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Milestone Report No. 8 (Jan.–Feb. 2010).

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The Place To Be

Baywide Seagrass Monitoring Program

Milestone Report No. 8 (Jan.–Feb. 2010).

Alastair Hirst, Simon Heislers, Sean Blake and Allister Coots.

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Executive Summary

Seagrass is an important habitat in Port Phillip Bay (PPB). The objective of the Seagrass Monitoring Program is to detect changes in seagrass health in PPB outside expected variability. The program consists of three main elements: 1) large-scale mapping of seagrass area; 2) small-scale assessment of seagrass health in the field; and 3) monitoring of environmental factors that are known to influence seagrass health.

This milestone report presents: (1) the results of small-scale monitoring of seagrass health for summer (January-February) 2010; and (2) a preliminary conceptual model examining the key drivers of seagrass distribution and abundance in PPB, developed from 2 years of monitoring to date. Summary information on factors that are known to influence seagrass health is provided in this report.

This report provides a detailed assessment of seagrass cover, stem/shoot density and length at two subtidal depths (shallow (1–2 m) and deep (3–5 m) plots) in six regions and intertidal seagrass plots in four of the regions. Upper (intertidal) and lower (subtidal) seagrass limits were monitored using geographically fixed transects.

Seagrass cover, length and stem/shoot density in summer 2010 were compared with the previous sampling date in spring 2009, and against measurements in summer 2009.

Seagrass health

Subtidal and intertidal seagrass beds support different seagrass species and are considered separately in this report.

Subtidal seagrass beds monitored in this study consisted of a single seagrass species *Heterozostera nigricaulis*. Intertidal seagrass beds tend to be dominated by *Zostera muelleri*, although the aquatic macrophyte *Lepilaena marina* was also present at the Swan Bay and Mud Islands intertidal plots. During summer 2010, *H. nigricaulis* established at Point Richards intertidal plot, where previously this plot had been dominated by *Z. muelleri*.

Subtidal

Subtidal seagrass health varied widely between plots consistent with previous observations. There were no major changes recorded between spring 2009 and summer 2010.

Seagrass cover, length and shooting stem densities remained high at Blairgowrie, Mud Islands and Swan Bay 2 shallow plots, and low at Point Richards, St Leonards and Kirk Point. Seagrass cover, length and shooting stem density continued to decline at the Swan Bay 1 shallow plot. This pattern is entirely consistent with past established trends for these plots. By comparison, seagrass health at deep subtidal plots exhibited signs of recovery following recent declines.

Maximum seagrass depth at Blairgowrie and Point Richards in summer 2010 was unchanged since spring 2009.

Intertidal

There have been major changes to the distribution and abundance of intertidal seagrass at Point Richards since the inception of the program in autumn 2008. This is illustrated by marked changes in the extent of intertidal seagrass along established monitoring lines at this location. In summer 2010, the Point Richards plot was re-colonised by *H. nigricaulis*, although previously this plot had been dominated by *Z. muelleri*.

Intertidal seagrass at Swan Bay, Mud Islands and St Leonards behaved in a way which is consistent with previous trends observed at these plots, and cover and shoot densities remained relatively high in summer 2010.

Factors that affect seagrass health

Benthic light availability exceeded conservative environmental requirements for seagrasses at all regions during November 2009–March 2010. Epiphyte cover varied as expected based on previous monitoring at these plots.

Conclusions

The health of seagrasses in PPB between spring 2009 and summer 2010 varied as expected, based on comparisons with studies of Zosteraceae species in PPB and elsewhere.

A preliminary conceptual model examining the role of key drivers and their relative importance in determining seagrass distribution and abundance in PPB is presented in this milestone

report. Evidence suggests that for the seagrass meadows examined, burial and erosion mediated by sediment transport processes (waves, currents) are more important drivers of seagrass abundance in PPB than light, depth or epiphyte cover. Seasonal variation in desiccation stress may also be important in determining the upper extent of seagrass distribution in intertidal habitats in PPB.

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Introduction

Seagrass is an important habitat in Port Phillip Bay (PPB). Seagrasses are highly productive ecosystems, supporting diverse faunal assemblages, many of commercial importance. Seagrass plants filter and retain nutrients, stabilise sediments and baffle wave energy, protecting adjacent coastal shorelines from erosion.

The Seagrass Monitoring Program is described in the Port of Melbourne Corporation (PoMC) Channel Deepening Baywide Monitoring Programs (CDBMP) Seagrass Monitoring Detailed Design (PoMC 2010).

The objective of this program is to detect changes in seagrass health in PPB outside expected variability. The program consists of three main elements:

- Annual large-scale monitoring of seagrass coverage at nine regions using aerial mapping and periodic video ground-truthing in April/May
- Small-scale monitoring of seagrass health for six of the nine regions at representative field assessment plots sampled quarterly
- Monitoring of key parameters that are known to affect seagrass health (including light, turbidity and epiphyte abundance).

Purpose of this Report

This milestone report covers the period January–February 2010. This report presents:

- A summary of results for the small-scale monitoring of seagrass health undertaken in summer (January-February) 2010
- A brief discussion of relevant observations for other factors considered to influence seagrass health, where relevant
- A discussion of trends in the data observed, along with statistical comparisons examining changes in seagrass health variables between spring 2009 and summer 2010, and summer 2009 and summer 2010
- Discussion of QA/QC issues and any irregularities, along with any associated implications for the data.

Previous results from this program were reported in Hirst *et al*. (2008; 2009a, b, c, d, e, 2010). The results of large-scale aerial imagery were presented in Hirst *et al.* (2009a, e).

Materials and Methods

Project design and methods for this program are described in PoMC (2010) and Hirst *et al.* (2008; 2009a, b, c, d). This milestone report focuses on changes to seagrass health. The format of this report has been simplified from past milestone reports in that figures and analyses for factors influencing seagrass health have been omitted (see also Exceptions to Detailed Design). These factors will be considered qualitatively in this report and in greater detail in the Final Report for the program.

This report comprises a single element:

- Small-scale monitoring of seagrass health in six regions (Table 1)

The location of field-assessment plots for small-scale seagrass monitoring in PPB is shown in Figure 1.

Data Management

QA/QC.

There were no significant field events observed or other QA/QC issues recorded during this reporting period.

Exceptions to Detailed Design

One exception to the Detailed Design (PoMC 2010) applies for the reporting period:

- ER 2010#64: Omission of light and epiphyte data and analyses from Milestone Report #8 and all subsequent reports.

This exception has not affected the conclusions reached in this report.

Table 1. Summary of small-scale seagrass monitoring plots within regions.

Region	Field Assessment Plots		
	Intertidal	Shallow (1–2 m)	Deep (2–5 m)
Kirk Point		✓	
Point Richards	✓	✓	✓
St Leonards 1	✓	✓	✓
St Leonards 2*			✓
Swan Bay 1	✓	✓#	
Swan Bay 2		✓	
Mud Islands	✓	✓	✓
Blairgowrie		✓	✓

* Contingency deep plot for St Leonards 1 deep.

Extra field-assessment plot established in July/Aug 2008 due to positional error in location of original Swan Bay shallow plot established in April/May 2008 (renamed to Swan Bay 2) relative to position of historic sampling plot (see Hirst *et al.* 2008b and ER2008#13).

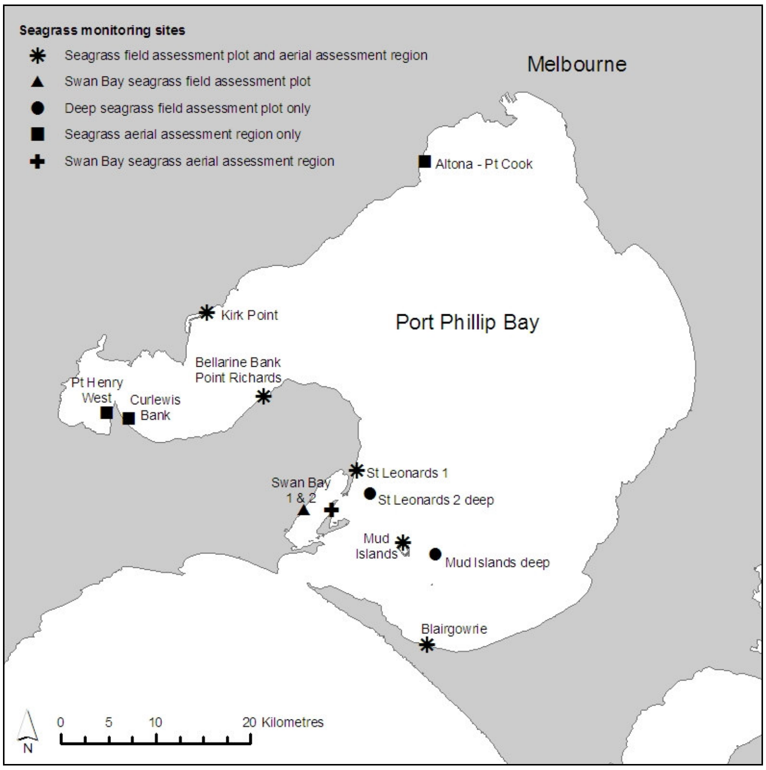

Figure 1. Locations of monitoring regions and small-scale field assessment plots in Port Phillip Bay.

Results

Tables and figures for the reporting period January-February (summer) 2010 are presented in Appendix 1.

Seagrass health

Statistically significant changes in seagrass variables between spring 2009 and summer 2010, and summer 2009 and summer 2010 are shown in Tables 3 and 4, and summarized below. Seagrass health figures for subtidal plots (shallow and deep) containing *H. nigricaulis* (Figures 7–12), and intertidal plots, typically dominated by *Z. muelleri* (Figure 13) are presented in Appendix 2.

Seagrass cover between spring 2009 and summer 2010:

- In shallow subtidal plots, increased at Mud Islands and Point Richards, decreased at Swan Bay 1 and St Leonards, and was unchanged Swan Bay 2, Blairgowrie and Kirk Point (Table 3)
- In the deep subtidal plots, increased at Blairgowrie, Mud Islands, St Leonards 1 and 2, and was unchanged at Point Richards (Table 3)
- In intertidal plots, increased at Mud Islands, and was unchanged at St Leonards, Swan Bay and Point Richards (Table 4).

Seagrass length between spring 2009 and summer 2010:

- In shallow subtidal plots, increased at Point Richards, decreased at Swan Bay 1 and St Leonards, and was unchanged at Blairgowrie, Mud Islands and Swan Bay 2 (Table 3)
- In the deep subtidal plots, decreased at St Leonards 2 and Point Richards, and was unchanged Blairgowrie, Mud Islands and St Leonards 1 (Table 3)
- In the intertidal plots, increased at Mud Islands and Point Richards, and was unchanged at Swan Bay and St Leonards (Table 4).

Shooting stem/shoot density between spring 2009 and summer 2010:

- In shallow subtidal plots, increased at Blairgowrie, decreased at Swan Bay 1 and 2, and St Leonards, and was unchanged at Mud Islands, Point Richards and Kirk Point (Table 3)
- In deep subtidal plots, increased at Blairgowrie, and was unchanged at Mud Islands, St Leonards 1 and 2, and Point Richards (Table 3)
- In the intertidal, increased at Mud Islands and Point Richards, and was unchanged at Swan Bay and St Leonards (Table 4). Colonisation by new *Heterozostera nigricaulis* plants was responsible for the increase in shoot densities observed at Point Richards in summer 2010 where previously *Zostera muelleri* had dominated this plot (Figure 2). *Z. muelleri* plants had been absent from this plot since winter 2009.

Seagrass cover in summer 2010 compared with summer 2009:

- In shallow subtidal plots, was higher at Swan Bay 2 and Point Richards, lower at Swan Bay 1, and unchanged at Blairgowrie, Mud Islands, St Leonards and Kirk Point (Table 3)
- In deep subtidal plots, was higher at Blairgowrie and St Leonards 1, lower at Mud Islands and St Leonards 2, and unchanged at Point Richards (Table 3)
- In intertidal plots, higher at Mud Islands and Swan Bay, and unchanged at St Leonards and Point Richards (Table 4).

Seagrass length in summer 2010 compared with summer 2009:

- In shallow subtidal plots, was higher at Mud Islands and Point Richards, lower at Swan Bay 1 and St Leonards, and unchanged at Blairgowrie and Swan Bay 2 (Table 3)
- In deep subtidal plots, was higher at Mud Islands and St Leonards 2, lower at Blairgowrie and St Leonards 1, and unchanged at Point Richards (Table 3)
- Was unchanged at all intertidal plots (Table 4).

Shooting stem/shoot density in summer 2010 compared with summer 2009:

- In shallow subtidal plots, was lower at Swan Bay 1, and unchanged at Blairgowrie, Mud Islands, Swan Bay 2, Point Richards, St Leonards and Kirk Point (Table 3)
- In deep subtidal plots, was higher at Blairgowrie and St Leonards 1, lower at Mud Islands and St Leonards 2, and unchanged at Point Richards (Table 3)
- In intertidal plots, was higher at Mud Islands and Swan Bay, and unchanged at St Leonards and Point Richards (Table 4).

Intertidal seagrass upper limits

Spatial changes in the monitoring lines for the upper extent of the intertidal seagrass at Mud Islands, St Leonards and Point Richards are presented in Figures 3-5.

The position of intertidal monitoring lines at Mud Islands had moved >2 m in sections between spring 2009 and summer 2010 (Figure 3). The position of lines 1 and 2 was similar to that recorded in spring 2009, although sections had migrated offshore by up to 2.8 m between spring 2009 and summer 2010. Line 3 had moved offshore by up to 10.3 m since summer 2009, and by up to 4.6 m at its eastern end between spring 2009 and summer 2010.

The positions of the intertidal monitoring lines at St Leonards (Figure 4) have remained relatively stable during the monitoring program and little variation was observed between spring 2009 and summer 2010.

The position of line 1 at Point Richards was similar to that recorded in spring 2009 (Figure 5). All intertidal seagrass at lines 3 and 4 was buried under sand by spring 2008. Intertidal seagrass along line 2 at Point Richards had disappeared under sand by spring 2009. Line 2 is located adjacent to the intertidal monitoring plot, where intertidal seagrass also disappeared during the same period. No intertidal seagrass was present along lines 2, 3 and 4 in summer 2010.

Subtidal seagrass lower limits

Video surveys of maximum seagrass depth were conducted at Blairgowrie and Point Richards in January and February (summer) 2010 (Figure 6). In summer 2010 shooting *H. nigricaulis* stems were observed at a significantly greater depth at Point Richards (mean depth = 9.2 m) than Blairgowrie (mean depth = 6.1 m). These differences have not always been evident (e.g. autumn 2009) as indicated by the significant interaction between location and date (location*date $F_{5,99} = 6.8$, $P<0.001$).

Maximum seagrass depth at Blairgowrie and Point Richards in summer 2010 was unchanged since spring 2009 (planned contrast, $P>0.05$). Maximum seagrass depth was significantly shallower in summer 2010 than summer 2009 at Blairgowrie (planned contrast, $P=0.031$) and Point Richards (planned contrast, $P=0.034$) (Figure 6).

Factors that affect seagrass health

Information on epiphyte cover and light attenuation were collected in summer 2010, but are not presented in detail here. These data varied during the reporting period as expected, based on results from previous monitoring, and were not required to interpret changes in seagrass health. In future milestone reports, epiphyte data will only be reported if 'significant' changes to seagrass health are detected.

Based on evidence from the literature and investigations in PPB, an average value of 15% of surface light was adopted as a conservative minimum annual light requirement for Zosteraceae species in the southern part of PPB (CEE 2007). Mean daily benthic light levels exceeded 15% of surface irradiance at all sites from November 2009 to March 2010.

Calculations were based on all data at Blairgowrie and Mud Islands, on 147 of 151 days at St Leonards, 114 of 151 days at Kirk Point (Long Reef), 106 of 151 days at Swan Bay, and 58 of 151 days at Point Richards. There were sufficient data to assess the influence of light on seagrass health during the reporting period, but light data will no longer be recorded in future reporting periods as part of this program.

Discussion

Seagrass abundance in PPB is dynamic at a range of spatial and temporal scales. Historical time series derived from coastal aerial photography show that seagrass abundance at large spatial scales (1-10 km) has varied substantially at a number of locations around PPB over the past 70 years (Ball *et al*. 2009a). At a much smaller spatial scale (1-10 m) seagrass cover, length and stem/shoot density is highly variable over much shorter time scales (months-years) (Hirst *et al*. 2008; 2009a, b, c, d, e, 2010).

After two years of monitoring, the program presents a preliminary conceptual model examining the role of key drivers – identified from the seagrass literature – and their relative importance in determining seagrass distribution and abundance in the southern and central regions of PPB for which we have good information on seagrass health and factors that influence seagrass health. The model provides a summary of key findings to date, and highlights areas that will be analysed in greater detail as part of a proposed Final Report for this Program.

Key drivers of seagrass distribution and abundance in PPB: a preliminary model

Light, depth and sediment transport processes are considered to be the primary factors determining seagrass distribution in subtidal environments, whereas desiccation stress is considered the most important factor determining the upper distribution of seagrass in intertidal environments (Larkum *et al*. 2006). Seagrasses have much higher light requirements than marine macroalgae and are typically restricted to clear, shallow waters. Depth and water clarity (turbidity) directly influence the amount of light reaching the benthos via their impact on light attenuation. Turbulent wave action can preclude seagrasses from exposed locations along the open coast in areas where there is sufficient light for seagrasses to grow. Water movement may also influence the stability of the seabed, via the transport and/or deposition of bottom sediments; Zosteraceae species, in particular, are sensitive to burial and erosion (Cabaco *et al*. 2008).

Light

The southern part of PPB is characterised by high water clarity. Light attenuation (K_d) rarely exceeded 0.5 m^{-1} during the course of this program (April 2008-April 2010). Periods of high turbidity (possibly associated with storm events) often corresponded with reductions in light attenuation, but were generally short in duration (e.g. 3-4 days) (Hirst *et al*. 2008; 2009a, b, c, d, e, 2010). There was no detectable relationship between variation in subtidal seagrass health and light attenuation, in part because whilst seagrass cover, length and stem densities varied appreciably between seasons, light attenuation remained relatively constant through time. Most seagrass beds of significant size in PPB are restricted to shallow waters (i.e. < 5 m) along the periphery of the southern shores of PPB or the Geelong Arm, or in shallow embayments such as Swan Bay (Blake and Ball 2001). Consequently, light is unlikely to be an important driver of seagrass distribution and abundance for seagrass meadows situated in these shallow waters.

Seasonal changes in the daily photoperiod and temperature are known to directly influence seagrass growth rates (Bulthuis 1987), but the extent to which variation in growth rates influences variation in seagrass cover, length and stem/shoot density is unclear at this point. Seasonal changes in day length (total light) and water temperature will be examined further in a Final Report for this program.

The pathway most commonly implicated in the loss of seagrass in southern Australia is that driven by elevated inputs of nutrients and/or suspended sediments into coastal systems (typically anthropogenic in origin), which lead to elevated levels of phytoplankton and epiphytic algal growth and productivity (Ralph *et al.* 2006). Higher loads of suspended particles associated with phytoplankton blooms and elevated turbidity impede light transmission to the benthos, leading to reduced seagrass productivity and mortality. There are few direct inputs of nutrients into the southern part of PPB, other than via diffuse run-off. Ambient nutrient levels in the southern half of PPB are typical of Victorian coastal waters (i.e. slightly oligotrophic) (EPA 2010). Water quality in the southern half of PPB is relatively high, and is unlikely to be an important driver of seagrass health in this part of the PPB.

Seagrasses are important sites for attachment of biota, including epiphytic algae and encrusting sessile invertebrates. In high abundance, epiphytic algae may cause excessive shading of seagrass leaves, although there is little evidence that high epiphyte cover is associated with low seagrass health in PPB. Epiphyte cover was often highest where seagrass cover was high, in part because the seagrass in these plots provide abundant substratum for epiphyte growth.

Depth

Video transects at Blairgowrie and Point Richards indicate that *H. nigricaulis* plants are largely restricted to depths less than 10 m (Figure 6), with most significant seagrass beds growing in water less than 5 m (Blake and Ball 2001). This finding is consistent with the predictions for seagrasses in PPB (CEE 2007). Assuming a minimum light requirement of 10% for *H. nigricaulis* (Bulthuis 1983) and an average K_d of 0.3 m^{-1} for PPB, the compensation depth for this species is approximately 10 m. Light and depth are important, in so far as they exclude seagrasses from deeper habitats in PPB.

Water movement and sediment transport

Seagrasses are sensitive to burial and erosion driven by changes in bottom sediment transport, and a number of studies have demonstrated high seagrass mortality as a result of natural or experimental burial and erosion (Ralph *et al*. 2006, Cabaco *et al*. 2008). Both processes have been implicated in the loss of seagrass in the intertidal zone at Point Richards (burial and erosion) and for deep plots at St Leonards (principally erosion) (Hirst *et al*. 2009c, e). It has been hypothesised that sediment transport processes, linked to changes in wind direction and intensity or currents, are likely to be important in determining long-term, decadal-scale variation in seagrass area observed in PPB over the past 70 years (Ball *et al.* 2009). Burial and erosion are likely to be important drivers of seagrass dynamics in PPB at a range of scales, but this program has limited data to elucidate further.

Desiccation stress

Desiccation is considered to be the primary factor determining the upper limit of seagrass in the intertidal zone. In particular, extreme summer temperatures may define the upper intertidal extent of seagrass. Where high temperatures coincide with prolonged exposure to the air (i.e. extreme low tides), damage caused by high desiccation/thermal stress may be irreparable.

Seagrass upper limits varied appreciably in PPB during this study. Intertidal seagrass disappeared at one location (Point Richards) and migrated appreciably seaward at another (Mud Islands). During the past 12 months the largest movements seaward in seagrass upper limits at Mud Islands were recorded during the warmer months (spring-summer-autumn) when temperatures are higher (see Hirst *et al*. 2009c, and this report). It will sometimes be difficult to distinguish variation in shoreline position from burial events that result in the loss of intertidal seagrass. Seasonal movements in the upper extent of intertidal seagrasses will be explored in more detail in the Final Report.

Seagrass health in summer 2010

Subtidal

Seagrass health varied appreciably between shallow subtidal plots in summer 2010 (Appendix 2 Figures 7 to 12). Seagrass cover, length and shooting stem densities remained high at Blairgowrie, Mud Islands and Swan Bay 2 shallow plots, and low at Point Richards, St Leonards and Kirk Point. Seagrass cover, length and shooting stem density continued to decline at the Swan Bay 1 shallow plot. This pattern is entirely consistent with established trends for these plots.

Seagrass health at deep subtidal plots exhibited signs of recovery following recent declines. Seagrass cover increased at four of the five deep subtidal plots: Blairgowrie, Mud Islands, St Leonards 1 and 2, but remained low at Point Richards. Prior to summer 2009, seagrass cover exceeded 40% at Mud Islands and St Leonards 2, but decreased substantially thereafter. Seagrass cover, length and shooting stem density have been low at Blairgowrie, Point Richards and St Leonards 1 throughout this study, but since winter 2009 seagrass cover and shooting stem density have increased appreciably at St Leonards 1 (Table 2).

By comparison there is little evidence of recovery at Point Richards and Kirk Point shallow plots. Both plots had substantial seagrass cover (>80%) prior to autumn 2008 (Hirst *et al*. 2010). The absence of recovery at these plots, in part, mirrors ongoing declines observed at the large-scale for each of these locations. Seagrass area at Point Richards is near historical lows, whereas seagrass area at Kirk Point has declined by up to 50% since 2007 (Hirst *et al*. 2009e).

Intertidal

Intertidal seagrass at St Leonards and Swan Bay has remained relatively stable throughout the course of this program (Appendix 2 Figure 13). Seagrass cover at Mud Islands dropped to 25% in winter 2009, but by summer 2010 seagrass had expanded to cover almost 100% of the plot, coupled with corresponding increases in seagrass length and shoot density. Intertidal seagrass at Swan Bay, Mud Islands and St Leonards behaved in a way which is consistent with previous trends observed at these plots.

Seagrass reappeared in the Point Richards plot between spring 2009 and summer 2010. Prior to this event, no seagrass has been recorded at this plot since winter 2009. Where previously this plot had been dominated by *Zostera muelleri, Heterozostera nigricaulis* plants were recorded in summer 2010. As this plot has been occupied by *Z. muelleri* since at least November 2005 (Ball *et al.* 2009b), it is likely that the new *H. nigricaulis* plants have grown from seeds or vegetative propagules rather than existing rhizome material in the sediment. The presence of dead *H. nigricaulis* stems and 'rhizome mats' at locations adjacent to the intertidal plot indicates that *H. nigricaulis* plants previously grew at this location. It is not clear why *H. nigricaulis* and not *Z. muelleri* has recolonised this plot but, given a history of *H. nigricaulis* growth at this location, this event is not considered unusual.

Conclusions

The health of seagrasses in PPB between spring 2009 and summer 2010 varied as expected, based on comparisons with studies of Zosteraceae species in PPB and elsewhere.

A preliminary conceptual model examining the role of key drivers and their relative importance in determining seagrass distribution and abundance in PPB is presented in this milestone report. Evidence suggests that burial and erosion mediated by sediment transport processes (waves, currents) are more important drivers of seagrass abundance in PPB than light, depth or epiphyte cover. Seasonal variation in desiccation stress may also be important in determining the upper extent of seagrass distribution in intertidal habitats in PPB.

Table 2. Long-term (monitoring program duration) and short-term (spring 2009-summer 2010) trends in seagrass health at each small-scale monitoring plot.

	Shallow (1-2 m)	Deep (2-5 m)	Intertidal
Blairgowrie	Seagrass cover/stem counts at this plot have remained high and relatively stable since spring 2008. Stem counts increased significantly in last quarter, but cover and length were unchanged.	Seagrass cover low (<15%), but slight increase in cover and stem density b/w spring 2009 & summer 2010.	
Mud Islands	Seagrass cover/stem counts at this plot have remained high and relatively stable since spring 2008. Seagrass cover increased in last quarter. Seagrass length higher than last summer (2009).	Most seagrass at this plot lost b/w summer & autumn 2009. Seagrass cover remains low (<15%), but significant increase in cover b/w spring 2009 & summer 2010	Seagrass cover but not shoot counts varied substantially b/w autumn 2008 and winter 2009. Significant increase in cover/shoot counts b/w spring 09 & summer 10.
Swan Bay 1	Seagrass cover has declined since major loss of cover b/w spring 2008 and summer 2009. Seagrass cover, length and stem count decreased in the last quarter.		Seagrass cover/shoot counts relatively stable b/w autumn 2008 and summer 2010
Swan Bay 2	Seagrass cover/stem counts at this plot have remained high and relatively stable since winter 2009. Stem counts decreased in the last quarter, but cover and length unchanged.		
St Leonards 1	Seagrass disappeared completely at this plot between spring 2009 and summer 2010. No seagrass at this plot.	Substantial growth of seagrass at this plot. Prior to summer 2009, seagrass cover <2%, but by summer 2010 seagrass covered 31% of plot.	Seagrass cover high in summer 2010. Seagrass cover/length/shoot counts increased significantly b/w spring 2009 and summer 2010.

St Leonards 2		Few living seagrass plants recorded at this plot in summer 2010. Most seagrass lost between spring and summer 09.	
Point Richards	No living seagrass at this plot (dominated by dead stems) since the beginning of study in autumn 2008	Seagrass cover very low (<2%) since the beginning of study in autumn 2008	Plot recolonised by *Heterozostera nigricaulis* plants in summer 2010. Plot previously supported *Zostera muelleri* plants prior to winter 2009.
Kirk Point	No seagrass at this plot.		

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Appendix 1. Results

Table 3. Summary of linear mixed effects model analysis testing for differences between all regions and sampling dates for seagrass cover, length and shooting stem density counts at shallow and deep subtidal plots. Planned statistical comparisons within each subtidal plot:
C1 - summer 2010 versus spring 2009
C2 – summer 2010 versus summer 2009

	arcsin (√% cover)		$\log_e$ (length)		$\log_e$ (count)	
Shallow plots						
Tukeys test (sum 10)	MI>B,SB2>SB1,PR>SL,KP		MI,SB2,B>SB1>PR>SL<KP		MI>B,SB2>SB1,PR>SL,KP	
Contrast	C1	C2	C1	C2	C1	C2
Blairgowrie (B)	+0.7	-0.2	-0.4	+1.3	+2.1*	+1.0
Mud Islands (MI)	+3.1**	+0.8	0	3.1**	-0.3	-1.0
Swan Bay 1 (SB1)	-3.1**	-4.0***	-4.5***	-7.1***	-6.8***	-13.0***
Swan Bay 2 (SB2)	+0.4	+7.2***	-0.3	0	-2.4*	-1.2
St Leonards (SL)	-2.0*	-1.6	-9.5***	-4.4***	-3.1**	-0.3
Pt Richards (PR)	+2.8**	+2.6**	+5.9***	+6.2***	+1.5	+1.0
Kirk Pt (KP)	-0.5	-0.9	-1.6		0	0
Deep plots						
Tukeys test (sum 10)	SL1>MI,SL2,B>PR		SL1>MI,SL2,B>PR		SL1>MI,B>PR,SL2	
Contrast	C1	C2	C1	C2	C1	C2
Mud Islands (MI)	+3.7***	-16.8***	-1.7	-4.5***	-0.2	-5.4***
St Leonards 2 (SL2)	+2.9**	-14.7***	-2.5*	-3.9***	+0.1	-16.2***
Blairgowrie (B)	+2.3*	+4.2***	+1.0	+3.4**	+4.1***	+7.8***
St Leonards 1 (SL1)	+6.5***	+10.4***	+1.3	+6.3***	+1.3	+11.9***
Pt Richards (PR)	-1.3	-0.5	-5.1***	-1.4	-1.3	-0.3

Blank $P>0.05$, *$P<0.05$, **$P<0.01$ and ***$P<0.001$
[1] Tukeys HSD post-hoc test between plots for summer 2010 only
+ t value indicates increase in variable; - a decrease in variable
green shading indicates significant increase in variable relative to previous samples; orange shading indicates significant decrease in variable relative to previous samples
NB. Global statistical outputs (i.e. F-ratios) of linear mixed-effects analysis not presented in this report

Table 4. Summary of 2-way ANOVA testing for differences between all regions and sampling dates for seagrass cover, length and shoot density counts at intertidal plots. Planned statistical comparisons within each intertidal plot:

C1 – summer 2010 versus spring 2009
C2 - summer 2010 versus summer 2009

	arcsin (√% cover)		log_e (length)		log_e (count)	
Tukeys test (sum 10)	MI,SB>SL>PR		MI,SB,SL>PR		MI,SB,SL>PR	
Planned contrasts	C1	C2	C1	C2	C1	C2
Mud Islands	+7.5***	+5.0***	+2.4*	+0.8	+2.1*	+4.3***
Swan Bay	+0.9	+3.3**	+0.3	+0.1	+0.3	+5.4***
St Leonards	+1.1	+1.0	-1.3	-0.4	+0.3	+1.1
Pt Richards	+0.7	-1.7	+4.0***	+1.2	+2.4*	-0.8

Blank $P>0.05$, $^{*}P<0.05$, $^{**}P<0.01$ and $^{***}P<0.001$
Tukeys HSD post-hoc test between plots for summer 2010 only
+ t value indicates increase in variable; - a decrease in variable;
green shading indicates significant increase in variable relative to previous samples; orange shading indicates significant decrease in variable relative to previous samples
NB. Global statistical outputs (i.e. F-ratios) of linear mixed-effects analysis not presented in this report

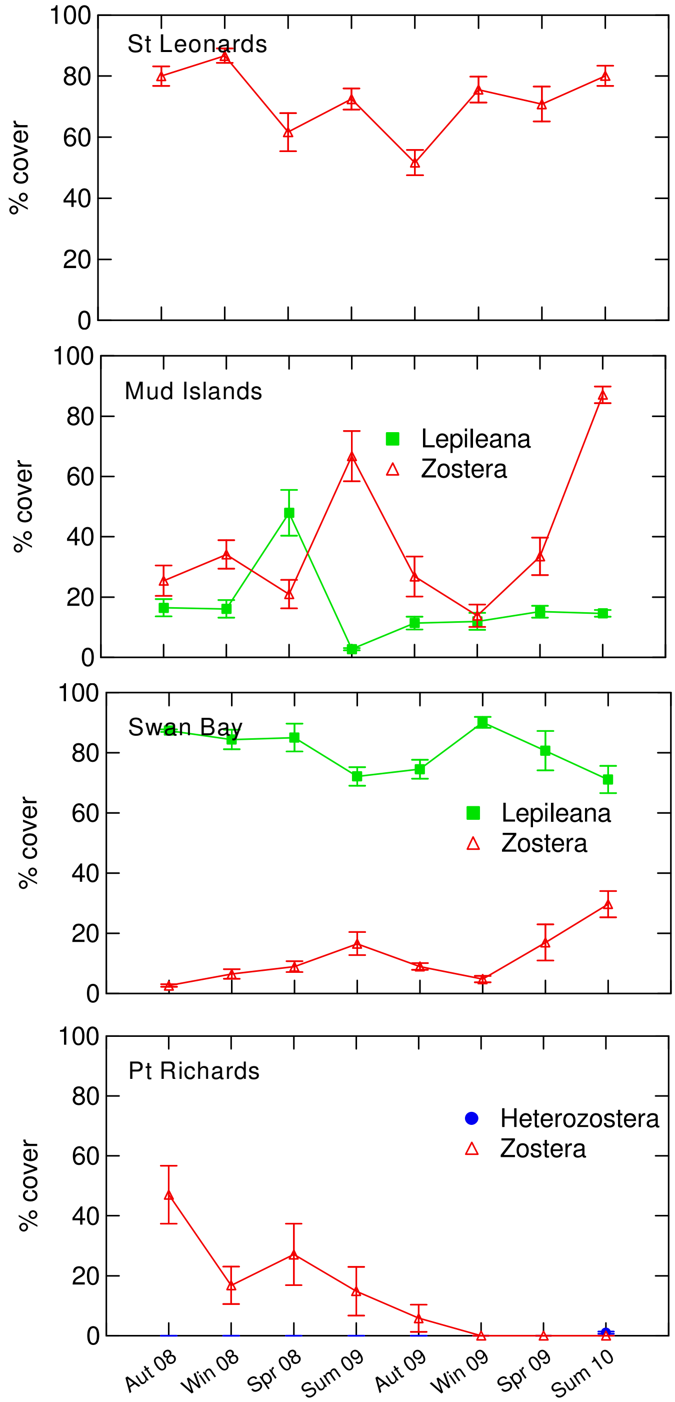

Figure 2. Variation in seagrass species composition (% cover) for intertidal plots at St Leonards, Mud Islands, Swan Bay and Point Richards between autumn 2008 and summer 2010. Note, *Heterozostera nigricaulis* plants appeared at Point Richards in summer 2010 (n.b. format of figures has changed from previous reports to enhance data presentation and interpretation).

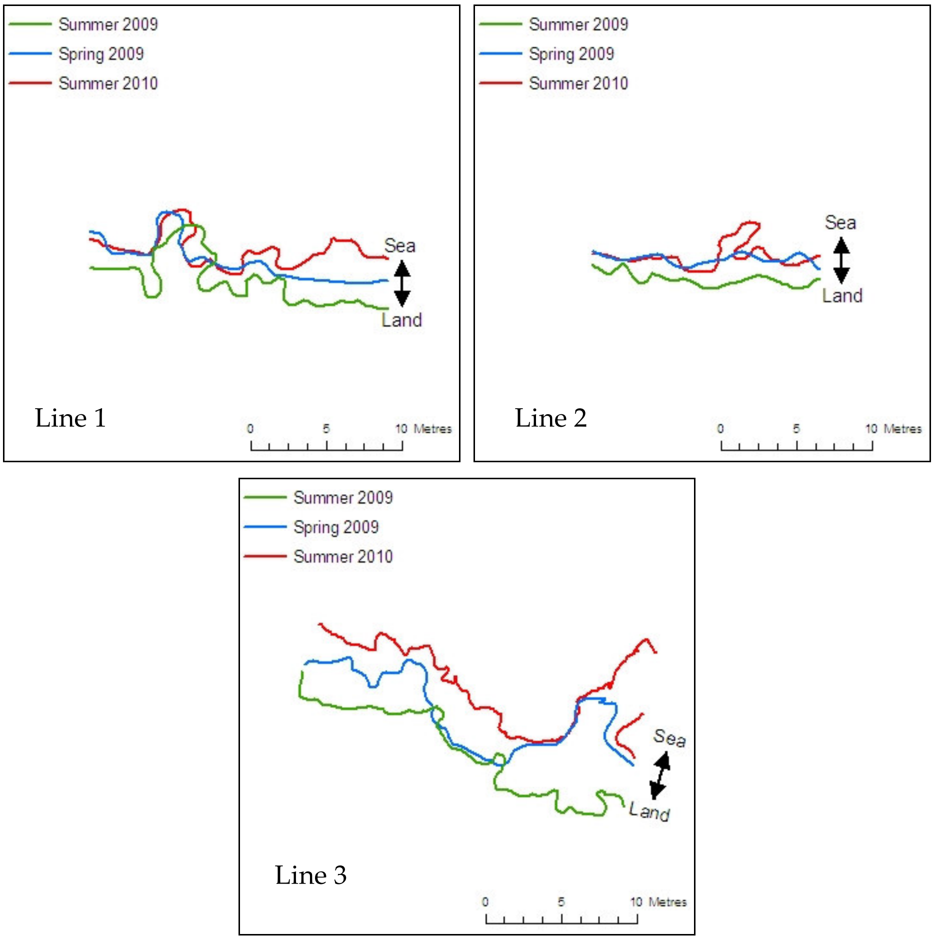

Figure 3. Mud Islands intertidal seagrass monitoring line positions recorded in summer and spring 2009, and summer 2010.

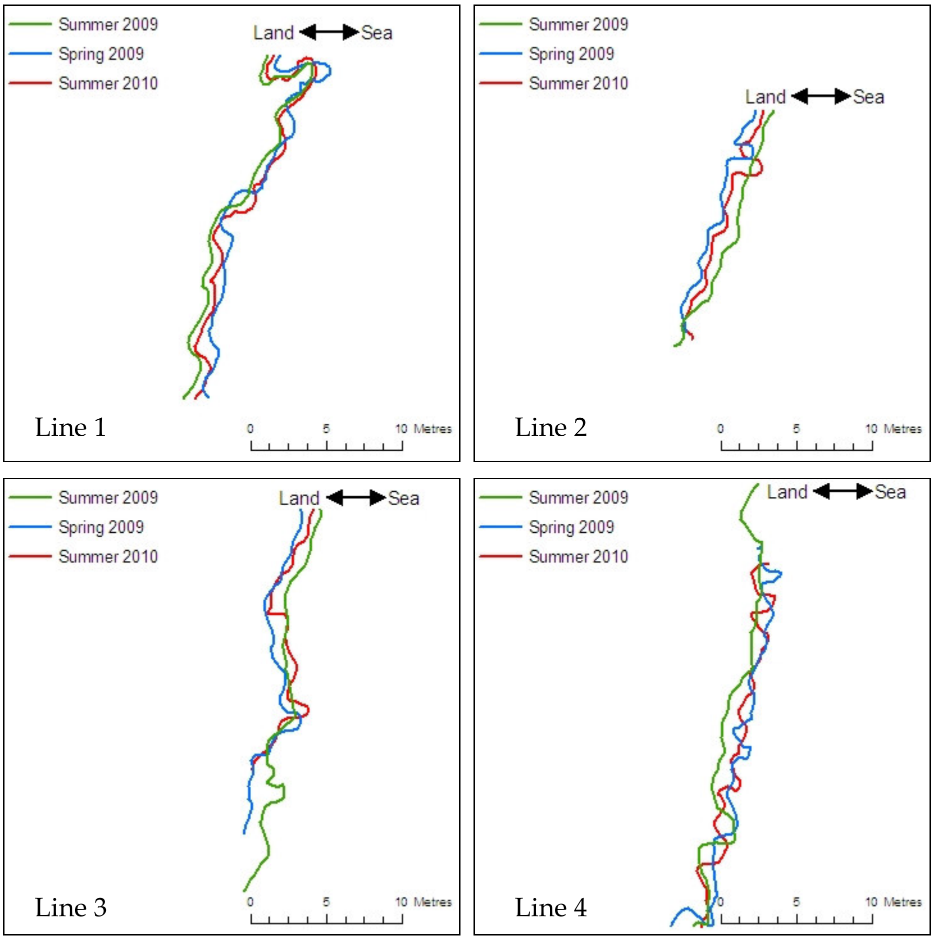

Figure 4. St Leonards intertidal seagrass monitoring line positions recorded in summer and spring 2009, and summer 2010. Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines.

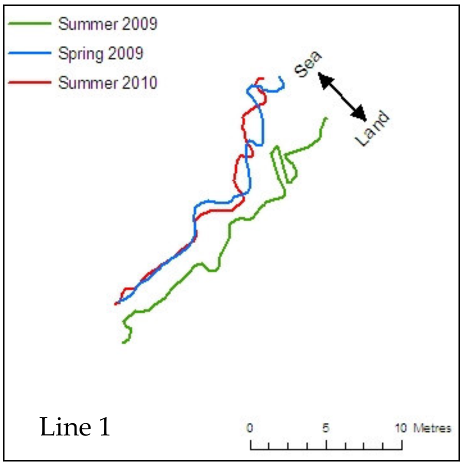

Figure 5. Point Richards (Bellarine Bank) intertidal seagrass monitoring line 1 positions recorded in summer and spring 2009, and summer 2010. Note, seagrass at lines 3 and 4 were completely buried by spring 2008 and at line 2 by spring 2009. No seagrass was recorded along lines 2, 3 or 4 in summer 2010.

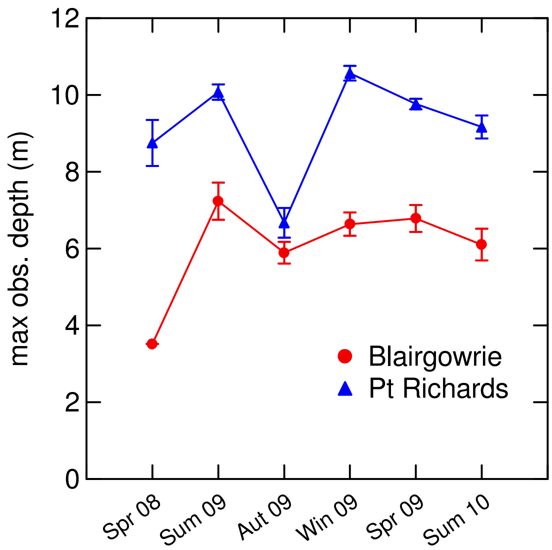

Figure 6. Mean (± se) maximum depth (m) of shooting *H. nigricaulis* stems observed on video transects offshore at Blairgowrie and Point Richards on six occasions between spring 2008 and summer 2010. Depths were corrected to the Australian Height Datum (AHD) (n.b. shooting stems were recorded on only a single transect at Blairgowrie in spring 2008; format of figure has changed from previous reports to enhance data presentation and interpretation).

Appendix 2. Seagrass health figures

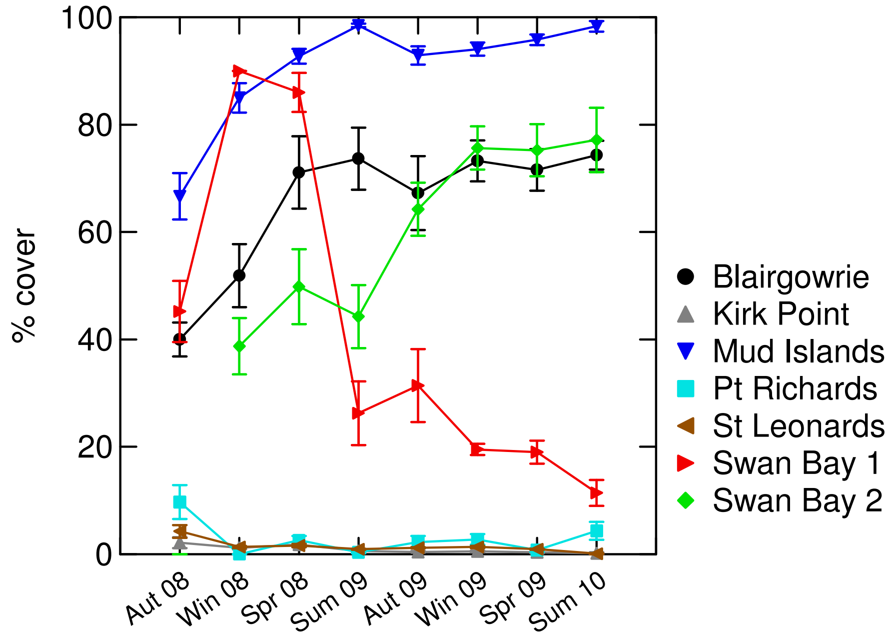

Figure 7. Mean (± se) seagrass cover (%) for *H. nigricaulis* at shallow subtidal plots sampled on eight occasions between autumn 2008 and summer 2010. Note no data was available for the Swan Bay 2 shallow plot in autumn 2008 (n.b. format of figure has changed from previous reports to enhance data presentation and interpretation).

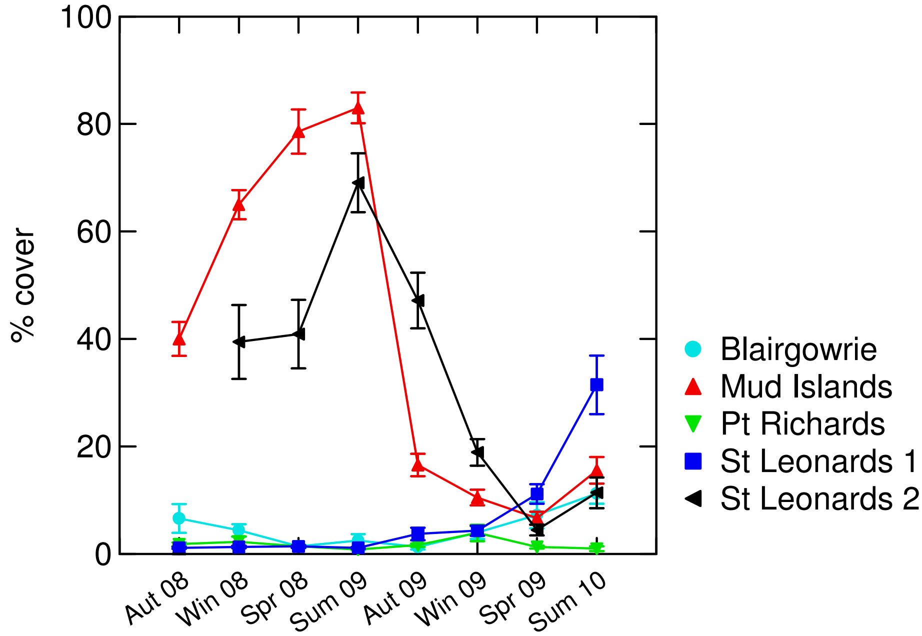

Figure 8. Mean (± se) seagrass cover (%) for *H. nigricaulis* at deep subtidal plots sampled on eight occasions between autumn 2008 and summer 2010 (n.b. no data were available for the St Leonards 2 deep plot in autumn 2008; format of figure has changed from previous reports to enhance data presentation).

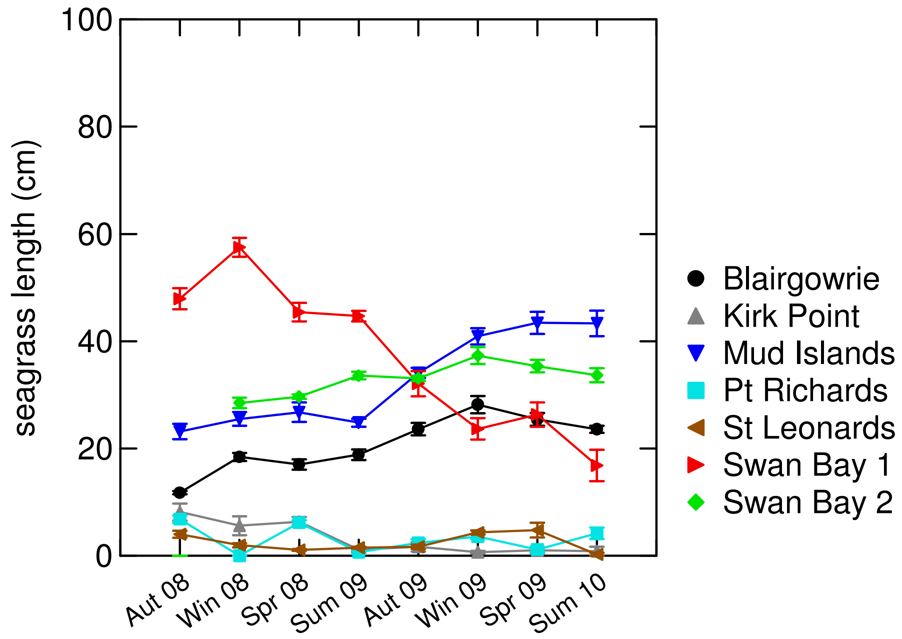

Figure 9. Mean (± se) seagrass length (cm) for *H. nigricaulis* at shallow subtidal plots sampled on eight occasions between autumn 2008 and summer 2010 (n.b. no data were available for the Swan Bay 2 shallow plot in autumn 2008; format of figure has changed from previous reports to enhance data presentation).

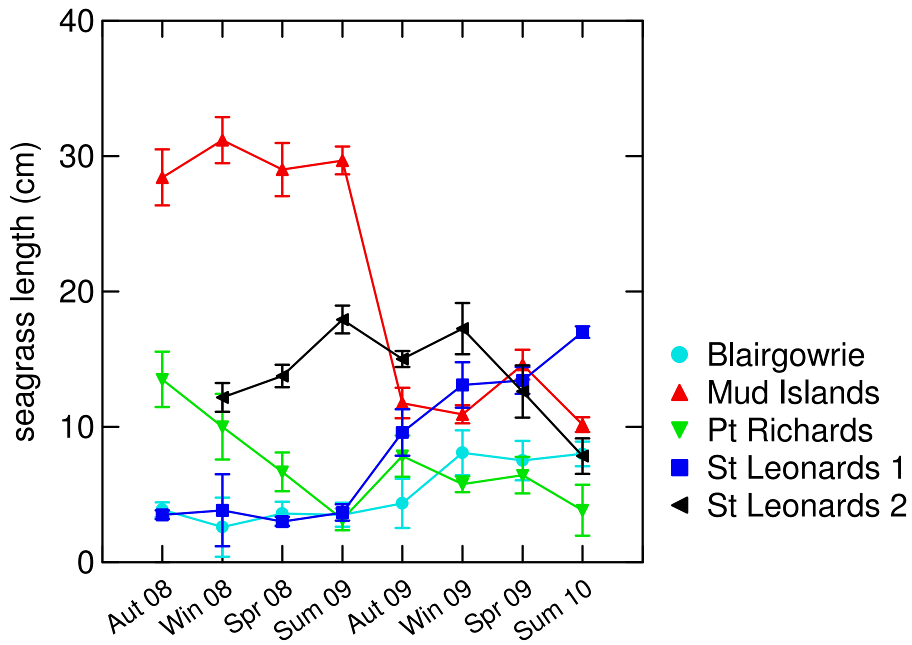

Figure 10. Mean (± se) seagrass length (cm) for *H. nigricaulis* at deep subtidal plots sampled on eight occasions between autumn 2008 and summer 2010 (n.b. no data were available for the St Leonards 2 deep plot in autumn 2008; format of figure has changed from previous reports to enhance data presentation).

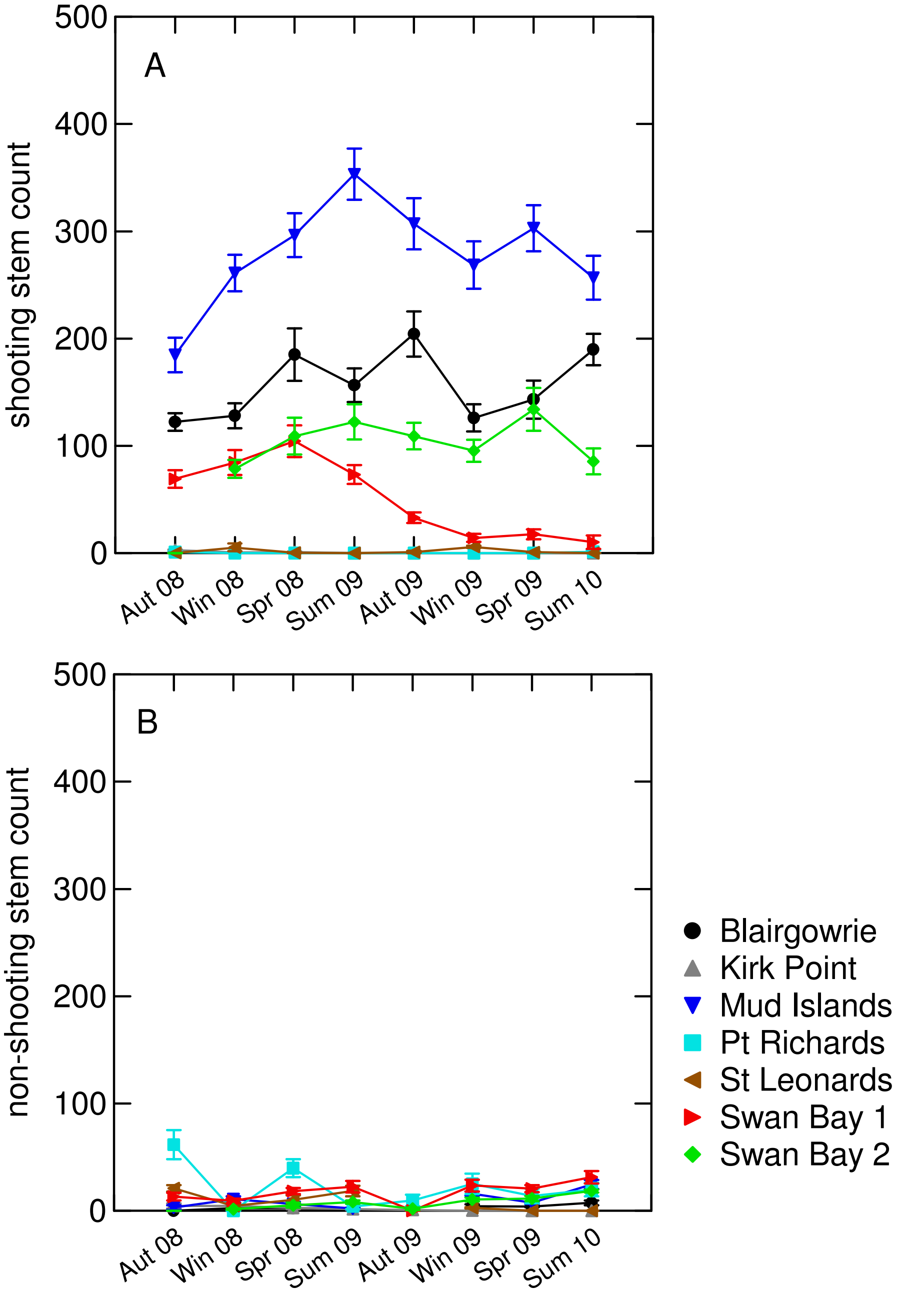

Figure 11. Mean (± se) A) shooting and B) non-shooting stem density count per 0.0625 m² quadrat for *H. nigricaulis* at shallow subtidal plots sampled on eight occasions between autumn 2008 and summer 2010. Note, no data were available for the Swan Bay 2 shallow plot in autumn 2008 (n.b. format of figures has changed from previous reports to enhance data presentation and interpretation).

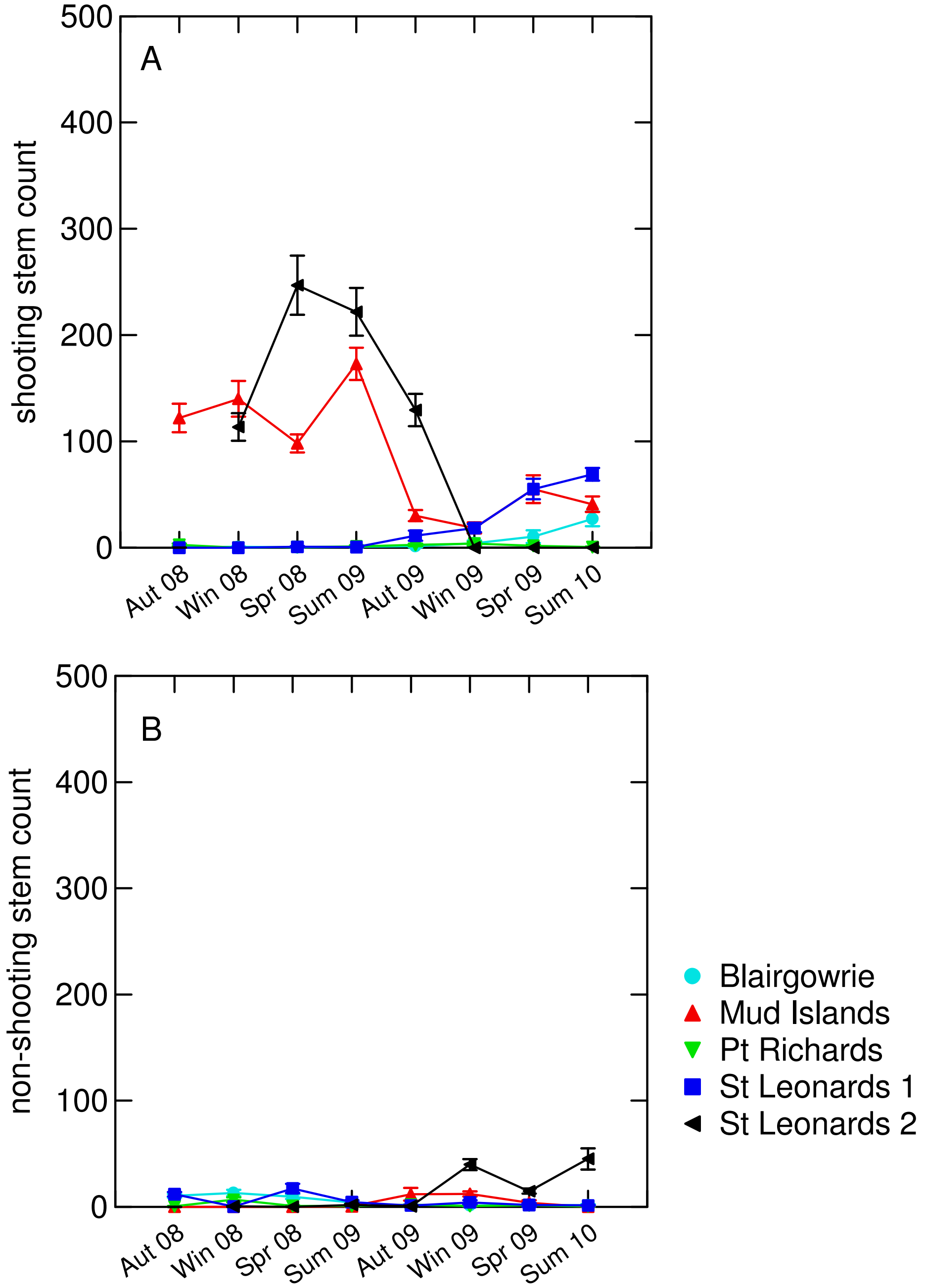

Figure 12. Mean (± se) A) shooting and B) non-shooting stem density count per 0.0625 m² quadrat for *H. nigricaulis* at deep subtidal plots sampled on eight occasions between autumn 2008 and summer 2010. Note, no data was available for the St Leonards 2 deep plot in autumn 2008 (n.b. format of figures has changed from previous reports to enhance data presentation and interpretation).

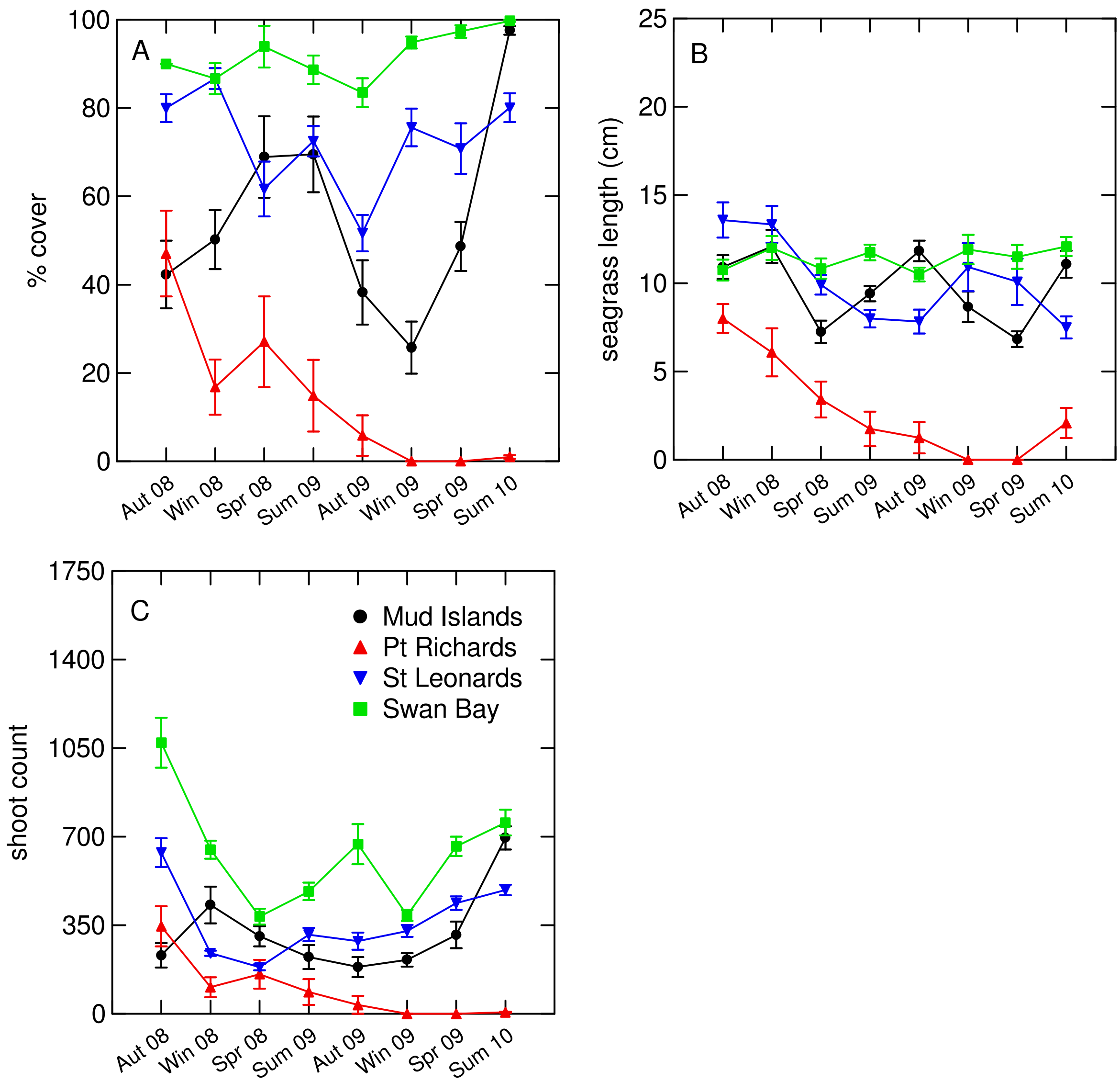

Figure 13. Mean (± se) combined seagrass A) cover (%), B) length, and C) shoot density count 0.0625 m^{-2} for intertidal plots sampled on eight occasions between autumn 2008 and summer 2010 (n.b. format of figures has changed from previous reports to enhance data presentation and interpretation).

Appendix 3. Data

Electronic data files are as follows:

- Seagrass health observations at plots and quadrats: CDP_seagrass_database_MR8.xls
- Intertidal seagrass upper limit boundaries: a separate shapefile exists for each region with the naming format Regioncode_UL_date_projection (e.g. MI_UL_12May08_MGA55.shp)
- Light logger data: Logger_data_November09_March10 xls.