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Baywide Seagrass Monitoring Program

Milestone Report No. 13
(April–May 2011)

No. 143
August 2011
Baywide Seagrass Monitoring Program

Milestone Report No. 13 (April–May 2011)

Alastair Hirst, Simon Heislers, Liz Morris, 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 autumn (April-May) 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 autumn 2011 were compared with the previous season (summer 2011), and against the mean of previous observations in autumn 2008–10.

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. Subtidal seagrass cover increased at Blairgowrie, St Leonards, and Kirk Point (shallow plots) and Mud Islands (deep plot) since summer 2011. Seagrass re-appeared at the Kirk Point shallow plot for first since spring 2008. Over the last year increases in seagrass cover were observed at Swan Bay 1, while a decline at Swan Bay 2 continued.

Maximum seagrass depth declined at Point Richards between and summer and autumn 2011, but was unchanged at Blairgowrie.

Intertidal

Seagrass health at Mud Islands and St Leonards intertidal plots was consistent with previous trends observed at these plots. A reduction in seagrass cover at Swan Bay in autumn 2011 since summer 2011 was due to a decline in previously dominant *Lepilaena marina*, and there is now an approximately equal cover of *Zostera muelleri*.

The upper extent of intertidal seagrass at Mud Islands and monitoring Lines 1 and 2 at St Leonards remained relatively stable since summer 2011. Line 3 at St Leonards shortened in length and back Line 4 recovered to its full length on its northern end since summer 2011.

At Point Richards there has been little significant regrowth since the re-appearance of seagrass at this plot in summer 2010. Seagrass was only present at upper intertidal monitoring Line 1, after Line 3 and backup Line 4 were again completely buried in autumn 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 autumn 2011. Epiphyte levels vary substantially between plots in this program, and 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 autumn 2011 varied as expected, based on analysis of past trends at individual field plots. Seagrass continued to regrow at two of the deeper subtidal plots, and variable responses were recorded within the Swan Bay shallow 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 recolonisation and expansion of seagrass meadows are less clearly understood.
# Table of Contents

Executive Summary .................................................................................................................. iii
Seagrass health ........................................................................................................................... iii
  Subtidal ................................................................................................................................. iii
  Intertidal ............................................................................................................................... iii
Factors that affect seagrass health ........................................................................................ iii
Conclusions ............................................................................................................................. iii

Introduction ............................................................................................................................ 1
Purpose of this Report ................................................................................................................ 1

Materials and Methods .......................................................................................................... 2
Data Management ....................................................................................................................... 2
  QA/QC .................................................................................................................................. 2

Results .................................................................................................................................... 4
Seagrass health .......................................................................................................................... 4
  Intertidal seagrass upper limits ............................................................................................ 5
  Subtidal seagrass lower limits ............................................................................................... 5
Factors that affect seagrass health ........................................................................................... 5

Discussion ............................................................................................................................... 6
Seagrass health in autumn 2011 ............................................................................................ 6
  Subtidal ................................................................................................................................. 6
  Intertidal ............................................................................................................................... 6
Conclusions ............................................................................................................................... 7

Acknowledgements ............................................................................................................... 9

References ............................................................................................................................... 10

Appendix 1. Seagrass health tables ......................................................................................... 11
Appendix 2. Seagrass health figures ......................................................................................... 13
Appendix 3. Data ....................................................................................................................... 23
List of Tables
Table 1. Summary of small-scale seagrass monitoring plots within regions............................................. 2
Table 2. Summary of trends in seagrass health at each small-scale monitoring plot between summer 2011 and autumn 2011 and over the duration of the monitoring program (2008–11).......................... 8
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........ 11
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...................................................... 12

List of Figures
Figure 1. Locations of monitoring regions and small-scale field assessment plots in Port Phillip Bay......... 3
Figure 2 Mean (± se) seagrass cover (%) for H. nigricaulis at shallow subtidal plots sampled on 13 occasions between autumn 2008 and autumn 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)............................................................................................................ 13
Figure 3. Mean (± se) seagrass cover (%) for H. nigricaulis at deep subtidal plots sampled on 13 occasions between autumn 2008 and autumn 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). .................................................................................................................................................................................. 13
Figure 4. Mean (± se) seagrass length (cm) for H. nigricaulis at shallow subtidal plots sampled on 13 occasions between autumn 2008 and autumn 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). ........................................................................................................................................................................... 14
Figure 5. Mean (± se) seagrass length (cm) for H. nigricaulis at deep subtidal plots sampled on 13 occasions between autumn 2008 and autumn 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). ........................................................................................................................................................................... 14
Figure 6. Mean (± se) A) shooting and B) non-shooting stem count per 0.0625 m^2 quadrat for H. nigricaulis at shallow subtidal plots sampled on 13 occasions between autumn 2008 and autumn 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). ........................................................................................................................................................................... 15
Figure 7. Mean (± se) A) shooting and B) non-shooting stem count per 0.0625 m^2 quadrat for H. nigricaulis at deep subtidal plots sampled on 13 occasions between autumn 2008 and autumn 2011. (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). ........................................................................................................................................................................... 15
Figure 8. Mean (± se) combined seagrass A) cover (%), B) length, and C) shoot count per 0.0625 m^2 quadrat for intertidal plots sampled on 13 occasions between autumn 2008 and autumn 2011. (NB Format of figures has changed from previous reports to enhance data presentation and interpretation). ........................................................................................................................................................................... 16
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 autumn 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). ........................................................................................................................................................................... 17
Figure 10. Mud Islands intertidal seagrass monitoring line positions recorded in autumn 2009–11 and autumn 2011........................................................................................................................................................................................................... 19
Figure 11. St Leonards intertidal seagrass monitoring line positions recorded in autumn 2009–11 and autumn 2011. Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines. .............................................................................................................................................................. 20

Figure 12. Point Richards (Bellarine Bank) intertidal seagrass monitoring line positions recorded in autumn 2009–11 and autumn 2011. Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines. (N.B. No seagrass was present at monitoring lines 2, 3 and 4 in autumn 2011). .......................................................................................................................................................................................... 21

Figure 13. Mean (± se) maximum depth (m) of shooting *H. nigricaulis* stems observed on video transects offshore at Blairgowrie and Point Richards on 9 occasions between spring 2008 and autumn 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). ................................................................................................................................. 22
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 autumn (April-May) 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 summer and autumn 2011, and between autumn 2011 and the mean of autumns 2008–10
- 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, 2011a, b).
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.

<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 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 autumn 2011 and the previous season, summer 2011, and between autumn 2011 and the mean of autumns from 2008 to 2010, are highlighted in Tables 3 and 4 (Appendix 1), and further summarized below.

Change in seagrass health over the duration of this program was examined by comparing seagrass health in autumn with summer 2011, and with the mean of the corresponding season (autumn) in 2008, 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 summer and autumn 2011:

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

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

Seagrass length between summer and autumn 2011:

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

Seagrass length between summer and autumn 2011 compared with the mean of summer in 2008–10:

- In shallow subtidal plots, increased at Blairgowrie, Swan Bay 1, St Leonards and Kirk Point, decreased at Point Richards, and was unchanged at Mud Islands and Swan Bay 2 (Table 3, Figure 6A). Seagrass shooting stems was recorded in 7 of the 12 quadrats at Kirk Point. The shallow subtidal plots at Swan Bay 2 and St Leonards were dominated by non-shooting stems in autumn 2011 (Figure 6A and 6B)
- In deep subtidal plots, increased at Mud Islands and St Leonards 2, decreased at Blairgowrie, and was unchanged at St Leonards 1 and Point Richards (Table 3, Figure 7A)
- In the intertidal plots, was unchanged at all plots (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 shooting stem/shoot density between summer and autumn 2011:

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

Seagrass cover in autumn 2011 compared with the mean of autumn in 2008–10:

- In shallow subtidal plots, was higher at Blairgowrie, Mud Islands, St Leonards and Kirk Point, lower at Swan Bay 2, and unchanged at Swan Bay 1 and Point Richards (Table 3, Figure 2)
- In deep subtidal plots, was higher at Blairgowrie and St Leonards 1, lower at St Leonards 2, and unchanged at Mud Islands and Point Richards (Table 3, Figure 3)
- In the intertidal plots, was unchanged at all plots (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 autumn 2011 compared with the mean of summer 2008–10:

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

Seagrass length in autumn 2011 compared with the mean of summer 2008–10:
In shallow subtidal plots, was higher at St Leonards and Kirk Point, lower at Swan Bay 2, and unchanged at Blairgowrie, Mud Islands, Swan Bay 1 and Point Richards (Table 3, Figure 4).

In deep subtidal plots, was higher at Blairgowrie and St Leonards 1, lower at St Leonards 2 and Point Richards, and unchanged at Mud Islands (Table 3, Figure 5).

In the intertidal plots, was higher at Mud Islands, and unchanged at Swan Bay, St Leonards and Point Richards (Table 4, Figure 8B).

Shooting stem/shoot density in autumn 2011 compared with the mean of autumn 2008–10:

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

In deep subtidal plots, was higher at Blairgowrie and St Leonards 1, lower at St Leonards 2, and was unchanged at Mud Islands and Point Richards (Table 3, Figure 7A).

In intertidal plots, was higher at Mud Islands, lower at Point Richards, and was unchanged at 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) have been relatively stable during the monitoring program. The maximum positional change in any of the lines was <2.0 m since summer 2011.

The upper extent of intertidal seagrass along Lines 1 and 2 at St Leonards had moved <1.5 m since summer 2011 (Figure 11). The northern section of Line 3 had moved by mostly <2.5 m and reduced in length at its southern end since summer 2011. The seagrass loss at the southern end of Line 3 returned it to a similar length observed during most of 2010, and was approximately 30% less than its original length. The backup Line 4 moved by <1.2 m of its position in summer 2011, and had recovered to its full length on its northern end.

The intertidal seagrass monitoring lines at Point Richards have been subject to sand deposition and seagrass burial during the monitoring program (Figure 12). Line 1 was mostly within 1 m of its position in summer 2011, apart from a short section near the centre of the line which moved seaward by up to 3.6 m. The seagrass at Line 2 was completely buried with sand by spring 2010 and had not recovered to its previous extent by autumn 2011. Lines 3 and 4 were completely buried again by autumn 2011 after Line 3 had partly recovered to its previous extent, and backup Line 4 had fully recovered to their previous extent by summer 2011, after both were buried in spring 2010.

Subtidal seagrass lower limits

Video surveys of maximum seagrass depth were conducted at Blairgowrie and Point Richards in autumn (May) 2011 (Figure 13). The maximum observed depth of shooting H. nigricaulis stems at Blairgowrie (mean depth = 7.0 m) and Point Richards (6.3 m) was similar in autumn 2011 ($F_{1,14}=0.6$, $P>0.05$). Seagrass was observed on all transects at Blairgowrie (n = 11), but only five of 11 transects at Point Richards during autumn 2011.

Maximum seagrass depth at Point Richards declined between summer and autumn 2011 (planned contrasts, $P=0.003$; Figure 13). Maximum seagrass depth at Point Richards in autumn 2011 was also significantly lower than autumn 2010 (planned contrast, $P<0.001$), but no different than autumn 2009 (planned contrast, $P>0.05$) (Figure 13).

Maximum seagrass depth at Blairgowrie was unchanged between summer and autumn 2011 (planned contrast, $P>0.05$; Figure 13). Maximum seagrass depth at Blairgowrie in autumn 2011 was no different than autumn 2010 (planned contrast, $P>0.05$), but significantly higher than autumn 2009 (planned contrast, $P=0.045$) (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 (>80%) at the Swan Bay 1 and 2 shallow plots in autumn 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, 2011a, b).

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 autumn 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 autumn 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 observations demonstrated the following trends:

- Seagrass cover, length and stem density at Blairgowrie (deep) were significantly greater than the long-term mean at this plot, whereas seagrass cover, length and stem-density at Mud Islands (deep) and Swan Bay 1 (shallow) were consistent with longer-term means at these plots (Table 2). The recent increase in seagrass cover at Mud Islands (deep) represents a partial return towards summer 2009 levels

- Seagrass re-colonised the Kirk Point shallow subtidal plot in autumn 2011. Seagrass shooting-stems were recorded at this plot for first time since spring 2008.

- Seagrass cover, length and stem density continued to decrease at Swan Bay 2 (shallow), and were significantly lower than the longer-term mean at this plot.

The health of seagrass at all other plots was either largely unchanged or displayed no clear trend over the past 12 months.

This pattern reflects the cycle of seagrass decline and recovery exhibited at the smaller spatial scale (1–10 m). The increase in seagrass health at the Swan Bay 1 (shallow) plot has occurred despite the continued high epiphyte cover recorded at this site, and contrasts with the continuing decline in seagrass health at the Swan Bay 2 (shallow) plot. Seagrass loss has been linked to a range of processes during this program, but it is not clear what conditions facilitate the recolonisation and regrowth of seagrass within any one plot.

Intertidal

The health of seagrass at intertidal plots was consistent with past seasonal trends recorded at these plots from 2008–10. Intertidal seagrass cover and length continued to increase at Mud Islands, and remained low at Point Richards. There was a reduction in seagrass cover at Swan Bay that reflected a loss of the previously dominant species L. marina. Autumn 2011 was the first occasion that L. marina and Z. muelleri were co-dominant within this plot. L. marina is endemic to Australia and has been recorded from a range of habitats. As a genus Lepilaena is considered to have a wide range of tolerance to salinity, but little is known about the distribution or ecology of L. marina (Westphalen et al. 2004).

Seagrass cover, length and stem density at Blairgowrie (deep) were significantly greater than the long-term mean at this plot, whereas seagrass cover, length and stem-density at Mud Islands (deep) and Swan Bay 1 (shallow) were consistent with longer-term means at these plots (Table 2). The recent increase in seagrass cover at Mud Islands (deep) represents a partial return towards summer 2009 levels

- Seagrass re-colonised the Kirk Point shallow subtidal plot in autumn 2011. Seagrass shooting-stems were recorded at this plot for first time since spring 2008.

- Seagrass cover, length and stem density continued to decrease at Swan Bay 2 (shallow), and were significantly lower than the longer-term mean at this plot.

The health of seagrass at all other plots was either largely unchanged or displayed no clear trend over the past 12 months.

This pattern reflects the cycle of seagrass decline and recovery exhibited at the smaller spatial scale (1–10 m). The increase in seagrass health at the Swan Bay 1 (shallow) plot has occurred despite the continued high epiphyte cover recorded at this site, and contrasts with the continuing decline in seagrass health at the Swan Bay 2 (shallow) plot. Seagrass loss has been linked to a range of processes during this program, but it is not clear what conditions facilitate the recolonisation and regrowth of seagrass within any one plot.

Intertidal

The health of seagrass at intertidal plots was consistent with past seasonal trends recorded at these plots from 2008–10. Intertidal seagrass cover and length continued to increase at Mud Islands, and remained low at Point Richards. There was a reduction in seagrass cover at Swan Bay that reflected a loss of the previously dominant species L. marina. Autumn 2011 was the first occasion that L. marina and Z. muelleri were co-dominant within this plot. L. marina is endemic to Australia and has been recorded from a range of habitats. As a genus Lepilaena is considered to have a wide range of tolerance to salinity, but little is known about the distribution or ecology of L. marina (Westphalen et al. 2004).
Seagrass cover remains very low at Point Richards, and there has been little recolonisation since seagrass reappeared at this plot in summer 2010. Intertidal monitoring line 2 remained devoid of seagrass at this plot, while a sparse cover of *Z. muelleri* which reappeared at intertidal monitoring lines 3 and 4 by summer 2011, had disappeared again by autumn 2011.

**Conclusions**

The health of seagrasses monitored in PPB during autumn 2011 varied as expected, based on analysis of past trends at individual field plots. Seagrass continued to regrow at two of the deeper subtidal plots, and variable responses were recorded within the Swan Bay shallow 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 recolonisation and expansion of seagrass meadows are less clearly understood.
Table 2. Summary of trends in seagrass health at each small-scale monitoring plot between summer 2011 and autumn 2011 and over the duration of the monitoring program (2008–11).

<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 and stem density increased in the last quarter and were higher than the longer-term seasonal trend. Seagrass length was unchanged.</td>
<td>Stem density decreased in the last quarter, while seagrass cover and length were unchanged. Seagrass cover, length and stem density were higher than the longer-term seasonal trends.</td>
<td>There was an increase in overall seagrass health in this plot compared to the longer-term seasonal trend.</td>
</tr>
<tr>
<td>Mud Islands</td>
<td>Seagrass cover decreased in the last quarter, but remained higher than longer-term seasonal trend. Seagrass length increased in the last quarter, and length and stem density were consistent with the longer-term seasonal trends.</td>
<td>Seagrass cover, length and stem density increased in the last quarter, and were consistent with the longer-term seasonal trends at this plot.</td>
<td>Seagrass cover decreased in the last quarter and was lower than the longer-term seasonal trend. This was mainly due to a reduction in the cover of <em>L. marina</em> which now had an equal cover with <em>Z. muelleri</em> for the first time at this plot during the monitoring program.</td>
</tr>
<tr>
<td>Swan Bay 1</td>
<td>Seagrass length and stem density increased in the last quarter, and overall seagrass health was consistent with the longer-term seasonal trend. Seagrass cover was unchanged in the last quarter. Macrualgal epiphyte cover remained high in autumn 2011.</td>
<td></td>
<td>Seagrass cover decreased in the last quarter and was lower than the longer-term seasonal trend. Most of the seagrass at this plot was lost between summer 2009 and spring 2009.</td>
</tr>
<tr>
<td>Swan Bay 2</td>
<td>Seagrass cover, length and stem density were unchanged in the last quarter, but were lower than the longer-term seasonal trend at this plot.</td>
<td>Seagrass cover and length decreased in the last quarter but seagrass cover, length and stem density were higher than the longer-term seasonal trends.</td>
<td>Seagrass health was unchanged in the last quarter, and was consistent with the longer-term seasonal trends at this plot.</td>
</tr>
<tr>
<td>St Leonards 1</td>
<td>There was an increase in overall seagrass health in this plot compared to the longer-term seasonal trend and compared to the previous quarter.</td>
<td>Seagrass cover, length and stem density were lower than the longer-term seasonal trend.</td>
<td>Seagrass health was unchanged in the last quarter, and was consistent with the longer-term seasonal trends at this plot.</td>
</tr>
<tr>
<td>St Leonards 2</td>
<td></td>
<td>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>
</tr>
<tr>
<td>Point Richards</td>
<td>Seagrass length and stem density decreased in the last quarter. Seagrass cover and length were consistent with the longer-term trend in this plot while stem density was higher.</td>
<td>Seagrass cover and stem density remain low, consistent with past trends at this plot.</td>
<td>Seagrass length increased while cover and stem density were unchanged since the last quarter. While the plot was recolonised by <em>H. nigricaulis</em> and <em>Z. muelleri</em> plants in summer 2010, the cover and stem density remained below the longer-term seasonal trend.</td>
</tr>
<tr>
<td>Kirk Point</td>
<td>Seagrass recolonised this plot in autumn 2011, so overall seagrass health increased in the last quarter and also compared to the longer-term seasonal trend.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Acknowledgements

Guy Werner, Camille White, Peter Young and Matt Koopman 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 include:

C1 – autumn 2011 versus summer 2011
C2 – autumn 2011 versus mean of autumns 2008–10

<table>
<thead>
<tr>
<th>Shallow plots</th>
<th>arcsin (% cover)</th>
<th>loge (length)</th>
<th>loge (count)</th>
</tr>
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<tbody>
<tr>
<td>Tukeys test (Aut 11)</td>
<td>M, B&gt;SB1&gt; SL, SB2, PR, KP</td>
<td>B, MI, SB1&gt;SB2, PR, SL&gt;KP</td>
<td>MI, B&gt;SB1, SB1, PR&gt;SB2, KP</td>
</tr>
<tr>
<td>Contrast</td>
<td>C1</td>
<td>C2</td>
<td>C1</td>
</tr>
<tr>
<td>Blairgowrie (B)</td>
<td>+5.9***</td>
<td>+9.9***</td>
<td>+0.5</td>
</tr>
<tr>
<td>Mud Islands (MI)</td>
<td>-3.8***</td>
<td>+2.7**</td>
<td>+2.7**</td>
</tr>
<tr>
<td>Swan Bay 1 (SB1)</td>
<td>+1.6</td>
<td>-1.6</td>
<td>+4.1***</td>
</tr>
<tr>
<td>Swan Bay 2 (SB2)</td>
<td>-1.8</td>
<td>-11.8***</td>
<td>0</td>
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<tr>
<td>St Leonards (SL)</td>
<td>+4.0***</td>
<td>+4.1***</td>
<td>+7.6***</td>
</tr>
<tr>
<td>Pt Richards (PR)</td>
<td>-0.2</td>
<td>+0.2</td>
<td>-2.9**</td>
</tr>
<tr>
<td>Kirk Pt (KP)</td>
<td>+3.9***</td>
<td>+3.6***</td>
<td>+5.9***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deep plots</th>
<th>arcsin (% cover)</th>
<th>loge (length)</th>
<th>loge (count)</th>
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</thead>
<tbody>
<tr>
<td>Tukeys test (Aut 11)</td>
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<td>SL1, B&gt;MI&gt;SL2, PR</td>
<td>SL1, B, MI&gt;PR, SL2</td>
</tr>
<tr>
<td>Contrast</td>
<td>C1</td>
<td>C2</td>
<td>C1</td>
</tr>
<tr>
<td>Blairgowrie (B)</td>
<td>-1.7</td>
<td>+11.1***</td>
<td>+1.7</td>
</tr>
<tr>
<td>Mud Islands (MI)</td>
<td>+5.6***</td>
<td>1.3</td>
<td>+4.7***</td>
</tr>
<tr>
<td>St Leonards 1 (SL1)</td>
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<td>+4.9***</td>
<td>-2.4*</td>
</tr>
<tr>
<td>St Leonards 2 (SL2)</td>
<td>+1.6</td>
<td>-6.7***</td>
<td>+0.1</td>
</tr>
<tr>
<td>Pt Richards (PR)</td>
<td>-1.1</td>
<td>-0.5</td>
<td>-1.6</td>
</tr>
</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 autumn 2011 only (P<0.05); 2 C2 contrasts between autumn 2009–11 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.
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 including:
C1 – autumn 2011 versus summer 2011
C2 – autumn 2011 versus mean of autumn’s 2008–10

<table>
<thead>
<tr>
<th>Planned contrasts</th>
<th>Tukeys test (Aut 11)</th>
<th>Planned contrasts</th>
<th>Tukeys test (Aut 11)</th>
</tr>
</thead>
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<tr>
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<td>MI&gt;SB, SL&gt;PR</td>
<td></td>
<td>MI&gt;SB, SL&gt;PR</td>
</tr>
<tr>
<td>Mud Islands (MI)</td>
<td>+0.9</td>
<td>MI, SL, SB&gt;PR</td>
<td>+3.9***</td>
</tr>
<tr>
<td>Swan Bay (SB)</td>
<td>-3.1**</td>
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</tr>
<tr>
<td>St Leonards (SL)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pt Richards (PR)</td>
<td>+0.9</td>
<td></td>
<td></td>
</tr>
</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 autumn 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.
Appendix 2. Seagrass health figures

Figure 2 Mean (± se) seagrass cover (%) for *H. nigricaulis* at shallow subtidal plots sampled on 13 occasions between autumn 2008 and autumn 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 13 occasions between autumn 2008 and autumn 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 13 occasions between autumn 2008 and autumn 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 13 occasions between autumn 2008 and autumn 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 m$^2$ quadrat for *H. nigricaulis* at shallow subtidal plots sampled on 13 occasions between autumn 2008 and autumn 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 13 occasions between autumn 2008 and autumn 2011. (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 13 occasions between autumn 2008 and autumn 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 autumn 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 autumn 2009–11 and autumn 2011.
Figure 11. St Leonards intertidal seagrass monitoring line positions recorded in autumn 2009–11 and autumn 2011. 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 autumn 2009–11 and autumn 2011. 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, 3 and 4 in autumn 2011).
Figure 13. Mean (± se) maximum depth (m) of shooting *H. nigricaulis* stems observed on video transects offshore at Blairgowrie and Point Richards on 9 occasions between spring 2008 and autumn 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_MR13.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)