.00	0.00	0.00	0.00
	F6	0.03	0.03	0 - 4	0.65
	F7	0.00	0.00	0.00	0.00
	F8	0.02	0.01	0 - 2	1.00
	F9	0.00	0.00	0.00	0.00
	F10	0.03	0.03	0 - 4	0.71
	F11	0.01	0.01	0 - 1	0.76
	R1	0.00	0.00	0.00	0.00
	R2	0.00	0.00	0.00	0.00
	R3	0.00	0.00	0.00	0.00
	R4	0.00	0.00	0.00	0.00
	R5	0.00	0.00	0.00	0.00
	R6	0.00	0.00	0.00	0.00
	R7	0.00	0.00	0.00	0.00
	R8	0.00	0.00	0.00	0.00
	R9	0.00	0.00	0.00	0.00
	R10	0.00	0.00	0.00	0.00
	R11	0.00	0.00	0.00	0.00
	R12	0.00	0.00	0.00	0.00

A-2: Summary of seagrass cover for fixed points along Foreshore Beach and the Rehabilitation area of Penrhyn Estuary

	GPS Coordinates (WGS 84)		2008 Survey Data Percentage Cover (sq. m)				2012 Survey Data Percentage Cover (sq. m)				2012 Field Observations and Comments	Direct Impacts from Construction (Yes/No)	Change in Seagrass Area between 2008 & 2012 (sq. m)
Seagrass Patch No.	**Easting**	**Northing**	***Halophila* spp.**	***P. australis***	***Z. capricorni***	**Total Seagrass Area**	***Halophila* spp.**	***P. australis***	***Z. capricorni***	**Total Seagrass Area**			
1	333212	6241214		5		5	<1	15	<1	20		No	15
2	333244	6241225		30		4	<1	20	<1	6		No	2
3	333304	6241190	5	50	20	4		25	5	12		No	8
4	333290	6241186	2		2	4				0.5		No	-3.5
5	333363	6241120			15	2	<1		15	9		No	7
6	333396	6241106		2		1		30		1		No	0
7	333423	6241075	2		80	10				0		No	-10
8	333431	6241063	2		5	5				0		No	-5
9	333547	6241013		50		1				0	New boat ramp	Yes	-1
10	333548	6241007			1	2				0	New boat ramp	Yes	-2
11	333563	6240999	20	40	1	3				0	New boat ramp	Yes	-3
12	333571	6241007		5	80	5				0	New boat ramp	Yes	-5
13	333591	6241009	2		40	7				0	Car park	Yes	-7
14	333593	6240870		1		2				0	No seagrass - dredged 14 m depth	Yes	-2
15	333669	6240923		5		3				0	No seagrass - dredged 8 m depth	Yes	-3
16	333679	6240881		1		5				0	No seagrass - dredged 8 m depth	Yes	-5
17	333729	6240913	1		80	12				0		Yes	-12
18	333743	6240886		5		4				0		Yes	-4
19	333761	6240874		1		1				0		Yes	-1
20	333865	6240785		30		4				0		Yes	-4
21	333859	6240774		15		4				0		Yes	-4
22	333978	6240801			80	6				0	Reclaimed land	Yes	-6
23	334269	6240597			10	5				0	Reclaimed land	Yes	-5
24	334294	6240581			90	20				0		Yes	-20
25	334315	6240545			80	10			80	10	Very short Z. capricorni (2 mm leaf length)	Yes	0

Seagrass Patch No.	GPS Coordinates (WGS 84)		2008 Survey Data Percentage Cover (sq. m)				2012 Survey Data Percentage Cover (sq. m)				2012 Field Observations and Comments	Direct Impacts from Construction (Yes/No)	Change in Seagrass Area between 2008 & 2012 (sq. m)
	Easting	Northing	*Halophila* spp.	*P. australis*	*Z. capricorni*	Total Seagrass Area	*Halophila* spp.	*P. australis*	*Z. capricorni*	Total Seagrass Area			
26	334345	6240576		80		1				0	Reclaimed land	Yes	-1
27	334357	6240453			90	4				0		Yes	-4
28	334361	6240424			5	2				0		Yes	-2

A-3: Summary of fixed point and patch sampling (0.25 m2) for Foreshore Beach and Penrhyn Estuary Rehabilitation Area

		Shoot Density			Leaf Length		
Location	**Site**	***Halophila* spp.**	***P. australis***	***Z. capricorni***	***Halophila* spp.**	***P. australis***	***Z. capricorni***
Foreshore Beach	1	2.00 (±2.00)	5.40 (±1.29)	0.00 (±0.00)	0.14 (±0.09)	28.74 (±1.84)	0.00 (±0.00)
	2	0.40 (±0.40)	9.00 (±1.73)	3.00 (±3.00)	0.00 (±0.10)	22.02 (±1.84)	0.01 (±0.01)
	3	0.00 (±0.00)	13.00 (±2.95)	0.00 (±0.00)	0.82 (±0.00)	22.88 (±1.30)	0.00 (±0.00)
	5	0.00 (±0.00)	0.00 (±0.00)	10.80 (±4.56)	0.84 (±0.62)	10.65 (±4.59)	0.10 (±0.14)
	6	0.00 (±4.46)	8.20 (±3.58)	10.20 (±0.00)	0.84 (±0.19)	10.44 (±1.45)	0.00 (±0.00)
	P1A	7.80 (±1.20)	0.00 (±0.00)	0.00 (±0.00)	0.56 (±0.19)	10.44 (±1.45)	0.00 (±0.00)
	P2A	4.20 (±5.26)	2.00 (±2.00)	0.00 (±0.00)	0.12 (±0.13)	0.44 (±0.13)	0.00 (±0.00)
	P1B	6.20 (±0.97)	0.00 (±0.00)	0.00 (±0.00)	1.18 (±0.07)	0.00 (±0.00)	0.00 (±0.00)
	P2B	0.20 (±2.54)	0.00 (±0.00)	0.00 (±0.80)	0.00 (±0.16)	0.00 (±0.00)	0.28 (±0.14)
Penrhyn Estuary Rehabilitation Estuary	P3A	2.00 (±2.00)	5.40 (±1.29)	0.00 (±0.00)	0.14 (±0.09)	28.74 (±1.84)	0.00 (±0.00)
	P3B	0.40 (±0.40)	9.00 (±1.73)	3.00 (±3.00)	0.00 (±0.10)	22.02 (±1.84)	0.01 (±0.01)
	P3C	0.00 (±0.00)	13.00 (±2.95)	0.00 (±0.00)	0.82 (±0.00)	22.88 (±1.30)	0.00 (±0.00)
	P3D	0.00 (±0.00)	0.00 (±0.00)	10.80 (±4.56)	0.84 (±0.62)	10.65 (±4.59)	0.10 (±0.14)
	6	0.00 (±4.46)	8.20 (±3.58)	10.20 (±0.00)	0.84 (±0.19)	10.44 (±1.45)	0.00 (±0.00)
	P1A	7.80 (±1.20)	0.00 (±0.00)	0.00 (±0.00)	0.56 (±0.19)	10.44 (±1.45)	0.00 (±0.00)
	P2A	4.20 (±5.26)	2.00 (±2.00)	0.00 (±0.00)	0.12 (±0.13)	0.44 (±0.13)	0.00 (±0.00)
	P1B	6.20 (±0.97)	0.00 (±0.00)	0.00 (±0.00)	1.18 (±0.07)	0.00 (±0.00)	0.00 (±0.00)
	P2B	0.20 (±2.54)	0.00 (±0.00)	0.00 (±0.80)	0.00 (±0.16)	0.00 (±0.00)	0.28 (±0.14)

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APPENDIX B
2013 SEAGRASS DATA

Appendix B: 2013 Seagrass Data

B-1: Summary of transect data for Foreshore Beach (transects F1 - F11) and the Rehabilitated area of Penrhyn Estuary (transects R1 - R11)

Seagrass species	Transect	Mean % Cover	Standard error	Range (min - max) % cover	Occurrence %
***Halophila* spp.**	F1	0.09	0.04	0-2	5.68
	F2	0.10	0.03	0-2	8.13
	F3	0.16	0.05	0-2	9.16
	F4	0.17	0.07	0-5	6.09
	F5	0.08	0.03	0-3	4.96
	F6	0.00	0.00	0.00	0.00
	F7	0.25	0.06	0-3	13.08
	F8	0.21	0.08	0-5	6.50
	F9	0.41	0.08	0-3	23.01
	F10	0.19	0.06	0-2	11.46
	F11	0.03	0.02	0-2	1.82
	R1	0.03	0.01	0 - 1	2.50
	R2	0.13	0.07	0 - 5	4.00
	R3	0.00	0.00	0.00	0.00
	R4	0.03	0.03	0 - 3	1.69
	R5	0.08	0.08	0 - 10	0.79
	R6	0.00	0.00	0.00	0.00
	R7	0.00	0.00	0.00	0.00
	R8	0.01	0.01	0 - 1	0.88
	R9	0.00	0.00	0.00	0.00
	R10	2.58	0.52	0 - 25	12.00
	R11	1.45	0.28	0 - 25	13.00
P. australis	F1	0.00	0.00	0.00	0.00
	F2	0.00	0.00	0.00	0.00
	F3	0.00	0.00	0.00	0.00
	F4	0.00	0.00	0.00	0.00
	F5	0.00	0.00	0.00	0.00
	F6	0.00	0.00	0.00	0.00
	F7	0.00	0.00	0.00	0.00
	F8	0.00	0.00	0.00	0.00
	F9	0.00	0.00	0.00	0.00
	F10	0.00	0.00	0.00	0.00
	F11	0.00	0.00	0.00	0.00
	R1	0.00	0.00	0.00	0.00
	R2	0.00	0.00	0.00	0.00
	R3	0.00	0.00	0.00	0.00
	R4	0.00	0.00	0.00	0.00
	R5	0.00	0.00	0.00	0.00

Seagrass species	Transect	Mean % Cover	Standard error	Range (min - max) % cover	Occurrence %
	R6	0.00	0.00	0.00	0.00
	R7	0.00	0.00	0.00	0.00
	R8	0.00	0.00	0.00	0.00
	R9	0.00	0.00	0.00	0.00
	R10	0.00	0.00	0.00	0.00
	R11	0.00	0.00	0.00	0.00
Z. capricorni	F1	0.34	0.09	0 - 3	16.85
	F2	0.20	0.07	0 - 5	9.68
	F3	0.02	0.01	0 - 1	1.52
	F4	0.01	0.01	0 - 1	0.86
	F5	0.00	0.00	0.00	0.00
	F6	0.00	0.00	0.00	0.00
	F7	0.11	0.08	0 - 10	2.29
	F8	0.00	0.00	0.00	0.00
	F9	0.04	0.02	0 - 2	3.51
	F10	0.13	0.07	0 - 5	5.15
	F11	0.94	0.35	0 - 25	14.41
	R1	0.00	0.00	0.00	0.00
	R2	0.00	0.00	0.00	0.00
	R3	0.02	0.02	0 - 2	1.00
	R4	0.00	0.00	0.00	0.00
	R5	0.00	0.00	0.00	0.00
	R6	0.00	0.00	0.00	0.00
	R7	0.00	0.00	0.00	0.00
	R8	0.00	0.00	0.00	0.00
	R9	0.22	0.18	0 - 25	1.45
	R10	0.05	0.05	0 - 10	0.50
	R11	0.05	0.05	0 - 10	0.50

B-2: Summary of seagrass cover for fixed points along Foreshore Beach and the Rehabilitation Area of Penrhyn Estuary

	2008 Survey Data				2008 Survey Data				2012 Survey Data					
	Percentage Cover (%)				Percentage Cover (%)				Percentage Cover (%)					
Seagrass Patch No.	***Halophila* spp.**	***P. australis***	***Z. capricorni***	**Total Seagrass Area (sq. m)**	***Halophila* spp.**	***P. australis***	***Z. capricorni***	**Total Seagrass Area (sq. m)**	***Halophila* spp.**	***P. australis***	***Z. capricorni***	**Total Seagrass Area (sq. m)**	**Direct Impacts from Construction (Yes/No)**	**Change in Seagrass Area between 2008 & 2012 (sq. m)**
1		5		5	<1	15	<1	20	<1	15		5	15	0
2		30		4	<1	20	<1	6	<1	3		4.4	2	0.4
3	5	50	20	4		25	5	12		5	>25	17.8	8	13.8
4	2		2	4				0.5	no seagrass found				-3.5	-4
5			15	2	<1		15	9	no seagrass found				7	-2
6		2		1		30		1			>25*		0	-1
Total				**20**				**48.5**				**27.2**	**28.5**	**7.2**

B-3: Summary of quadrat data (0.25 m^2) for patches at Foreshore Beach and Penrhyn Estuary

		Shoot Density			Leaf Length		
Location	**Site**	*Halophila* spp.	*P. australis*	*Z. capricorni*	*Halophila* spp.	*P. australis*	*Z. capricorni*
Foreshore Beach	P1A	37.80 (±4.10)	0.00 (±0.00)	7.00 (±4.36)	3.20 (±0.18)	0.00 (±0.00)	0.40 (±0.07)
	P2A	5.40 (±2.77)	0.00 (±0.00)	0.00 (±0.00)	0.08 (±0.06)	0.00 (±0.00)	0.00 (±0.00)
	P1B	0.40 (±0.40)	0.00 (±0.00)	0.00 (±0.00)	1.36 (±0.23)	0.00 (±0.00)	0.00 (±0.00)
	P2B	76.0 (±33.03)	0.00 (±0.00)	0.00 (±0.00)	1.74 (±0.16)	0.00 (±0.00)	0.00 (±0.00)
Penrhyn Estuary	P3A	47.60 (±22.03)	0.00 (±0.00)	0.00 (±0.00)	0.68 (±0.09)	0.00 (±0.00)	0.00 (±0.00)
	P3B	16.00 (±7.59)	0.00 (±0.00)	0.00 (±0.00)	1.21 (±0.15)	0.00 (±0.00)	0.00 (±0.00)
	P3C	17.60 (±11.91)	0.00 (±0.00)	0.00 (±0.00)	0.32 (±0.06)	0.00 (±0.00)	0.00 (±0.00)
	P3D	34.80 (±20.73)	0.00 (±0.00)	0.00 (±0.00)	0.42 (±0.06)	0.00 (±0.00)	0.00 (±0.00)

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APPENDIX C
STATISTICAL RESULTS

C-1: Foreshore Beach

Permanova Transects

Factors

Name	Abbrev.	Type	Levels
Time	Ti	Random	2

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Ti	1	1.6634E-2	1.6634E-2	0.28901	0.6141	9694
Res	20	1.1511	5.7555E-2			
Total	21	1.1677				

Permanova Shoot Density

Factors

Name	Abbrev.	Type	Levels
Time	Ti	Random	2
Patch Number	Pa	Random	4

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Ti	1	7022.5	7022.5	2.3351	0.2997	828
Pa	3	10151	3383.8	1.1252	0.2725	826
TixPa	3	9022.1	3007.4	4.1988	**0.0058**	9961
Res	32	22920	716.24			
Total	39	49116				

Pair Wise Shoot Density

Term 'TixPa' for pairs of levels of factor 'Time'

Within level 'P1A' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	10.156	**0.0067**	45

Within level 'P1B' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	0.48668	0.6823	29

Within level 'P2A' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	0.76277	0.7304	4

Within level 'P2B' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	2.0844	0.0724	57

Permanova Leaf Length

Factors

Name	Abbrev.	Type	Levels
Time	Ti	Random	2
Patch Number	Pa	Random	4

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Ti	1	9.1394	9.1394	1.611	0.2926	838
Pa	3	20.18	6.7268	1.1857	0.4464	840
TixPa	3	17.02	5.6732	8.8523	**0.0006**	9958
Res	32	20.508	0.64087			
Total	39	66.847				

Pair Wise Leaf Length

Within level 'P1A' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	10.132	**0.0065**	52

Within level 'P1B' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	0.50479	0.673	35

Within level 'P2A' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	0.35355	1	3

Within level 'P2B' of factor 'Patch Number'

Groups	t	P(perm)	Unique perms
2012, 2013	0.47814	0.5805	66

C-2: Quibray Bay Planting Areas

Permanova Shoot Density

Factors

Name	Abbrev.	Type	Levels
Treatment	Tr	Fixed	2
Site	Si	Random	4

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Tr	1	100	100	0.25388	1	3
Si(Tr)	2	787.78	393.89	3.8953	0.0271	8680
Res	32	3235.8	101.12			
Total	35	4123.6				

Pair Wise Shoot Density

Within level 'Transplant' of factor 'Treatment'

Groups	t	P(perm)	Unique perms
P1, P2	0.32381	0.7586	76

Within level 'Control' of factor 'Treatment'

Groups	t	P(perm)	Unique perms
C1, C2	3.4081	0.0001	58

Permanova Leaf Length

Factors

Name	Abbrev.	Type	Levels
Treatment	Tr	Fixed	2
Site	Si	Random	4

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Tr	1	578.4	578.4	1.0682	0.6693	3
Si(Tr)	2	1082.9	541.46	15.141	0.0001	9954
Res	32	1144.4	35.762			
Total	35	2805.7				

Pair Wise Leaf Length

Within level 'Transplant' of factor 'Treatment'

Groups	t	P(perm)	Unique perms
P1, P2	4.3982	0.0001	576

Within level 'Control' of factor 'Treatment'

Groups	t	P(perm)	Unique perms
C1, C2	0.77108	0.4579	241

C-3: Quibray Bay Experimental Sites

Permanova Shoot Density

Factors

Name	Abbrev.	Type	Levels
Time	Ti	Random	5
Treatment	Tr	Fixed	5
Site	Si	Random	3

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms	
Ti	4	1311.3	327.83	4.4469	0.0052	9951	RED
Tr	4	37865	9466.4	19.235	0.0001	9926	RED
Si(Tr)	10	1385.9	138.59	1.8799	0.0756	9935	RED
TixTr	16	5718	357.38	4.8477	**0.0001**	9934	
TixSi(Tr)	40	2948.8	73.72	1.6746	0.0158	9903	TERM NOT USED
Res	150	6603.3	44.022				
Total	224	55833					

Permanova Leaf Length

Factors

Name	Abbrev.	Type	Levels
Time	Ti	Random	5
Treatment	Tr	Fixed	5
Site	Si	Random	3

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms	
Ti	4	10356	2589.1	18.825	0.0001	9956	RED
Tr	4	63455	15864	11.858	0.0001	9909	RED
Si(Tr)	10	2975.3	297.53	2.1633	0.0421	9944	RED
TixTr	16	16830	1051.9	7.6483	**0.0001**	9919	
TixSi(Tr)	40	5501.3	137.53	1.5975	0.0235	9875	TERM NOT USED
Res	150	12914	86.091				
Total	224	1.1203E5					

Port Botany Post Construction Monitoring
Annual Report 2013

APPENDIX E

WATER QUALITY ANNUAL MONITORING REPORT 2013

Cardno
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Port Botany Post Construction Environmental Monitoring

Water Quality Annual Report 2013

EL1112046

Prepared for Sydney Ports Corporation

September 2013

Cardno
Shaping the Future

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A	30 June 2013	Andrew Bradford	JACB	Dr Peggy O'Donnell	POD
1	17 September 2013	Andrew Bradford	JACB	Dr Peggy O'Donnell	POD

Executive Summary

This report summarises the results of the Water Quality Monitoring Program from March 2012 to March 2013 and compares these results with earlier investigations carried out as part of the Port Botany Expansion pre-construction monitoring.

As part of the Port Botany Expansion Project, Sydney Ports has rehabilitated Penrhyn Estuary, located adjacent to the port expansion. Penrhyn Estuary is a small waterway of approximately 80 ha located to the north of Brotherson Dock which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978. As a result of the Port Botany Expansion, the tidal exchange of the estuary has been altered, primarily due to changes in the channel that links the estuary to Botany Bay between the new port terminal and Foreshore Beach. As a result of these changes, there is reduced flushing in Penrhyn Estuary and an associated potential for a reduction in water quality.

Pre-construction water quality monitoring was commissioned by SPC to investigate water quality conditions in the estuary and at control sites within Botany Bay, and to establish estuary flushing characteristics. The results of that monitoring were used to develop numerical models to predict post-construction water quality outcomes and are also used to form a baseline comparison for post-construction water quality monitoring.

As part of the Penrhyn Estuary Habitat Enhancement Plan (PEHEP), a water quality monitoring plan has been designed to monitor post-construction water quality and flushing within Penrhyn Estuary, using physicochemical water quality parameters. Analyses of these water quality parameters describe the effects of the Port Botany Expansion construction on estuarine water quality. These data will also be used to assess the potential for eutrophic conditions to form post-construction and to determine the altered recovery time and flushing rates of the Estuary post-construction.

Results of monitoring up to 27 months post-construction indicate that water quality outcomes in Penrhyn Estuary are suitable to support the habitats enhanced by the PEHEP. No indication of a potential for the formation of eutrophic conditions has been observed. The analysis of variance between pre and post-construction water quality has not identified any negative change in the post-construction water quality, although some parameters show some variance from pre-construction measurements. Trigger levels adopted from ANZECC (2000) guidelines have in some cases been exceeded, particularly for Total Suspended Sediments, although these exceedances have generally been associated with similar water quality conditions at control monitoring locations in Botany Bay outside Penrhyn Estuary. In general, ambient nutrient concentrations in Penrhyn Estuary have not exceeded predicted nutrient concentrations derived from numerical modelling of post-construction estuary conditions.

With due consideration of expected background variability of the monitored water quality parameters and the early stage of this monitoring program, water quality in Penrhyn Estuary is currently meeting the targets of the PEHEP.

There are no recommendations to alter the water quality monitoring program at this stage.

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Appendices

1 Introduction

1.1 Background

As part of the Port Botany Expansion Project, Sydney Ports has rehabilitated Penrhyn Estuary, located adjacent to the port expansion. Penrhyn Estuary is a small waterway of approximately 30 ha located to the north of Brotherson Dock which was artificially created during the reclamation of the Botany foreshore between 1975 and 1978. Since its creation, it has been utilised by a diverse group of migratory birds. The purpose of the rehabilitation works was to enhance the existing intertidal habitat and to expand the estuary as a long term habitat for migratory shorebirds. This involved the removal of mangroves, weeds and introduced species, the enhancement of existing saltmarsh and the creation of new saltmarsh habitat. An extensive area of fore dune was also levelled to create an intertidal feeding and roosting habitat for key species of migratory shorebirds that currently use the estuary, and to potentially attract a greater number of shorebirds upon completion. The design, methodology and ongoing maintenance for the estuary are outlined within the Penrhyn Estuary Habitat Enhancement Plan (PEHEP).

Due to the Port Botany Expansion works and associated habitat enhancement, tidal exchange within Penrhyn Estuary has been altered. Tidal flow to the enhanced Penrhyn Estuary now occurs through a channel that has been created between the new port terminal and Foreshore Beach.

Accordingly, the Port Botany Expansion Environmental Impact Statement (EIS) showed that there would be a reduction in flushing of Penrhyn Estuary, because exchange with Botany Bay would be limited by the channel. A potential, albeit unlikely, issue associated with reduced flushing is the eutrophication of the Estuary.

A Surface Water Quality Monitoring Plan (SWQMP) was implemented prior to construction in order to monitor the flushing of Penrhyn Estuary at that stage, using physicochemical water quality parameters, to assess the potential for eutrophic conditions to form.

The purpose of the PEHEP water quality monitoring is to monitor the Estuary water quality for a period of time post-construction to confirm that flushing of the Estuary is sufficient to prevent eutrophic conditions from forming and to ensure that the water quality is suitable to support the Estuaries various habitats.

Table 1 provides a summary of relevant events during the Port Botany expansion project.

Table 1 Timeframe for water quality monitoring and major habitat enhancement events in Penrhyn Estuary to April 2013

Activity	Date	Comments
Before Construction Survey 1	11 December 2003	*(Source: SPC 2003 and 2004)*
Before Construction Survey 2	20 January 2004	*(Source: SPC 2003 and 2004)*
Before Construction Survey 3	17 March 2004	*(Source: SPC 2003 and 2004)*
Before Construction Survey 4	22 April 2004	*(Source: SPC 2003 and 2004)*
Before Construction Survey 5	10 June 2004	*(Source: SPC 2003 and 2004)*
Before Construction Survey 6	12 August 2004	*(Source: SPC 2003 and 2004)*
Before Construction Survey 7	15 October 2004	*(Source: SPC 2003 and 2004)*
Construction	January - July 2008	Removal and relocation of sand dunes Turbidity monitoring buoys installed Water quality monitoring commenced Silt curtains installed Significant rainfall recorded in February
Construction	August 2008 – end March 2009	Mangrove removal by hand, weed clearing Saltmarsh transplanting No machine work in inner estuary (peak bird

Activity	Date	Comments
		season) CSD dredging in Botany Bay from September Water quality monitoring
Construction	End March - July 2009	Central estuary filled, sand augmented with mud and seagrass wrack Filamentous algal bloom (until September 2009) Sand stockpiled for later filling outer estuary (80,000 m^3) Dredging in Botany Bay complete April Water quality monitoring
Construction	August 2009 – March 2010	Saltmarsh area augmented (Nov) and planted (Dec) New boat ramp opened (Nov) Filling of outer estuary begins, less seagrass wrack than in inner estuary Tidal flow maintained throughout filling/contouring Water quality monitoring
Construction	April 2010 – July 2011	Further saltmarsh planting Flushing channel contoured using small dredger Filling outer estuary complete by end Dec 2010 Significant rainfall recorded in May, November and December 2011
After Construction Survey 1	15 March 2012 26 March 2012	Monthly surveys Significant rainfall recorded in March
After Construction Survey 2	26 April 2012	Monthly surveys
After Construction Survey 3	23 May 2012	Monthly surveys
After Construction Survey 4	21 June 2012	Monthly surveys Significant rainfall recorded in June
After Construction Survey 5	18 July 2012	Monthly surveys
After Construction Survey 6	11 September 2012	Monthly surveys
After Construction Survey 7	29 October 2012	Monthly surveys
After Construction Survey 8	3 December 2012	Monthly surveys
After Construction Survey 9	18 December 2012	Monthly surveys
After Construction Survey 10	24 January 2013	Monthly surveys
After Construction Survey 11	8 March 2013	Monthly surveys

1.2 Aims

The primary aim of the PEHEP water quality monitoring is to assess the adequacy of the altered flushing of the Estuary to achieve suitable water quality outcomes to maintain the aims of the overall plan. The post-construction water quality monitoring component of the PEHEP is to assess water quality outcomes and flushing within the Penrhyn Estuary, using physicochemical water quality parameters. Analysis of these water quality parameters describes the effects of the Port Botany Expansion construction on estuarine water quality. This data are used to assess the potential for eutrophic conditions to form post-construction and to determine the altered recovery time and flushing rates of the Estuary post-construction.

The PEHEP water quality monitoring design aligns with the pre-construction water quality monitoring such that interpretive analyses can be undertaken by comparing pre- and post-construction data.

The dry weather sampling provides reliable data to compare with the following:

> Water quality data conducted prior to the Port Botany Expansion project;

> Modelling predictions carried out to support the EIS; and

> ANZECC (2000) guideline trigger-values.

The wet weather sampling provides reliable data to compare the recovery of the Estuary from transient to ambient water quality with the flushing times (measured as e-folding time) for systems considered to be oligotrophic, mesotrophic and eutrophic. Therefore the focus of this sampling is to reliably capture data that describes the change in water quality in the Estuary from the peak post-storm concentrations towards normal ambient concentrations.

The results of the water quality monitoring are also to help inform and interpret the broader ecological processes in the estuary. Results of the ecological monitoring components of the PEHEP will also be supported by further analysis of the water quality results where required.

This report aims to present the data collected during the first year of post construction sampling, covering the period March 2012 to March 2013. Initial analysis of this data in comparison to pre-construction measurements will be made, along with comparison to stated target water quality outcomes and expected modelled outcomes as defined in the EIS. These comparisons will be further refined and strengthened as the monitoring program progresses and more data are collected.

1.3 Review of Existing Information

Numerous water quality investigations have been conducted within the Penrhyn Estuary varying by frequency, spatial resolution and depth of analyses. Below is a summary of existing water quality studies completed prior to the expansion of port facilities:

1.3.1 Botany Bay Council

The Council of the City of Botany Bay (CCB) has collected water quality data across the local government area (LGA) since 1996. Grab samples were collected and generally under dry weather conditions. Samples were collected between January 1996 and May 2000 at varying intervals. Parameters included a full physiochemical and nutrient suite, metals and hydrocarbons (Lawson & Treloar 2003). Due to limited spatial resolution within the estuary (only site 23 located in Penrhyn Estuary) this data set will not be utilised for comparison.

1.3.2 EPA Harbour watch

The NSW Environmental Protection Authority (EPA) program involved the sampling of a number of sites including Sydney Harbour, Pittwater and Botany Bay. Sampling occurred on a six day cycle and analysis for faecal contamination indicator organisms were conducted. Data are available from 1995 to 2000 at the foreshore beach site (Lawson & Treloar, 2003). Due to the limited scope of analyses this data set will not be utilised for comparison.

1.3.3 ORICA Voluntary Environmental Program

Orica has collected data within the catchment and the estuary as part of various regulatory and voluntary monitoring programs. Sampling events occurred between May 1999 and July 2001 on a quarterly frequency. Parameters included a physio-chemical suite, volatile chlorinated hydrocarbons and semi-volatile hydrocarbons (Lawson & Treloar, 2003). Due to the limited spatial resolution (only two sites within the Penrhyn Estuary – SW028 old boat ramp and SW048 new boat ramp) and lack of tidal sampling regime this data set will not be utilised.

1.3.4 Data Collected For Parallel Runway EIS

Studies associated with the preparation of the Environmental Impact Statement (EIS) for the Parallel Runway at Kingsford Smith Airport were conducted over a period of 1989-1993. Sampling of surface water quality was conducted at 11 sites within Botany Bay from February to May 1990. Parameters included physio – chemical, nutrients, metals, hydrocarbons and faecal coliforms (Lawson & Treloar, 2003). Due to the limited sampling period this data set will not be included for comparison.

1.3.5 Data Collected by Lawson & Treloar for Port Botany Expansion 2002

As part of the Port Botany Expansion water quality modelling, Lawson & Treloar on behalf of Sydney Ports Corporation conducted a diurnal surface water investigation within the Penrhyn Estuary and catchment. This study would provide details of any diurnal variability. The study was conducted on 6th June 2002 and recorded parameters included a full in-situ physio-chemical suite (Lawson & Treloar 2003). Due to the limited spatial distribution within the estuary (only one site actually within Penrhyn Estuary) and isolated sampling period this data set will not be utilised in data comparisons.

1.3.6 Estuary Nutrient Modelling by Lawson and Treloar 2003

As part of the Environmental Impact Statement (EIS) prepared for Sydney Ports Corporation, Lawson and Treloar Pty Ltd conducted numerical modelling of nutrient dynamics within Penrhyn Estuary. For this exercise the modelling package MUSIC was used with baseline water quality data provided from the above listings of available data. Using the MUSIC modelling package the impacts of estuary enclosure and enhancement were investigated. Results from the modelling package produced average dry weather concentrations of total nitrogen and total phosphorous, which indicate that there would be an increase in nutrient loads within the Penrhyn Estuary (Lawson & Treloar 2003). These predicted increased nutrient levels will be used for comparison on the post-construction water quality data.

1.3.7 Data Collected by Sydney Ports Corporation for Port Botany Expansion 2003-2004

As part of pre-construction monitoring, Thiess on behalf of Sydney Ports Corporation conducted dry weather water quality monitoring within Penrhyn Estuary. Water quality monitoring was designed to observe pre-construction water quality and flushing within Penrhyn Estuary, using physicochemical water quality and nutrient parameters.

Sampling was undertaken on 7 occasions between December 2003 and October 2004 (see **Table 1**) incorporating both in-situ and grab sampling techniques. During this monitoring exercise 8 different locations were used (D1 – D8). Sites D1 – D4 were directly located within Penrhyn Estuary while sites D7 and D8 were located to the northern part of Botany Bay and are used as reference sites (see Figure 1). For in-situ sampling a Yeokal 611 multi-parameter water quality sonde was utilised. The instrument was calibrated immediately prior to use and deployed from a vessel, where top, mid and bottom measurements were recorded. Recorded parameters included: conductivity, pH, dissolved oxygen (DO) and temperature.

Grab sampling of water is assumed to have been collected using Niskin type sampling bottles and sent to the laboratory for analysis. Samples were analysed by the NATA accredited ALS Environmental laboratory and included a full physiochemical and nutrient suite, metals and hydrocarbons.

The sampling of all sites was repeated twice to provide a description of water quality over both ebb and flood tide conditions for each sampling exercise. It should also be noted that sampling only occurred under ‘dry’ conditions, of which no rain was recorded in the 3 days prior to monitoring.

Due to the similar spatial distribution of sampling locations, sampling frequency and recorded parameters this data set will be used as the primary comparison to the current post-construction data presented, as discussed in Section 4.

Figure 1 Pre-Construction Water Quality Monitoring Locations (SPC 2004)

2 Methods

2.1 Sampling Design

2.1.1 Monitoring Locations

As shown on **Figure 2** there are six dry weather monitoring locations. These sampling locations have been selected to provide an appropriate spatial description of water quality throughout the Estuary.

Two of these sampling locations are in the northern part of Botany Bay and are to be used as reference sites (S5 and S6) because they are sufficiently removed from the immediate influence of Penrhyn Estuary to act as control sites. Samples collected at high water from sample locations S4, S5 and S6 are expected to provide a description of the ambient water quality conditions in Botany Bay. The purpose of sampling at locations S4 to S6 is to provide information on background nutrient concentrations in Botany Bay, because model predictions indicate that Bay nutrient levels will have a significant influence on Estuary nutrient levels post-construction.

Dry weather sampling within Springvale Drain (SD) and Floodvale Drain (FD) is also undertaken at the two locations shown on **Figure 2** as part of source characterisation. These locations correspond to previous pre-construction sampling within these drains.

Wet weather monitoring has not been conducted in this reporting period of March 2012 to March 2013 and so is not fully described. The wet weather sampling is to be conducted at locations S1-S4 only as this component of the monitoring is to specifically determine the flushing rate of the estuary and thus measurement of conditions at control sites and in the catchment for source characterisation is not required.

2.1.2 Indicators

The PEHEP monitoring has been designed to assess water quality following the completion of the Port Botany Expansion. Hence the selection of appropriate indicators required consideration of the following issues:

> Measurement of the potential for the formation of eutrophic conditions in Penrhyn Estuary;

> Comparison with existing data (pre-construction data);

> Practicality of sampling of certain parameters; and

> Availability of ANZECC (2000) guideline trigger-values.

The physicochemical and nutrient parameters provided in Table 2 are monitored as part of this PEHEP monitoring program. **Table 2** also provides the relevant ANZECC (2000) guideline trigger values for comparison. The adopted trigger values are for 'slightly disturbed estuaries in South-East Australia'. This classification was selected during the EIS development to closely align with the intended water quality outcomes required for the successful implementation of the PEHEP, and not as an assessment of the classification of Port Botany as a whole.

Table 2 Parameters to be Monitored and Corresponding ANZECC (2000) Trigger-Values

Parameter	Units	ANZECC (2000) Trigger-Value
Physicochemical		
Conductivity (salinity)	mS/cm	N/A
pH	pH units	7 to 8.5
Total Suspended Solids (TSS)	mg/L	6
Biological Oxygen Demand (BOD) (Ultimate)	mg/L	N/A
Dissolved Oxygen (DO)	mg/L	>6 (80 to 110% saturation)
Temperature	ºC	N/A

Parameter	Units	ANZECC (2000) Trigger-Value
		Guideline is comparative for change in time
Photosynthetically Active Radiation (PAR)	µmoles/ m^2/sec	N/A
Nutrients		
Total Nitrogen (TN)	mg/L	0.3
Total Phosphorous (TP)	mg/L	0.03
Chlorophyll a (chl-a)	µg/L	<5 (ANZECC guideline is <4 however detection limit for the baseline data set was 5 µg/L.)

The summary of the parameters to be monitored for all components of the water quality sampling are provided in **Table 3**. In-situ parameters are measured using a YSI 6600 multi-parameter sonde and grab water samples to be sent for laboratory analysis are collected using a submersible pump. Sample analysis is conducted by the NATA certified laboratories of ALS Environmental Group.

Table 3 Locations and Methods Used to Monitor Indicators

Sampling – Weather and Locations	Methods and Parameters to be Monitored	
	Vertically Profiled Using YSI 6600 Sonde	Mid-Depth Water Sample
Dry Weather Sampling – Sites S1 to S6	Conductivity, pH, DO, PAR, temperature	TSS, TN, TP, chl-a
Dry Weather Sampling – Sites SD and FD	Conductivity, pH, DO, temperature	TSS, BOD, TN, TP, chl-a
Wet Weather Sampling – Sites S1 to S4	Conductivity	Conductivity

Figure 2 Water quality monitoring sampling locations

2.2 Summary of Sampling Procedures

2.2.1 Field Preparations

Preparation of required equipment and supplies is completed following each sampling exercise to ensure that sufficient consumables are in stock and required maintenance tasks are carried out in time for the following sampling exercise. In particular, sufficient supplies of instrument calibration standards and water sample bottles are kept in stock to allow for two sampling exercises. The YSI 6600 multi-parameter sonde is calibrated the working day prior to each sampling exercise.

Dry weather sampling is scheduled in advance and as the date approaches conditions and forecasts are monitored to ensure that the sampling constraints are met. The constraints to sampling are as follows:

> Dry weather: no significant rainfall to be recorded at the Penrhyn Estuary rain gauge in the four days prior to sampling

> Wave and weather conditions to be suitable for safe navigation of the small water craft. In general this is decided based on forecast wind below 15 knot gusts and wave conditions in Botany Bay of under 0.5 metres significant wave height

> Holding times of water samples not to be exceeded before laboratory analysis. This is particularly important for analysis of chlorophyll-a samples which must be processed within 48 hours of sampling. Should sampling occur on a Friday, prior arrangements must be made with the ALS laboratory

In addition to the required equipment and consumables for sampling, all required safety equipment such as personal flotation devices (PFD's) are kept in good working order. Prior to sampling exercises, all required field documentation is prepared including toolbox safety forms, sampling checklists and chain of custody documentation for laboratory samples.

2.2.2 Vessel Based Sampling

Sampling of Sites 1-6 was conducted from one of Cardno's small water craft using two Cardno field personnel. The vessel is launched from the Foreshore Road boat ramp following a toolbox meeting and the sites are sampled consecutively with the following procedure used at each site:

> Site positions are checked against a handheld GPS unit

> Vessel is anchored to ensure the position is held during sampling. In the shallower estuary sites, the anchor is lowered carefully to limit disturbing sediment and the measurements do not commence until any disturbed sediment has been allowed to settle.

> The time and current wave and weather conditions are recorded on the field log sheet

> The YSI 6600 multi-parameter sonde is deployed from the side of the vessel and measurements are allowed to stabilise prior to a slow profile of the full depth being conducted. Measurements are recorded on the log sheet for near surface (approx. 0.2m depth), at mid depth, and near bed (approx. 0.5m above bed). Measurements from the full profile are stored on the instrument. The stability of parameters is monitored on a display unit during the profile.

> A submersible pump and non-contaminating hose is used to collect the grab water samples. The pump is lowered to mid-depth and run to allow more than three times the hose volume to be pumped prior to a composite sample being collected in a non-contaminating plastic bucket. The bucket is rinsed with the pumped water prior to the sample being collected. The laboratory supplied sample bottles are then filled from the composite sample.

> At one of the sites, selected at random prior to sampling, field replicate samples are collected from the same composite water sample.

> Water samples are stored in chilled eskies.

> Once all sites are sampled, the vessel is demobilised at the boat ramp and the sampling personnel drive to the Floodvale and Springvale drain sites.

> Following drain sampling, the next round of sampling is conducted in the same manner at Sites 1-6 once the tide has reached the next stage (to cover both high and low tidal stages in each sampling exercise).

> All sampling is conducted in daylight hours to ensure safety and also to provide conditions suitable for measurement of PAR.

2.2.3 Drain Sampling

The drains were accessed via McPherson Road by vehicle.

> Each drain is inspected and if sufficient water flow is observed and with sufficient depth to collect water samples, sampling takes place. If water is ponding or no water is present in the drain then no sampling takes place. This is to ensure that only samples that are representative of dry weather catchment inflows to the estuary are recorded.

> The YSI 6600 multi-parameter sonde is allowed to stabilise in the drain water before measurements are logged. Once the parameters are stable, a series of measurements are recorded over a period of approximately two minutes and average values are recorded on the log sheet.

> Water grab samples are collected in a rinsed bucket and transferred to the laboratory supplied sample bottles. Care is taken to ensure sediment is not stirred up during sampling.

> Water samples are labelled and stored in chilled eskies.

2.2.4 Sample Handling

Water samples were labelled with laboratory supplied labels and the sampling locations and times are recorded during the sampling exercise. Laboratory chain of custody documentation was completed following each sampling exercise and signed off by the laboratory courier on receipt of the samples. Samples were kept in chilled eskies during and following the sampling exercise and sufficient ice was used to ensure samples were kept below the recommended temperature (less than 4°C) until arrival at the ALS laboratory.

2.2.5 Data Management

Following a sampling exercise, all log sheets were reviewed for completeness and archived. Data were uploaded from the YSI 6600 multi-parameter sonde and archived. Post processing of the in-situ profile measurements is carried out using MATLAB scripts to average measurements into discrete depth bins. These depth averaged bins are then used to extract final near surface, mid-depth and near-bed measurements for each parameter. During this procedure data spikes are removed and data affected by interference from bed sediment is discarded.

Results from the laboratory analyses are reviewed on receipt and archived.

Summary data spread sheets of final results were updated following each sampling exercise to ensure all data were collated and maintained in a central location.

2.3 Sampling Dates

Dates of dry weather water quality monitoring carried out by Cardno during this reporting period of March 2012 to March 2013 are listed in **Table 4** below.

Table 4 Dry Weather Water Quality Monitoring Summary

Date of Sampling	Sites Sampled	Notes
15 March 2012	S1-6 FD	Low water sampling only due to vessel issue No flow in Springvale Drain
26 March 2012	S1-6	Completed high water sampling from 15 March
26 April 2012	S1-5 FD, SD	No sampling at S6 due to high winds
23 May 2012	S1-6 FD	No flow in Springvale Drain
21 June 2012	S1-6 FD, SD	No variation to planned sampling
18 July 2012	S1-6 FD	S6 only sampled on high tide No flow in Springvale Drain
11 September 2012	S1-6	No flow in either Springvale or Floodvale Drains
29 October 2012	S1-6	No flow in either Springvale or Floodvale Drains
3 December 2012	S1-6 FD	No flow in Springvale Drain
18 December 2012	S1-6	No flow in either Springvale or Floodvale Drains
24 January 2013	S1-6	S6 only sampled on high tide due to strong winds during low tide sampling No flow in either Springvale or Floodvale Drains
8 March 2013	S1-6 FD	No flow in Springvale Drain

3 Summary of Results

Full listings of all parameters can be found in **Appendix A**. The following data summaries present data as 'box and whisker' plots which present data as follows:

> The centreline of the box is the median recorded value;

> The top and bottom of the box represent the 25th and 75th percentiles;

> The top and bottom lines of the whiskers are the most extreme data values not considered outliers;

> Any possible outliers are marked automatically with a small cross if the value is +/- 2.7 times the variance of the dataset.

Trends in data are discussed in the following sections, along with consideration of causes for observed outliers.

3.1 In-situ Parameters

3.1.1 Water Temperature

As shown in **Figure 3**, water temperature measurements have varied over the course of the reporting period, as is expected with seasonal variations. The greater variance is strongly related to depth at the sampling site, with temperature variations increasing inversely with depth as shallower depths allow greater influence due to atmospheric conditions. Median temperatures for all sites are similar at approximately 19 degrees C.

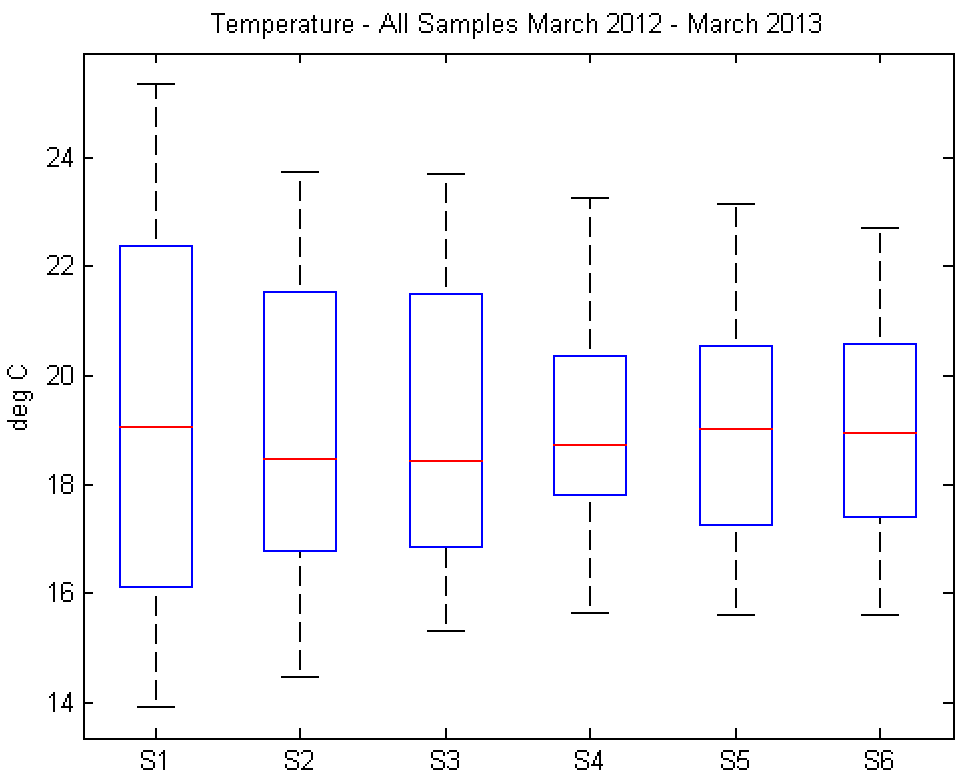

Figure 3 'Box and whisker' plot of all temperature samples, Sites 1-6

3.1.2 pH

Measurements of pH for the reporting period are presented in **Figure 4**. As expected, there is some variation in pH measurements according to relative influence of freshwater catchment inflows at the sampling location. The shallow depth and proximity to catchment outflows at Site 1 produces the higher variance towards neutral pH conditions. Similarly, the relative proximity of Sites 5 and 6 to the Botany Bay heads produces a much stronger correlation to ambient ocean pH levels. The low pH outlier at Site 1 was measured in March 2012 and may be associated with high recorded rainfall during that month and thus expected higher catchment inflows to the estuary. As such, the record has been retained in the dataset.

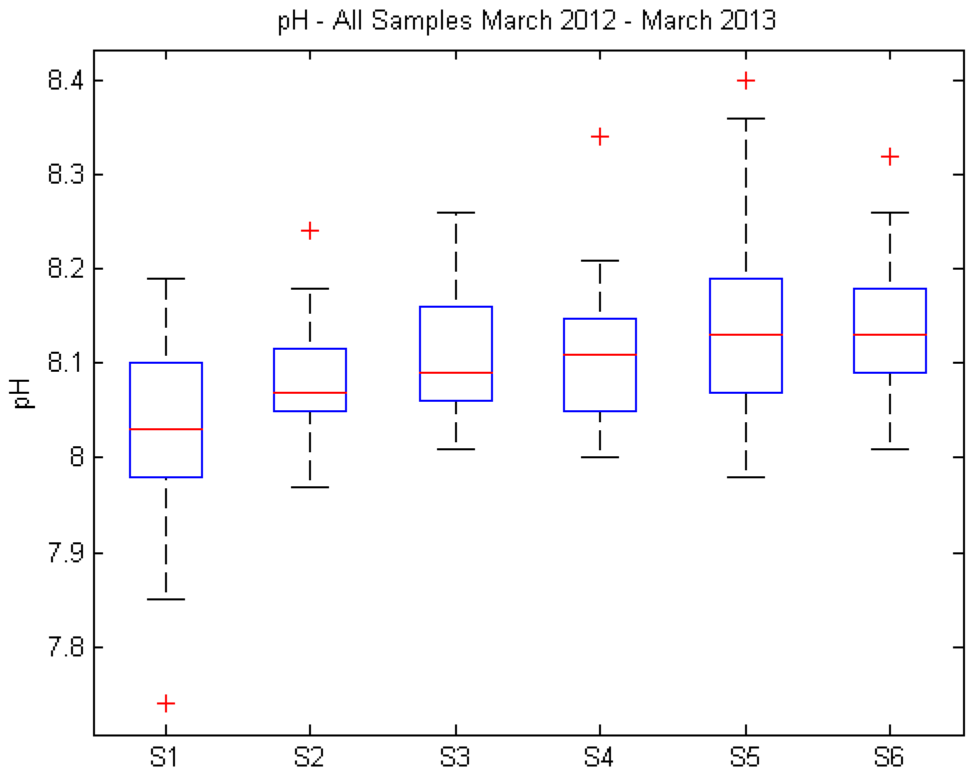

Figure 4 'Box and whisker' plot of all pH samples, Sites 1-6

3.1.3 Dissolved Oxygen

Dissolved Oxygen presented as percentage saturation is shown in **Figure 5**. In general, the measurements have been consistent across all sites during this reporting period. Site 4 is likely influenced by being at the edge of the dredged berth pocket, and thus dissolved oxygen is lower due to this site's deeper depth of approximately 10 metres LAT. The high outliers at Sites 1, 2, 5 and 6 appear erroneous; however, these measurements are likely the result of relatively rapid diurnal temperature changes causing a reduction in the ideal oxygen saturation levels. These measurements were recorded in December 2012 at a time when cool ocean temperatures and high diurnal atmospheric temperature ranges allow low night water temperatures to develop which then warm during the daytime. Non-ideal atmospheric oxygen transfer rates allow oxygen saturation to remain high during these temperature rises. Calibration records of the instrument prior to and following the December 2012 sampling show an acceptable drift in the calibration of the DO sensor. Overall, the DO measurements indicate that the estuary has not been susceptible to eutrophic conditions forming during this monitoring period.

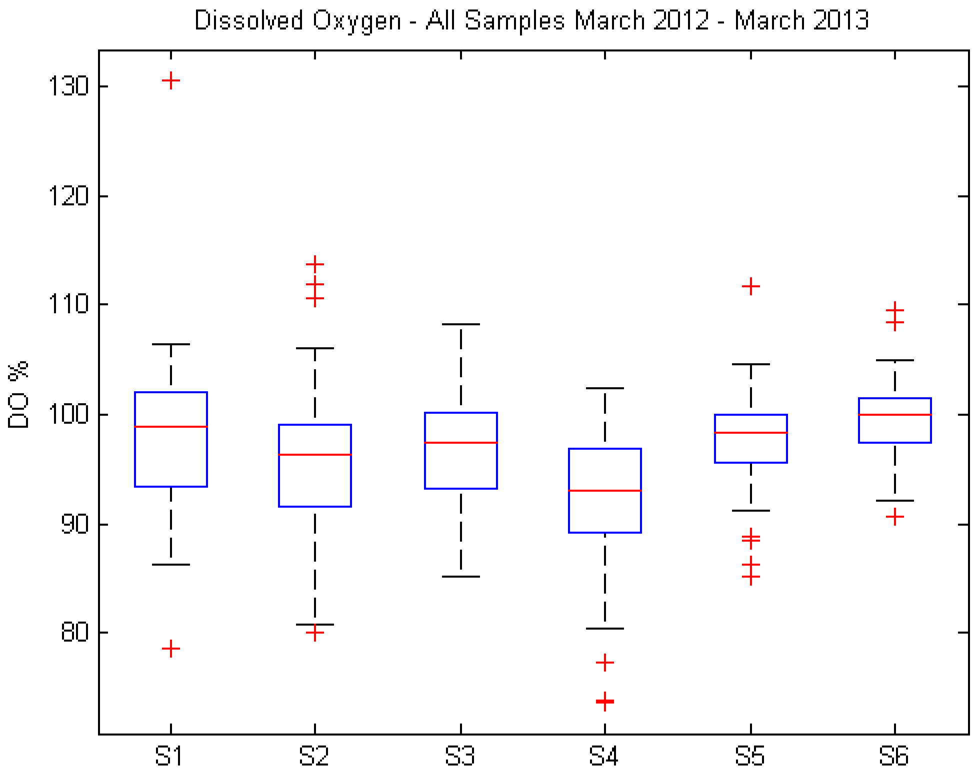

Figure 5 'Box and whisker' plot of all DO samples, Sites 1-6

3.1.4 Electrical Conductivity

Measurements of electrical conductivity are shown in **Figure 6**. As expected, the estuary sites show greater variation in EC due to the greater influence of freshwater inflows from the catchment. The control sites all show high correlation to ocean salinities. Site 1 had the highest range of EC and the lowest median value, indicating that the upper estuary may have flushing times greater than four days (the period of dry weather required prior to monitoring exercises being conducted), although this may also be due to surface layers of lower salinity formed in the shallow upper estuary waters by freshwater inflows. The higher density of saline water means that low salinity catchment inflows can form a surface layer in calm weather conditions when mixing is low. The flushing of the estuary will be investigated further during the wet weather monitoring exercises.

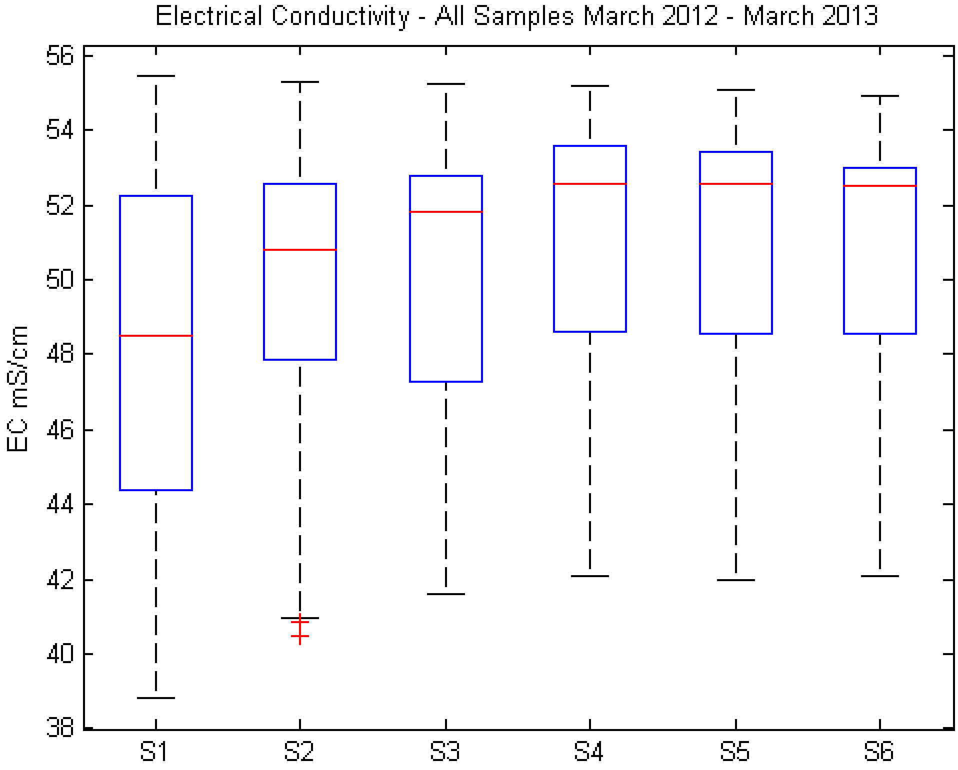

Figure 6 'Box and whisker' plot of all EC samples, Sites 1-6

3.1.5 Photosynthetically Active Radiation

Photosynthetically Active Radiation (PAR) has been measured during all sampling and results are summarised in **Table 5**. These measurements have not been further analysed at this stage of the monitoring as the primary aim of this parameter is to inform results from other monitoring components of the PEHEP. Particularly, poor outcomes in the Seagrass or Benthos monitoring programs may require assessment of the PAR to determine the impact of light attenuation on those habitats. No pre-construction data are available for comparison and no target levels have been determined. In general, PAR has only been observed to consistently reach extinction (no available PAR) at Site 4 due to the depth at this site. The shallow depth at Site 1 does not allow suitable profiles to be conducted to provide useful PAR measurements.

Table 5 Summary of PAR measurements

	Photosynthetically Active Radiation (PAR) µmoles/ m^2/sec		
Site	**Minimum**	**Maximum**	**Average**
S1			
S2	38	2121.8	658.96
S3	3	2251.7	502.97
S4	0	2209	206.71
S5	2	1854	350.89
S6	18.57	1931	412.05

3.2 Laboratory Analysed Indicators

Results for the parameters Total Nitrogen (TN), Total Phosphorous (TP), Total Suspended Solids (TSS) and chlorophyll-a are taken from the results of laboratory analysis of grab water samples. This analysis was conducted by ALS Environmental. All parameters have a Limit of Reporting (LOR) which is the lowest value able to be detected with confidence by the analysis procedure for that parameter. Results in this section presented at the LOR are either a measurement at the LOR value, or are reported by the laboratory as "<LOR".

3.2.1 Total Nitrogen

Total Nitrogen measurements are shown in **Figure 7**. The median value for all sites is below the LOR of 0.1mg/L for the laboratory analysis. Sites 1 and 4 show the greatest variability in the TN measurements, although consistently low concentrations are being measured. The highest outliers were measured in the estuary, the highest being from sampling in March 2012 which followed higher than average rainfalls during the start of 2012. The slight trend for higher measurements at Site 4 may indicate the influence of outflows from the Millpond and Engine Ponds catchments on this site. The overall trend is for low nitrogen levels in both estuary and control sites.

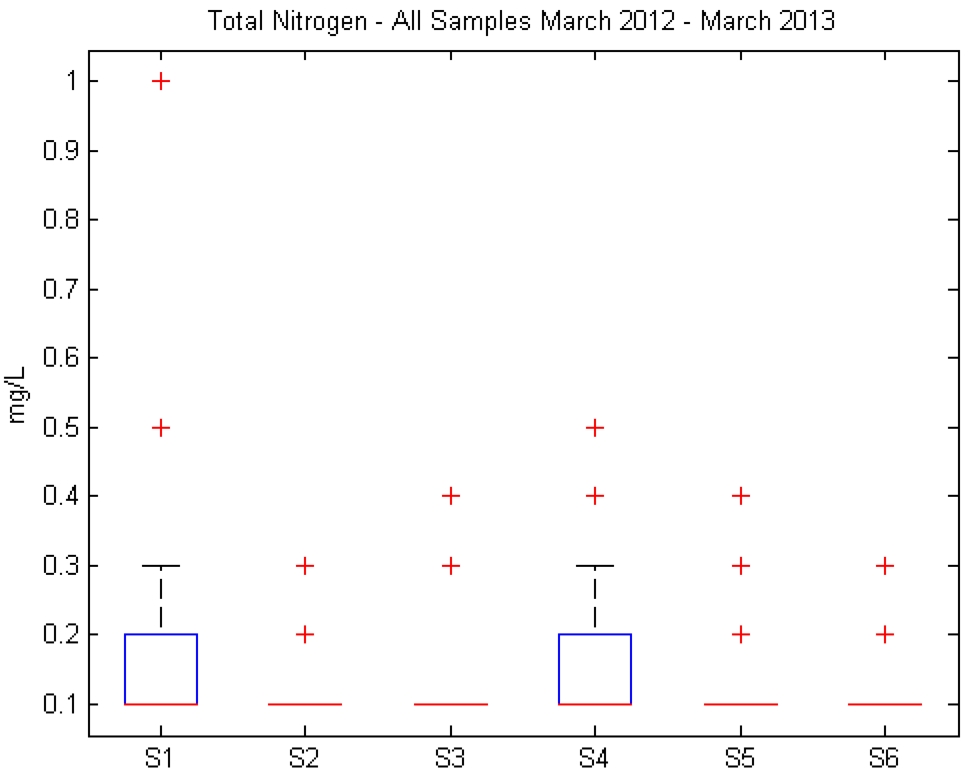

Figure 7 'Box and whisker' plot of all TN samples, Sites 1-6

3.2.2 Total Phosphorous

Total Phosphorous measurements are shown in **Figure 8**. As for Total Nitrogen, the median values for all sites is below the LOR of 0.01mg/L for the laboratory analysis. The outlier of 0.56mg/L at Site 1 was measured in March 2012, which was also the highest TN measurement at this site. Again, this may be attributed to higher than average rainfalls during the start of 2012. The high value at Site 3 was also measured at this time. There is no indication of an overall trend for the TP measurements, with all sites showing consistently low readings.

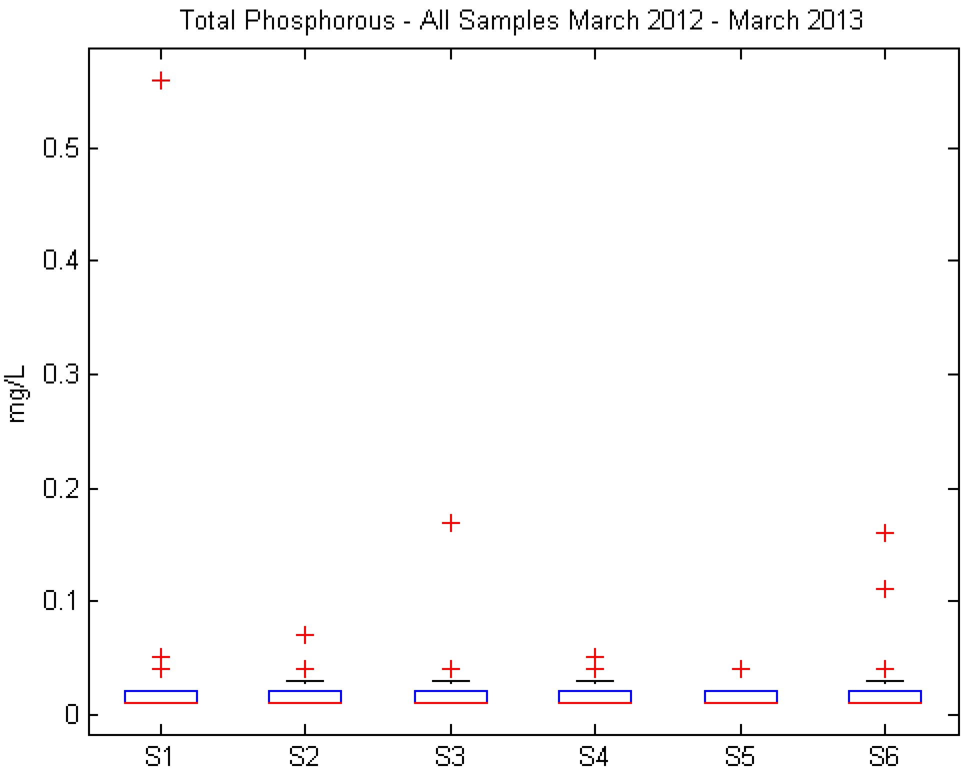

Figure 8 'Box and whisker' plot of all TP samples, Sites 1-6

3.2.3 Total Suspended Solids

Total Suspended Solids results are shown in **Figure 9** and show high variability which is expected for this parameter. The median value for all sites is 10mg/L or less. Site 6 shows the lowest variability and lowest median and this is likely due to the proximity of this site to the entrance of Botany Bay and thus the influence of ocean conditions. There is no clear trend for estuary sites to record higher TSS than control sites, although Site 4 may be influenced by inflows from the Engine Pond and Mill Pond catchments. Site 3 recorded the highest range of measurements (excluding the outlier at Site 4) and this may be due to the expected higher tidal currents in the Penrhyn Estuary channel generating higher potential for sediment resuspension. However, the lower median value at Site 3 does not strongly support this assumption.

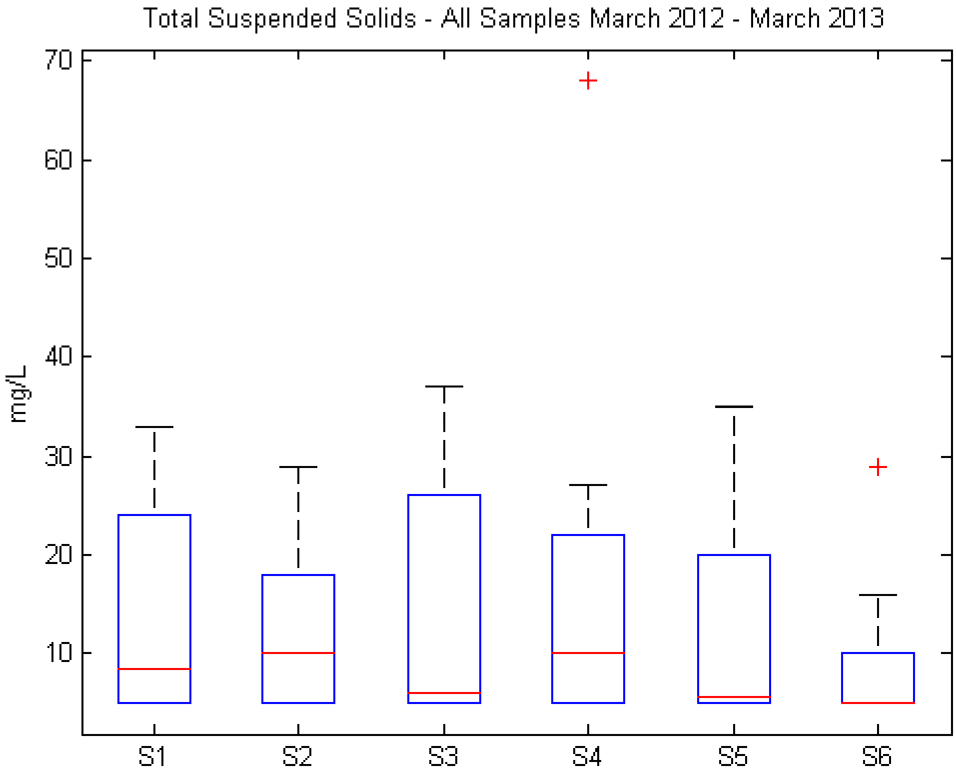

Figure 9 'Box and whisker' plot of all TSS samples, Sites 1-6

3.2.4 Chlorophyll-a

Chlorophyll-a measurements are presented in **Figure 10** and all sites have a median value at the LOR of the laboratory analysis. There is no trend for estuary sites to report higher values than control sites, and no sites show any consistently elevated values. The outlier of 36 mg/m^3 at Site 3 corresponds to the July 2012 sampling and no observed conditions during or prior to that monitoring provides a likely explanation for a high reading.

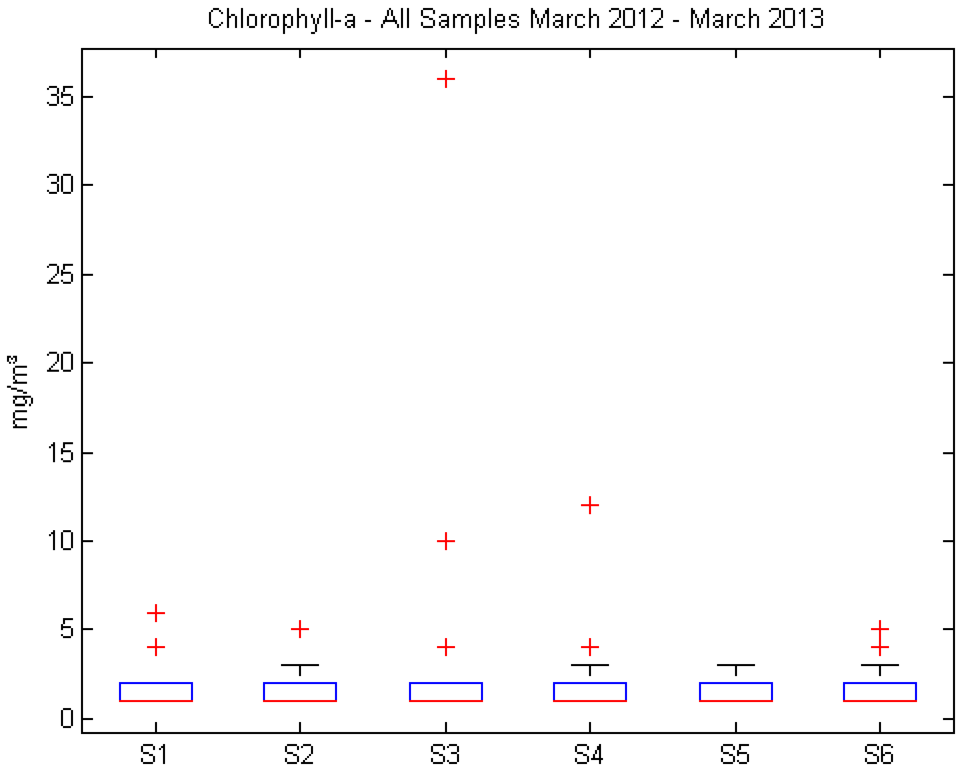

Figure 10 'Box and whisker' plot of all chlorophyll-a samples, Sites 1-6

4 Data Analysis

4.1 Analytical Methods

4.1.1 Comparison of Pre and Post Construction Water Quality Monitoring

Univariate permutational analyses of variance using PRIMER 6.0 (PERMANOVA+) were used to test for environmentally significant differences in the water quality parameters measured between Pre-Construction and Post-Construction periods. The pre-construction data set used is for the period December 2003 to October 2004 and includes results from seven sampling exercises completed for SPC. Only data comparable with the post-construction monitoring has been used in this analysis and full listings of the pre-construction data used are provided in Appendix B. Post-construction data are taken from Cardno's monitoring exercises conducted from March 2012 to March 2013. Factors in each univariate PERMANOVA were:

> Phase (fixed, orthogonal) – 2 levels (Pre-construction and Post-construction);

> Treatment (fixed, orthogonal) – 2 levels (Impact and Control);

> Tide (fixed, orthogonal) – 2 levels (High and Low) and

> Site (random, nested within Treatment) – 3 sites nested within Impact and 2 sites nested within Control.

The four-factor PERMANOVA used Euclidean dissimilarity matrices with unrestricted data permutation methodology applied. While pooling of lower-level terms with the 'Residual' term was done where appropriate (i.e. if *p*-perm of pooled term was ≥ 0.25), results for both the pooled and the unpooled versions were presented where applicable. Where a term (factor or interaction) was significant at *p*-perm ≤ 0.05, pair-wise permutational tests were used in *post hoc* analyses to identify between which levels of factors or interaction strata were statistically different.

It should be noted that due to different units of measurement for DO (mg/L pre-constructions and % saturation post-construction) this parameter was not compared using the phase factor.

Site 4 has been excluded from this comparison due to the significant change to the depth at this site between pre and post-construction conditions. As this site is intended as a measurement of ambient conditions close to the estuary, this site remains useful as a comparison with pre and post-construction measurements, but not when comparing between these conditions.

Tabulated results of the PERMANOV univariate analyses are provided in Appendix C.

4.1.2 Comparison to ANZECC Guideline Trigger Values

A direct comparison of the measured parameters with the relevant ANZECC trigger values described in Table 2 will be presented and discussed.

4.1.3 Comparison to Modelled Nutrient Concentrations

As discussed in Section 1.3.6, modelling was conducted during the preparation of the Port Botany Expansion EIS using the MUSIC numerical modelling package (Lawson and Treloar 2003). This modelling included ambient nutrient concentrations in Penrhyn Estuary for the post-construction estuary configuration. From this modelling, an average ambient estuary concentration of Total Nitrogen was predicted to be 0.15 mg/L and Total Phosphorous of 0.015 mg/L. These values will be used as an additional comparison for the measured results. Due to the nature of the modelling assumptions, the high and low water measurements during each sampling exercise will be averaged to more closely correlate to the average ambient conditions described by the modelling process.

4.2 Results

4.2.1 pH

There is a significant Phase x Treatment interaction for pH irrespective of Tide. Pairwise comparisons revealed that the mean (±SE) pH levels at Control locations was higher during post-construction (8.13 ±

0.01) compared to pre-construction (8.09 ± 0.02) Phase irrespective of Tide as shown in **Figure 11**. Pairwise comparisons revealed no difference in the mean pH levels at the Impact location between Phases irrespective of Tide.

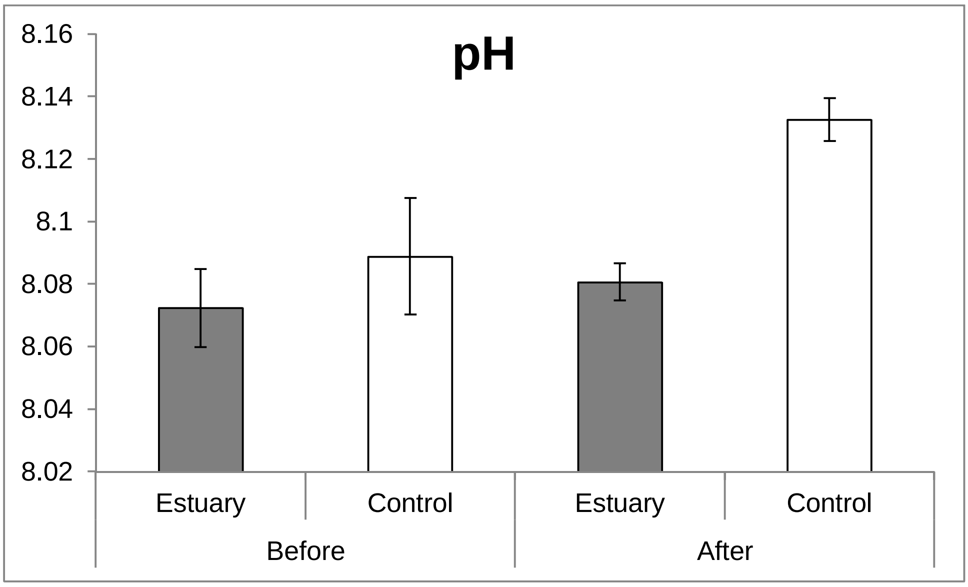

Figure 11 Average pH pre and post-construction showing standard error for estuary and control sites

4.2.2 Dissolved Oxygen

Treatment or Tide did not significantly influence the concentrations on DO post-construction shown in **Figure 13**. In contrast, Treatment did significantly influence concentrations of DO pre-construction with mean DO levels (±SE) significantly higher in Control Sites (7.47mg/L ± 0.25) than Estuary Sites (7.00mg/L ±0.25) shown in **Figure 12**. This indicates a greater difference between DO measurements between the Estuary and Botany Bay during pre-construction monitoring. The conversion of DO measurements between mg/L and percentage saturation is not trivial and so direct comparison of phase factor was not used. However, the DO readings both pre and post construction indicate that both the estuary and bay waters are well oxygenated.

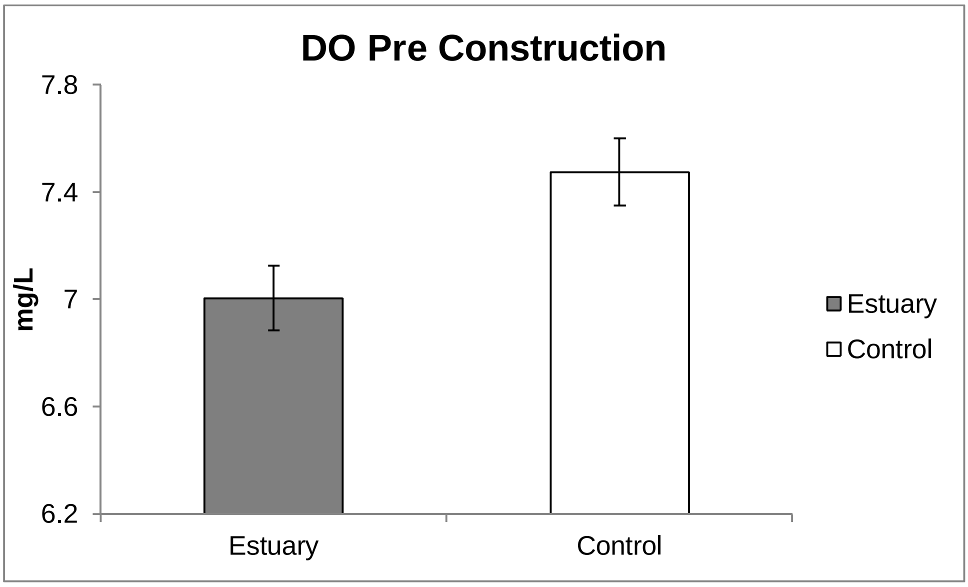

Figure 12 Average DO pre-construction showing standard error for estuary and control sites

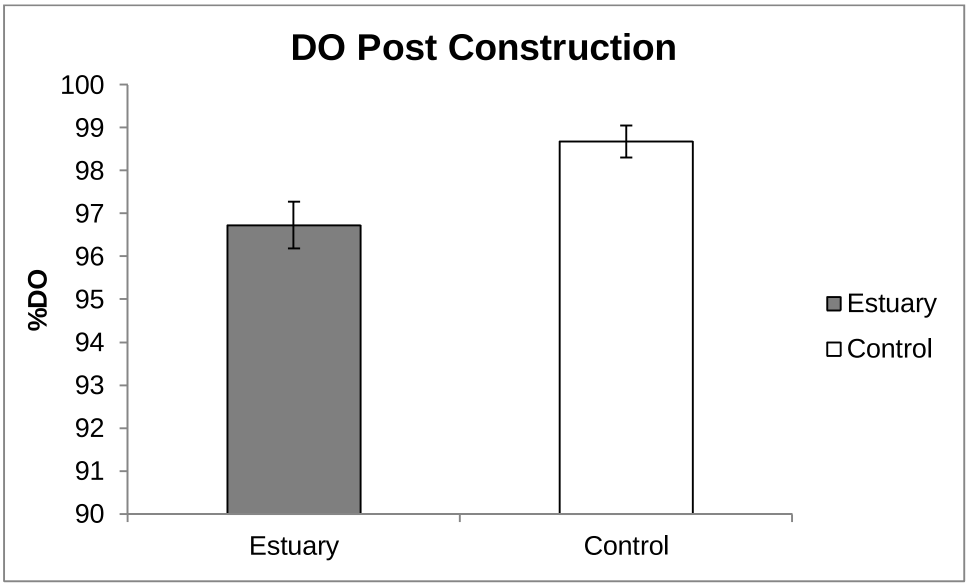

Figure 13 Average DO post-construction showing standard error for estuary and control sites

4.2.3 Electrical Conductivity

There are no significant Phase x Treatment interactions and no significant differences among Treatments (irrespective of Phase and Tide) or Tide (irrespective of Phase and Treatment) for measured EC. Mean EC levels (±SE) shown in **Figure 14** were significantly lower during post-construction (49.8mS/cm ±0.3) compared to pre-construction (57.9mS/cm ± 0.2) irrespective of Tide or Treatment. The pre-construction readings appear higher than expected for this environment, and there is possibly an instrumentation issue in the pre-construction data. Both data sets show higher EC in the control sites as is expected.

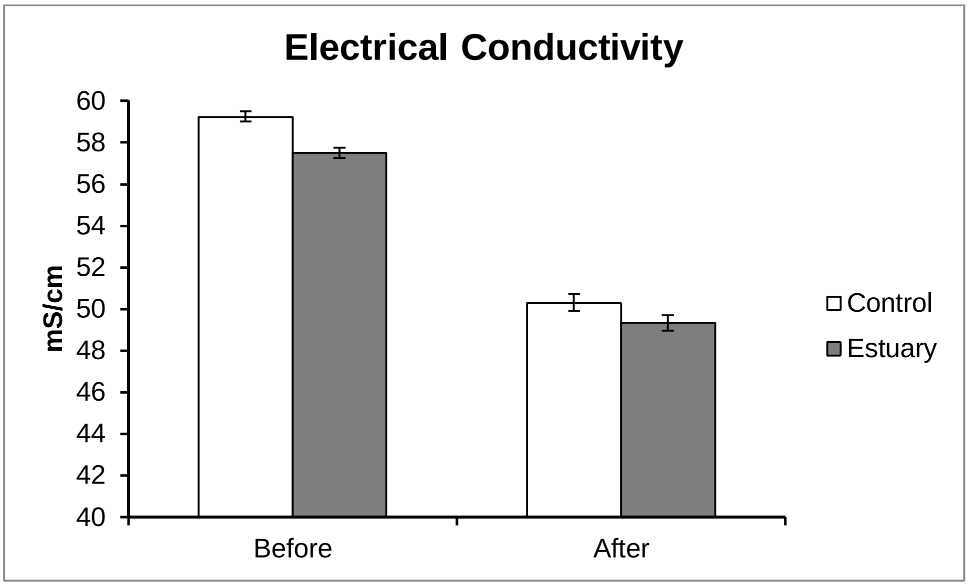

Figure 14 Average EC pre and post-construction showing standard error for estuary and control sites

4.2.4 Total Nitrogen

Phase, Treatment or Tide did not significantly influence the concentrations of TN as shown in **Figure 15**. There was also no significant Phase x Treatment interaction indicating that TN has not changed between pre and post-construction Phases at the estuary or control locations irrespective of Tide.

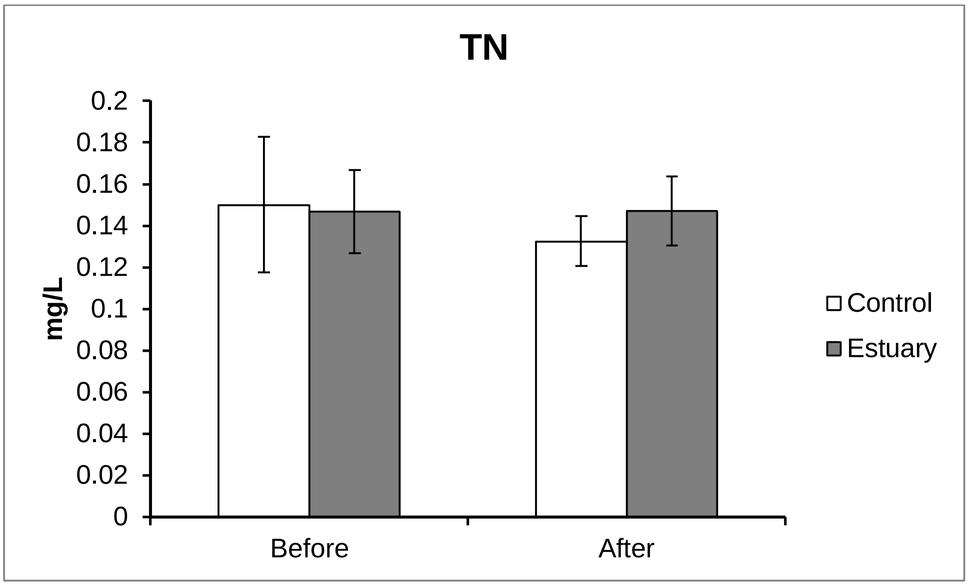

Figure 15 Average TN pre and post-construction showing standard error for estuary and control sites

4.2.5 Total Phosphorous

Phase, Treatment or Tide did not significantly influence the concentrations of TP as shown in **Figure 16**. There was also no significant Phase x Treatment interaction indicating that TP has not changed between pre and post-construction Phases at the estuary or control locations irrespective of Tide.

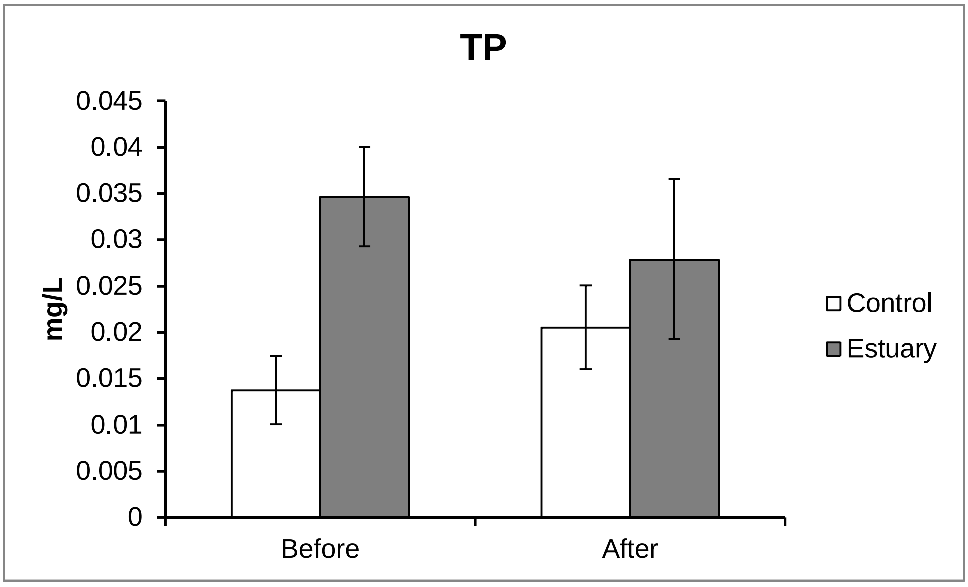

Figure 16 Average TP pre and post-construction showing standard error for estuary and control sites

4.2.6 Total Suspended Solids

For TSS there were no significant Phase x Treatment interactions and no significant differences among Phase (irrespective of Treatment and Tide) and Treatment (irrespective of Phase and Tide). TSS concentrations differed significantly between high and low tide as shown in **Figure 18**. During high tide, mean TSS concentrations (±SE) were significantly higher (14.4mg/L ± 1.2) compared to low tide (11.1mg/L ± 0.9) irrespective of Phase or Treatment, indicating a higher impact from flood currents on sediment suspension than ebb currents. Control sites in pre-construction did show higher average TSS than estuary sites, in contrast to post-construction measurements (as shown in **Figure 17**), although this relationship was not significant in the analysis.

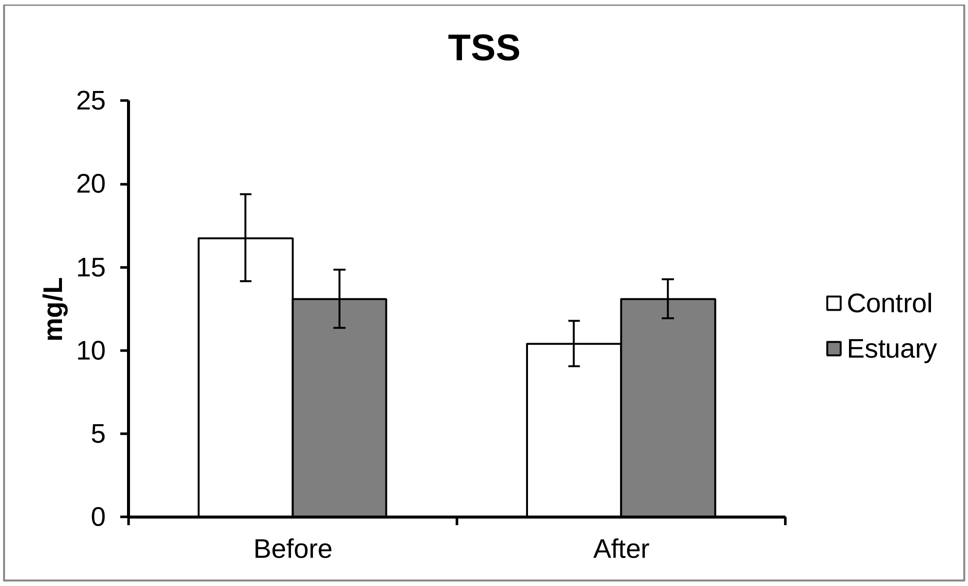

Figure 17 Average TSS pre and post-construction showing standard error for estuary and control sites

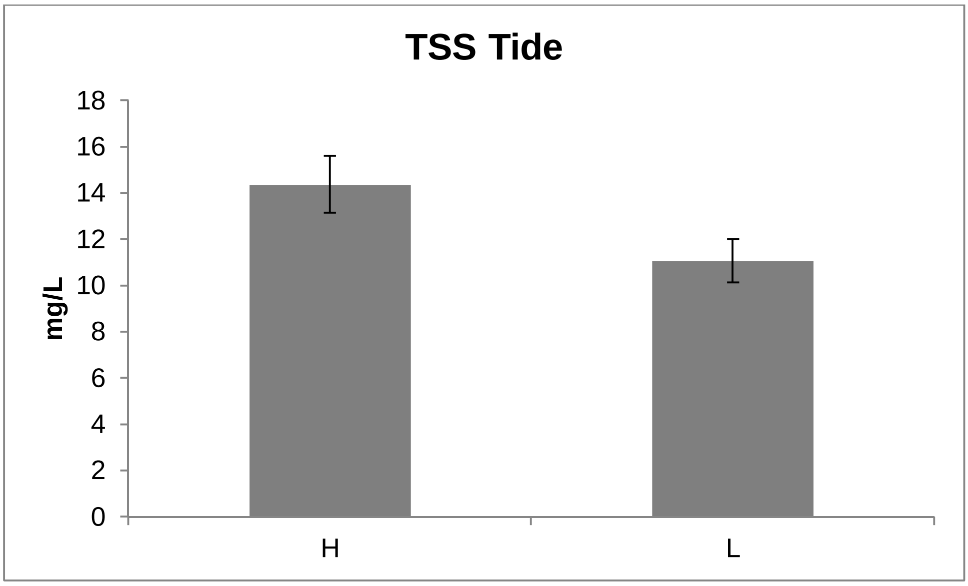

Figure 18 Average TSS including pre and post-construction showing standard error for high and low tide measurements

4.2.7 Chlorophyll-a

Phase, Treatment or Tide did not significantly influence the concentrations of Chlorophyll-a as shown in **Figure 19**. There was also no significant Phase x Treatment interaction indicating that Chlorophyll-a concentrations have not changed significantly between pre and post-construction Phases at the estuary or control locations irrespective of Tide.

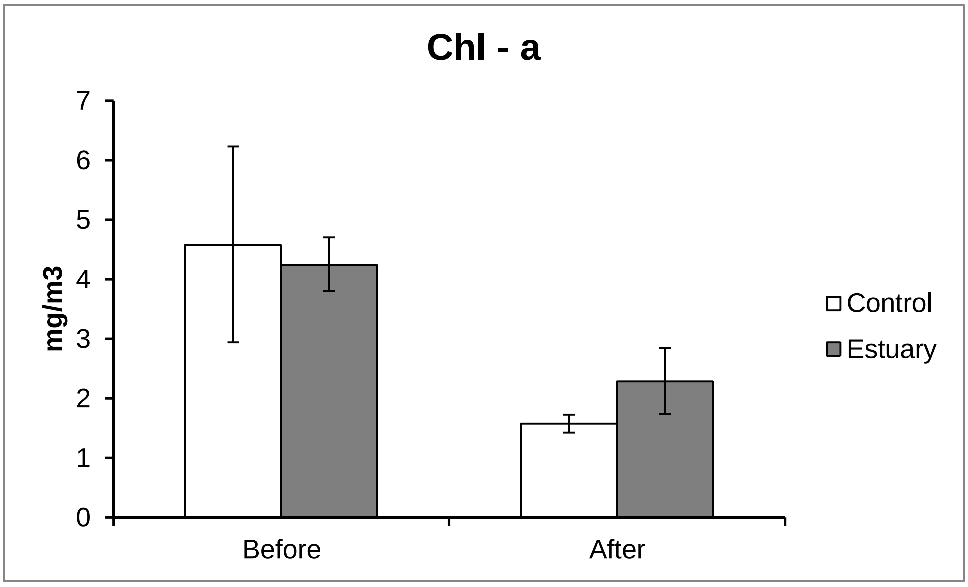

Figure 19 Average Chl-a pre and post-construction showing standard error for estuary and control sites

4.2.8 Summary of ANZECC Trigger Value Exceedances

Table 6 summarises exceedances of ANZECC trigger values for all parameters with defined triggers. All individual measurements from the post-construction monitoring from March 2012 to March 2013 are used for this comparison. All parameters, with the exception of pH, recorded some exceedances.

Table 6 Measured Exceedances of ANZECC (2000) Trigger-Values

Parameter	Total Samples	Total Exceedances	Exceedances Sites 1-3	Exceedances Sites 4-6
Physicochemical				
pH	330	0	0	0
Total Suspended Solids (TSS)	129	64	36	28
Dissolved Oxygen (DO)	330	4	1	3
Nutrients				
Total Nitrogen (TN)	129	5	3	2
Total Phosphorous (TP)	129	20	11	9
Chlorophyll a (chl-a)	129	4	3	1

Only TSS records a significant proportion of records over the trigger value with approximately half of all records exceeding the trigger of 10 mg/L. Estuary sites (Sites 1-3) record slightly more exceedances than Botany Bay control sites (Sites 4-6), although during some sampling exercises Site 6 was unable to be sampled due to high wind and wave conditions in Botany Bay. These conditions are expected to produce higher TSS concentrations so this may bias the comparison of estuary and control exceedances. Given the strong influence of the ambient Botany Bay conditions on the water quality within the estuary, the exceedances of TSS are not considered a flag for the development of poor water quality outcomes as a result of the Port Expansion works. Results of the ecological monitoring, particularly the Seagrass monitoring, will be considered to assess the influence of sedimentation and light attenuation on any identified negative outcomes in those monitoring results.

Total Phosphorous also recorded a number of exceedances, accounting for approximately 15% of records. As for TSS, these TP exceedances have been recorded in both estuary and control sites at similar rates. Thus these exceedances are not considered a significant negative water quality outcome at this stage of monitoring.

The exceedances for DO, Chlorophyll-a and TN are not considered to be significant due to the low proportion of exceedances in these data sets. The trend for these parameters, as discussed in Section 3, is for a trend of low measurements.

4.2.9 Summary of Average Nutrient Concentrations against Modelled Predictions of Concentrations

Figure 20 shows average Total Nitrogen concentrations and **Figure 21** shows average Total Phosphorous concentrations for each sampling exercise during post-construction monitoring between March 2012 and March 2013. Shown in these plots is the ANZECC trigger value adopted for these nutrient parameters and the results of the modelled nutrient concentrations for the post-construction estuary configuration. As discussed in Section 3.2.1 and 3.2.2, measurements have trended below the LOR for the laboratory analysis of these nutrient concentrations.

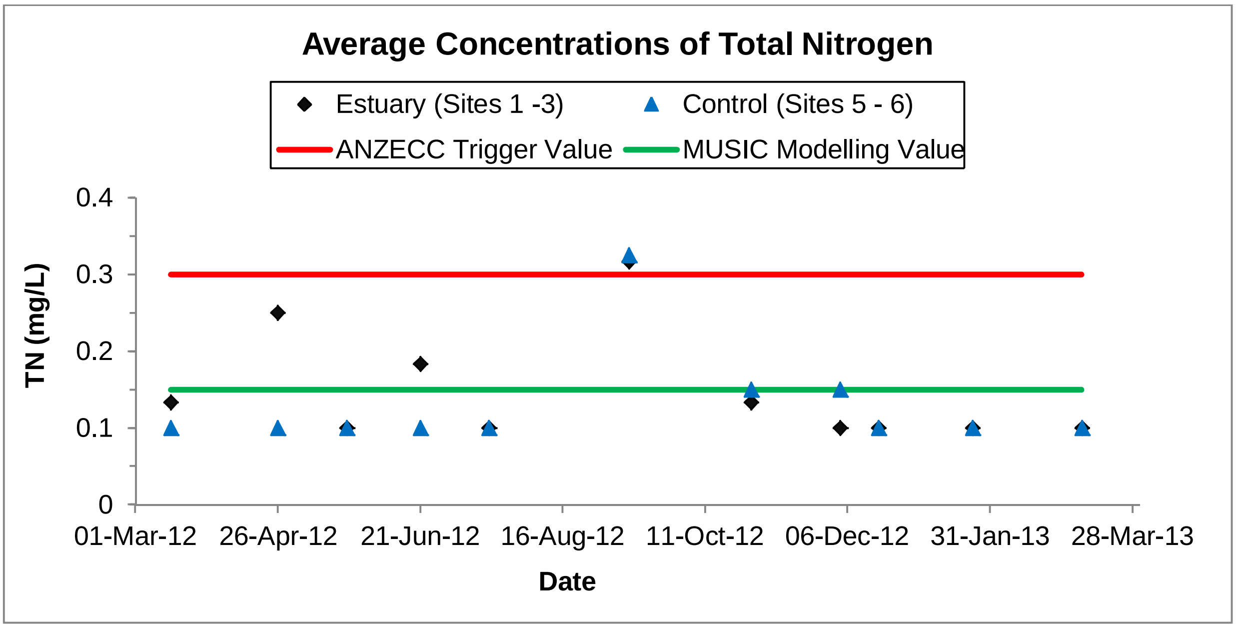

Figure 20 Average Concentration of Total Nitrogen for each Sampling Event, compared to ANZECC Trigger and Modelled Ambient Concentration

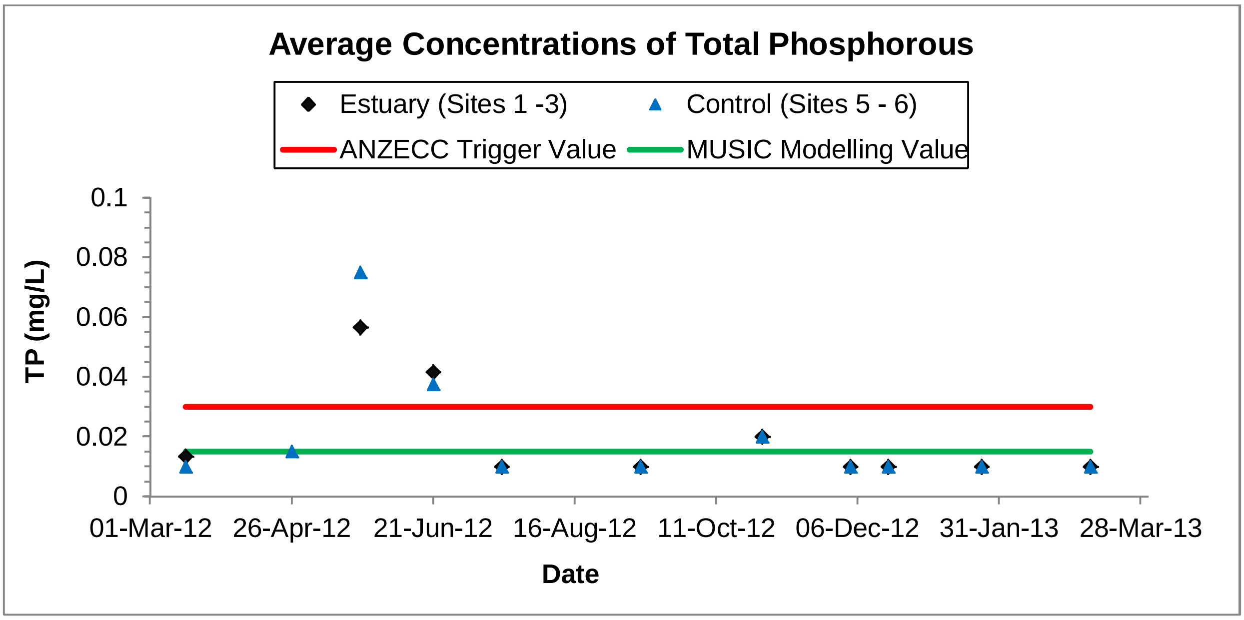

Figure 21 Average Concentration of Total Phosphorous for each Sampling Event, compared to ANZECC Trigger and Modelled Ambient Concentration

4.3 Interpretation of Results

A summary of outcomes for all parameters is presented in **Table 7**.

4.3.1 Comparison of Pre and Post Construction Water Quality Monitoring

The univariate analyses of pre and post-construction water quality results did not identify any significant indications of degradation in water quality as a result of the Port Expansion works. All parameters, with the exception of EC, displayed no significance variance between pre and post-construction conditions. There was some variation identified in the comparison between control and estuary DO results, although this indicates a positive closer correlation between the estuary and control water quality for this parameter. The identified higher EC readings during pre-construction monitoring are unexpectedly high, and without a more complete description of the pre-construction monitoring methodology or instrument calibration records, this trend cannot be fully explained. The post-construction EC measurements have shown consistency within expected ranges.

4.3.2 Comparison to ANZECC Guideline Trigger Values

Only TSS records a significant proportion of records over the trigger value with approximately half of all records exceeding the trigger of 10 mg/L. Estuary sites (Sites 1-3) record slightly more exceedances than Botany Bay control sites (Sites 4-6), although during some sampling exercises Site 6 was unable to be sampled due to high wind and wave conditions in Botany Bay. These conditions are expected to produce higher TSS concentrations so this may bias the comparison of estuary and control exceedances. Given the strong influence of the ambient Botany Bay conditions on the water quality within the estuary, the exceedances of TSS are not considered a flag for the development of poor water quality outcomes as a result of the Port Expansion works. Results of the ecological monitoring, particularly the Seagrass monitoring, will be considered to assess the influence of sedimentation and light attenuation on any identified negative outcomes in those monitoring results.

Total Phosphorous also recorded a number of exceedances, accounting for approximately 15% of records. As for TSS, these TP exceedances have been recorded in both estuary and control sites at similar rates. Thus these exceedances are not considered a significant negative water quality outcome at this stage of monitoring. The trend for these exceedances reveals a correlation with the higher rainfall recorded during the six months of 2012 and this is due to higher expected catchment nutrient loads in runoff produced by this rainfall.

The exceedances for DO, Chlorophyll-a and TN are not considered to be significant due to the low proportion of exceedances in these data sets. The trend for these parameters, as discussed in Section 3, is for a trend of low measurements. As for TP, the TN exceedances are primarily associated with higher rainfall events.

4.3.3 Comparison to Modelled Nutrient Concentrations

As described in **Section 4.3.2**, higher nutrient concentrations have been measured primarily in the first six months of 2012 and these are correlated to higher rainfall in the Sydney area. Overall, measurements of TN and TP averaged for sampling events have been below the modelled concentrations. In general, the estuary nutrient concentrations closely follow the control conditions, reinforcing the assumption that water quality in Botany Bay is the main driver of estuary water quality although TN shows some divergence in the April and June sampling in 2012. The higher nutrient concentration measurements from the high rainfall periods in 2012 show the importance of investigating the estuary flushing rates, and this will be specifically investigated during the wet weather sampling to be completed.

Table 7 Summary of Water Quality Outcomes

Parameter	Post-Construction Data Quality	Pre vs Post Construction Results	ANZECC Exceedances	Modelled Nutrient Comparison
Physicochemical				
Temperature	✓	NA	No guideline	NA
pH	✓	↑ Within reasonable limits	None	NA
DO	✓	=	Few	NA
EC	✓	↓ Within reasonable limits	No guideline	NA
PAR	✓ Limited analysis	NA	No guideline	NA
TSS	✓ Possible outliers	=	↑ Frequent exceedance	NA
Nutrients				
TN	✓ Possible outliers	=	Few	✓
TP	✓ Possible outliers	=	↑ Occasional exceedance	✓
Chl-a	✓	=	Few	NA

5 Conclusions

The post construction water quality monitoring component of the PEHEP has produced a sound data set to provide initial assessments of the water quality of Penrhyn Estuary in its post Port Botany Expansion state. Overall, data measurements show consistent good water quality outcomes in both the estuary and outer Botany Bay control sites, with observed spatial and temporal variations in the data closely following expected trends. Significant rainfall events have been observed to impact water quality outcomes for longer timeframes than are used to define dry weather conditions for this monitoring and this has been particularly noted for nutrient concentrations. Overall trends in the monitoring to date show strong indications of suitable water quality outcomes to support the estuary habitats targeted by the PEHEP.

Comparison of pre-construction and post-construction water quality monitoring results have identified few areas of significant variance in water quality for the parameters measured consistently in both data sets. The identified variance in EC and pH values is not of concern at this stage of the monitoring given that post-construction results are within expected ranges.

Some exceedances of ANZECC trigger values have been recorded, particularly for TSS measurements and to a less extent with nutrient concentrations. The exceedances of TSS concentrations is consistent with pre-construction monitoring and applies to both estuary and control sites. Nutrient concentrations in excess of trigger values have generally followed periods of significant rainfall and are likely an indication of long recovery times of water quality throughout Botany Bay following these events.

Trends for nutrient concentrations indicate that modelled nutrient concentrations prepared for the port expansion EIS are conservative and are not being consistently exceeded in this post-construction monitoring.

Results from this study are limited by the relatively short timeframe covered by these measurements and results and conclusions will continue to be developed as the data set is expanded. The conclusions will also be aided by the results of wet weather monitoring once results of this component of the monitoring are available. Particularly, the recovery times of the estuary following high catchment outflows will provide further confidence to the assessment of water quality outcomes in the estuary.

6 Recommendations

No changes to the Water Quality Monitoring program are recommended at this stage.

7 Acknowledgements

This report was written by Andrew Bradford, Matthew Smith and Dr Lachlan Barnes, and reviewed by Dr Peggy O'Donnell. The field team included Matthew Smith, James Donald, Andrew Bradford, Yesmin Chikhani, Sean Smith and Oliver Silver.

8 References

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APPENDIX A
POST-CONSTRUCTION WATER QUALITY DATA

Appendix A: Post Construction WQ Data

A-1: ALS Lab Results

Location	Suspended Solids (SS) mg/L			Total Nitrogen as N mg/L			Total Phosphorus as P mg/L			Chlorophyll a mg/m^3			Biological Oxygen Demand (BOD) mg/L		
Site	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12
	15/03/2012 - Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 - Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 - Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 - Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 - Low 26/03/2012 - High	26/04/2012	23/05/2012
S1-Low tide	27	18	30	0.3	1	0.1	0.02	0.56	0.05	1	1	2	n/a	n/a	n/a
S2-Low tide	14	25	26	0.1	0.1	0.1	0.01	0.03	0.07	2	2	1	n/a	n/a	n/a
S3-Low tide	24	30	26	0.1	0.1	0.1	0.01	0.02	0.03	2	2	1	n/a	n/a	n/a
S4-Low tide	68	27	16	0.2	0.1	0.1	0.02	0.01	0.01	2	2	1	n/a	n/a	n/a
S5-Low tide	14	35	26	0.1	0.1	0.1	0.01	0.01	0.01	1	3	1	n/a	n/a	n/a
S6-Low tide	15	n/a	29	0.1	n/a	0.1	0.01	n/a	0.11	3	n/a	1	n/a	n/a	n/a
S1-High tide	5	33	24	0.1	0.1	0.1	0.01	0.01	0.01	2	1	1	n/a	n/a	n/a
S2-High tide	5	29	25	0.1	0.1	0.1	0.01	0.04	0.01	3	3	1	n/a	n/a	n/a
S3-High tide	5	37	14	0.1	0.1	0.1	0.02	0.03	0.17	4	1	2	n/a	n/a	n/a
S4-High tide	5	22	18	0.1	0.4	0.1	0.01	0.02	0.02	3	2	1	n/a	n/a	n/a
S5-High tide	5	27	28	0.1	0.1	0.1	0.01	0.02	0.02	2	1	1	n/a	n/a	n/a
S6-High tide	5	n/a	10	0.1	n/a	0.1	0.01	n/a	0.16	2		1	n/a	n/a	n/a
FD	5	13	10	2.3	2.4	2.2	0.12	0.16	0.2	1	1	1	6	3	16
SD	n/a	7	n/a	n/a	0.7	n/a	n/a	0.08	n/a	n/a	1	n/a	n/a	9	n/a
Date	Jun-12	Jul-12		Jun-12	Jul-12		Jun-12	Jul-12		Jun-12	Jul-12		Jun-12	Jul-12	
	21/06/2012	18/07/2012		21/06/2012	18/07/2012		21/06/2012	18/07/2012		21/06/2012	18/07/2012		21/06/2012	18/07/2012	
S1-Low tide	30	20		0.5	0.1		0.04	0.01		1	2		n/a	n/a	
S2-Low tide	18	10		0.1	0.1		0.04	0.01		1	1		n/a	n/a	
S3-Low tide	26	27		0.1	0.1		0.04	0.01		1	36		n/a	n/a	
S4-Low tide	25	24		0.1	0.1		0.03	0.04		1	2		n/a	n/a	
S5-Low tide	5	26		0.1	0.1		0.04	0.01		1	1		n/a	n/a	
S6-Low tide	6	n/a		0.1	n/a		0.03	n/a		1	n/a		n/a	n/a	
S1-High tide	5	13		0.1	0.1		0.05	0.01		1	1		n/a	n/a	
S2-High tide	5	18		0.2	0.1		0.04	0.01		1	1		n/a	n/a	
S3-High tide	6	27		0.1	0.1		0.04	0.01		1	1		n/a	n/a	
S4-High tide	11	24		0.1	0.5		0.04	0.05		1	1		n/a	n/a	
S5-High tide	5	20		0.1	0.1		0.04	0.01		1	1		n/a	n/a	
S6-High tide	5	15		0.1	0.1		0.04	0.01		1	1		n/a	n/a	
FD	6	5		1.6	2.8		0.06	0.14		1	1		3	4	
SD	6	n/a		2.2	n/a		0.09	n/a		1	n/a		3	n/a	
Date	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12
	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012
S1-Low tide	5	13	8	0.3	0.2	0.1	0.01	0.02	0.01	1	1	4	n/a	n/a	n/a
S2-Low tide	5	11	16	0.3	0.2	0.1	0.01	0.02	0.01	1	1	5	n/a	n/a	n/a
S3-Low tide	6	5	5	0.3	0.1	0.1	0.01	0.02	0.01	1	1	4	n/a	n/a	n/a
S4-Low tide	5	10	5	0.3	0.1	0.3	0.01	0.02	0.01	1	1	1	n/a	n/a	n/a
S5-Low tide	5	10	6	0.4	0.1	0.2	0.01	0.02	0.01	1	1	3	n/a	n/a	n/a
S6-Low tide	5	6	5	0.3	0.1	0.2	0.01	0.02	0.01	1	1	5	n/a	n/a	n/a
S1-High tide	9	5	5	0.3	0.1	0.1	0.01	0.02	0.01	1	1	6	n/a	n/a	n/a
S2-High tide	5	5	10	0.3	0.1	0.1	0.01	0.02	0.01	1	1	5	n/a	n/a	n/a
S3-High tide	5	5	5	0.4	0.1	0.1	0.01	0.02	0.01	1	1	10	n/a	n/a	n/a

Location	Suspended Solids (SS) mg/L			Total Nitrogen as N mg/L			Total Phosphorus as P mg/L			Chlorophyll a mg/m^3			Biological Oxygen Demand (BOD) mg/L		
Date	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12
	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012
S4-High tide	5	5	5	0.3	0.1	0.1	0.01	0.02	0.01	1	1	4	n/a	n/a	n/a
S5-High tide	5	5	5	0.3	0.1	0.1	0.01	0.02	0.01	1	1	2	n/a	n/a	n/a
S6-High tide	5	5	5	0.3	0.3	0.1	0.01	0.02	0.01	1	1	2	n/a	n/a	n/a
FD	n/a	n/a	6	n/a	n/a	1.6	n/a	n/a	0.14	n/a	n/a	2	n/a	n/a	3
SD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Date	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13
	18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013
S1-Low tide	6	5	5	0.1	0.1	0.1	0.01	0.01	0.01	1	1	2	n/a	n/a	n/a
S2-Low tide	5	5	5	0.1	0.1	0.1	0.01	0.01	0.01	1	1	2	n/a	n/a	n/a
S3-Low tide	13	5	5	0.1	0.1	0.1	0.01	0.01	0.01	2	1	1	n/a	n/a	n/a
S4-Low tide	16	5	5	0.1	0.1	0.1	0.01	0.01	0.01	1	1	12	n/a	n/a	n/a
S5-Low tide	11	5	5	0.1	0.1	0.1	0.01	0.01	0.01	1	1	2	n/a	n/a	n/a
S6-Low tide	16	n/a	5	0.1	n/a	0.1	0.01	n/a	0.01	2	n/a	4	n/a	n/a	n/a
S1-High tide	26	6	5	0.1	0.1	0.1	0.01	0.01	0.01	1	1	2	n/a	n/a	n/a
S2-High tide	10	8	8	0.1	0.1	0.1	0.01	0.01	0.01	2	1	1	n/a	n/a	n/a
S3-High tide	5	7	5	0.1	0.1	0.1	0.01	0.01	0.01	2	1	2	n/a	n/a	n/a
S4-High tide	10	6	5	0.1	0.1	0.1	0.02	0.01	0.01	2	2	3	n/a	n/a	n/a
S5-High tide	6	5	5	0.1	0.1	0.1	0.01	0.01	0.01	2	1	2	n/a	n/a	n/a
S6-High tide	5	5	5	0.1	0.1	0.1	0.01	0.01	0.01	1	1	3	n/a	n/a	n/a
FD	n/a	n/a	10	n/a	n/a	7.4	n/a	n/a	0.25	n/a	n/a	3	n/a	n/a	23
SD	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

A-2: In Situ Water Quality Results Summary

Location		Temperature degrees C			Conductivity mS/cm			pH pH units			Dissolved Oxygen %			Photosynthetically Active Radiation (PAR) µ mol photons/m^2/s			
Date	Depth (m)	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12	Mar-12*	Apr-12	May-12	PAR Depth (m)
		15/03/2012 -Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 -Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 -Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 -Low 26/03/2012 - High	26/04/2012	23/05/2012	15/03/2012 -Low 26/03/2012 - High	26/04/2012	23/05/2012	
S1 - Low - Mid	0.25	23.06	17.34	16.8	43.57	46.15	52.15	7.74	8.02	7.99	78.6	100	86.2	n/a	n/a	n/a	
S2 - Low - Top	0.5	21.42	17.51	17.94	46.8	48.46	53.29	8	8.05	8.06	85.3	100	89	n/a	199	891	0.5
S2 - Low - Mid	1	21.29	17.56	18.01	49.88	49.56	53.36	8.01	8.06	8.06	87.6	99.1	89	n/a	118	962	1
S2 - Low - Bottom	1.5	21.28	18.62	18.03	51.82	51.2	53.46	8.02	8.08	8.07	80	99.1	89	n/a	38	199	2
S3 - Low - Top	0.5	21.77	17.91	17.5	45.1	51.4	53.21	8.24	8.08	8.07	100	96.5	93.1	n/a	93	896	0.5
S3 - Low - Mid	1.5	21.73	18.5	17.73	45.79	51.86	53.34	8.23	8.09	8.07	100	96.7	92.3	n/a	14	391	1.5
S3 - Low - Bottom	2	21.56	18.76	17.81	48.51	52.04	53.42	8.17	8.1	8.08	100	97	92.1	n/a	3	118	2.5
S4 - Low - Top	2	21.14	18.65	18.11	48.83	51.88	53.58	8.21	8.13	8.09	91	98.4	93.6	n/a	583	842	0.5
S4 - Low - Mid	6	20.38	18.94	18.36	53.57	52.41	53.65	8.15	8.13	8.09	87.8	95.1	91.1	n/a	3	81	6
S4 - Low - Bottom	10	20.36	19.29	18.59	54.04	53.71	53.88	8.13	8.09	8.09	88	85.5	89	n/a	0	0	11
S5 - Low - Top	1	21.44	19.01	18.03	46.66	52.31	53.4	8.21	8.15	8.09	100	99.7	95.6	n/a	41	480	0.5
S5 - Low - Mid	3	20.58	19	18.31	52.87	52.45	53.81	8.12	8.15	8.1	95.6	99.3	93.7	n/a	10	102	3
S5 - Low - Bottom	6	20.54	19.04	18.43	53.78	52.51	53.87	8.13	8.13	8.1	94	98.6	93.1	n/a	2	13	6
S6 - Low - Top	1	21.39	n/a	18.58	44.88	n/a	54	8.25	n/a	8.11	100	n/a	95.1	n/a	n/a	426	1
S6 - Low - Mid	3	20.76	n/a	18.57	51.36	n/a	54.01	8.18	n/a	8.11	100	n/a	94.7	n/a	n/a	95	3
S6 - Low - Bottom	6	20.64	n/a	18.64	53.71	n/a	54.03	8.15	n/a	8.11	100	n/a	94.3	n/a	n/a	32	6
S1 - High - Mid	0.25	20.95	16.5	17.16	49.01	48.65	48.81	8.06	8.03	7.94	97.6	94.1	100	n/a	n/a	n/a	
S2 - High - Top	0.5	20.44	16.77	17.81	49.87	48.81	51.33	8.13	8.05	8	100	95.5	98.1	2056	832	814	0.5
S2 - High - Mid	1	20.29	17.14	18.24	50	49.65	51.91	8.16	8.04	8	96.4	94.8	96.3	1339	486	555	1
S2 - High - Bottom	1.5	20.4	18.37	18.31	50.78	51.4	53.33	8.12	8.05	8.08	90.8	91.8	98.2	247	258	247	2
S3 - High - Top	1	20.28	18.18	18.26	51.79	51.27	53.17	8.16	8.08	8.06	98.8	92.7	94.6	2189	1326	1314	0.5
S3 - High - Mid	2	20.28	18.24	18.26	52.84	51.27	53.2	8.17	8.08	8.06	92.3	92.9	93.1	958	639	573	1.5
S3 - High - Bottom	3	20.19	18.42	18.26	53.3	51.62	53.22	8.16	8.08	8.06	91.2	93	92.9	154	251	58	3
S4 - High - Top	2	20.31	18.64	18.19	52.55	52.08	53.39	8.18	8.13	8.09	85.4	96.1	97	2209	862	1269	0.5
S4 - High - Mid	6	20.09	18.75	18.41	53.8	52.31	53.7	8.15	8.13	8.09	87	94.4	93.4	39	44	35	6
S4 - High - Bottom	10	20.09	18.97	18.57	54.09	53.04	53.83	8.14	8.07	8.09	84.8	91.4	89.5	1	2	5	10
S5 - High - Top	1	20.51	19.05	18.51	50.23	52.59	53.36	8.22	8.14	8.1	100	95.6	98	1854	957	1364	0.5
S5 - High - Mid	3	20.2	18.93	18.27	54.07	52.88	53.59	8.19	8.4	8.11	96.6	94.2	97	394	217	409	3
S5 - High - Bottom	6	20.14	19.14	18.33	54.26	53.21	53.78	8.19	8.12	8.1	96.6	88.9	93.8	62	22	48	6
S6 - High - Top	1	20.74	n/a	17.47	51.69	n/a	52.65	8.16	n/a	8.09	100	n/a	100	1931	n/a	1709	0.5
S6 - High - Mid	3	20.56	n/a	18.18	52.49	n/a	53.55	8.17	n/a	8.11	100	n/a	98.7	330	n/a	505	3
S6 - High - Bottom	6	20.28	n/a	18.41	53.97	n/a	53.87	8.18	n/a	8.12	100	n/a	97.6	185	n/a	197	6
FD	0.3	22.37	18.44	15.49	0.75	0.79	0.56	7.08	7.01	7.02	25	19.6	20.5	n/a	n/a	n/a	
SD	0.3	n/a	17.48	n/a	n/a	0.48	n/a	n/a	7.11	n/a	n/a	57.1	n/a	n/a	n/a	n/a	

Date	Depth (m)	Jun-12	Jul-12		Jun-12	Jul-12		Jun-12	Jul-12		Jun-12	Jul-12		Jun-12	Jul-12		PAR Depth (m)
		21/06/2012	18/07/2012		21/06/2012	18/07/2012		21/06/2012	18/07/2012		21/06/2012	18/07/2012		21/06/2012	18/07/2012		
S1 - Low - Mid	0.25	13.92	15.24		44.36	38.82		7.98	8.01		102.64	101.95					
S2 - Low - Top	0.5	15.96	14.46		50.01	40.49		8.05	8.05		92.91	96.98		930.66	867.63		0.5
S2 - Low - Mid	1	16.8	14.56		52.39	40.83		8.05	8.06		93.23	97.09		576.13	571.19		1
S2 - Low - Bottom	1.5	16.95	14.61		52.65	40.97		8.06	8.06		93.84	97.19		337.04	317.45		1.5
S3 - Low - Top	0.5	15.4	15.72		50.99	41.61		8.05	8.15		93.24	98.82		259.39	994.55		0.5
S3 - Low - Mid	1.5	16.84	15.65		52.96	41.63		8.07	8.15		93.88	98.68		125.86	447.35		1.5
S3 - Low - Bottom	2	16.95	15.66		52.92	41.65		8.08	8.15		93.59	98.49		93.8	377.47		2
S4 - Low - Top	2	17.02	15.86		53.23	42.1		8.09	8.18		91.44	100.88		77.41	255.26		2
S4 - Low - Mid	6	17.51	15.78		53.8	42.2		8.1	8.17		90.32	98.16		3.85	35.4		6
S4 - Low - Bottom	10	17.64	15.87		54.04	42.26		8.11	8.16		89.66	94.94		0.40288	4.1829		10
S5 - Low - Top	1	16.84	15.74		53.04	41.95		8.12	8.18		97.06	103.39		149.3	640.96		1
S5 - Low - Mid	3	16.9	16.02		53.12	42.2		8.12	8.18		96.03	103.4		47.72	231.58		3
S5 - Low - Bottom	6	17.19	16.09		53.48	42.26		8.12	8.17		95.3	103.02		18	81.08		6
S6 - Low - Top	1	16	n/a		52.01	n/a		8.13	n/a		98.43	n/a		80.64	n/a		1
S6 - Low - Mid	3	16.58	n/a		52.75	n/a		8.13	n/a		97.67	n/a		41.81	n/a		3
S6 - Low - Bottom	6	17.29	n/a		53.71	n/a		8.14	n/a		97.42	n/a		18.57	n/a		6
S1 - High - Mid	0.25	15.52	14.49		51.24	41.4		8.05	8.05		88.74	91.52		n/a	n/a		0.25
S2 - High - Top	0.5	15.47	15.07		51.08	41.82		8.08	8.12		90.35	93.09		226.4	339.98		0.5
S2 - High - Mid	1	16.08	15.08		51.78	41.82		8.08	8.13		90.6	92.93		153.04	242.45		1
S2 - High - Bottom	1.5	16.84	15.08		52.6	41.82		8.1	8.13		90.99	92.82		114.02	163.47		1.5
S3 - High - Top	1	16.25	15.33		52.02	42.02		8.1	8.16		91.42	93.68		188.73	251.53		1
S3 - High - Mid	2	16.79	15.34		52.76	42.02		8.11	8.16		92.11	93.58		109.18	104.28		2
S3 - High - Bottom	3	16.89	15.35		52.84	42.02		8.11	8.16		91.85	93.62		63.61	79.11		3
S4 - High - Top	2	16.33	15.72		52.42	42.24		8.11	8.18		92.95	96.47		125.79	218.03		2
S4 - High - Mid	6	16.57	15.77		52.76	42.26		8.11	8.18		91.29	95.41		23.47	28.18		6
S4 - High - Bottom	10	17.06	16.12		53.33	42.4		8.11	8.17		90.29	93.97		3.9414	7.0631		10
S5 - High - Top	1	16.67	15.81		52.81	42.25		8.13	8.19		95.87	100.33		246.19	680.99		1
S5 - High - Mid	3	17.25	15.88		53.66	42.28		8.13	8.2		95.84	99.92		128.29	276.26		3
S5 - High - Bottom	6	17.43	16.02		53.85	42.36		8.14	8.19		95.06	99.6		50.33	94.43		6
S6 - High - Top	1	16.4	15.64		52.65	42.2		8.13	8.2		96.95	101.68		308.64	832.28		1
S6 - High - Mid	3	16.79	15.7		53.14	42.24		8.13	8.2		96.86	101.47		157.95	371.77		3
S6 - High - Bottom	6	17.45	15.75		53.91	42.27		8.14	8.2		96.97	101.11		80.8	209.16		6
FD	0.3	14.79	14.22		0.85	0.5		7.23	7.35		36.73	37.91		n/a	n/a		
SD	0.3	13.16	n/a		1.12	n/a		7.34	n/a		34.15	n/a		n/a	n/a		

Date	Depth (m)	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	Sep-12	Oct-12	Nov-12	PAR Depth (m)
		11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	11/09/2012	29/10/2012	3/12/2012	
S1 - Low - Mid	0.25	16.13	20.24	22.39	41.96	48.35	52.25	8.16	8.1	8.03	99.35	103.54	103.12	n/a	n/a	n/a	0.25
S2 - Low - Top	0.5	15.82	20.68	21.92	41.92	48.49	52.56	8.16	8.09	8.07	97.18	105.71	105.39	1233.2	1463.3	108.59	0.5
S2 - Low - Mid	1	15.81	n/a	21.74	41.92	n/a	52.64	8.16	n/a	8.08	97.01	n/a	105.72	682.01	1262.5	55.7	1
S2 - Low - Bottom	1.5	15.81	n/a	21.66	41.93	n/a	52.69	8.16	n/a	8.08	96.97	n/a	106.04	397.93	1076.9	41.53	1.5
S3 - Low - Top	0.5	15.83	18.96	21.63	41.88	48.4	52.64	8.17	8.11	8.05	97.49	101.51	101.92	1093.7	2251.7	150.78	0.5
S3 - Low - Mid	1.5	15.83	18.95	21.6	41.89	48.4	52.65	8.17	8.11	8.05	96.79	101.39	102.03	383.84	1149.3	59.03	1.5
S3 - Low - Bottom	2	15.83	n/a	21.63	41.89	n/a	52.65	8.17	n/a	8.05	96.74	n/a	102.03	196.72	869	n/a	2
S4 - Low - Top	2	15.65	18.58	21.11	42.15	48.55	52.68	8.21	8.14	8.06	99.15	99.62	100.92	302.34	1102.8	114.86	2
S4 - Low - Mid	6	15.65	18.09	18.75	42.14	48.6	52.96	8.21	8.14	8.03	98.8	94.78	86.62	85.6	224.01	17.33	6
S4 - Low - Bottom	10	15.63	17.9	18.21	42.14	48.62	52.93	8.21	8.13	8.03	98.21	92.1	81.71	13.64	n/a	4.04	10
S5 - Low - Top	1	15.67	18.58	21.29	42.11	48.53	52.77	8.2	8.15	8.09	99.2	101.03	101.63	527.9	1288.9	253.09	1
S5 - Low - Mid	3	15.67	18.53	20.36	42.11	48.54	52.84	8.2	8.15	8.08	99.05	100.62	98.16	216.22	878.22	89.54	3
S5 - Low - Bottom	6	15.61	18.33	19.44	42.11	48.62	52.92	8.2	8.15	8.07	98.36	99.98	92.41	81.06	362.56	28.54	6
S6 - Low - Top	1	15.61	18.71	20.32	42.07	48.56	52.88	8.18	8.11	8.11	101.46	101.41	104.16	756.47	1765.8	320.8	1
S6 - Low - Mid	3	15.61	18.31	20	42.07	48.57	52.93	8.18	8.12	8.11	101.37	100.92	103.05	431.98	955.93	147.2	3
S6 - Low - Bottom	6	15.6	18.2	19.58	42.07	48.6	52.96	8.19	8.13	8.11	101.22	100.92	100.96	206.18	423.64	60.58	6
S1 - High - Mid	0.25	16	17.87	21.48	41.91	48.33	52.67	8.17	7.85	8.04	100.62	95.2	98.4	n/a	n/a	n/a	0.25
S2 - High - Top	0.5	16.78	18.01	21.32	41.85	48.46	52.57	8.15	8.1	8.04	101.04	95.58	98.4	991.34	773.09	406.95	0.5
S2 - High - Mid	1	16.48	17.97	21.26	41.93	48.46	52.61	8.16	8.09	8.05	100.44	95.22	98.5	514.74	433.74	389.77	1
S2 - High - Bottom	1.5	16.24	17.86	21.23	41.99	48.46	52.64	8.18	8.08	8.06	100.01	94.87	98.8	327.27	320.28	269.03	1.5
S3 - High - Top	1	16.14	18.04	21.19	42.11	48.51	52.7	8.2	8.12	8.03	100.73	96.11	101.3	753.58	564.18	270.77	1
S3 - High - Mid	2	16.08	18	21.13	42.12	48.52	52.72	8.2	8.11	8.04	100.5	95.75	100.7	411.5	332.97	152.87	2
S3 - High - Bottom	3	16.05	17.99	21.1	42.12	48.52	52.75	8.21	8.11	8.04	100.38	95.5	98.5	117.53	232.69	62.48	3
S4 - High - Top	2	16.05	18.13	21.07	42.14	48.53	52.69	8.21	8.14	8.06	100.55	99.24	96	330.82	394.97	81.81	2
S4 - High - Mid	6	n/a	17.92	20.55	n/a	48.62	52.74	n/a	8.14	8.06	n/a	93.11	92.1	n/a	65.28	11.38	6
S4 - High - Bottom	10	n/a	17.83	19.14	n/a	48.63	52.82	n/a	8.14	8.05	n/a	92.23	84.7	n/a	12.78	1.61	10
S5 - High - Top	1	15.94	18.05	20.98	42.13	48.58	52.67	8.21	8.15	8.04	101.69	98.81	96.9	724.07	1748.9	236.51	1
S5 - High - Mid	3	15.92	17.99	19.56	42.13	48.65	52.8	8.21	8.16	8.07	101.61	98.88	91.2	436.04	649.13	83.65	3
S5 - High - Bottom	6	15.91	17.9	19.02	42.13	48.74	52.83	8.21	8.18	8.07	101.27	98.77	88.4	156.83	216.35	35.34	6
S6 - High - Top	1	15.96	17.92	19.7	42.14	48.72	52.88	8.21	8.18	8.09	103.41	102.26	96.8	922.96	1270	141.15	1
S6 - High - Mid	3	15.96	17.84	19.04	42.14	48.75	52.96	8.21	8.18	8.09	103.3	101.76	92.2	523.03	780.31	69.27	3
S6 - High - Bottom	6	15.96	17.75	18.96	42.15	48.77	52.97	8.21	8.18	8.09	103.17	101.14	90.7	231.27	408.31	34.9	6
FD	0.3	n/a	n/a	21.04	n/a	n/a	0.04	n/a	n/a	7.56	n/a	n/a	28.4	n/a	n/a	n/a	0.3
SD	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.3

Date	Depth (m)	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13	Dec-12	Jan-13	Feb-13	PAR Depth (m)
		18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013	18/12/2012	24/01/2013	8/03/2013	
S1 - Low - Mid	0.25	20.66	25.36	23.36	52.48	55.45	47.17	8.01	7.97	8.15	99.78	106.33	93.43	n/a	n/a	n/a	
S2 - Low - Top	0.5	20.45	23.7	23.74	52.37	55.31	46.76	8.02	8	8.15	98.79	104.78	91.46	2121.8	1783.7	1826.2	0.5
S2 - Low - Mid	1	20.38	23.56	22.2	52.4	55.27	48.48	8.02	8.01	8.12	98.54	104.51	88.12	1500.7	885.6	967.52	1
S2 - Low - Bottom	1.5	20.31	n/a	21.87	52.44	n/a	49.9	8.02		8.07	98.33	n/a	88.92	1431	n/a	638.91	1.5
S3 - Low - Top	0.5	20.29	23.69	22.67	52.47	55.19	45.91	8.04	n/a	8.26	98.68	105.34	99.65	595.37	1693.2	2081	0.5
S3 - Low - Mid	1.5	20	23.63	22.26	52.55	55.22	49.24	8.04	8.01	8.13	97.73	105.62	98.88	382.28	810.6	1034.2	1.5
S3 - Low - Bottom	2	19.91	n/a	21.93	52.56	n/a	50.18	8.04	n/a	8.07	97.34	n/a	100.83	282.57	n/a	786.27	2
S4 - Low - Top	2	19.64	23.27	22.51	52.58	55.19	45.25	8.03	8.04	8.34	94.24	102.07	97.87	883.22	791.72	1006.4	2
S4 - Low - Mid	6	19.2	23.15	20.59	52.55	55.17	51.79	8.03	8.04	8.08	90.64	101.2	80.36	77.56	100.21	97.52	6
S4 - Low - Bottom	10	19.1	n/a	19.01	52.55	n/a	52.99	8.03	n/a	8.01	89.53	n/a	73.87	8.9		17.12	10
S5 - Low - Top	1	19.67	23.15	22.6	52.56	55.06	44.78	8.03	8	8.36	96.42	101.87	111.62	547.26	773.24	1285.6	1
S5 - Low - Mid	3	19.63	23.09	21.93	52.58	55.05	45.94	8.03	8	8.3	95.77	101.49	100.13	279.5	258.49	502.81	3
S5 - Low - Bottom	6	19.46	22.8	20.68	52.56	54.99	51.61	8.03	7.98	8.11	94.9	99.59	93.88	35.99	56.71	164.13	6
S6 - Low - Top	1	19.78	n/a	22.7	52.53	n/a	45.99	8.03	n/a	8.26	98.4	n/a	109.43	999.47	n/a	682.85	1
S6 - Low - Mid	3	19.48	n/a	21.62	52.5	n/a	49.49	8.04	n/a	8.15	97.24	n/a	104.86	509.71	n/a	223.05	3
S6 - Low - Bottom	6	19.48	n/a	21.3	52.51	n/a	52.32	8.04	n/a	8.07	96.76	n/a	103.19	176.31	n/a	74.82	6
S1 - High - Mid	0.25	24.5	22.59	21.89	52.81	55.01	46.75	8.16	7.97	8.19	130.53	98.06	90.83	n/a	n/a	n/a	0.25
S2 - High - Top	0.5	22.28	22.39	21.79	52.57	54.97	46.67	8.08	7.97	8.24	113.77	96.22	84.46	1512.4	1712.4	290.58	0.5
S2 - High - Mid	1	21.54	22.36	21.66	52.44	54.97	47.69	8.07	7.97	8.15	111.85	95.98	80.7	758.93	1017.8	197.37	1
S2 - High - Bottom	1.5	21.29	22.32	21.33	52.46	54.97	49.84	8.06	7.97	8.07	110.54	95.85	82.47	446.38	746.69	120.37	1.5
S3 - High - Top	1	21.95	22.65	21.41	52.52	54.92	47.7	8.06	8.01	8.16	108.3	97.79	85.14	954.91	566.61	101.89	1
S3 - High - Mid	2	21.28	22.63	21.08	52.46	54.9	50.9	8.06	8.01	8.07	106.9	97.45	87.06	598.33	269.17	51.84	2
S3 - High - Bottom	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3
S4 - High - Top	2	21.08	22.73	21.1	52.5	55.02	50.07	8.05	8.03	8.16	102.45	97.38	84.57	756.92	220.12	77.13	2
S4 - High - Mid	6	19.55	22.71	20.22	52.51	55.02	52.3	8.04	8.03	8.04	94.26	96.2	77.31	65.83	13.58	19	6
S4 - High - Bottom	10	19.21	22.66	19.2	52.5	55.02	53.03	8.01	8.02	8	89.14	94.32	73.66	9.66	1.25	2.55	10
S5 - High - Top	1	20.84	22.69	21.73	52.53	55.03	46.23	8.05	8.04	8.3	104.52	99.15	97.09	1260.7	444.24	234.55	1
S5 - High - Mid	3	20.51	22.65	20.88	52.54	55.02	50.79	8.04	8.04	8.14	103.35	98.73	86.22	579.34	183.71	92.4	3
S5 - High - Bottom	6	19.07	22.59	20.24	52.55	55.01	52.51	8.05	8.05	8.05	98.09	98.49	85.2	187.17	64.46	34.14	6
S6 - High - Top	1	20.51	21.95	22.14	52.52	54.94	44.53	8.01	8.03	8.32	102.94	100.33	108.34	1501.5	401.86	302.15	1
S6 - High - Mid	3	19.56	21.95	21.61	52.55	54.94	51.62	8.02	8.03	8.16	100.83	100.1	96.73	785.93	200.7	178.92	3
S6 - High - Bottom	6	18.97	21.92	21.42	52.51	54.94	52.78	8.02	8.03	8.07	99.46	99.88	94.52	376.97	82.95	78.77	6
FD	0.3	n/a	n/a	22.56	n/a	n/a	0.18	n/a	n/a	7.19	n/a	n/a	20.9	n/a	n/a	n/a	
SD	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

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APPENDIX B
PRE-CONSTRUCTION WATER QUALITY DATA

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Appendix B: Pre-Construction WQ data

B-1: ALS Lab Results

Location	Date	Suspended Solids (SS) mg/L	Total Nitrogen as N mg/L	Total Phosphorus as P mg/L	Chlorophyll a mg/m^3	Biochemical Oxygen Demand mg/L
D2H	11/12/2003	9		0.06	2.5	1
D2L	11/12/2003	5		0.06	9	1
D3H	11/12/2003	9		0.04	2.5	1
D3L	11/12/2003	7		0.05	6	1
D4H	11/12/2003	5		0.02	2.5	1
D4L	11/12/2003	12		0.05	2.5	1
D2H	20/1/2004	0.5		0.03	2.5	1
D2L	20/1/2004	7		0.07	7	1
D3H	20/1/2004	0.5		0.03	2.5	1
D3L	20/1/2004	3		0.04	2.5	1
D4H	20/1/2004	17		0.06	2.5	1
D4L	20/1/2004	7		0.03	2.5	2
D2H	17/3/2004	16	0.1	0.16	6	4
D2L	17/3/2004	9	0.1	0.08	2.5	3
D3H	17/3/2004	9	0.05	0.08	2.5	2
D3L	17/3/2004	10	0.1	0.07	2.5	3
D4H	17/3/2004	14	0.1	0.08	2.5	3
D4L	17/3/2004	7	0.05	0.06	2.5	2
D2H	22/4/2004	23	0.05	0.005	11	1
D2L	22/4/2004	33	0.05	0.03	14	3
D3H	22/4/2004	24	0.05	0.005	8	1
D3L	22/4/2004	20	0.05	0.005	10	1
D4H	22/4/2004	15	0.05	0.005	7	2

Location	Date	Suspended Solids (SS) mg/L	Total Nitrogen as N mg/L	Total Phosphorus as P mg/L	Chlorophyll a mg/m^3	Biochemical Oxygen Demand mg/L
D4L	22/4/2004	22	0.1	0.005	2.5	2
D2H	10/6/2004	69	0.2	0.005	2.5	1
D2L	10/6/2004	5	0.2	0.01	2.5	1
D3H	10/6/2004	17	0.05	0.12	2.5	1
D3L	10/6/2004	15	0.3	0.005	8	1
D4H	10/6/2004	14	0.2	0.005	7	1
D4L	10/6/2004	21	0.1	0.005	7	1
D7H	10/6/2004	14	0.1	0.005	8	1
D7L	10/6/2004	17	0.05	0.005	2.5	1
D8H	10/6/2004	30	0.1	0.03	22	1
D8L	10/6/2004	21	0.1	0.005	2.5	1
D2H	12/8/2004	15	0.05	0.03	2.5	1
D2L	12/8/2004	16	0.3	0.03	2.5	1
D3H	12/8/2004	20	0.05	0.03	2.5	1
D3L	12/8/2004	16	0.05	0.02	2.5	1
D4H	12/8/2004	7	0.2	0.02	2.5	1
D4L	12/8/2004	9	0.05	0.02	2.5	1
D7H	12/8/2004	31	0.05	0.02	2.5	1
D7L	12/8/2004	22	0.1	0.03	2.5	1
D8H	12/8/2004	23	0.05	0.04	2.5	1
D8L	12/8/2004	17	0.05	0.01	2.5	1
D2H	15/10/2004	11	0.4	0.005	2.5	1
D2L	15/10/2004	8	0.3	0.005	2.5	1
D3H	15/10/2004	6	0.3	0.005	2.5	1
D3L	15/10/2004	2	0.3	0.005	6	1
D4H	15/10/2004	12	0.3	0.005	2.5	1
D4L	15/10/2004	3	0.2	0.005	2.5	1

Location	Date	Suspended Solids (SS) mg/L	Total Nitrogen as N mg/L	Total Phosphorus as P mg/L	Chlorophyll a mg/m^3	Biochemical Oxygen Demand mg/L
D7H	15/10/2004	5	0.3	0.005	2.5	1
D7L	15/10/2004	6	0.3	0.005	2.5	1
D8H	15/10/2004	5	0.3	0.005	2.5	1
D8L	15/10/2004	10	0.3	0.005	2.5	1

B-2: In Situ Water Quality Results Summary

Location	Date	Time (EST)	Water	Sample	Conductivity mS/cm			Temperature degrees C			pH ph units			Dissolved Oxygen mg/L		
			Depth (m)	Depth (m)	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
D2H	11/12/2003				53.2	52.9	53.4	20.9	20.5	20.2	8.2	8.2	8.1	9	8.9	8.9
D2L	11/12/2003				51.2	50.9	50.9	23.3	23.4	23.9	8	7.9	7.9	10.2	10.2	10.1
D3H	11/12/2003				53	52.9	52.8	20.9	21.2	21.3	8	7.9	7.9	8.9	9.1	9
D3L	11/12/2003				52.1	52.3	52.8	23.1	22.9	22.5	8.1	8.1	8.1	10.1	10	9.7
D2H	20/01/2004				53.7	53.5	53.4	21.6	21.6	21.5	8.1	8.1	8.1	7.6	7.5	7.4
D2L	20/01/2004					53.2			22.6			8.1			7.2	
D3H	20/01/2004				54.2	53.2	52.7	21.5	21.4	21.5	8.1	8.1	8.2	8	7.6	7.3
D3L	20/01/2004					53.5			22.6			8.1			7.3	
D2H	17/03/2004	16:20	3.94	3.74	58.19	58.15	58.18	22.4	22.4	22.4	8.1	8.1	8.1	5.9	6.1	6.1
D2L	17/03/2004	10:00	3.55	3.35	56.05	58.08	57.99	22.2	22.0	22.0	7.9	8.0	8.0	5.1	5.5	5.4
D3H	17/03/2004	16:35	4.20	4.00	58.23	58.23	58.22	22.3	22.3	22.3	8.1	8.1	8.1	5.6	5.7	5.7
D3L	17/03/2004	10:25	3.80	3.60	57.66	58.02	58.09	22.2	22.0	22.0	8.0	8.0	8.0	5.4	5.3	5.6
D4H	17/03/2004	16:45	2.60	2.40	58.27	58.22	58.22	22.3	22.3	22.3	8.1	8.1	8.1	5.8	5.7	5.8
D4L	17/03/2004	10:40	1.50	1.30	58.04		58.03	22.1		22.1	8.0		8.0	5.7		5.7
D2H	22/04/2004	08:55	3.30	3.10	58.11	58.17	58.73	20.1	20.2	20.4	8.1	8.2	8.1	6.2	5.8	5.0

Location	Date	Time (EST)	Water	Sample	Conductivity mS/cm			Temperature degrees C			pH ph units			Dissolved Oxygen mg/L		
			Depth (m)	Depth (m)	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
D2L	22/04/2004	14:15	3.65	3.45	58.05	58.70	58.89	20.8	20.7	20.5	8.1	8.1	8.1	7.1	6.9	6.0
D3H	22/04/2004	09:20	4.90	4.70	58.30	58.77	59.13	20.4	20.3	20.0	8.2	8.2	8.2	6.2	6.0	5.6
D3L	22/04/2004	14:35	3.75	3.55	58.37	58.98	59.06	21.1	20.3	20.3	8.2	8.2	8.2	6.9	6.6	6.5
D4H	22/04/2004	09:35	2.25	2.05	58.40	58.43	58.47	20.6	20.4	20.5	8.2	8.2	8.1	6.3	6.3	6.2
D4L	22/04/2004	14:55	1.70	1.50	58.64	58.61	58.76	21.0	21.1	20.8	8.2	8.2	8.2	7.0	6.9	6.9
D2H	10/06/2004	12:45	3.38	3.18	59.60	59.81	60.00	16.5	16.5	16.7	8.1	8.1	8.1	7.0	7.1	7.2
D2L	10/06/2004	06:40	3.70	3.50	58.99	59.38	59.95	16.2	16.5	16.7	8.1	8.0	8.3	5.7	6.4	6.3
D3H	10/06/2004	13:10	5.92	5.72	60.06	60.11	60.10	17.0	17.0	16.9	8.2	8.1	8.1	7.2	7.2	7.2
D3L	10/06/2004	07:15	4.08	3.88	59.70	60.08	60.13	16.5	16.7	16.7	8.1	8.2	8.2	6.5	6.5	6.5
D4H	10/06/2004	13:25	1.90	1.70	59.89	59.99	59.98	17.1	17.2	17.1	8.2	8.2	8.2	7.9	7.7	7.4
D4L	10/06/2004	7:30	1.30	1.10	59.80		59.90	16.2		16.4	8.2		8.2	6.7		6.8
D7H	10/06/2004	14:10	7.30	7.10	60.26	60.25	60.22	17.3	17.3	17.2	8.2	8.2	8.2	7.2	7.2	7.2
D7L	10/06/2004	08:30	6.10	5.90	60.28	60.28	60.27	17.4	17.5	17.4	8.1	8.2	8.1	6.9	6.9	6.7
D8H	10/06/2004	14:30	7.80	7.60	60.43	60.44	60.36	18.4	18.2	17.8	8.1	8.2	8.1	7.0	7.1	7.2
D8L	10/06/2004	08:45	6.64	6.44	60.14	60.14	60.16	16.7	16.7	16.7	8.2	8.2	8.2	7.1	7.0	6.9
D2H	12/08/2004	15:15	3.70	3.50	59.85	59.88	60.10	15.6	15.5	15.5	8.1	8.2	8.2	7.1	7.2	7.1

Location	Date	Time (EST)	Water	Sample	Conductivity mS/cm			Temperature degrees C			pH ph units			Dissolved Oxygen mg/L		
			Depth (m)	Depth (m)	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
D2L	12/08/2004	09:50	4.10	3.90	59.87	59.73	59.98	15.5	15.7	15.7	8.1	8.1	8.2	5.8	5.9	5.9
D3H	12/08/2004	15:35	5.42	5.22	60.09	60.11	60.12	15.7	15.5	15.4	8.2	8.2	8.1	7.2	7.3	7.1
D3L	12/08/2004	10:10	4.50	4.30	59.88	59.93	60.10	15.4	15.4	15.5	8.1	8.1	8.2	6.1	6.2	6.1
D4H	12/08/2004	15:50	2.50	2.30	60.13	60.15	60.14	15.8	15.7	15.6	8.1	8.1	8.2	7.4	7.4	7.3
D4L	12/08/2004	10:25	1.50	1.30	59.93		59.97	15.5		15.5	8.1		8.2	6.3		6.3
D7H	12/08/2004	16:25	7.80	7.70	60.20	60.21	60.23	15.7	15.3	15.3	8.1	8.2	8.2	7.7	7.5	7.5
D7L	12/08/2004	11:10	7.10	6.90	60.23	60.24	60.24	15.7	15.7	15.5	8.2	8.2	8.2	6.7	6.8	6.6
D8H	12/08/2004	16:45	8.00	6.80	60.40	60.46	60.43	15.8	15.5	15.4	8.1	8.1	8.1	7.5	7.4	7.3
D8L	12/08/2004	11:25	7.04	6.84	60.19	60.17	60.19	15.4	15.4	15.3	8.1	8.1	8.2	6.9	6.9	6.8
D2H	15/10/2004	06:55	3.70		56.51	56.45	56.44	19.0	19.0	19.0	7.8	7.8	7.8	6.4	6.5	6.5
D2L	15/10/2004	12:45	3.40		56.07	56.92	56.90	20.1	20.1	20.0	7.8	7.8	7.8	8.9	8.8	9.5
D3H	15/10/2004	07:15	4.80		56.36	56.32	56.31	19.1	19.1	19.1	7.8	7.8	7.8	6.7	6.5	6.4
D3L	15/10/2004	13:00	3.90		57.02	57.28	57.20	20.3	20.0	19.7	7.9	7.9	7.9	8.3	8.5	8.1
D4H	15/10/2004	07:35	1.90		55.95		55.60	19.1		19.1	7.8		7.9	6.8		6.7
D4L	15/10/2004	13:15	1.40		55.82		56.26	20.5		20.4	7.9		7.9	7.5		7.9
D7H	15/10/2004	08:35	8.30		57.23	57.24	57.20	18.0	17.8	17.7	7.9	7.9	7.9	7.5	7.6	7.7

Location	Date	Time (EST)	Water	Sample	Conductivity mS/cm			Temperature degrees C			pH ph units			Dissolved Oxygen mg/L		
			Depth (m)	Depth (m)	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
D7L	15/10/2004	14:00	7.00		57.37	57.33	57.34	18.9	18.9	18.6	8.0	8.0	8.0	8.0	8.4	9.7
D8H	15/10/2004	09:00	8.50		57.02	57.11	57.12	18.6	18.5	18.3	7.9	7.9	7.9	7.6	7.7	7.8
D8L	15/10/2004	14:15	6.90		57.05	57.01	57.08	19.2	19.2	18.9	8.0	8.0	8.0	9.2	9.5	8.4

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APPENDIX C
STATISTICAL RESULTS

Appendix C: PERMANOVA Results

C-1: PERMANOVA Results

	TN				Chl - a			
Source	df	MS	Pseudo-F	P(perm)	df	MS	Pseudo-F	P(perm)
Ph	1	1.77E-03	0.66762	0.4778	1	165.31	8.3871	0.0722
Tr	1	7.18E-04	4.13E-02	^0.8526	1	0.82584	9.92E-02	^0.7509
Ti	1	3.46E-03	0.35181	0.7839	1	31.61	2.4387	0.1138
PhxTr	1	1.90E-03	0.717	0.4636	1	6.9901	0.35464	0.5795
PhxTi	1	5.72E-03	0.31847	0.6466	1	7.2191	0.55694	0.4269
TrxTi	1	1.52E-03	0.15497	0.9322	1	40.316	3.1103	0.0782
PhxTrxTi	1	3.12E-03	0.17367	0.7349	1	49.623	3.8283	0.0597
Si(Tr)	3	1.81E-02	1.378	0.2479	3	7.0168	0.54133	0.6388
PhxSi(Tr)	3	1.04E-03	7.96E-02	0.9661	3	21.614	1.6675	*0.1769*
TixSi(Tr)	3	9.32E-03	0.71135	0.5295	*3*	*17.341*	*1.3213*	*0.2746*
PhxTixSi(Tr)	3	1.87E-02	1.4268	0.2323	*3*	*3.0096*	*0.22931*	*0.8772*
Residual/Pooled	128	1.31E-02			146	12.962		
Total	147				159			
	TSS				EC			
Source	df	MS	Pseudo-F	P(perm)	df	MS	Pseudo-F	P(perm)
Ph	1	267.14	2.8167	0.0899	1	5618	380.36	**0.0001**
Tr	1	7.4144	7.82E-02	0.7885	1	147.36	7.1534	^0.0524
Ti	1	422.11	4.4508	**0.035**	1	2.8682	0.19419	0.66
PhxTr	1	266.4	2.8089	0.0963	1	4.3973	0.29771	0.5843
PhxTi	*1*	*0.23355*	*4.65E-03*	*0.9465*	1	2.5839	0.17494	0.6815
TrxTi	*1*	*0.17929*	*3.91E-03*	*0.948*	1	0.1624	1.10E-02	0.9184
PhxTrxTi	*1*	*6.1909*	*0.12313*	*0.7579*	1	0.72248	4.89E-02	0.822
Si(Tr)	*3*	*65.973*	*0.65217*	*0.5869*	3	22.072	1.4944	0.2141
PhxSi(Tr)	*3*	*45.604*	*0.45082*	*0.7141*	*3*	*4.9225*	*0.32702*	0.8033
TixSi(Tr)	*3*	*30.254*	*0.29907*	*0.8229*	*3*	*2.1212*	*0.14092*	0.939
PhxTixSi(Tr)	*3*	*35.894*	*0.35482*	*0.787*	*3*	*0.67023*	*4.45E-02*	0.9873
Residual/Pooled	155	94.841			396	14.77		
Total	159				406			

pH					**TP**			
Source	df	MS	Pseudo-F	P(perm)	df	MS	Pseudo-F	P(perm)
Ph	1	2.82E-02	3.2932	0.0687	1	2.13E-07	8.20E-05	0.9934
Tr	1	9.95E-02	2.626	^0.1868	1	5.35E-03	2.0632	0.1226
Ti	1	9.23E-05	1.08E-02	0.9196	1	2.33E-03	0.8999	0.4186
PhxTr	1	4.14E-02	4.8313	**0.0317**	1	1.28E-03	0.49147	0.4619
PhxTi	1	9.64E-03	1.1251	0.2914	*1*	*7.78E-06*	*3.33E-03*	*0.9577*
TrxTi	1	2.28E-02	2.6568	0.1054	*1*	*4.46E-04*	*0.23538*	*0.7777*
PhxTrxTi	1	1.66E-02	1.9417	0.1632	*1*	*5.14E-04*	*0.22026*	*0.6852*
Si(Tr)	3	4.53E-02	5.2859	**0.0007**	*3*	*2.02E-03*	*0.7505*	*0.5165*
PhxSi(Tr)	*3*	*2.08E-03*	*0.24065*	0.8664	*3*	*5.59E-04*	*0.20791*	*0.8944*
TixSi(Tr)	*3*	*9.54E-03*	*1.1055*	0.3449	*3*	*1.67E-03*	*0.62198*	*0.5959*
PhxTixSi(Tr)	*3*	*4.58E-03*	*0.53082*	0.6539	*3*	*2.23E-03*	*0.83108*	*0.4612*
Residual/Pooled	396	8.57E-03			155	2.59E-03		
Total	406				159			
Pairwise Comparisons		**Nested Terms**	Estuary: E3=E2					
Ranked from largest (left) to smallest (right)			Estuary: E4>E2					
			Estuary: E4>E3					
			Control: C7=C8					
		PhasexTreatment	Estuary: Before=After					
			Control: After>Before					
DO Pre-Construction					**DO Post-Construction**			
Source	df	MS	Pseudo-F	P(perm)	df	MS	Pseudo-F	P(perm)
Tr	1	5.8072	4.435	**0.04**	1	181.58	2.362	^0.2295
Ti	1	0.35699	0.27264	0.6076	1	74.11	2.4279	0.1243
TrxTi	1	1.18E-02	9.03E-03	0.9236	1	1.0951	3.59E-02	0.8483
Si(Tr)	3	0.84013	0.62352	0.606	3	77.761	2.5475	0.0543
TixSi(Tr)	3	0.16867	0.12518	0.945	*3*	*31.493*	*1.0321*	0.3744
Res	137	1.3094			259	30.524		
Total	140				265			