Baywide Seagrass Monitoring Program

Milestone Report No. 12
(January–February 2011)

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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:

- Large-scale mapping of seagrass area
- Small-scale assessment of seagrass health in the field, and
- 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 summer (January-February) 2011
(2) Information on factors that are known to influence seagrass health where this aids interpretation of changes in seagrass health.

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 summer 2011 were compared with the previous season (spring 2010), and against the mean of previous observations in summer 2009 and 2010.

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. Seagrass cover remained high at Blairgowrie (shallow plot) and Mud Islands (shallow), and low at Point Richards (shallow) and St Leonards 1 (shallow) in summer 2011. Subtidal seagrass cover increased at Blairgowrie and St Leonards 1 (deep plots) since 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 summer 2011, and contained little living seagrass. No seagrass was present at Kirk Point in summer 2011.

Maximum seagrass depth at Blairgowrie and Point Richards was unchanged between spring 2010 and summer 2011, and showed no consistent seasonal trend. Seagrass cover continued to be sparse along these offshore transects.

Intertidal
Seagrass health at Swan Bay, Mud Islands and St Leonards intertidal plots was consistent with previous trends observed at these plots; seagrass cover and length remained relatively high in summer 2011. At Point Richards there has been little significant regrowth since the re-appearance of seagrass at this plot in summer 2010.

The upper extent of intertidal seagrass at Mud Islands, Point Richards and monitoring Lines 1 and 2 at St Leonards has remained relatively stable since spring 2010. Intertidal seagrass along line 3 at St Leonards moved landward by up to 4 m at its northern end since spring 2010; some of the seagrass lost at the southern end of Line 3 between winter 2009 and summer 2010 had recovered by summer 2011.

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 summer 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 summer 2011 varied as expected, based on analysis of past trends at individual field plots. Seagrass has continued to recover at two of
the deeper subtidal plots. The conceptual model developed in this program has advanced a number of mechanisms that explain the loss of seagrass in PPB (e.g. sediment movement, epiphytes), but the specific conditions that facilitate the recovery and expansion of seagrass meadows are less clearly understood.
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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 summer (January-February) 2011
- 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 spring 2010 and summer 2011, and between summer 2011 and the mean of summer 2009 and 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, 2010a, b, c, d, 2011).
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 was simplified from Milestone Report No.8 (Hirst et al. 2010b) onwards. Figures and analyses for factors influencing seagrass health have only been included where changes to seagrass health are detected. 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.

| 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 historical 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 cover, length and stem/shoot density between summer 2011 and the previous season, spring 2010, and between summer 2011 and the mean of summer 2009 and 2010, are shown in summary in Table 2 and in detail in Table 3 (Appendix 1), and further summarized below.

Change in seagrass health over the duration of this program was examined by comparing seagrass health in summer 2011 with spring 2010, and with the mean of the corresponding summer season in 2009 and 2010.

Seagrass health data for subtidal plots (shallow and deep) containing Heterozostera nigricaulis, and intertidal plots, typically dominated by Zostera muelleri are presented in Figures 2-9 (Appendix 2).

Seagrass cover between spring 2010 and summer 2011:
- In shallow subtidal plots, increased at Mud Islands, decreased at Swan Bay 2 and Point Richards, and was unchanged at Blairgowrie, Swan Bay 1, St Leonards and Kirk Point (Table 3, Figure 2)
- In the deep subtidal plots, increased at Blairgowrie, Mud Islands and St Leonards 1, and was unchanged at St Leonards 2 and Point Richards (Table 3, Figure 3)
- In intertidal plots, increased at Mud Islands, and was unchanged at Swan Bay, St Leonards and Point Richards (Table 4, Figure 8A).

Intertidal plots at Mud Islands and Swan Bay supported both Z. muelleri and Lepilaena marina plants. The intertidal plot at Mud Islands in summer 2011 continued to be dominated by Z. muelleri, whereas the intertidal plot at Swan Bay continued to be dominated by L. marina plants in summer 2011 (Figure 9).

Seagrass length between spring 2010 and summer 2011:
- In shallow subtidal plots, increased at Swan Bay 1 and Kirk Point, decreased at Blairgowrie and Swan Bay 2, and was unchanged at Mud Islands, St Leonards and Point Richards (Table 3, Figure 4)
- In the deep subtidal plots, increased at St Leonards 1, and was unchanged at Blairgowrie, Mud Islands, St Leonards 2 and Point Richards (Table 3, Figure 5)
- In the intertidal plots, increased at Mud Islands, and was unchanged at Swan Bay, St Leonards and Point Richards (Table 4, Figure 8B).

Shooting stem/shoot density between spring 2010 and summer 2011:
- In shallow subtidal plots, increased at Mud Islands, decreased at Swan Bay 2, and was unchanged at Blairgowrie, Swan Bay 1, St Leonards, Point Richards and Kirk Point (Table 3, Figure 6A). The shallow subtidal plot at Swan Bay 2 was dominated by non-shooting stems in summer 2011 (Figure 6B)
- In deep subtidal plots, increased at Mud Islands, decreased at St Leonards 1, and was unchanged Blairgowrie, St Leonards 2 and Point Richards (Table 3, Figure 7A). Deep subtidal plots at St Leonards 2 were dominated by non-shooting stems in summer 2011 (Figure 7B)
- In the intertidal plots, increased at Swan Bay, and was unchanged at Mud Islands, St Leonards and Point Richards (Table 4, Figure 8C). The intertidal plot at Point Richards comprised a mix of H. nigricaulis and Z. muelleri plants that was not easily separated in the field (Figure 9).

Seagrass cover in summer 2011 compared with the mean of summer in 2009 and 2010:
- In shallow subtidal plots, was higher at Blairgowrie and Point Richards, lower at Swan Bay 2, and was unchanged at Mud Islands, Swan Bay 1, St Leonards and Kirk Point (Table 3, Figure 5).
- In deep subtidal plots, was higher at Blairgowrie and St Leonards 1, lower at Mud Islands and St Leonards 2, and was unchanged at Point Richards (Table 3, Figure 3).
- In intertidal plots, was higher at Mud Islands, and was unchanged at Swan Bay, St Leonards and Point Richards (Table 4, Figure 8A).
Seagrass length in summer 2011 compared with the mean of summer in 2009 and 2010:

- In shallow subtidal plots, was higher at St Leonards, Point Richards and Kirk Point, lower at Swan Bay 1 and 2, and was unchanged at Blairgowrie and Mud Islands (Table 3, Figure 4).
- In deep subtidal plots, was higher at Blairgowrie, St Leonards 1 and Point Richards, and lower at Mud Islands and St Leonards 2 (Table 3, Figure 5).
- In the intertidal plots was unchanged (Table 4, Figure 8C).

Shooting stem/shoot density in summer 2011 compared with the mean of summer in 2009 and 2010:

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

**Intertidal seagrass upper limits**

Spatial changes in the monitoring lines, indicating the upper extent of intertidal seagrass at Mud Islands, St Leonards and Point Richards are presented in Figures 10–12 (Appendix 2).

The positions of the intertidal monitoring lines at Mud Islands (Figure 10) were relatively stable between spring 2010 and summer 2011. The maximum positional change in any of the lines was <1.7 m seawards since spring 2010. Seagrass cover lost from the western end of Line 1 by spring 2010 had recovered by summer 2011.

The upper extent of intertidal seagrass along Lines 1 and 2 at St Leonards had moved <1.5 m since spring 2010 (Figure 11). Line 3 had moved landward by up to 4 m at its northern end since spring 2010. Some of the seagrass lost at the southern end of Line 3 between winter 2009 and summer 2010 had recovered by summer 2011, although it is still approximately 20% less than its original length in autumn 2008. The backup Line 4 was up to 4 m landward of its position in spring 2010, and had reduced in length by approximately 2 m on its northern end.

The intertidal seagrass monitoring lines at Point Richards have undergone large changes during the monitoring program, due to sand deposition and seagrass burial (Figure 12). Line 1 moved landward by up to 2.5 m since spring 2010. The seagrass at Line 2 was completely buried with sand by spring 2010 and had not recovered by summer 2011. Line 3 was also buried with sand by spring 2010 and had partly recovered by summer 2011. The backup Line 4 was completely buried with sand by spring 2010, but had completely recovered by summer 2011.

**Subtidal seagrass lower limits**

Video surveys of maximum seagrass depth were conducted at Blairgowrie and Point Richards in summer (January) 2011 (Figure 13). The maximum observed depth of shooting *H. nigricaulis* stems converged at Blairgowrie (mean depth = 7.7 m) and Point Richards (mean depth = 8.3 m) ($F_{1,15}=0.6, P>0.05$) transects in summer 2011. Seagrass was observed on all transects at Blairgowrie ($n=11$), but only along six of 11 transects at Point Richards during summer 2010.

Maximum seagrass depth at Blairgowrie and Point Richards did not vary between spring 2010 and summer 2011 (planned contrasts, $P>0.05$; Figure 13). Maximum seagrass depth at Blairgowrie in summer 2011 was significantly higher than summer 2010 (planned contrast, $P=0.002$), but no different than summer 2009 (planned contrast, $P>0.05$) (Figure 13).

Maximum seagrass depth at Point Richards in summer 2011 was no different than summer 2010 (planned contrast, $P>0.05$), but significantly lower than summer 2009 (planned contrast, $P=0.001$) (Figure 13).

**Factors that affect seagrass health**

Epiphyte cover for the shallow, deep and intertidal plots varied significantly 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 summer 2011.
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, 2011).

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, and shading impacts by, macroalgal epiphytes may also be a localised source of seagrass mortality in PPB (e.g. in Swan Bay) (Hirst et al. 2010b).

Seagrass health in summer 2011

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 summer 2011, consistent with the variable pattern of seagrass health observed at the small spatial scale for subtidal seagrasses over the duration this program.

Subtidal seagrass demonstrated the following clear trends over the past 12 months (i.e. since summer 2010):

- Seagrass cover, length and stem density increased at Blairgowrie (deep), Point Richards (shallow) and St Leonards 1 (deep) plots. At Blairgowrie (deep) and St Leonards (deep) seagrass covered >40% of plots where prior to summer 2010 little seagrass existed (i.e. <2%).

- Seagrass cover, length and stem density decreased at Mud Islands (deep).

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

This pattern reflects the cycle of seagrass decline and recovery exhibited at the smaller 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 and regrowth of seagrass within any one plot. Seagrass re-colonisation and growth occurs via three main mechanisms: regeneration from seeds, regeneration from vegetative fragments/propagules, and regrowth from existing or adjacent seagrass patches via rhizome elongation (vegetative growth).

Initially plots at Blairgowrie and St Leonards 1 (deep) were dominated by dead stems, indicative of previously higher cover of seagrass. Prior to winter 2009 these plots supported a very sparse cover of living seagrass (i.e. <2% cover). It is likely the growth in cover observed between winter 2009 and summer 2011 is a product of vegetative growth originating from this sparse cover of seagrass plants. The relative importance of vegetative growth versus sexual modes of seagrass recruitment at this scale is impossible to determine without examining the genetic relatedness of seagrass plants. It is also unclear why conditions at both of these deeper plots have favoured seagrass growth/recruitment in the period winter 2009 to summer 2011, when contrasted with the period prior to winter 2009.

Intertidal

The health of seagrass at intertidal plots was consistent with past seasonal trends recorded at these plots from 2008–2010. Intertidal seagrass cover and length remained high at Swan Bay and low at Point Richards. Shoot densities at Swan Bay between autumn 2008 and summer 2011 have been highly variable, reflecting in part, variation in the species composition of intertidal plots comprising a mixture of Z. muelleri and L. marina plants.
Seagrass cover remains very low at Point Richards, and there has been little recolonisation since seagrass reappeared at this plot in summer 2010. A sparse cover of *Z. muelleri* had reappeared along intertidal monitoring lines 3 and 4 by summer 2011.

**Conclusions**

The health of seagrasses monitored in PPB during summer 2011 varied as expected, based on analysis of past trends at individual field plots. Seagrass has continued to recover at two of the deeper subtidal plots. The conceptual model developed in this program has advanced a number of mechanisms that explain the loss of seagrass in PPB (e.g. sediment movement, epiphytes), but the conditions that facilitate the recovery and expansion of seagrass meadows are less clearly understood.
Table 2. Summary of trends in seagrass health at each small-scale monitoring plot between spring 2010 and summer 2011 and over the duration of the monitoring program (2008–2011).

<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>Blairgowrie</td>
<td>Seagrass cover in summer 2011 was higher than the longer-term seasonal trend at this plot. Seagrass length and stem density in summer 2011 were consistent with past trends. No change in seagrass health (cover, length and density) since spring 2010.</td>
<td>Seagrass cover, length and stem density in summer 2011 were higher than the seasonal trends at this plot. Cover increased in the last quarter. Seagrass covered approx. 42% of the plot in summer 2011.</td>
<td></td>
</tr>
<tr>
<td>Mud Islands</td>
<td>Seagrass cover increased in the last quarter. Overall, seagrass health in summer 2011 was comparable with the longer-term seasonal trends at this plot.</td>
<td>Seagrass cover and stem density increased in the last quarter, but were significantly lower than the longer-term seasonal trends at this plot.</td>
<td>Seagrass cover increased over the longer-term. Seagrass cover and length increased in the last quarter, but are consistent with past seasonal trends at this plot.</td>
</tr>
<tr>
<td>Swan Bay 1</td>
<td>Seagrass cover remained low (&lt;20%) at this plot in summer 2011. Seagrass length increased in the last quarter, although seagrass length and stem density were lower than the longer-term seasonal trend at this plot. Macroalgal epiphyte cover remained high in summer 2011.</td>
<td></td>
<td>Seagrass at this plot is dominated by <em>Leptlaena marina</em>. <em>Z. muelleri</em> comprises &lt;40% of the plots. Seagrass cover and length have been high and relatively stable over the duration of the program. Shoot density increased in the last quarter, and although variable was comparable to past seasonal trends at this plot.</td>
</tr>
<tr>
<td>Swan Bay 2</td>
<td>Seagrass cover, length and stem density decreased in the last quarter. The plot in summer 2011 was dominated by non-shooting stems covered by a high cover of macroalgal epiphytes. There is little living seagrass at this plot.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Description</td>
<td>Seagrass cover and length changes</td>
<td>Seagrass health and past trends</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>St Leonards 1</td>
<td>This plot was dominated by non-shooting stems in summer 2011.</td>
<td>Increased again in the last quarter.</td>
<td>Unchanged since spring 2010; comparable with past trends.</td>
</tr>
<tr>
<td></td>
<td>Seagrass cover, length and stem density in summer 2011 were higher than the longer-term seasonal trend at this plot.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>St Leonards 2</td>
<td>Few living seagrass plants remained in summer 2011. Seagrass cover, length and stem density were lower than the longer-term seasonal trend. Most of the seagrass at this plot was lost between summer 2009 and spring 2009.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point Richards</td>
<td>Seagrass cover decreased in the last quarter. Seagrass cover, length and stem density were higher in summer 2010 than the longer-term seasonal trend at this plot.</td>
<td>Increased low, consistent with past trends.</td>
<td>Recolonised by H. nigricaulis and Z. muelleri plants in summer 2010, but cover remains low (&lt;1% cover), consistent with the longer-term seasonal trend at this plot.</td>
</tr>
<tr>
<td>Kirk Point</td>
<td>No seagrass at this plot in summer 2011.</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 – summer 2011 versus spring 2010
C2 – summer 2011 versus mean of summer 2009 and 2010

<table>
<thead>
<tr>
<th>Shallow plots</th>
<th>Tukeys test (Sum 11)</th>
<th>arcin ((%) cover)</th>
<th>loge (length)</th>
<th>loge (count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blairgowrie (B)</td>
<td>C1 &gt; C2</td>
<td>-1.0</td>
<td>+2.7**</td>
<td>-2.7**</td>
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<tr>
<td>Mud Islands (MI)</td>
<td>C1 &gt; C2</td>
<td>+7.6***</td>
<td>+0.9</td>
<td>+0.1</td>
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<tr>
<td>Swan Bay 1 (SB1)</td>
<td>C1 &gt; C2</td>
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<td>+2.6**</td>
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<tr>
<td>Swan Bay 2 (SB2)</td>
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<td>-16.3***</td>
<td>-7.9***</td>
</tr>
<tr>
<td>St Leonards (SL)</td>
<td>C1 &gt; C2</td>
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<td>+0.7</td>
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<tr>
<td>Pt Richards (PR)</td>
<td>C1 &gt; C2</td>
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<td>+2.6**</td>
<td>-1.6</td>
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<tr>
<td>Kirk Pt (KP)</td>
<td>C1 &gt; C2</td>
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<td>+0.7</td>
<td>+5.6***</td>
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<table>
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<tr>
<th>Deep plots</th>
<th>Tukeys test (Sum 11)</th>
<th>arcin ((%) cover)</th>
<th>loge (length)</th>
<th>loge (count)</th>
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<td>Blairgowrie (B)</td>
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<td>+11.5***</td>
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<tr>
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<td>+10.1***</td>
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<td>Pt Richards (PR)</td>
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Tukeys HSD post-hoc test between plots for summer 2011 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 general linear model analysis 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 – summer 2011 versus spring 2010
C2 – summer 2011 versus mean of summer 2009 and 2010

<table>
<thead>
<tr>
<th>Planned contrasts</th>
<th>Tukeys test (Sum 11)</th>
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<tr>
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<td>+2.4*</td>
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</tr>
<tr>
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<td>-2.1*</td>
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</tbody>
</table>

Blanks indicate $P>0.05$, *$P<0.05$, **$P<0.01$ and ***$P<0.001$

1 Tukeys HSD post-hoc test between plots for summer 2011 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 12 occasions between autumn 2008 and summer 2011. (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 12 occasions between autumn 2008 and summer 2011. (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 12 occasions between autumn 2008 and summer 2011. (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 12 occasions between autumn 2008 and summer 2011. (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 12 occasions between autumn 2008 and summer 2011. (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 12 occasions between autumn 2008 and summer 2011. (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, Mud Islands, Swan Bay and Point Richards between autumn 2008 and summer 2011. *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 summer 2009–11 and spring 2010.
Figure 11. St Leonards intertidal seagrass monitoring line positions recorded in summer 2009–11 and spring 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 summer 2009–11 and spring 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 line 2 in summer 2011).
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 summer 2011. 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_MR12.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)