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Baywide Seagrass Monitoring Program

Milestone Report No. 11
(October–November 2010)

No. 124
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Baywide Seagrass Monitoring Program

Milestone Report No. 11 (October – November 2011)

Alastair Hirst, Simon Heislers, David Ball, 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) Results of small-scale monitoring of seagrass health for spring (October-November) 2010
2) Information on factors that are known to influence seagrass health where this aids interpretation of changes in seagrass health from small-scale monitoring.

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 regions. Upper (intertidal) and lower (subtidal) seagrass limits were monitored using geographically fixed transects. Seagrass cover, length and stem/shoot density in spring 2010 were compared with the previous season (winter 2010), and against the mean of Spring 2008 and 2009 observations.

Seagrass health

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

Subtidal seagrass beds monitored in this study supported a single seagrass species *Heterozostera nigricaulis*. Intertidal seagrass beds tend to be dominated by *Zostera muelleri*, although the aquatic macrophyte *Lepilaena marina* was present at Swan Bay and Mud Islands, and the intertidal plot at Point Richards has been colonised by *H. nigricaulis* in addition to *Z. muelleri*.

Subtidal

Subtidal seagrass health varied widely between plots consistent with previous observations. No major changes in seagrass health were recorded between winter and spring 2010. Seagrass cover remained high at Blairgowrie (shallow plot) and Mud Islands (shallow), and low at Blairgowrie (deep plot), Point Richards (shallow) and St Leonards 1 (shallow and deep) in spring 2010. Subtidal plots at Mud Islands (deep), Point Richards (deep), St Leonards 2 (deep) and Swan Bay 1 and 2 (shallow) were dominated by non-shooting stems in spring 2010, and contained little living seagrass. No seagrass was present at Kirk Point in spring 2010.

Maximum seagrass depth at Blairgowrie increased between winter and spring 2010, but was unchanged at Point Richards.

Intertidal

Seagrass health at Swan Bay, Mud Islands and St Leonards intertidal plots was consistent with previous trends observed at these plots, and seagrass cover and length remained relatively high in spring 2010. At Point Richards there has been little significant regrowth since the reappearance of seagrass at this plot in summer 2010.

The positions of the intertidal seagrass monitoring lines have remained relatively stable at Mud Islands and St Leonards. Sparse seagrass cover observed along upper intertidal monitoring lines 2–4 at Point Richards in winter 2010 had disappeared by spring 2010.

Factors that affect seagrass health

Epiphyte cover varied as expected, based on previous monitoring. Macroalgal epiphyte cover remained high at Swan Bay 1 and 2 shallow subtidal plots in spring 2010. Epiphyte levels vary substantially between plots in this program, but may be locally important drivers of seagrass health in those areas of PPB where macroalgal growth, cover and biomass are high.

Conclusions

The health of seagrasses monitored in PPB during spring 2010 varied as expected, based on analysis of past trends at individual field plots. Factors observed to influence seagrass health between winter and spring 2010 were broadly consistent with the conceptual model developed for seagrasses in PPB. This emphasises the role of sediment movement and high epiphyte loadings play in determining seagrass health in the Bay.
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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 aerial assessment 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 (epiphyte abundance).

Purpose of this Report

This milestone report presents:

- A summary of results for the small-scale monitoring of seagrass health undertaken in spring (October-November) 2010
- A brief discussion of relevant observations for other factors considered to influence seagrass health
- A discussion of trends in the data observed, along with statistical comparisons examining changes in seagrass health variables between winter and spring 2010, and between spring 2010 and mean of spring 2008 and 2009 observations
- 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, 2010a, b, c, d).
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 from small-scale monitoring. The format of this report is simplified from Milestone Report No.8 (Hirst et al. 2010b) onwards, such that figures and analyses for factors influencing seagrass health have only been included where changes to seagrass health have been detected. These factors are considered qualitatively in this report, and will be considered in greater detail in the Final Report for the program.

This report comprises the results of:

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

Data Management QA/QC.

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

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

<table>
<thead>
<tr>
<th>Region</th>
<th>Field Assessment Plots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intertidal</td>
</tr>
<tr>
<td>Kirk Point</td>
<td>✓</td>
</tr>
<tr>
<td>Point Richards</td>
<td>✓</td>
</tr>
<tr>
<td>St Leonards 1</td>
<td>✓</td>
</tr>
<tr>
<td>St Leonards 2*</td>
<td>✓</td>
</tr>
<tr>
<td>Swan Bay 1</td>
<td>✓</td>
</tr>
<tr>
<td>Swan Bay 2</td>
<td>✓</td>
</tr>
<tr>
<td>Mud Islands</td>
<td>✓</td>
</tr>
<tr>
<td>Blairgowrie</td>
<td>✓</td>
</tr>
</tbody>
</table>

* 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

Seagrass health

Statistically significant changes in seagrass variables between winter and spring 2010, and between spring 2010 and the mean of spring in 2008 and 2009, are shown in Tables 3 and 4 (Appendix 1), and further summarized below. Temporal change in seagrass health over longer time periods was examined by comparing seagrass health in spring 2010 with the mean of the corresponding season in 2008 and 2009. Seagrass health figures for subtidal plots (shallow and deep) containing *Heterozostera nigricaulis* (Figures 1-7), and intertidal plots, typically dominated by *Zostera muelleri* (Figure 8-9), are presented in Appendix 2.

Seagrass cover between winter and spring 2010:
- In shallow subtidal plots, increased at Mud Islands, decreased at Blairgowrie, and was unchanged at Swan Bay 1 and 2, St Leonards, Point Richards and Kirk Point (Table 3, Figure 2)
- In the deep subtidal plots, increased at Blairgowrie and St Leonards 1, decreased at St Leonards 2, and was unchanged at Mud Islands and Point Richards (Table 3, Figure 3)
- In intertidal plots, was unchanged at all plots (Table 4, Figure 8A).

Seagrass length between winter and spring 2010:
- In shallow subtidal plots, increased at Swan Bay 1 and Kirk Point, and was unchanged at Blairgowrie, Mud Islands, Swan Bay 2, St Leonards and Point Richards (Table 3, Figure 4)
- In the deep subtidal plots, decreased at St Leonards 2, and was unchanged at Blairgowrie, Mud Islands, St Leonards 1 and Point Richards (Table 3, Figure 5)
- In the intertidal plots, decreased at Point Richards, and was unchanged at Mud Islands, Swan Bay and St Leonards (Table 4, Figure 8B).

Shooting stem/shoot density between winter and spring 2010:
- In shallow subtidal plots, increased at Swan Bay 1, St Leonards and Point Richards, and was unchanged at Blairgowrie, Mud Islands, Swan Bay 2, and Kirk Point (Table 3, Figure 6A). The shallow subtidal plot at Swan Bay 2 was dominated by non-shooting stems in spring 2010 (Figure 6B)
- In deep subtidal plots, increased at Blairgowrie and St Leonards 1, and was unchanged St Leonards 2, Mud Islands and Point Richards (Table 3, Figure 7A). Deep subtidal plots at Mud Islands and St Leonards 2 were dominated by non-shooting stems in spring 2010 (Figure 7B)
- In the intertidal plots, increased at Mud Islands, decreased at Swan Bay, and was unchanged at St Leonards and Point Richards (Table 4, Figure 8C).

Seagrass cover in spring 2010 compared with the mean of spring in 2008 and 2009:
- In shallow subtidal plots, was higher at Blairgowrie and Point Richards, lower at Mud Islands, Swan Bay 1 and 2, and unchanged at St Leonards and Kirk Point (Table 3, Figure 2)
- 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, Figure 3)
- In intertidal plots, was lower at Point Richards, and unchanged at Mud Islands, Swan Bay and St Leonards (Table 4, Figure 8A).

Seagrass length in spring 2010 compared with the mean of spring in 2008 and 2009:
- In shallow subtidal plots, was higher at Blairgowrie and Point Richards, lower at Swan Bay 1 and 2 and Kirk Point, and unchanged at Mud Islands and St Leonards (Table 3, Figure 2)
- 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, Figure 3)
- In intertidal plots, was lower at St Leonards and unchanged at Mud Islands, Swan Bay and St Leonards (Table 4, Figure 8A).

Seagrass length in spring 2010 compared with the mean of spring in 2008 and 2009:
- In shallow subtidal plots, was higher at Blairgowrie and Point Richards, lower at Swan Bay 1 and 2 and Kirk Point, and unchanged at Mud Islands and St Leonards (Table 3, Figure 2)
- In deep subtidal plots, was higher at Blairgowrie and St Leonards 1, and lower at Mud Islands, St Leonards 2 and Point Richards (Table 3, Figure 3)
- In the intertidal plots was lower at St Leonards and unchanged at Point Richards, Mud Islands and Swan Bay (Table 4, Figure 8C).
Shooting stem/shoot density in spring 2010 compared with the mean of spring in 2008 and 2009:

- In shallow subtidal plots, was higher at Point Richards, lower at Swan Bay 1 and 2, and unchanged at Blairgowrie, Mud Islands, St Leonards and Kirk Point (Table 3, Figure 6A).
- 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, Figure 7A).
- In intertidal plots, was lower at Swan Bay and Point Richards, and unchanged at Mud Islands and St Leonards (Table 4, Figure 8C).

Intertidal plots at Mud Islands and Swan Bay supported both *Z. muelleri* and *Lepilaena marina*. The intertidal plot at Mud Islands in spring 2010 was dominated by *Z. muelleri*, whereas the intertidal plot at Swan Bay continued to be dominated by *L. marina* in spring 2010. The intertidal plot at Point Richards comprised a mix of *H. nigricaulis* and *Z. muelleri* plants that was not easily separated in the field. The St Leonards plot continued to comprise only *Z. muelleri* (Figure 9).

**Intertidal seagrass upper limits**

Spatial changes in the monitoring lines, indicating the upper extent of the intertidal seagrass at Mud Islands, St Leonards and Point Richards, are presented in Figures 10–12.

The position of the intertidal monitoring lines at Mud Islands (Figure 10) has regularly moved by distances of up to approximately 5 m between seasons and years. Line 1 reduced in length by approximately 25% between winter and spring 2010 due to reduced seagrass cover at its western end. The remaining seagrass was within 1 m of its winter 2010 position. Line 2 migrated seaward by up 2 m, and Line 3 was within 1.3 m of its winter 2010 position.

The position of the intertidal monitoring lines at St Leonards (Figure 11) have remained relatively stable since autumn 2008, and were mostly within 1.5 m of their winter 2010 position in spring 2010. Line 3 reduced in total length by approximately 30% between winter 2009 and summer 2010, and its position/length has remained stable since then. Line 4 increased in length by approximately 60% between winter and spring 2010, and is within approximately 5 m of its full length last recorded in summer 2009.

The intertidal seagrass monitoring lines at Point Richards (Figure 12) have undergone large changes during the monitoring program due to sand deposition and seagrass burial. No seagrass was present along lines 2–4 in spring 2010. The remaining monitoring line, line 1, was in a similar position to that recorded in winter 2010.

**Subtidal seagrass lower limits**

Video surveys of maximum seagrass depth were conducted at Blairgowrie and Point Richards in spring (October) 2010 (Figure 13). In spring 2010 shooting *H. nigricaulis* stems were observed at similar depths at Blairgowrie (mean depth = 8.1 m) and Point Richards (mean depth = 8.9 m) ($F_{1,20}=2.2$, $P>0.05$). Seagrass was observed on all transects at Blairgowrie and Point Richards in spring 2010 ($n=11$).

Maximum seagrass depth at Blairgowrie was significantly deeper in spring 2010 than winter 2010 (planned contrast, $P=0.002$; Figure 13), spring 2008 and spring 2009. Maximum seagrass depth at Point Richards in spring 2010 was unchanged since winter 2010 and spring 2008 (planned contrast, $P>0.05$), but shallower than spring 2009 (planned contrast, $P=0.047$) (Figure 13).

**Factors that affect seagrass health**

Epiphyte cover for the shallow, deep and intertidal plots varied between regions during the reporting period, consistent with past results. Macroalgal epiphyte cover remained high (>90%) at Swan Bay 1 and 2 shallow plots in spring 2010.
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. 2009). At a much smaller spatial scale (1–10 m), seagrass cover, length and stem/shoot density varied considerably over much shorter time scales (months-years) (Hirst et al. 2008; 2009a, b, c, d, e, 2010a, b, c, d).

Sediment transport (burial and erosion), depth and light are considered to be the primary factors determining distribution and abundance of subtidal seagrass beds in PPB (Hirst et al. 2010a, 2010c). Sediment transport in conjunction with desiccation stress are considered to be the most important factors determining the distribution, abundance and upper extent of intertidal seagrass beds in PPB (Hirst et al. 2010a). Stochastic processes (random small scale disturbances such as the accumulation of drift algae, grazing and sand ‘blow-outs’) may also be important in determining the abundance of seagrass at smaller spatial scales (Larkum et al. 2006). Competition with macroalgal epiphytes may be a localised source of seagrass mortality in PPB (e.g. Swan Bay).

Seagrass health in spring 2010

Recent and longer-term trends in seagrass health over the duration of this program are summarised in Table 2.

Subtidal

Subtidal seagrass health varied appreciably between plots in spring 2010 (Table 2). Seagrass cover in spring 2010 was:

- >80% at Blairgowrie (shallow) and Mud Islands (shallow) plots
- <40% at Blairgowrie (deep), Point Richards (shallow) and St Leonards 1 (shallow and deep) plots
- dominated by non-shooting stems at Mud Islands (deep), Point Richards (deep), St Leonards 2 (deep) plots, and Swan Bay 1 and 2 (shallow), and contained little living seagrass
- absent at Kirk Point.

Subtidal seagrass within plots demonstrated the following clear trends over the past 12 months (i.e. since spring 2009):

- Seagrass cover, length and stem density increased at Blairgowrie (shallow and deep), Point Richards (shallow) and St Leonards 1 (deep) plots
- Seagrass cover, length and stem density decreased at Mud Islands (deep), St Leonards 2 (deep) and Swan Bay 2 (shallow).

The health of seagrass at all other plots was either largely unchanged or displayed no clear trend over this period.

The continual decline of seagrass at the deep plots at Mud Islands and St Leonards 2 between spring 2009 and 2010 followed large declines in the previous 12 months. Seagrass cover increased at Blairgowrie and St Leonards 1 deep plots where previously there had been little seagrass cover (i.e. <2% prior to spring 2009). This pattern reflects the cycle of seagrass decline and recovery exhibited at the small spatial scale (1–10 m). Seagrass loss has been linked to a range of processes during this program, but it is not clear what conditions facilitate the recovery of seagrass within a plot.

Seagrass colonisation is likely to occur via three main mechanisms: regeneration from seeds, regeneration from vegetative fragments/propagules, and recolonisation from surrounding or adjacent seagrass patches via rhizome elongation. It is unlikely that seagrass regenerates from existing rhizome networks characterised by dead vertical rhizomes (i.e. black stems without shoots). It is currently unclear how individually important these mechanisms are.

Intertidal

With the exception of Point Richards, the health of seagrass at intertidal plots was consistent with seasonal trends recorded at these plots between 2008 and 2010 (Table 2). Intertidal seagrass cover and length has been high and stable at Swan Bay throughout the course of this program (Appendix 2, Figure 8). In contrast, shoot density
at this plot has declined by 88% since autumn 2010. As 86% of the seagrass cover at this plot comprises *L. marina*, the reductions in shoot density are likely to involve changes to structure of *L. marina* assemblages at the plot, rather than *Z. muelleri*.

Seagrass cover remains very low at Point Richards, and there has been little recolonisation of this plot since seagrass reappeared in summer 2010. The sparse seagrass cover observed along upper intertidal monitoring lines 2–4 in winter 2010 had disappeared by spring 2010.

**Conclusions**

The health of seagrasses monitored in PPB during spring 2010 varied as expected, based on analysis of past trends at individual field plots. Factors observed to influence seagrass health between winter and spring 2010 were broadly consistent with the conceptual model developed for seagrasses in PPB. This emphasises the role sediment movement and high epiphyte loadings play in determining seagrass health in the Bay.
Table 2. Summary of trends in seagrass health at each small-scale monitoring plot between winter and spring 2010, and over the duration of the monitoring program (2008–10).

<table>
<thead>
<tr>
<th></th>
<th>Shallow (1–2 m)</th>
<th>Deep (2–5 m)</th>
<th>Intertidal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blairgowrie</strong></td>
<td>Seagrass cover and length in spring 2010 were higher than the longer-term seasonal trends at this plot. Seagrass cover was lower in the last quarter, but length and stem density were unchanged.</td>
<td>Seagrass cover, length and stem density in spring 2010 were higher than the seasonal trends at this plot. Cover increased in the last quarter. Seagrass covered approx. 28% of the plot in spring 2010.</td>
<td></td>
</tr>
<tr>
<td><strong>Mud Islands</strong></td>
<td>Seagrass cover rebounded in the last quarter. Seagrass cover in spring 2010 was slightly lower than the longer-term trend. Seagrass length and stem density were comparable to the longer-term trend.</td>
<td>Seagrass cover, length and stem density in spring 2010 were appreciably lower than the seasonal trends at this plot. Most of the seagrass at this plot was lost between summer and autumn 2009. The plot was dominated by non-shooting stems in spring 2010.</td>
<td>Seagrass cover at this plot has varied substantially (26–97%) over the duration of this program. Seagrass shoot density increased between winter and spring 2010, and seagrass cover remained unchanged.</td>
</tr>
<tr>
<td><strong>Swan Bay 1</strong></td>
<td>Seagrass cover remained low (&lt;20%) following major loss of cover between spring 2008 and summer 2009. Seagrass length and stem density increased in the last quarter. Macroalgal epiphyte cover remained high in spring 2010.</td>
<td>Seagrass cover, length and shoot density has been high and relatively stable over the duration of the program. Seagrass at this plot is dominated by <em>L. marina</em>. Seagrass shoot density decreased in the last quarter, and levels in spring 2010 are lower than the longer-term trend at this plot.</td>
<td></td>
</tr>
<tr>
<td><strong>Swan Bay 2</strong></td>
<td>Seagrass cover, length and stem density in spring 2010 were lower than the longer-term trend at this plot. The plot is now dominated by non-shooting stems. Macroalgal epiphyte cover remained high.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Observations and Trends</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>St Leonards 1</td>
<td>Few living seagrass plants were recorded in spring 2010, consistent with past trends at this plot. Seagrass cover, length and stem density in spring 2010 were much higher than the longer-term trend at this plot. Seagrass cover and stem density increased in the last quarter. While there was little seagrass in autumn 2008, the plot in spring 2010 supports seagrass that covers 37% of the plot reaching a mean length of 25 cm.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>St Leonards 2</td>
<td>Few living seagrass plants were recorded in spring 2010. Plot dominated by non-shooting stems. Seagrass cover, length and stem density were all lower than seasonal trends. Seagrass cover peaked in summer 2009, declining thereafter.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point Richards</td>
<td>Seagrass stem densities increased between winter and spring 2010. Seagrass cover, length and stem density were higher in spring 2010 than the longer-term seasonal trend at this plot. Seagrass cover remains low (&lt;2%) consistent with past trends at this plot.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirk Point</td>
<td>No seagrass present at this plot since summer 2009. Plot recolonised by <em>H. nigricaulis</em> and <em>Z. muelleri</em> plants in summer 2010. Seagrass cover and shoot density in spring 2010 were lower than the longer-term trend at this plot.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Acknowledgements

Guy Werner, Camille White and Peter Young participated in the SCUBA diver surveys. Some of the field work was undertaken with the charter vessel ‘Reel Easy’ skippered by Ian Garland.
References


## Appendix 1. Seagrass health tables

Table 3. Summary of linear mixed effects model analysis testing for differences between 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** – spring 2010 versus winter 2010
- **C2** – spring 2010 versus mean of spring in 2008 and 2009

<table>
<thead>
<tr>
<th></th>
<th>Shallow plots</th>
<th>Deep plots</th>
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<tr>
<td></td>
<td>Tukeys test (Spr 10)</td>
<td>Tukeys test (Spr 10)</td>
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<tr>
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<td>SL1,B&gt;SL2,MI,PR</td>
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<td><strong>Contrast</strong></td>
<td><strong>Shallow plots</strong></td>
<td><strong>Deep plots</strong></td>
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<td>C2</td>
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<tr>
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<tr>
<td>St Leonards (SL)</td>
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<td></td>
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<td>C2</td>
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<tr>
<td>Pt Richards (PR)</td>
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<td>C2</td>
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<tr>
<td>Kirk Pt (KP)</td>
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<td>C1</td>
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<td></td>
<td>C2</td>
<td>C2</td>
</tr>
</tbody>
</table>

**arcsin (\% cover)** | **loge (length)** | **loge (count)**
--- | --- | ---
Blairgowrie (B) | -2.1* | +4.5*** | -0.2 | -0.5
Mud Islands (MI) | +5.3*** | -3.3** | -1.7 | -1.4
Swan Bay 1 (SB1) | -0.9 | -11.6*** | +3.6*** | -10.0*** | +2.8*** | -8.8***
Swan Bay 2 (SB2) | +0.8 | -14.5*** | +0.9 | -5.0*** | -0.2 | -11.8***
St Leonards (SL) | +0.7 | +1.7 | +0.5 | +1.9 | +2.7** | +1.2
Pt Richards (PR) | +0.7 | +5.1*** | +1.1 | +5.4*** | +2.8** | +8.3***
Kirk Pt (KP) | +0.6 | -1.3 | +2.8** | -5.9*** | 0 | -0.8
St Leonards 1 (SL1) | +3.9** | +11.2*** | -0.9 | +6.7*** | +4.0*** | +9.6***
Pt Richards (PR) | +0.5 | -0.6 | +2.0 | -2.1* | -0.5 | -1.0

<table>
<thead>
<tr>
<th></th>
<th>Shallow plots</th>
<th>Deep plots</th>
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<td><strong>Contrast</strong></td>
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<td>Pt Richards (PR)</td>
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</tbody>
</table>

**arcsin (\% cover)** | **loge (length)** | **loge (count)**
--- | --- | ---
Blairgowrie (B) | 0 | -14.4*** | -0.3 | -8.7*** | +0.5 | -14.0***
Mud Islands (MI) | -4.5*** | -7.8*** | -2.8*** | -4.3*** | +0.3 | -8.8***
Swan Bay 1 (SB1) | +3.3*** | +9.7*** | -0.1 | +7.4*** | +3.9*** | +13.1***
Swan Bay 2 (SB2) | +3.9** | +11.2*** | -0.9 | +6.7*** | +4.0*** | +9.6***
Pt Richards (PR) | +0.5 | -0.6 | +2.0 | -2.1* | -0.5 | -1.0

*Blank P>0.05, *P<0.05, **P<0.01 and ***P<0.001
1 Tukeys HSD post-hoc test between plots for spring 2010 only (P<0.05)
+ 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 sampling dates for seagrass cover, length and shoot density counts at intertidal plots. Planned statistical comparisons within each intertidal plot:

C1 – spring 2010 versus winter 2010
C2 – spring 2010 versus mean of spring in 2008 and 2009

<table>
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<tr>
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<th>arcsin (% cover)</th>
<th>loge (length)</th>
<th>loge (count)</th>
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<td>Mud Islands</td>
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<tr>
<td></td>
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<td>+0.4</td>
<td>-3.3**</td>
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</tbody>
</table>

Blank P>0.05, *P<0.05, **P<0.01 and ***P<0.001

1 Tukeys HSD post-hoc test between plots for spring 2010 only (P<0.05)
+ 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 GLM analysis not presented in this report
Appendix 2. Seagrass health figures

Figure 2. Mean (± se) seagrass cover (%) for *H. nigricaulis* at shallow subtidal plots sampled on 11 occasions between autumn 2008 and spring 2010. (NB 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 and interpretation).

Figure 3. Mean (± se) seagrass cover (%) for *H. nigricaulis* at deep subtidal plots sampled on 11 occasions between autumn 2008 and spring 2010. (NB 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 4. Mean (± se) seagrass length (cm) for *H. nigricaulis* at shallow subtidal plots sampled on 11 occasions between autumn 2008 and spring 2010. (NB 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 5. Mean (± se) seagrass length (cm) for *H. nigricaulis* at deep subtidal plots sampled on ten occasions between autumn 2008 and spring 2010. (NB 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 6. Mean (± se) A) shooting and B) non-shooting stem count per 0.0625 m² quadrat for *H. nigricaulis* at shallow subtidal plots sampled on 11 occasions between autumn 2008 and spring 2010. (NB no data were available for the Swan Bay 2 shallow plot in autumn 2008. Format of figures has changed from previous reports to enhance data presentation and interpretation).
Figure 7. Mean (± se) A) shooting and B) non-shooting stem count per 0.0625 m² quadrat for *H. nigricaulis* at deep subtidal plots sampled on 11 occasions between autumn 2008 and spring 2010. (NB no data were available for the St Leonards 2 deep plot in autumn 2008. Format of figures has changed from previous reports to enhance data presentation and interpretation).
Figure 8. Mean (± se) combined seagrass A) cover (%), B) length, and C) shoot count per 0.0625 m² quadrat for intertidal plots sampled on 11 occasions between autumn 2008 and spring 2010. (NB Format of figures has changed from previous reports to enhance data presentation and interpretation).
Figure 9. Variation in seagrass species composition (% cover) for intertidal plots at St Leonards (Z. muelleri), Mud Islands, Swan Bay and Point Richards between autumn 2008 and spring 2010. *Heterozostera nigricaulis* plants appeared at Point Richards in summer 2010. (NB format of figures has changed from previous reports to enhance data presentation and interpretation).
Figure 10. Mud Islands intertidal seagrass monitoring line positions recorded in spring 2008–10 and winter 2010.
Figure 11. St Leonards intertidal seagrass monitoring line positions recorded in spring 2008–10 and winter 2010. Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines.
Figure 12. Point Richards (Bellarine Bank) intertidal seagrass monitoring line positions recorded in winter 2008–10 and autumn 2010. Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines. (NB No seagrass was present at monitoring lines 2–4 in spring 2010).
Figure 13. Mean (± se) maximum depth (m) of shooting *H. nigricaulis* stems observed on video transects offshore at Blairgowrie and Point Richards on eight occasions between spring 2008 and spring 2010. Depths were corrected to the Australian Height Datum (AHD). (NB shooting stems were recorded on only a single transect at Blairgowrie in spring 2008).
Appendix 3. Data

Electronic data files are as follows:

- Seagrass health observations at plots and quadrats: CDP_seagrass_database_MR11.xls
- Seagrass maximum depth limits: combined_deep_limits_data.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_21July10_MGA55.shp)