

Port Botany Post Construction Environmental Monitoring

Shorebirds Monitoring
Peak Summary Report

March 2012

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Summary

This report summarises data collected for the post-construction peak season September 2011 – March 2012 shorebird monitoring works. Changes to shorebird populations at Penrhyn Estuary were analysed by comparing counts with previous peak seasons to determine any correlations with the pre-construction and construction phases of the Port Botany Expansion.

Weekly surveys of shorebirds were carried out at low and high tide at the study site, Penrhyn Estuary, and at selected reference sites from the start of September 2011 to the end of March 2012. 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.

Peak counts of Bar-tailed Godwit, Red Knot, Pacific Golden Plover and Red-necked Stint were all higher than the previous year, however, were not consistent within the season, resulting in low averages. Numbers of Bar-tailed Godwit at Penrhyn Estuary slightly increased since the previous peak season, however, still remain significantly lower than counts in previous years, indicating that this species has likely been affected by activities associated with the Port Botany Expansion. The Curlew Sandpiper followed a declining trend at Penrhyn Estuary and at the reference site, similar to populations across southeast Australia. Populations of Red-necked Stint have remained stable at the reference site, while numbers have declined at Penrhyn Estuary. No distinct patterns in mean numbers of Pacific Golden Plover feeding at Penrhyn were observed, with counts remaining low over time. Counts of Double-banded Plover were extremely variable within and among seasons, with no significant differences in relation to the reference site. Nocturnal observations reveal some key species are using the site more frequently after dusk, however it is too early to draw conclusive results.

The PEHEP 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.

As the new estuary configuration evolves, with the break down of silts and organic material supporting colonisation of more benthic organisms, it is expected that shorebirds will continue to return in larger numbers.

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 west 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 and non-migratory shorebirds. Some species are found elsewhere in Botany Bay while others occur only at Penrhyn Estuary. 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 shorebird 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 are to expand the intertidal feeding habitat, secure roosting habitat in the form of three 'high tide' islands and restoration of 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 PEHEP 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.

1.2 Purpose of this report

This report provides a summary of the data collected for the post-construction peak season September 2011- March 2012 as part of the shorebird monitoring works. The purpose of this study is to measure changes to shorebird populations at Penrhyn Estuary during the post-construction phase of the Port Botany Expansion compared with the pre-construction phase. This report will document the progress of the monitoring performed and provide preliminary discussion, which will identify any important observations during fieldwork and inspection of the raw data collected. A more detailed annual report will be submitted in April 2013 for the twelve-month period ending March 2013.

2 Monitoring Methodology

Weekly surveys of shorebirds were carried out at low and high tide at the study site, Penrhyn Estuary, and at selected reference sites from the start of September 2011 to the end of March 2012. 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 1 and Appendix A).

Table 1 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	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	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		Tidal estuarine mudflats Tidal sand flats Sandy beaches Rocky shores	Pacific Golden Plover

2.1 Study Site

Penrhyn Estuary is a small estuary created incidentally during the construction of Port Botany in the 1970's. Silts and nutrients enter the estuary via two stormwater channels, Springvale and Floodvale drains, providing suitable substrate for a range of benthic organisms, in turn attracting a variety of migratory and non-migratory 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.

2.2 Reference sites

Southern Botany Bay

Three reference sites were 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 sandspit 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 sandspit. 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.

Parramatta Estuary

Sites around Parramatta River Estuary were used as reference locations for the Curlew Sandpiper. 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.

Boat Harbour

Boat Harbour is a medium-sized sandstone reef (approximately 3ha) located on the northeast of Bate Bay. 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.

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. It's 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 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.

2.3 Data analysis

Analysis of variance (ANOVA) was used to test the general hypothesis that any measurable differences in numbers of key species of birds (i.e. Bar-tailed Godwit, Curlew Sandpiper, Red-necked Stint, Pacific Golden Plover, Red Knot and Double-banded Plover) at Penrhyn Estuary was similar to those changes shown by independent reference locations, through time. Prior to analysis of variance, the data sets were examined for homogeneity of variances using Cochran's test (Winer *et al.*, 1991) and where necessary, transformations were performed to stabilise the variances. If the transformation was not successful at $P = 0.05$, the analysis was done using the raw data (Winer *et al.*, 1991).

For this monitoring program, surveys of birds have been completed on a number of occasions every month at low- and high-tide at Penrhyn Estuary and selected reference locations, since December 2006. For comparisons of numbers of key species among summer seasons (i.e. Bar-tailed Godwit, Curlew Sandpiper, Red-necked Stint, Pacific Golden Plover) data collected within the first summer season had to be excluded from analysis because surveys were only done over 3 months (i.e. December 2006 to March 2007)

compared to seven months within subsequent 'summer' seasons (i.e. September to March). Because only one set of each of summer and winter (i.e. April to August) 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 program is not temporally confounded (Underwood, 1992). Instead, analyses were done to compare differences in numbers of the key species surveyed at each of low- and high-tide within summer or winter (i.e. Double-banded Plover) seasons at Penrhyn compared to chosen reference locations. The mean count for each species of bird was calculated for each month for each of 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).

For the Bar-tailed Godwit, asymmetrical analysis of variance (ANOVA) was used to examine differences in total numbers of individuals between Penrhyn Estuary and the reference locations (i.e. Quibray Bay, Riverside Drive, Woodlands Road). The analyses of low- and high-tide data were done according to the model: Time (4 levels, fixed) and Location (4 levels, random and orthogonal). After running the full model analysis, a second analysis was done on only those data associated with the reference locations. The asymmetrical component, or Impact versus Reference partition, was calculated by subtracting the sums of squares of the second analysis from those of the first. What was left was the variance associated with the data from the Impact location. For a full account of these analyses and their logic see Underwood (1994).

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 program is not spatially confounded (Underwood, 1994). For these species, analysis of variance was used to examine differences between Penrhyn Estuary and the appropriate reference location treating Times as a fixed factor with 4 levels and locations as a random factor with 2 levels.

3 Preliminary Findings

3.1 Peak Counts at Penrhyn Estuary

Table 2 shows the peak counts of key species of shorebirds during the four years of the construction and post-construction phase compared to peaks during the pre-construction phase at Penrhyn Estuary.

Table 2 Peak counts of key species at Penrhyn Estuary

	High Tide (Roosting)					Low Tide (Feeding)				
	Pre-construction	Construction			Post-construction	Pre-construction	Construction			Post-construction
	Target (Peak)	2008/09 Peak count	2009/10 Peak count	2010/11 Peak count	2011/12 Peak count	Target (Peak)	2008/09 Peak count	2009/10 Peak count	2010/11 Peak count	2011/12 Peak count
Bar-tailed Godwit	95	58	48	31	42	58	40	36	13	31
Red Knot	3	2	2	0	1	3	5	2	0	1
Pacific Golden Plover	9	9	6	13	16	9	9	6	13	16
Curlew Sandpiper	2	0	0	0	0	2	0	1	0	0
Red-necked Stint	25	5	0	6	14	29	5	5	6	24
Double-banded Plover	37	29	31	19	20	33	33	31	22	20

3.2 Key Species

Bar-tailed Godwit

There was a slight increase in sightings of Bar-tailed Godwit at Penrhyn Estuary in summer 2011-2012 compared to the previous season (Figure 1), however low and high tide counts still remained significantly lower than in surveys done prior to summer 2010-2011 (Table 3, Figure 1). In comparison, counts at reference locations have remained relatively stable, with no significant difference over time (Table 3, Figure 1).

Table 3 Summary of a-ANOVA's comparing numbers of Bar-tailed Godwit at Penrhyn Estuary to reference locations (Quibray Bay, Riverside Drive, Woodlands Road)

Bar-tailed Godwit Source	df	Low-tide MS	F	High-tide MS	F
Time (Ti)	4	245.14		10.29	
Location (Lo)	3	138.60		52.50	
Impact v Refs	1	282.38		0.44	
Refs	2	66.72		78.53	
Ti x Lo	12	114.58		2.46	
Ti x Impact v Refs	4	214.33	3.49 *	5.05	3.84 *
Ti x Refs	8	64.71	1.05 ns	1.17	0.89 ns
Residual	120	61.48		1.32	
Cochran's test			0.16 ns		0.13 ns
Transformation			none		Ln(x+1)

ns = not significant ($P > 0.05$)

* = significant ($P < 0.05$)

** = significant ($P < 0.01$)

Refs = References

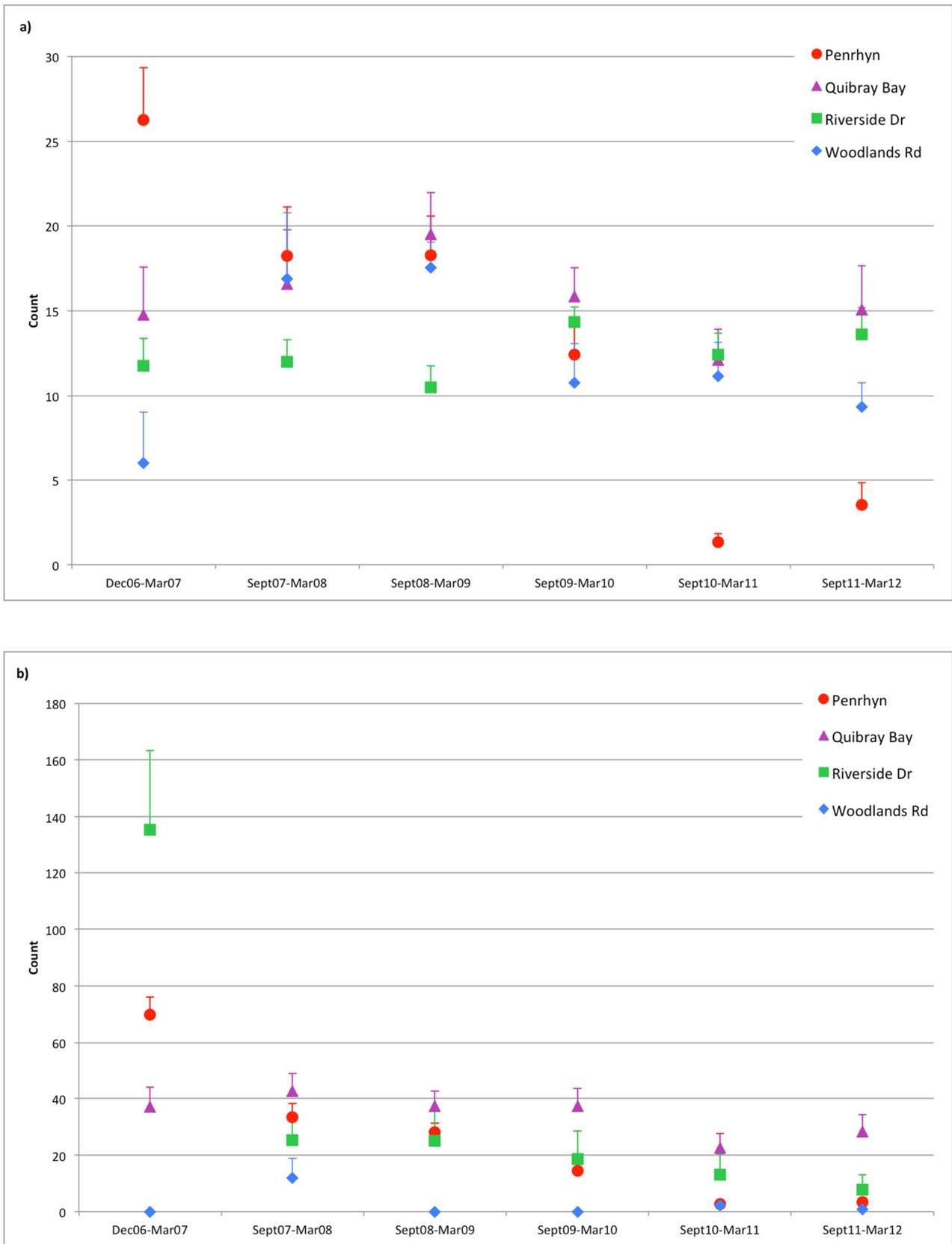


Figure 1 Mean (+SE) number of Bar-tailed Godwit at a) low-tide and b) high-tide

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

Curlew Sandpiper

Mean counts of Curlew Sandpiper at both low and high tide were significantly greater at the reference site (Parramatta Estuary) in the first four samples (Table 4, Figure 2). Since 2010, sightings at Parramatta Estuary have declined to a similar state at Penrhyn Estuary, averaging less than two birds per season (Figure 2). The Curlew Sandpiper has not been recorded at Penrhyn Estuary since summer 2007/2008, except for one sighting in 2009. The declining trend at both sites suggests that populations of Curlew Sandpiper are being impacted at a larger scale than the activities associated with the Port Botany Expansion project.

Table 4 Summary of ANOVA's comparing numbers of Curlew Sandpipers at Penrhyn Estuary compared to reference location (Parramatta Estuary)

Curlew Sandpiper Source	df	Low-tide		High-tide	
		MS	F	MS	F
Time (Ti)	4	53.58		69.72	
Location (Lo)	1	370.84		375.38	
Ti x Lo	4	51.43	4.28 *	67.30	5.84 *
Residual	60	12.02		11.52	
<hr/>					
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

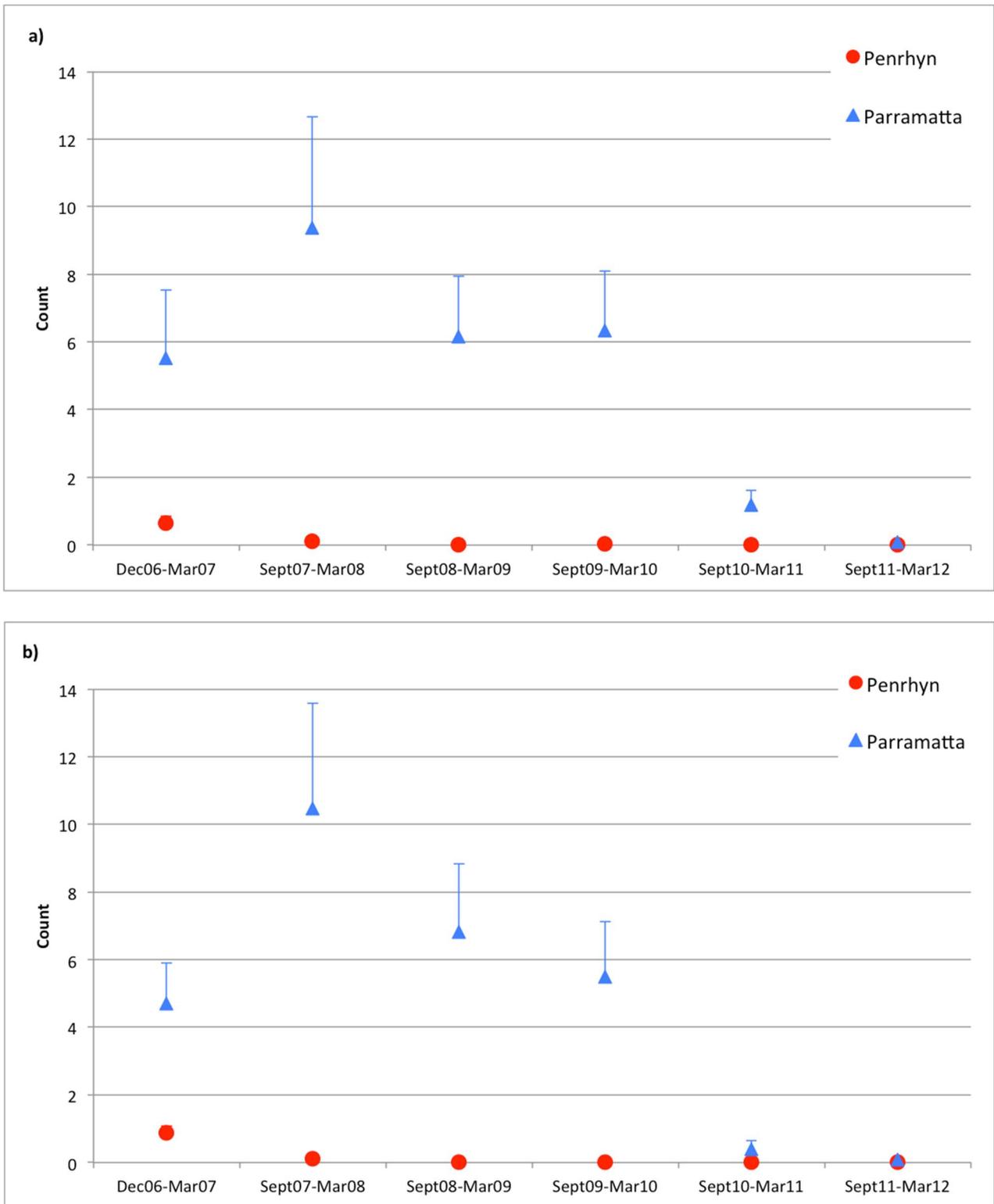


Figure 2 Mean (+SE) number of Curlew Sandpiper at a) low-tide and b) high-tide

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

Red-necked Stint

Mean numbers of Red-necked Stint were significantly greater at the reference site (Boat Harbour) at both low and high tide throughout the study period, with little change over time (Table 5, Figure 3). Numbers of Red-necked Stint at Penrhyn Estuary have remained very low since summer 2007-2008 (commencement of construction phase; Figure 3).

Table 5 Summary of ANOVA's comparing numbers 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)	4	240.75	0.57 ns	0.92	0.92 ns
Location (Lo)	1	27888.11	97.92 *	261.62	261.62 **
Ti x Lo	4	292.10	0.40 ns	0.94	0.94 ns
Residual	60	284.80		0.40	
Cochran's test					
			0.33 ns		0.27 ns
Transformation					
			none		Ln(x+1)

ns = not significant ($P > 0.05$)

* = significant ($P < 0.05$)

** = significant ($P < 0.01$)

Refs = References

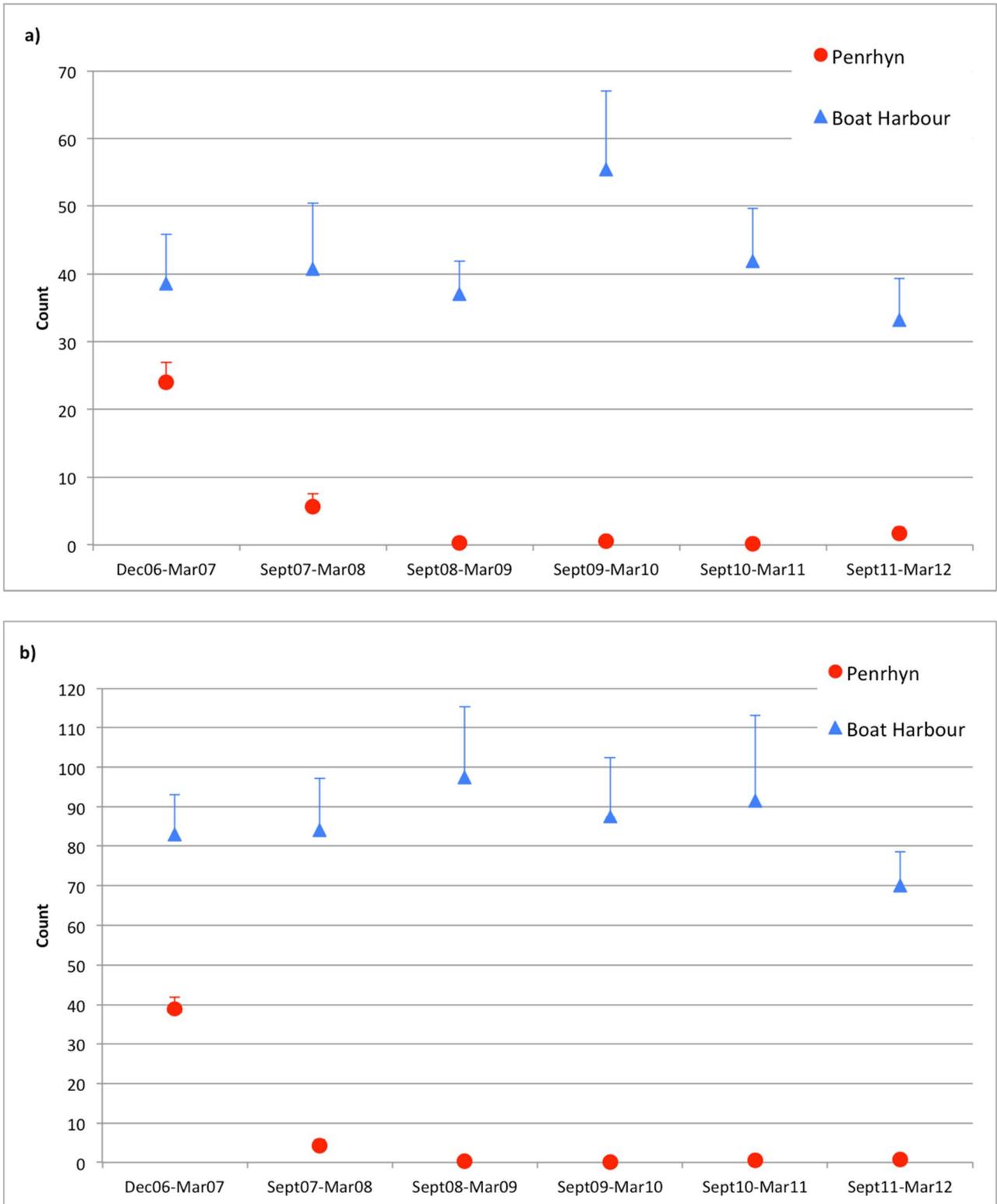


Figure 3 Mean (+SE) number of Red-necked Stint at a) low-tide and b) high-tide
 NB: data collected within the Dec06-Mar07 summer season were not included in analyses.

Pacific Golden Plover

Mean numbers of Pacific Golden Plover sighted at the Hunter Estuary during low-tide were significantly greater than at Penrhyn Estuary throughout the study period ($F_{1,60} = 90.55, P < 0.01$; Figure 4). Notably, differences among summer seasons were not significant ($F_{4,4} = 0.94, P > 0.05$; Figure 4). Overall, numbers at Penrhyn Estuary have been relatively small (averaging <5 individuals, and a maximum count of 16 birds) throughout the study period.

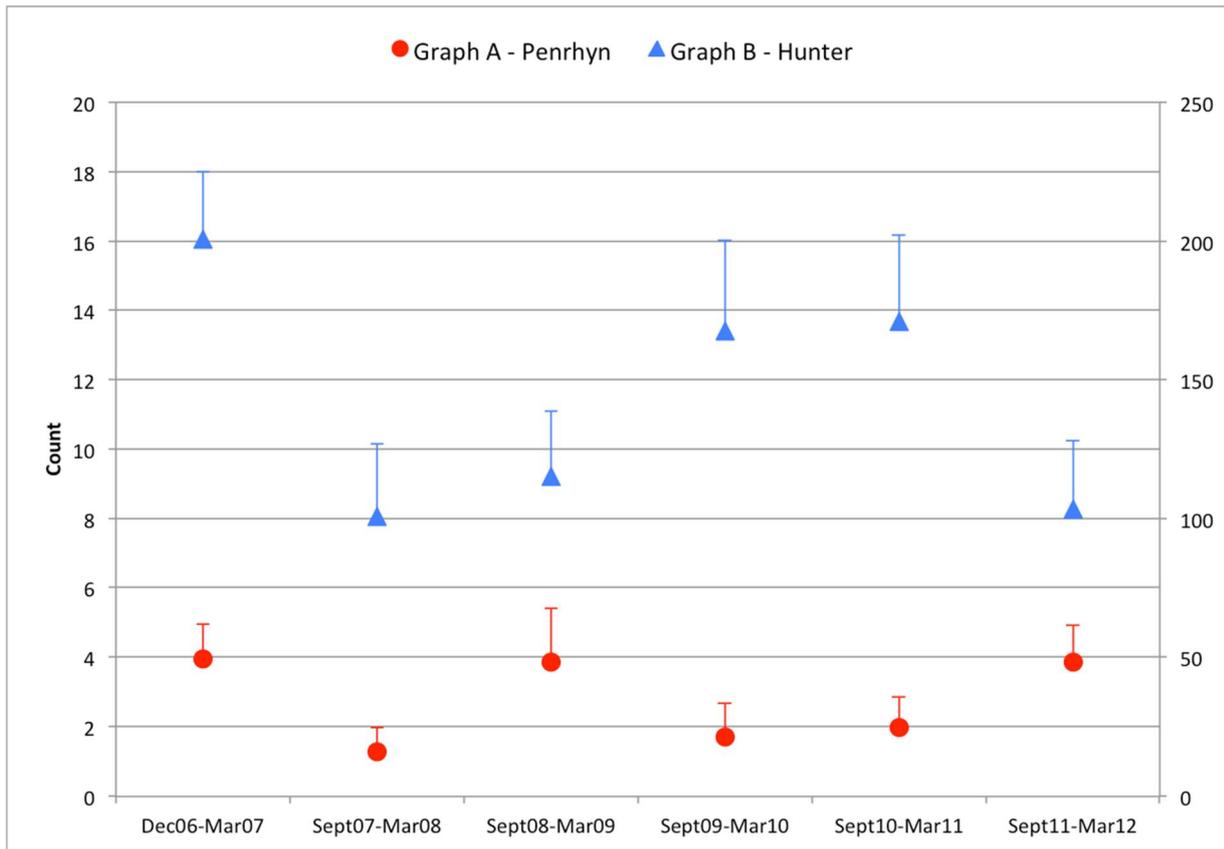


Figure 4 Mean (+SE) number of Pacific Golden Plover at low-tide

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

Double-banded Plover

No significant differences were found at any scales examined for low and high tides (Table 6). In general, numbers of Double-banded Plover were extremely variable at Penrhyn Estuary within and among seasons (Figure 5). Notably, there has been a decline in numbers of Double-banded Plover at Boat Harbour since the last survey.

Table 6 Summary of ANOVA's comparing numbers of Double-banded Plover at Penrhyn Estuary to the reference location (Boat Harbour)

Double-banded Plover Source	df	Low-tide		High-tide	
		MS	F	MS	F
Time (Ti)	4	2.06	1.34 ns	2.43	1.44 ns
Location (Lo)	1	2.77	2.80 ns	0.55	0.52 ns
Ti x Lo	4	1.54	1.56 ns	1.69	1.62 ns
Residual	49	0.99		1.04	
Cochran's test			0.24 ns		0.27 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 Knot

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 analyse the available data.

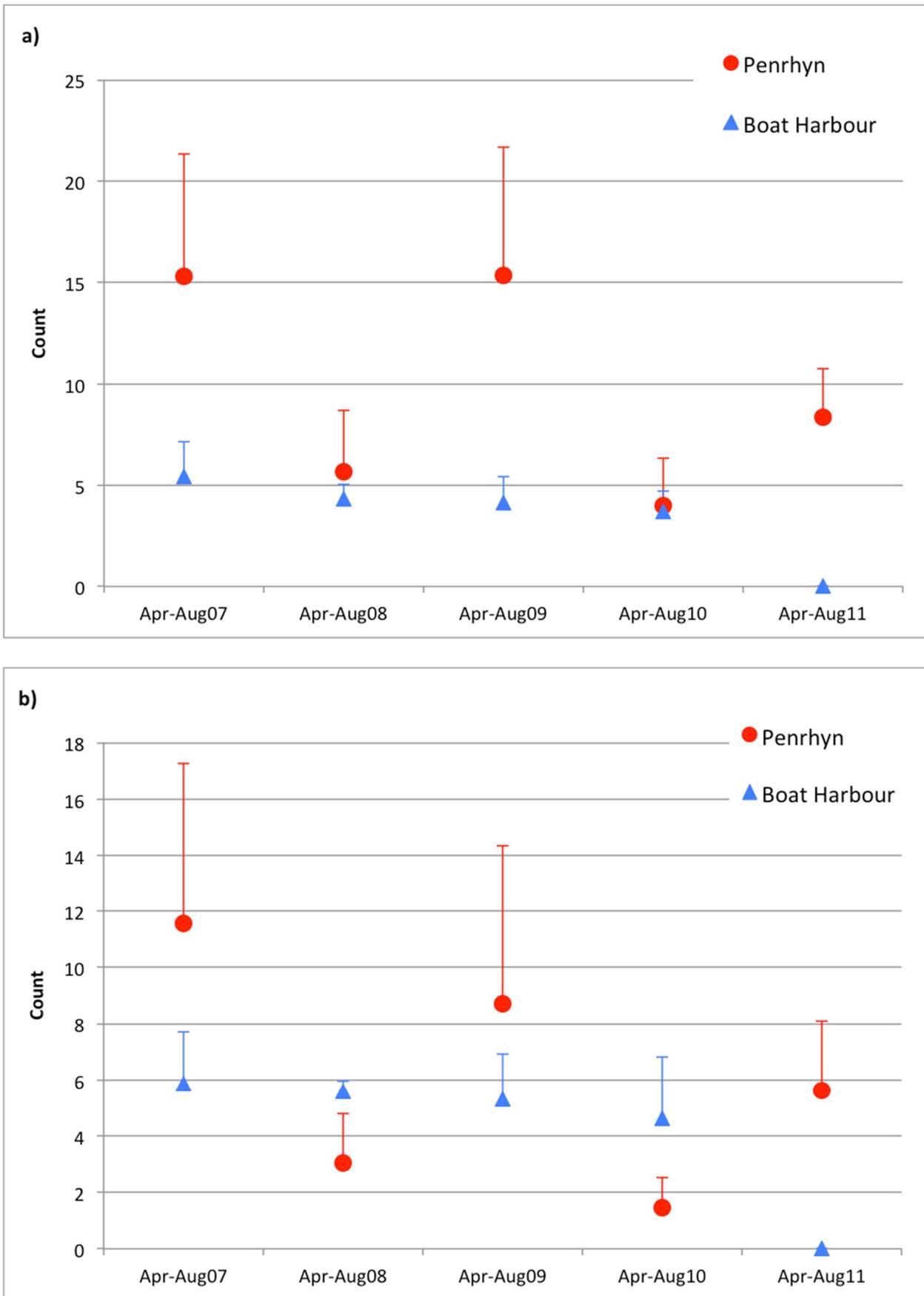


Figure 5 Mean (+SE) number of Double-banded Plover at a) low-tide and b) high-tide

4 Discussion

4.1 Key species

Analysis of shorebird populations during the 2011-2012 peak season revealed a decline in most species since the pre-construction phase, though explanations are species specific. It is important to note that peak counts of Bar-tailed Godwit, Red Knot, Pacific Golden Plover and Red-necked Stint were all higher than the previous year, however, did not remain consistently high within the season, resulting in low mean numbers.

Numbers of Bar-tailed Godwit at Penrhyn Estuary slightly increased at both low and high tide since the previous peak season, however, still remain significantly lower than counts in previous years. Although counts at reference sites in Botany Bay have also fluctuated, these have not changed significantly over time. This result indicates that activities associated with the Port Botany Expansion are likely to have contributed to the decline of Bar-tailed Godwit at Penrhyn Estuary.

Mean counts of Curlew Sandpiper at both low and high tide were significantly greater at the reference site, Parramatta Estuary, between 2007-2010. The Curlew Sandpiper has not been recorded at Penrhyn Estuary since commencement of the Port Botany Expansion works (2007-2008), with the exception of one individual sighting in summer 2009. However, since 2009 marked declines in numbers have also been observed at the reference site following the declining trend across southeast Australia, suggesting that the absence of Curlew Sandpiper is most likely related to events occurring at a larger scale than those associated with the Port Botany Expansion project.

Mean numbers of Red-necked Stint were significantly greater, and have remained relatively stable at Boat Harbour. Numbers at Penrhyn Estuary have remained low since pre-construction observations, suggesting that the decline is unlikely to be directly related to the Port Botany Expansion. Notably, peak counts at Penrhyn for this peak season were the highest recorded since pre-construction.

No distinct patterns in mean numbers of Pacific Golden Plover feeding at Penrhyn were observed in relation to the reference location at the Hunter Estuary. Fluctuations in numbers among summer seasons at Penrhyn Estuary were likely to be related to natural variation rather than an impact from activities associated with expansion of the port.

Analyses revealed no significant differences in mean numbers of Double-banded Plover at any of the scales examined for low and high tides. Mean counts for this peak season (2011-12) were higher at Penrhyn Estuary than the reference site, however, were extremely variable within and among seasons. This could potentially be evidence of disturbance (Warwick and Clarke, 1994), though numbers were variable in pre-construction years also. It is therefore likely that disturbances prior to the Port Botany Expansion were contributing to this variability. Less variability was evident within the seasons of 2010/11 and 2011/12 as well as an apparent increase in mean numbers of Double-banded Plover for this peak season, indicates that the recent removal of disturbances (human, predation by foxes etc.) in line with the PEHEP works may be successfully reducing the impact of disturbance on this species.

Nocturnal observations have been conducted fortnightly since February 2012. Preliminary observations reveal some key species, including Bar-tailed Godwit and Pacific Golden Plover, are using the site more frequently during nocturnal periods. However, it is too early to draw conclusive results. Analysis after the next peak season will help understand patterns of usage of the estuary by shorebirds.

4.2 Penrhyn Estuary: Issues for management

The PEHEP works have expanded both feeding and roosting habitat for shorebirds, and has eliminated much disturbance in the estuary. Three islands provide secure roosting sites away from potential disturbances (fox predation) at high tide. It is important to note, however, that wind erosion has occurred on Big Island, resulting in a shallow basin on top of the island. Shorebirds prefer areas with an open aspect to detect any dangers, and so remedial action is proposed to prevent further loss of sand material. It is also important to note that without constant fox management nesting birds are exposed to fox predation at low tide.

Observations have revealed that the new estuary configuration has provided valuable shorebird habitat, with increased peak counts of some species since the previous season. As the silts and organic material used to create the tidal flats continue to break down and is colonised by more benthic organisms, it is expected that shorebirds will continue to return in larger numbers.

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Port Botany Expansion –
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APPENDIX A

FIELD SAMPLING
LOCATIONS





Figure A1 Penrhyn Estuary Post-Construction



Figure A2 Monitoring Locations on Botany Bay Southern Shores and Boat Harbour



Figure A3 Monitoring locations within Parramatta River Estuary



Figure A4 Pacific Golden Plover diurnal roosting and foraging sites in the Hunter River Estuary