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Baywide Seagrass Monitoring Program

Milestone Report No. 14
(July–August 2011)

No. 151
November 2011
Baywide Seagrass Monitoring Program

Milestone Report No. 14 (July–August 2011)

Alastair Hirst, David Ball, Simon Heislers, Julia Kent, Peter Young, 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
- Monitoring of environmental factors that are known to influence seagrass health.

This milestone report presents:

- Large-scale seagrass mapping from aerial photography flown in autumn (April-May) 2011
- Results of small-scale monitoring of seagrass health for winter (July-August) 2011
- 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 winter 2011 were compared with the previous season (autumn 2011), and against the mean of previous observations in winter 2008–10.

Seagrass mapping

Seagrass area at Blairgowrie, Point Richards and St Leonards in autumn 2011 was within expected variability at both yearly and decadal time scales, compared to statistical criteria calculated from historical data up to and including 2008 (Ball and Young 2011). There were insufficient historical data for Mud Islands, Kirk Point and Swan Bay to calculate statistical criteria for these regions (Ball et al. 2009).

The largest annual change in seagrass area in the aerial assessment regions for the period 2008–2011 occurred between 2010 and 2011, although the changes were not uniform across all larger seagrass regions. Seagrass area doubled at St Leonards, increased by 75% at Blairgowrie, by 50% at Altona and Kirk Point (all and inner), and by 20% at Point Henry West, but remained unchanged at Curlewis Bank, Mud Islands, Point Richards and Swan Bay.

These changes were accompanied by increases in seagrass area at the larger, regional spatial scale across PPB. With the exception of Corio Bay, Mud Islands and Swan Bay seagrass area increased by >5% in all larger PPB seagrass regions between 2010 and 2011. Increases of >60% were observed for Mornington Peninsula, St Leonards and Bellarine Bank.

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 seagrass health varied widely between plots consistent with previous observations. Seagrass cover increased at Kirk Point (shallow), Mud Islands (deep) and St Leonards 1 (deep) since autumn 2011. Seagrass cover, length and density increased at the Kirk Point (shallow) after it reappeared in autumn 2011.

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

Intertidal

The health of seagrass at intertidal plots was consistent with past seasonal trends recorded at these plots. Intertidal seagrass cover, length and shoot density remained high at Mud Islands, St Leonards and Swan Bay and low at Point Richards. An increase in *Z. muelleri* and concurrent decrease in *L. marina* means *Z. muelleri* is now the dominant seagrass species at Swan Bay.
The positions of the intertidal monitoring lines at Mud Islands have remained relatively stable during the monitoring program. The maximum positional change in any of the lines was <3 m in a predominantly seaward direction since autumn 2011.

The upper extent of intertidal seagrass at St Leonards moved <2 m along Lines 1 and 2 since autumn 2011, whilst Line 3 recovered to its full length due to seagrass regrowth at its southern end.

The intertidal seagrass monitoring lines at Point Richards have been subject to substantial sand deposition and seagrass burial during the monitoring program. Seagrass along lines 2, 3, and 4 (backup) had either partially or entirely recovered by winter 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
Seagrass area increased within five of the nine aerial assessment regions, and nine of the 12 larger seagrass regions, between 2010 and 2011. Seagrass area remained unchanged elsewhere.

Seagrass health at the small spatial scale mostly either increased or remained unchanged during this period. The health of seagrasses monitored in PPB during winter 2011 varied as expected, based on analysis of past trends.

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). The recent increases in seagrass area in PPB may be linked to climatic variation, particularly rainfall patterns, but the exact mechanism/s that promote re-colonisation and expansion of seagrass meadows in PPB remain unknown.
## Table of Contents

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

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

**Materials and Methods** ................................................................................................................ 2
  Video ground-truthing......................................................................................................................... 2
  Data Management............................................................................................................................... 2
  Exceptions to Detailed Design.............................................................................................................. 2

**Results** ........................................................................................................................................ 5
  Seagrass mapping............................................................................................................................... 5
  Seagrass health.................................................................................................................................. 5
  Intertidal seagrass upper limits .......................................................................................................... 6
  Subtidal seagrass lower limits............................................................................................................. 6
  Factors that affect seagrass health..................................................................................................... 6

**Discussion** ................................................................................................................................... 8
  Seagrass mapping in winter 2011 ....................................................................................................... 8
    Historical seagrass mapping assessment.......................................................................................... 8
  Seagrass health in winter 2011 ......................................................................................................... 8
    Subtidal........................................................................................................................................... 8
    Intertidal....................................................................................................................................... 9
    Seagrass health trends at the large and small scale 2008–2011...................................................... 9
  Conclusions....................................................................................................................................... 10

**Acknowledgements** ....................................................................................................................... 13

**References** .................................................................................................................................... 14
Appendix 1. Results .................................................................................................................. 16

Seagrass mapping ..................................................................................................................... 16
Altona ........................................................................................................................................ 16
Blairgowrie ............................................................................................................................... 16
Curlewis Bank .......................................................................................................................... 16
Kirk Point ................................................................................................................................. 16
Mud Islands ............................................................................................................................... 16
Point Henry West ...................................................................................................................... 16
Point Richards .......................................................................................................................... 16
St Leonards ............................................................................................................................... 16
Swan Bay .................................................................................................................................. 17
Mapping accuracy .................................................................................................................... 23
Broad-scale assessment of seagrass changes .......................................................................... 23

Appendix 2. Seagrass health tables ....................................................................................... 26

Appendix 3. Seagrass health figures ....................................................................................... 28

Appendix 4. Mapping error matrices ..................................................................................... 38

Appendix 5. Data ....................................................................................................................... 42
List of Tables

Table 1. Summary of small-scale seagrass monitoring plots within regions.................................................................2
Table 2. Changes to video ground-truthing sites in 2011.................................................................................................4
Table 3. Summary of trends in seagrass health at each small-scale monitoring plot between autumn 2011 and winter 2011 and over the duration of the monitoring program (2008–11) ..............................................11
Table 4. Percentage total seagrass cover at PPB aerial assessment regions 2008–11 ....................................................17
Table 5. Summary of overall mapping accuracy autumn 2011 .....................................................................................23
Table 6. Broad-scale assessment of seagrass/vegetation changes for the 12 larger seagrass regions between 2010 and 2011 ..................................................................................................................................................25
Table 7. 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. ..... 26
Table 8. Summary of general linear model analysis testing for differences between sampling dates for seagrass cover, length and shoot density counts at intertidal plots..........................................................27
Table 9. Altona 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .................................................................................................................38
Table 10. Blairgowrie 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .........................................................................................38
Table 11. Curlewis Bank 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .........................................................................................38
Table 12. Kirk Point (all regions) 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .....................................................................................39
Table 13. Kirk Point (inner region) 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .....................................................................................39
Table 14. Mud Islands 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .........................................................................................39
Table 15. Point Henry West 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .....................................................................................40
Table 16. Point Richards 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .........................................................................................40
Table 17. St Leonards 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .........................................................................................40
Table 18. Swan Bay 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data .........................................................................................41

List of Figures

Figure 1. Map of PPB showing the location of nine aerial assessment regions and 12 larger seagrass regions. Note there are three seagrass regions that do not contain aerial assessment regions: Point Wilson to Point Lillias, Coles Channel and South Sand ..........................................................................................................................3
Figure 2. Locations of monitoring regions and small-scale field assessment plots in Port Phillip Bay. .... 3
Figure 3. Historical seagrass trends at Blairgowrie (——), Point Richards (——) and St Leonards (——) aerial assessment regions 1939–2011 projected against annual rainfall anomaly for Victoria 1935–2010 (mean annual rainfall = 648 mm yr\(^{-1}\)). Shown are the WW II (1937–1945) and recent (1997–2009) droughts. Data source: Ball et al. (2009), Bureau of Meteorology.

Figure 4. Percentage cover of seagrass habitat categories at aerial assessment regions in April 2011.

Figure 5. Aerial photography at Altona aerial assessment region flown 6 April 2011, overlayed with video sites ground-truthed 29 April 2011.

Figure 6. Aerial photography at Blairgowrie aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 27 April 2011.

Figure 7. Aerial photography at Curlewis Bank aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 30 May 2011.

Figure 8. Aerial photography at Kirk Point aerial assessment region flown 6 April 2011, overlayed with video sites ground-truthed 30 April 2011.

Figure 9. Aerial photography at Mud Islands aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 19 April 2011.

Figure 10. Aerial photography at Point Henry West aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 28 April 2011.

Figure 11. Aerial photography at Point Richards aerial assessment region flown 6 April 2011, overlayed with video sites ground-truthed 6 May 2011.

Figure 12. Aerial photography at St Leonards aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 19 April 2011.

Figure 13. Aerial photography at Swan Bay aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 20 May 2011.

Figure 14 Mean (± se) seagrass cover (%) for *H. nigricaulis* at shallow subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 15. Mean (± se) seagrass cover (%) for *H. nigricaulis* at deep subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 16. Mean (± se) seagrass length (cm) for *H. nigricaulis* at shallow subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 17. Mean (± se) seagrass length (cm) for *H. nigricaulis* at deep subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 18. 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 14 occasions between autumn 2008 and winter 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 19. 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 14 occasions between autumn 2008 and winter 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 20. Mean (± se) combined seagrass A) cover (%), B) length, and C) shoot count per 0.0625 m² quadrat for intertidal plots sampled on 14 occasions between autumn 2008 and winter 2011. (NB Format of figures has changed from previous reports to enhance data presentation and interpretation). ................................................................. 32

Figure 21. Variation in seagrass species composition (% cover) for intertidal plots at St Leonards, Mud Islands, Swan Bay and Point Richards between autumn 2008 and winter 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)................................................................. 33

Figure 22. Mud Islands intertidal seagrass monitoring line positions recorded in winter 2009–11 and autumn 2011. ..................................................................................................................................................... 34

Figure 23. St Leonards intertidal seagrass monitoring line positions recorded in winter 2009–11 and autumn 2011. Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines. ........................................................................................................................................... 35

Figure 24. Point Richards (Bellarine Bank) intertidal seagrass monitoring line positions recorded in winter 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).................................................................................................................................................... 36

Figure 25. Mean (± se) maximum depth (m) of shooting H. nigricaulis stems observed on video transects offshore at Blairgowrie and Point Richards on 10 occasions between spring 2008 and winter 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). ......................................................................................................................... 37
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 large-scale monitoring of seagrass beds with aerial mapping and underwater video ground-truthing undertaken in autumn (April–May) 2011
- A summary of results for the small-scale monitoring of seagrass health undertaken in winter (July-August) 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 autumn and winter 2011, and between winter 2011 and the mean of winters 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, c).
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 two elements:

- Annual large-scale monitoring of seagrass area at nine aerial assessment regions nested within 12 larger seagrass regions in PPB using aerial mapping and periodic ground-truthing (Figure 1)
- Small-scale monitoring of seagrass health in six regions (Table 1, Figure 2).

The location of field-assessment plots for small-scale seagrass monitoring in PPB is shown in Figure 2.

Video ground-truthing

The positions of some video ground-truthing sites were moved in 2011 due to changes in the distribution of seagrass habitat since 2010 (Table 2). Some video sites at Point Henry West, Curlewis Bank and Swan Bay were not ground-truthed in 2011 because shallow depths prevented vessel access.

Some video sites that lay outside the aerial assessment regions, and that were ground-truthed in 2008–09 to assist with the interpretation of the aerial photography, were no longer required and were discontinued in 2010 (i.e. Altona, Kirk Point, St Leonards and Swan Bay).

Data Management

Significant field events observed during this reporting period were weather related (principally rainfall and river flow).

There were no significant QA/QC issues recorded during this reporting period.

Exceptions to Detailed Design

Exceptions to the Detailed Design (PoMC 2010) relevant to this report are documented in Exception Report ER2011–95, and summarised as follows:

- Milestone Report No. 14 late.

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

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>Blaigowrie</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. 2009a and ER2008#13).
Figure 1. Map of PPB showing the location of nine aerial assessment regions and 12 larger seagrass regions. Note there are three seagrass regions that do not contain aerial assessment regions: Point Wilson to Point Lillias, Coles Channel and South Sand.

Figure 2. Locations of monitoring regions and small-scale field assessment plots in Port Phillip Bay.
Table 2. Changes to video ground-truthing sites in 2011.

<table>
<thead>
<tr>
<th>Aerial assessment region</th>
<th>Video sites moved in 2011</th>
<th>Video sites not surveyed in 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altona</td>
<td>2a, 3, 4, 8, 12a, 16</td>
<td>7, 12b</td>
</tr>
<tr>
<td>Blairgowrie</td>
<td>1, 8, 10, 11, 16</td>
<td></td>
</tr>
<tr>
<td>Curlewis Bank</td>
<td>1, 3, 4, 5, 7, 14</td>
<td>4, 8, 10</td>
</tr>
<tr>
<td>Kirk Point</td>
<td>1, 3, 4, 5, 7, 14</td>
<td>13, 18</td>
</tr>
<tr>
<td>Mud Islands</td>
<td>1, 6, 9, 13, 15, 17, 19, 23</td>
<td>4, 5, 6, 12</td>
</tr>
<tr>
<td>Point Henry West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point Richards</td>
<td>6, 11, 23, 28, 30</td>
<td></td>
</tr>
<tr>
<td>St Leonards</td>
<td>2, 6, 14, 15, 16, 17</td>
<td></td>
</tr>
<tr>
<td>Swan Bay</td>
<td>25, 28</td>
<td>2, 4, 5, 6, 8, 9, 10, 11, 12, 16, 17, 18, 21, 22, 27, 29, 30, 31, 32, 33</td>
</tr>
</tbody>
</table>
Results

Tables and figures incorporating data from the reporting period April-May (autumn) 2011 and July-August (winter) 2011 mapping are presented in Appendix 1, 2 & 3. Historical data showing seagrass area in Port Phillip Bay and rainfall anomaly are presented in Figure 3.

Seagrass mapping
Seagrass area in autumn 2011:
• Was within 1% of the total area in autumn 2010 at Curlewis Bank, Mud Islands, Point Richards and Swan Bay
• Increased at Altona, Blairgowrie, Kirk Point (all region and inner), Point Henry West (macroalgae and seagrass) and St Leonards.

Seagrass area in autumn 2011 was within expected variability at yearly and decadal scales at the three regions for which sufficient historical seagrass data were available to derive robust measures of variability (i.e. Blairgowrie, Point Richards and St Leonards) (Ball et al. 2009, Ball and Young 2011).

Seagrass area increased by > 5% in 9 of the 12 larger seagrass regions between 2010 and 2011, including an increase by >60% in the Mornington Peninsula, St Leonards and Bellarine Bank seagrass regions.

Seagrass health
Change in seagrass health was examined by comparing seagrass health in winter 2011 with corresponding season (winter) in 2008, 2009 and 2010. Statistically significant changes in seagrass cover, length and stem/shoot density for these comparisons are detailed in Table 7 and 8 (Appendix 2), and summarized below.

Seagrass cover between autumn and winter 2011:
• In shallow subtidal plots, increased at Kirk Point, and was unchanged at Blairgowrie, Mud Islands, Swan Bay 1 and 2, and Point Richards (Table 7, Figure 14)

Intertidal plots at Mud Islands and Swan Bay supported both Z. muelleri and Lepilaena marina. The intertidal plot at Mud Islands in winter 2011 continued to be dominated by Z. muelleri, whereas the intertidal plot at Swan Bay had approximately 60% Z. muelleri cover and 20% L. marina cover, after having equal amounts of each in autumn 2011 (Figure 21).

Seagrass health data for subtidal plots (shallow and deep) containing Heterozostera nigricaulis, and intertidal plots typically dominated by Zostera muelleri, are presented in Figures 14–21 (Appendix 3).

Seagrass cover between autumn and winter 2011:
• In deep subtidal plots, increased at Mud Islands and St Leonards 1, decreased at Blairgowrie, and was unchanged at St Leonards 2 and Point Richards (Table 7, Figure 15)

Seagrass length between autumn and winter 2011:
• In shallow subtidal plots, increased at Kirk Point, and was unchanged at Blairgowrie, Mud Islands, Swan Bay 1 and 2, St Leonards Point Richards, (Table 7, Figure 16)

Shooting stem/shoot density between autumn and winter 2011:
• In shallow subtidal plots, increased at Kirk Point, and was unchanged at Blairgowrie, Mud Islands, Swan Bay 1 and 2, and St Leonards (Table 7, Figure 18A).

In deep subtidal plots, increased at Mud Islands, St Leonards 2 and Point Richards, and was unchanged at Blairgowrie and St Leonards 1 (Table 7, Figure 17)

In intertidal plots, decreased at Point Richards, and was unchanged at Mud Islands, Swan Bay and St Leonards (Table 8, Figure 20B).

Seagrass cover in winter 2011, compared with the mean of winter in 2008–10:
• In shallow subtidal plots, was higher at Blairgowrie, Mud Islands, St Leonards and
Kirk Point, lower at Swan Bay 1 and 2, and unchanged at Point Richards (Table 7, Figure 14)

- In deep subtidal plots, was higher at Blairgowrie, Mud Islands and St Leonards 1, lower at St Leonards 2, and unchanged at Point Richards (Table 7, Figure 15)
- In intertidal plots, was higher at Mud Islands, lower at Swan Bay, and unchanged at St Leonards and Point Richards (Table 8, Figure 20A).

Seagrass length in winter 2011, compared with the mean of winter 2008–10:

- In shallow subtidal plots, was higher at Mud Islands, Swan Bay 1, St Leonards, Point Richards and Kirk Point, lower at Swan Bay 2, and unchanged at Blairgowrie (Table 7, Figure 16).
- In deep subtidal plots, was higher at Blairgowrie, Mud Islands and St Leonards 1, lower at St Leonards 2 and unchanged at Point Richards (Table 7, Figure 17)
- In intertidal plots, was unchanged at all sites (Table 8, Figure 20B).

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

- In shallow subtidal plots, was higher at Blairgowrie, Swan Bay 1, St Leonards and Kirk Point, lower at Swan Bay 2, and unchanged at Mud Islands and Point Richards (Table 7, Figure 18A)
- In deep subtidal plots, was higher at Blairgowrie, Mud Islands and St Leonards 1, and was unchanged at St Leonards 2 and Point Richards (Table 7, Figure 19A)
- In intertidal plots, was lower at Swan Bay and Point Richards, and was unchanged at Mud Islands and St Leonards (Table 8, Figure 20C).

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 22–24 (Appendix 3).

The upper extent of intertidal seagrass along Lines 1 and 2 at St Leonards moved <2 m since autumn 2011 (Figure 23). Line 3 recovered to its full length with seagrass regrowth at its southern end. The northern end of Line 3 was within 1.5 m of its position in autumn 2011. The backup Line 4 moved by <2 m of its position in autumn 2011.

The intertidal seagrass monitoring lines at Point Richards have been subject to sand deposition and seagrass burial during the monitoring program (Figure 24). Line 1 was within 2.5 m of its position in autumn 2011. The seagrass at Line 2 was completely buried with sand by spring 2010 and had not recovered by autumn 2011. Line 2 partially recovered by winter 2011 with seagrass along approximately 60% of its western half. Lines 3 and 4 were completely buried by autumn 2011, with Line 3 partly recovering by winter 2011. Backup Line 4 had almost fully recovered to its previous extent by winter 2011.

Subtidal seagrass lower limits

Video surveys of maximum seagrass depth were conducted at Blairgowrie and Point Richards in winter (August) 2011. The mean maximum observed depth of shooting *H. nigricaulis* stems was 7.0 m along the Blairgowrie transects and 9.7 m along the Point Richards transects in winter 2011 (Figure 25). Seagrass was observed on ten of 11 transects at Blairgowrie, and seven of 11 transects at Point Richards during winter 2011.

Maximum seagrass depth was greater at Point Richards than Blairgowrie (F1,200 = 168, P<0.001) in all seasons except autumn 2009 and autumn 2011 (Figure 25).

Maximum seagrass depth at Blairgowrie was unchanged between autumn and winter 2011 (planned contrast, t = 0.539, P>0.05). Maximum seagrass depth at Blairgowrie in winter 2011 was no different than winter 2010 or 2009 (planned contrasts, P>0.05) (Figure 25).

Maximum seagrass depth at Point Richards increased between autumn and winter 2011 (planned contrast, t = 3.37, P<0.001). Maximum seagrass depth at Point Richards in winter 2011 was no different than winter 2009 or winter 2010 (planned contrasts, P>0.05) (Figure 25).

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 the Swan Bay 1 and 2 shallow plots in winter 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).

Previous studies suggest that 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 mapping in winter 2011

Seagrass area at Blairgowrie, Point Richards and St Leonards in autumn 2011 was within expected variability at both yearly and decadal time scales, compared to statistical criteria calculated from historical data up to and including 2008 (Ball and Young 2011). There were insufficient historical data for Mud Islands, Kirk Point and Swan Bay to calculate statistical criteria for these regions (Ball et al. 2009).

Historical seagrass mapping assessment

When compared with the historical record for six of the aerial assessment regions (Ball et al. 2009), seagrass area in autumn 2011 was:

- Similar to 1972 and 2006–07 at Blairgowrie
- Second highest recorded at Kirk Point since 1962, with the highest cover recorded in 2007
- Similar to 2008–09 and the third lowest recorded at Point Richards since 1946
- Similar to 1993, 2003 and 2006 at St Leonards
- Consistent with previous years at Swan Bay, which has remained relatively stable since the 1970s, apart from a large decline in 1998
- The third lowest recorded at Mud Islands since 1984, but within 2% of total cover in 2006 and 2008–10.

Seagrass health in winter 2011

Recent and longer-term trends in seagrass health over the duration of this program are summarised in Table 3.

Subtidal

Subtidal seagrass health varied appreciably between plots in winter 2011, consistent with the variable pattern of seagrass health observed at the small spatial scale for subtidal seagrasses over the duration this program.

Seagrass cover in subtidal shallow and deep plots has displayed varying trends since the inception of the program in autumn 2008. Trends in seagrass cover at subtidal plots can be broadly split into four categories:

- Plots where seagrass cover has steadily increased since autumn 2008 including at Blairgowrie (shallow) and Mud Islands (shallow)
- Plots where seagrass cover reached >60% cover, then declined by >80% over a period of two to three seasons, including at Swan Bay 1 and 2 (shallow), Mud Islands (deep) and St Leonards 2 (deep). At some of these plots seagrass cover has remained low, although at others such as Swan Bay 1 (shallow) and Mud Islands (deep) seagrass has recovered substantially
- Plots where seagrass cover was initially very low (<5% cover), but has increased to >15% cover since late 2009, including at Kirk Point (shallow), Blairgowrie (deep) and St Leonards 1 (deep)
- Plots where seagrass cover has remained consistently low (<10%) since autumn 2008, including Point Richards (shallow and deep) and St Leonards (shallow)
Intertidal
The health of seagrass at intertidal plots was consistent with past seasonal trends recorded at these plots. Intertidal seagrass cover, length and shoot density remained high at Mud Islands, St Leonards and Swan Bay and low at Point Richards. Between autumn and winter 2011 there has been a shift in the dominance of seagrass species at Swan Bay. Where previously seagrass at Swan Bay was dominated by L. marina, Z. muelleri cover now exceeds that of L. marina for the first time since the inception of the plot in autumn 2008. L. marina cover has been declining, whilst Z. muelleri cover has increased, since spring 2010. Z. muelleri now dominates intertidal seagrass communities at both the Swan Bay and Mud Islands plots.

Seagrass cover remains very low at Point Richards, and there has been little further growth since seagrass reappeared at this plot in summer 2010.

Seagrass health trends at the large and small scale 2008–2011
The trends observed in seagrass health at the small-scale, and seagrass area at the large-scale, reflect a range of processes operating at the scale of individual plots, seagrass beds/meadows, and at the regional level within PPB.

The largest annual change in seagrass area in the aerial assessment regions for the period 2008–2011 occurred between 2010 and 2011 (Hirst et al. 2009e, 2010d, this study), although the changes were not uniform across all the aerial assessment regions. Seagrass area doubled at St Leonards, increased by 75% at Blairgowrie, by 50% at Altona and Kirk Point (all and inner), and by 20% at Point Henry West, but remained unchanged at Curlewis Bank, Mud Islands, Point Richards and Swan Bay. At Point Henry West seagrass cover increased at the expense of macroalgal cover between 2010 and 2011. Change in cover within the aerial assessment regions were accompanied by overall increases in seagrass area across PPB.

Seagrass area increased by >5% in 9 of the 12 larger seagrass regions between 2010 and 2011. Increases of >60% were observed for Mornington Peninsula, St Leonards and Bellarine Bank, although seagrass extent at the latter remains very low in comparison to historical levels (Ball et al. 2009). Increases in seagrass area at larger, regional scale were accompanied by the re-colonisation of seagrass at the small-scale where seagrass had previously been absent (e.g. Kirk Point shallow plot) or substantial increases in cover where cover had previously been very low (e.g. Blairgowrie and St Leonards deep plots). During this program the loss of seagrass cover at individual plots has generally been linked to processes operating at the larger-spatial scale such as sediment movement (Hirst et al. 2009e, Hirst et al. 2010d) or the presence of very high epiphytic macroalgal covers that may be regionally abundant (Hirst et al. 2010c). The loss of seagrass at St Leonards and Point Richards was linked to the erosion and sand accretion (seagrass burial) (Hirst et al. 2009e, Hirst et al. 2010d), and the losses at Swan Bay were linked to epiphytic loads which have been consistently higher in Swan Bay throughout this program (Hirst et al. 2010c). Swan Bay is a shallow, protected embayment with restricted circulation and direct inputs of terrestrial run-off from the surrounding catchment. Seagrass cover has declined at both subtidal plots in Swan Bay since autumn 2008, but the variation in the timing of these events (i.e. separated by a period of 15 months) implies that processes operating at a regional scale may not be manifested uniformly either in time or space at smaller spatial scales.

It is less clear what conditions promote the expansion of seagrass area at a larger-scale. Such conditions may include the presence of suitable propagules (including seeds) or rhizomes from which seagrass can regrow, suitable or stable substratum, sufficient light and nutrients for seagrass growth and the proximity of adjacent seagrass beds as a source of new propagules and/or rhizomes. In many regions seagrass re-colonised areas, between 2010 and 2011, that had historically supported seagrass in the past (Ball et al. 2009).

Clues regarding the potential causes of seagrass decline and recovery at the larger spatial scale can be partly inferred from examining historical trends in seagrass area in PPB. Analysis of historical time series derived from aerial photography showed that seagrass cover along the southern margins of PPB increased from the 1960s to the 1990s, and then declined rapidly from the late 1990s onwards (Ball et al. 2009) (Figure 3). Between 1998 and 2009, >90% of seagrass cover disappeared at Blairgowrie and Point Richards. Large expanses (approximately 50% of area) of seagrass also disappeared at St Leonards. This decline coincided with a prolonged period of drought in southern Australia (1998–2009) (Figure 3) which was characterised by water quality featuring lower nutrient and freshwater inputs, less algal blooms
and increased clarity in the southern and central regions of PPB (Spooner et al. 2011). Higher overall seagrass historically existed in the southern part of PPB during wetter climatic conditions punctuated by droughts during the early 1940s (World War II drought) and recent ‘Big Dry’ (Ummenhoff et al. 2009), and during a period of higher nutrient loadings in PPB from catchment/external sources (Spooner et al. 2010). Following a decade of declining seagrass area in some parts and relative stability in others, seagrass area in PPB increased appreciably in five of the nine aerial assessment regions and nine of the 12 larger seagrass regions (>5% change) between autumn 2010 and 2011; a period characterised by above-average rainfall in 2010. Ball et al. (2009) observed that historically low levels of seagrass recorded at Blairgowrie in 1939 coincided with a drought period which occurred in 1937–45.

In the context of the conceptual model describing seagrass change in PPB, the links between climate and total seagrass extent remain largely untested to date, and the mechanisms behind such climatic driven variability therefore remain unclear. Paradoxically, seagrass area declined at a number of locations in the southern part of PPB, during a period when water clarity and overall quality were increasing; conditions generally considered optimal for seagrass survival and growth. Nutrient limitation may have contributed to the decline of seagrass area in the southern part of PPB, particularly as the input of nutrients into the southern half of PPB also diminished throughout the drought. Nutrient limitation has been implicated in regulating seagrass area in the Great Barrier Reef (Udy et al. 1999), and growth of H. nigricaulis has been shown to be nitrogen limited in PPB (Bulthuis et al. 1992).

Conclusions

Seagrass area increased appreciably within five of the nine aerial assessment regions, and nine of the 12 larger seagrass regions, between 2010 and 2011. Seagrass area remained unchanged elsewhere.

Seagrass health at the small spatial scale either increased or remained largely unchanged during this period. The health of seagrasses monitored in PPB during winter 2011 varied as expected, based on analysis of past trends.

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). The recent increases in seagrass area in PPB may be linked to climatic variation, particularly rainfall patterns, but the exact mechanism/s that promote re-colonisation and expansion of seagrass meadows in PPB remain unknown.
Table 3. Summary of trends in seagrass health at each small-scale monitoring plot between autumn 2011 and winter 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>There was no change to seagrass health in this plot in the last quarter. Seagrass cover and stem density were higher than the longer-term seasonal trend.</td>
<td>Seagrass cover and stem density decreased in the last quarter, while seagrass length was unchanged. Overall seagrass health was higher than the longer-term seasonal trends.</td>
<td></td>
</tr>
<tr>
<td>Mud Islands</td>
<td>There was no change to seagrass health in this plot in the last quarter. Seagrass cover and length were higher than longer-term seasonal trends, whilst stem density was consistent with the longer-term seasonal trend.</td>
<td>Seagrass cover, length and stem density increased in the last quarter, and were higher than the longer-term seasonal trends at this plot.</td>
<td>Seagrass cover in this plot was higher than the longer-term seasonal trend. There was no change in seagrass health in the last quarter.</td>
</tr>
<tr>
<td>Swan Bay 1</td>
<td>There was no change to seagrass health in this plot in the last quarter. Seagrass length and stem density were higher than longer-term seasonal trends, and seagrass cover was lower than the longer-term seasonal trend.</td>
<td></td>
<td>Seagrass cover in this plot was higher than the longer-term seasonal trend. but there was no change in seagrass health in the last quarter. There was a reduction in the cover of <em>L. marina</em> and an increase in cover of <em>Z. muelleri</em>. For the first time during the monitoring program, <em>Z. muelleri</em> is the dominant species at this plot.</td>
</tr>
<tr>
<td>Swan Bay 2</td>
<td>There was no change to seagrass health in this plot in the last quarter. Overall seagrass health was lower than the longer-term seasonal trend at this plot.</td>
<td>Seagrass cover increased in the last quarter. Overall seagrass health was higher 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 1</td>
<td>There was no change to seagrass health in this plot in the last quarter. Seagrass health in this plot was higher than longer-term seasonal trends.</td>
<td></td>
<td>Seagrass cover increased in the last quarter. Overall seagrass health was higher than the longer-term seasonal trend.</td>
</tr>
<tr>
<td>St Leonards 2</td>
<td></td>
<td>Seagrass length increased at this plot in the last quarter. Seagrass cover 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>Seagrass length increased at this plot in the last quarter. Overall seagrass health was consistent with past trends at this plot.</td>
</tr>
<tr>
<td>Point Richards</td>
<td>Seagrass stem density decreased in the last quarter. Seagrass cover and stem density were consistent with longer-term seasonal trends, while seagrass length was higher than the longer-term seasonal trend.</td>
<td>Seagrass length increased at this plot in the last quarter. Overall seagrass health was consistent with past trends at this plot.</td>
<td>There was no change to seagrass health in this plot in the last quarter. Seagrass length and stem density were lower than longer-term seasonal trends.</td>
</tr>
<tr>
<td>Kirk Point</td>
<td>After seagrass recolonised this plot in autumn 2011, overall seagrass health continued to increase in the last quarter and remains higher than the longer-term seasonal trend.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Figure 3. Historical seagrass trends at Blairgowrie (---), Point Richards (—) and St Leonards (—) aerial assessment regions 1939–2011 projected against annual rainfall anomaly for Victoria 1935–2010 (mean annual rainfall = 648 mm yr⁻¹). Shown are the WW II (1937–1945) and recent (1997–2009) droughts.

Data source: Ball et al. (2009), Bureau of Meteorology
Acknowledgements

Guy Werner, Camille White 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. Results

Detailed results for the reporting period July-August (winter) 2011, for small-scale assessment of seagrass health, and for the reporting period April–May (autumn) 2011 for large-scale aerial assessment, are provided in this section. Preliminary results for aerial assessment of the Blairgowrie, Point Richards and St Leonards regions were presented in Ball and Young (2011).

Seagrass mapping
The percentage total seagrass cover at the aerial assessment regions between 2008 and 2011 is presented in Table 4. The percentage cover of seagrass habitat categories in autumn (April) 2011 is shown in Figure 4. Aerial photography from April 2011 of the aerial assessment regions overlayed with ground-truthing sites classified by habitat categories from April-May 2011 is shown in Figures 5–13.

Altona
Total seagrass cover at Altona increased from 25% in 2010 to 48% in 2011, and was predominantly medium-dense *H. nigricaulis* (Figures 4 and 5). Seagrass length was 30–40 cm and epiphytic macroalgal cover was mostly <20%.

*Caulerpa remotifolia* was widespread at this region in 2008–09 and declined in density and distribution by 2010. While seagrass remained the dominant vegetation at this region in 2011, *C. remotifolia* cover growing amongst seagrass increased at video sites 1, 6 and 8 (Note: site 8 was moved approximately 6 m east in 2011).

Blairgowrie
Total seagrass cover at Blairgowrie increased from 4% in 2010 to 7% in 2011, and was predominantly medium-dense *H. nigricaulis* (Figures 4 and 6). Seagrass length was 5–30 cm and epiphytic macroalgal cover was mostly <20%.

*Bathybrittania* was widespread at this region in 2008–09 and declined in density and distribution by 2010. While seagrass remained the dominant vegetation at this region in 2011, B. brittania cover growing amongst seagrass increased at video sites 1, 6 and 8 (Note: site 8 was moved approximately 6 m east in 2011).

Curlewis Bank
Total seagrass cover at Curlewis Bank was 98% in 2011 and within 1% of the cover in 2010. The seagrass was predominantly medium-dense continuous *H. nigricaulis* (Figures 4 and 7). Seagrass length was 10–50 cm and epiphytic macroalgal cover varied across the region from <20% to >80%.

Kirk Point
Total seagrass cover at the Kirk Point aerial assessment region increased from 63% in 2010 to 95% in 2011, and was predominantly medium-dense *H. nigricaulis* (Figures 4 and 8). The greatest increase in seagrass cover since 2010 was observed in the inner zone at the Kirk Point region. Seagrass length was 10–50 cm and epiphytic macroalgal cover varied across the region from <20% to >80%.

Mud Islands
Total seagrass cover at Mud Islands was 41% in 2011 and within 1% of the cover in 2010. The seagrass was predominantly medium-dense *H. nigricaulis* (Figures 4 and 9). Seagrass length was 10–50 cm and epiphytic macroalgal cover varied across the region from <20% to >80%.

Point Henry West
Total vegetation cover (seagrass and macroalgae with seagrass) at Point Henry West covered 100% in 2011 and within 1% of the total cover of vegetation in 2010 (82% seagrass + 17% seagrass and macroalgae). The proportion of seagrass increased between 2010 and 2011 at the expense of macroalgal cover (Figures 4 and 10). This was due to a decline in macroalgae cover within a narrow band of mixed macroalgae and seagrass, previously observed in 2009–10 running parallel to the shore, and approximately 200 m from the beach between video sites 15–18 (Figure 10). This area was dominated by seagrass in 2011.

The seagrass was predominantly medium-dense *H. nigricaulis*. Seagrass length was 10–50 cm and epiphytic macroalgal cover varied across the region from <20% to 21–80%.

Point Richards
Total seagrass cover at Point Richards was 8% in 2011 and within 1% of the cover in 2010. The seagrass predominantly consisted of fragmented medium-dense *H. nigricaulis* beds in the shallow nearshore zone (depths <2 m) (Figures 4 and 11). Areas of macroalgae with sparse and very sparse seagrass stems observed in 2010 were still present at video sites 31 and 35. Macroalgae with sparse and very sparse seagrass stems at video sites 3 and 21 in 2010 were replaced with bare sediment by 2011. Seagrass length was 5–20 cm and epiphytic macroalgal cover varied across the region from <20% to >80%.

St Leonards
Total seagrass cover increased from 10% in 2010 to 20% in 2011, and consisted of narrow beds of medium-dense *H. nigricaulis* separated by expanses of bare sediment (Figures 4 and 12).
Seagrass length was 20–40 cm and epiphytic macroalgal cover was <20%.

**Swan Bay**

Total seagrass cover at Swan Bay was unchanged at 100% in 2010 and 2011, and consisted of predominantly medium-dense seagrass (Figures 4 and 13). The subtidal zone was *H. nigricaulis* and the intertidal zone was *Z. muelleri* intermixed with *L. marina*. *Zostera muelleri* length was 10–20 cm, *L. marina* length was 10 cm, and epiphytic macroalgal cover was <20% for both species. Seagrass length for the subtidal *H. nigricaulis* was 30–50 cm and epiphytic macroalgal cover was mostly <20%.

The video sites at the centre of the aerial assessment region were discontinued as they were too shallow to access by vessel on any tide.

<table>
<thead>
<tr>
<th>Year</th>
<th>Altona(^1)</th>
<th>Blairgowrie</th>
<th>Curlewis Bank</th>
<th>Kirk Point (all region)</th>
<th>Kirk Point (inner)</th>
<th>Mud Islands</th>
<th>Point Henry West(^1)</th>
<th>Point Richards</th>
<th>St. Leonards</th>
<th>Swan Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>(31)</td>
<td>6</td>
<td>94</td>
<td>ND</td>
<td>78</td>
<td>42</td>
<td>88 (11)</td>
<td>8</td>
<td>12</td>
<td>98</td>
</tr>
<tr>
<td>2009</td>
<td>(27)</td>
<td>6</td>
<td>97</td>
<td>49</td>
<td>38</td>
<td>41</td>
<td>77 (22)</td>
<td>8</td>
<td>13</td>
<td>99</td>
</tr>
<tr>
<td>2010</td>
<td>25</td>
<td>4</td>
<td>99</td>
<td>63</td>
<td>45</td>
<td>40</td>
<td>82 (17)</td>
<td>7</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>2011</td>
<td>48</td>
<td>7</td>
<td>98</td>
<td>95</td>
<td>93</td>
<td>41</td>
<td>99 (1)</td>
<td>8</td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

\(^1\)Total vegetation cover at Altona (2008–09) and Point Henry West (2008–10) included areas of macroalgae with seagrass and are shown in brackets as the proportion of seagrass as a percentage of total vegetation cover could not be determined. At Point Henry West the areas shown in brackets were medium-dense macroalgae with seagrass. ND = No Data

![Figure 4. Percentage cover of seagrass habitat categories at aerial assessment regions in April 2011.](image-url)
Figure 5. Aerial photography at Altona aerial assessment region flown 6 April 2011, overlayed with video sites ground-truthed 29 April 2011.

Figure 6. Aerial photography at Blairgowrie aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 27 April 2011.
Figure 7. Aerial photography at Curlewis Bank aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 28 April 2011.

Figure 8. Aerial photography at Kirk Point aerial assessment region flown 6 April 2011, overlayed with video sites ground-truthed 30 May 2011.
Figure 9. Aerial photography at Mud Islands aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 19 April 2011.

Figure 10. Aerial photography at Point Henry West aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 28 April 2011.
Figure 11. Aerial photography at Point Richards aerial assessment region flown 6 April 2011, overlayed with video sites ground-truthed 6 May 2011.

Figure 12. Aerial photography at St Leonards aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 19 April 2011.
Figure 13. Aerial photography at Swan Bay aerial assessment region flown 7 April 2011, overlayed with video sites ground-truthed 20 May 2011.
Mapping accuracy

Error matrices comparing the classification of video ground-truthing and aerial mapping data for the aerial assessment regions are presented in Appendix 4. A summary of the overall mapping accuracies for each region is presented in Table 5. Overall mapping accuracies were >90%, except Swan Bay.

The incorrectly classified video sites at Swan Bay were due to one ground-truthing site with very sparse patchy seagrass (video site 3) mapped as sparse patchy seagrass, and two ground-truthing sites with very sparse macroalgae (video sites 25 and 28) mapped as sparse patchy seagrass.

The dark coloured underlying sediments at Swan Bay combined with the presence of drift and epiphytic algae can affect the accuracy of mapping at this region. This is a particular problem for distinguishing sparse and very sparse seagrass categories from each other and also bare sediment. These were the primary causes of the three incorrectly mapped video sites at Swan Bay in 2011.

Three video sites at Point Richards (12, 27 and 35) were assessed as being incorrectly classified in the mapping, reducing the mapping accuracy to 91%. The actual seagrass cover observed in the video ground-truthing matched the mapping classification, but the overall vegetation density classification at the video sites was elevated by the presence of macroalgae. This would not have affected the overall accuracy of the assessment of total seagrass cover at this site.

<table>
<thead>
<tr>
<th>Aerial assessment region</th>
<th>Ground-truthing sites correctly classified in mapping</th>
<th>Total ground-truthing sites</th>
<th>Overall mapping accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altona</td>
<td>17</td>
<td>17</td>
<td>100</td>
</tr>
<tr>
<td>Blairgowrie</td>
<td>24</td>
<td>25</td>
<td>96</td>
</tr>
<tr>
<td>Curlewis Bank</td>
<td>12</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>Kirk Point (inner)</td>
<td>14</td>
<td>14</td>
<td>100</td>
</tr>
<tr>
<td>Kirk Point (all)</td>
<td>22</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>Mud Islands</td>
<td>15</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Point Henry West</td>
<td>12</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>Point Richards</td>
<td>32</td>
<td>35</td>
<td>91</td>
</tr>
<tr>
<td>St Leonards</td>
<td>17</td>
<td>17</td>
<td>100</td>
</tr>
<tr>
<td>Swan Bay</td>
<td>10</td>
<td>13</td>
<td>77</td>
</tr>
</tbody>
</table>

Broad-scale assessment of seagrass changes

Overall changes in seagrass/vegetation cover within the major PPB seagrass regions were compared using a broad-scale visual assessment of the 2010 and 2011 aerial photography. Changes between 2010 and 2011 are summarised in Table 6. With the exception of the Mud Islands region, all regions showed an increase in seagrass area between 2010 and 2011.

Seagrass area increased in the Mornington Peninsula region by approximately 65% since 2010. Seagrass area remains low in this region, hence small increases in overall cover resulted in large percentage change between 2010 and 2011.

In the South Sand region, seagrass was largely distributed across the western and central areas in 2010. This was again the case in 2011, with an overall increase in cover of approximately 35%. The exception was the south end of the central section where there was a noticeable decrease in cover. The eastern side of the region remained stable. It is unclear whether the changes in vegetation area were due to seagrass or macroalgae cover.

The Mud Islands region showed a decline in overall area of around 5%. This was most noticeable on the western shore, and appears to be due to sand inundation on the outer edges of the beds. Seagrass cover also decreased in the north-west section where a sand spit encroached further into the seagrass beds. There were both increases and decreases along the east shore resulting in no net change. A decrease was observed at the small seagrass bed where the deep monitoring plot is located.

The nearshore seagrass beds at the St Leonards region increased in area by approximately 60% from 2010. This was primarily due to expansion of the shallow subtidal seagrass beds between...
the St Leonards Yacht Club and the entrance to Swan Bay.

The area of intertidal seagrass beds at Swan Bay appeared similar to 2010. An overall increase of approximately 1% was observed, primarily due to increases in cover of subtidal beds to the north of Swan Island.

The deeper areas within the Coles Channel seagrass region around the St. Leonards 1 & 2 deep plots had an overall increase in vegetation cover (assumed to be a mix of seagrass and macroalgae) of approximately 20%. A small increase was also present on the west bank of the West Channel, but no changes occurred along the eastern bank of the channel.

The Bellarine Bank region had an overall increase in total seagrass cover of approximately 70% across the region. The greatest gains were visible in seagrass beds offshore from Clifton Springs and for an area south of the Point Richards boat ramp.

The Curlewis Bank seagrass beds offshore from Hermsley Road at the boundary of Curlewis and Bellarine Banks increased by 20% between 2010 and 2011.

The Corio Bay region was mostly unchanged with a small increase (5%) in seagrass area throughout the region. A decrease was observed in an offshore region to the west of the Avalon boat ramp.

The Point Wilson to Point Lillias coast had small losses and gains in seagrass but with an overall increase of approximately 10%. To the north of Point Wilson the 2011 imagery was obscured making it difficult to accurately assess seagrass change in the deeper regions.

The Kirk Point to Wedge Point region had an overall increase in vegetation area of approximately 30%. The majority of increase occurred inshore between the Spit Wildlife Reserve and Kirk Point. To the east of Kirk Point the increase was not as large and there was a decrease in cover around Wedge Point. The offshore area at this region is typically dominated by macroalgae and much of this appeared unchanged from 2010.

Seagrass area in the Altona region increased by approximately 15%. Most of the increase in seagrass area was in the inshore region. Seagrass cover also decreased, primarily around the entrance to Altona Creek and around the new western rock groyne. The offshore area was primarily dominated by macroalgae and showed little change.

Seagrass changes mapped in the aerial assessment regions between 2010 and 2011 (see above) were generally consistent with the observations from the broad-scale visual assessment of the corresponding PPB larger seagrass regions.
Table 6. Broad-scale assessment of seagrass/vegetation changes for the 12 larger seagrass regions between 2010 and 2011.

<table>
<thead>
<tr>
<th>PPB Seagrass Region</th>
<th>Aerial assessment region</th>
<th>seagrass/vegetation cover changes 2010–11*</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mornington Peninsula</td>
<td>Blairgowrie</td>
<td>65% increase</td>
<td>Overall increase in seagrass cover and density across the region.</td>
</tr>
<tr>
<td>South Sand</td>
<td>NA</td>
<td>35% increase</td>
<td>Overall increase across the region but a decrease in the deeper water of the south central section.</td>
</tr>
<tr>
<td>Mud Islands</td>
<td>Mud Islands</td>
<td>5% decrease</td>
<td>Overall a small decrease in cover. The north west section had both increases and decreases, the western section decreased and the eastern section remained constant. There was a very small increase in the southern most section.</td>
</tr>
<tr>
<td>Swan Bay</td>
<td>Swan Bay</td>
<td>1% increase</td>
<td>A small increase in the deeper water to the north of Swan Island. Shallow mud flats appeared unchanged.</td>
</tr>
<tr>
<td>St Leonards – nearshore</td>
<td>St Leonards</td>
<td>60% increase</td>
<td>Overall increase across the region. Most change occurred in the shallow subtidal zone south of St Leonards boat ramp.</td>
</tr>
<tr>
<td>Coles Channel</td>
<td>NA</td>
<td>20% increase</td>
<td>Noticeable increase in cover along the east bank of Coles Channel. Slight increase in the central region and no change detected in the east of the region.</td>
</tr>
<tr>
<td>Bellarine Bank</td>
<td>Point Richards</td>
<td>70% increase</td>
<td>Largest increases were around the Pt Richards and Clifton Springs boat ramps.</td>
</tr>
<tr>
<td>Curlewis Bank</td>
<td>Curlewis Bank</td>
<td>20% increase</td>
<td>Around Hermsley Road there was relatively little vegetation, but it showed a large increase of &gt;100%. The majority of the rest of the region showed only a small increase in cover of about 5%.</td>
</tr>
<tr>
<td>Corio Bay</td>
<td>Point Henry West</td>
<td>5% increase</td>
<td>A small increase throughout the region. The exception was an offshore patch to the west of Avalon boat ramp that experienced a decrease.</td>
</tr>
<tr>
<td>Point Wilson to Point Lillias</td>
<td>NA</td>
<td>10% increase</td>
<td>Mixed increases and decreases throughout region but with an overall net increase. The majority of the increase was in the intertidal and shallow subtidal zones.</td>
</tr>
<tr>
<td>Kirk Point to Wedge Point</td>
<td>Kirk Point</td>
<td>30% increase</td>
<td>General increase throughout the region, primarily in the inshore beds. Most noticeable increase between Spit Wildlife Reserve and Kirk Point. The large areas of submerged vegetation offshore were considered to be primarily macroalgae and showed little variation.</td>
</tr>
<tr>
<td>Altona to Point Cook</td>
<td>Altona</td>
<td>15% increase</td>
<td>General increase in the inshore area. A decline was noted around the entrance to Altona Creek and around the new rock groyne constructed to the west of Altona Pier.</td>
</tr>
</tbody>
</table>

*green shading indicates an increase in seagrass area of >5% since 2010
Appendix 2. Seagrass health tables

Table 7. 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 – winter 2011 versus autumn 2011
C2 – winter 2011 versus mean of winter 2008–10

<table>
<thead>
<tr>
<th>Shallow plots</th>
<th>arc sin (% cover)</th>
<th>log e (length)</th>
<th>log e (count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tukeys test (Win 11)</td>
<td>B,MI&gt;SB1,KP,SL&gt;SB2,PR</td>
<td>B,MI,SB1,KP&gt;SL&gt;SB2,PR</td>
<td>B,MI&gt;SB1,KP,SL&gt;SB2,PR</td>
</tr>
<tr>
<td>Contrast</td>
<td>C1</td>
<td>C2</td>
<td>C1</td>
</tr>
<tr>
<td>Blairgowrie (B)</td>
<td>-0.3</td>
<td>+8.4***</td>
<td>+1.5</td>
</tr>
<tr>
<td>Mud Islands (MI)</td>
<td>+1.1</td>
<td>+5.8***</td>
<td>+1.5</td>
</tr>
<tr>
<td>Swan Bay 1 (SB1)</td>
<td>+0.6</td>
<td>-4.9***</td>
<td>+1.9</td>
</tr>
<tr>
<td>Swan Bay 2 (SB2)</td>
<td>+0.5</td>
<td>-12.3***</td>
<td>-0.4</td>
</tr>
<tr>
<td>St Leonards (SL)</td>
<td>-0.5</td>
<td>+3.7***</td>
<td>+0.1</td>
</tr>
<tr>
<td>Pt Richards (PR)</td>
<td>-1.9</td>
<td>-0.4</td>
<td>+1.3</td>
</tr>
<tr>
<td>Kirk Pt (KP)</td>
<td>+4.8***</td>
<td>+8.4***</td>
<td>+6.4***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deep plots</th>
<th>arc sin (% cover)</th>
<th>log e (length)</th>
<th>log e (count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tukeys test (Win 11)</td>
<td>MI,SL1&gt;SB2,PR</td>
<td>SL1&gt;SB2,PR</td>
<td>MI,SL1&gt;SB2,PR</td>
</tr>
<tr>
<td>Contrast</td>
<td>C1</td>
<td>C2</td>
<td>C1</td>
</tr>
<tr>
<td>Blairgowrie (B)</td>
<td>-5.0***</td>
<td>+3.9***</td>
<td>-0.8</td>
</tr>
<tr>
<td>Mud Islands (MI)</td>
<td>+3.5**</td>
<td>+3.8***</td>
<td>+2.2*</td>
</tr>
<tr>
<td>St Leonards 1 (SL1)</td>
<td>+3.5***</td>
<td>+10.2***</td>
<td>+0.9</td>
</tr>
<tr>
<td>St Leonards 2 (SL2)</td>
<td>-0.4</td>
<td>-5.7***</td>
<td>+2.9**</td>
</tr>
<tr>
<td>Pt Richards (PR)</td>
<td>+0.2</td>
<td>-0.9</td>
<td>+2.4*</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 winter 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.
Table 8. 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 subtidal plot include:
C1 – winter 2011 versus autumn 2011
C2 – winter 2011 versus mean of winter 2008–10

<table>
<thead>
<tr>
<th></th>
<th>arcsin (% cover)</th>
<th>loge (length)</th>
<th>loge (count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tukeys test (Aut 11)†</td>
<td>MI&gt;SB,SL&gt;PR</td>
<td>MI,SB,SL&gt;PR</td>
<td>MI,SL,SB&gt;PR</td>
</tr>
<tr>
<td>Planned contrasts</td>
<td>C1</td>
<td>C1</td>
<td>C1</td>
</tr>
<tr>
<td>Mud Islands (MI)</td>
<td>-1.7</td>
<td>-1.3</td>
<td>-0.7</td>
</tr>
<tr>
<td>Swan Bay (SB)</td>
<td>+0.8</td>
<td>+0.2</td>
<td>-0.8</td>
</tr>
<tr>
<td>St Leonards (SL)</td>
<td>-0.5</td>
<td>+1.4</td>
<td>+0.1</td>
</tr>
<tr>
<td>Pt Richards (PR)</td>
<td>-0.1</td>
<td>-0.4</td>
<td>-0.4</td>
</tr>
</tbody>
</table>

Blank P>0.05, *P<0.05, **P<0.01 and ***P<0.001
† Tukeys HSD post-hoc test between plots for winter 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 3. Seagrass health figures

Figure 14. Mean (± se) seagrass cover (%) for *H. nigricaulis* at shallow subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 15. Mean (± se) seagrass cover (%) for *H. nigricaulis* at deep subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 16. Mean (± se) seagrass length (cm) for *H. nigricaulis* at shallow subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 17. Mean (± se) seagrass length (cm) for *H. nigricaulis* at deep subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 18. Mean (± se) A) shooting and B) non-shooting stem count per 0.0625 m² quadrat for H. nigricaulis at shallow subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 19. Mean (± se) A) shooting and B) non-shooting stem count per 0.0625 m² quadrat for *H. nigricaulis* at deep subtidal plots sampled on 14 occasions between autumn 2008 and winter 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 20. Mean (± se) combined seagrass A) cover (%), B) length, and C) shoot count per 0.0625 m² quadrat for intertidal plots sampled on 14 occasions between autumn 2008 and winter 2011. (NB Format of figures has changed from previous reports to enhance data presentation and interpretation).
Figure 21. Variation in seagrass species composition (% cover) for intertidal plots at St Leonards, Mud Islands, Swan Bay and Point Richards between autumn 2008 and winter 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 22. Mud Islands intertidal seagrass monitoring line positions recorded in winter 2009–11 and autumn 2011.
Figure 23. St Leonards intertidal seagrass monitoring line positions recorded in winter 2009–11 and autumn 2011.

Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines.
Figure 24. Point Richards (Bellarine Bank) intertidal seagrass monitoring line positions recorded in winter 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 25. Mean (± se) maximum depth (m) of shooting *H. nigricaulis* stems observed on video transects offshore at Blairgowrie and Point Richards on 10 occasions between spring 2008 and winter 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 4. Mapping error matrices

### Table 9. Altona 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Ground-truthing Data</th>
<th>Medium-dense &amp; Medium-dense Patchy Macroalgae/Seagrass</th>
<th>Sparse &amp; Sparse Patchy Seagrass</th>
<th>Bare Sediment</th>
<th>Total</th>
<th>User’s Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Macroalgae/Seagrass</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>0</td>
<td>6</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Producer’s Accuracy</td>
<td>100%</td>
<td>ND</td>
<td>100%</td>
<td>Overall accuracy</td>
<td>100%</td>
</tr>
</tbody>
</table>

1Correctly classified data includes four ground-truthing sites with medium-dense macroalgae with seagrass.

### Table 10. Blairgowrie 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Ground-truthing Data</th>
<th>Medium-dense &amp; medium-dense patchy seagrass</th>
<th>Sparse &amp; sparse patchy seagrass</th>
<th>Bare sediment</th>
<th>Total</th>
<th>User’s Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-dense &amp; medium-dense patchy seagrass</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; sparse patchy seagrass</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>Bare sediment</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>15</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>0</td>
<td>15</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Producer’s Accuracy</td>
<td>90%</td>
<td>ND</td>
<td>100%</td>
<td>Overall accuracy</td>
<td>96%</td>
</tr>
</tbody>
</table>

1Correctly classified data includes one ground-truthing site with very sparse macroalgae, one ground-truthing site with very sparse patchy seagrass stems with macroalgae and one ground-truthing site with very sparse patchy seagrass and stems with macroalgae.

### Table 11. Curlewis Bank 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Ground-truthing Data</th>
<th>Medium-dense &amp; Medium-dense Patchy Macroalgae/Seagrass</th>
<th>Sparse &amp; Sparse Patchy Seagrass</th>
<th>Bare Sediment</th>
<th>Total</th>
<th>User’s Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Macroalgae/Seagrass</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Producer’s Accuracy</td>
<td>100%</td>
<td>ND</td>
<td>100%</td>
<td>Overall accuracy</td>
<td>100%</td>
</tr>
</tbody>
</table>

1Correctly classified data includes five sites with medium-dense macroalgae with seagrass.
Table 12. Kirk Point (all regions) 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Mapping Data</th>
<th>Ground-truthing Data</th>
<th>Medium-dense &amp; Medium-dense Patchy Macroalgae/Seagrass</th>
<th>Sparse &amp; Sparse Patchy Seagrass</th>
<th>Bare Sediment</th>
<th>Total</th>
<th>User's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Seagrass</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>22</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>22</td>
<td>Overall accuracy 100%</td>
</tr>
</tbody>
</table>

*Correctly classified data includes two ground-truthing sites with medium-dense seagrass and stems and one ground-truthing site with medium-dense macroalgae with seagrass.

Table 13. Kirk Point (inner region) 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Mapping Data</th>
<th>Ground-truthing Data</th>
<th>Medium-dense &amp; Medium-dense Patchy Seagrass</th>
<th>Sparse &amp; Sparse Patchy Seagrass</th>
<th>Bare Sediment</th>
<th>Total</th>
<th>User's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Seagrass</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>Overall accuracy 100%</td>
</tr>
</tbody>
</table>

*Correctly classified data includes one ground-truthing site with medium-dense macroalgae with seagrass.

Table 14. Mud Islands 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Mapping Data</th>
<th>Ground-truthing Data</th>
<th>Medium-dense &amp; Medium-dense Patchy Seagrass</th>
<th>Sparse &amp; Sparse Patchy Seagrass</th>
<th>Bare Sediment</th>
<th>Total</th>
<th>User's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Seagrass</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>15</td>
<td>Overall accuracy 100%</td>
</tr>
</tbody>
</table>

*Correctly classified data includes one ground-truthing site with medium-dense macroalgae with seagrass.

*Correctly classified data includes one ground-truthing site with very sparse seagrass stems.
Table 15. Point Henry West 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Mapping Data</th>
<th>Medium-dense &amp; Medium-dense Patchy Seagrass</th>
<th>Sparse &amp; Sparse Patchy Seagrass</th>
<th>Bare Sediment</th>
<th>Total</th>
<th>User's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Seagrass</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>Overall accuracy 100%</td>
</tr>
<tr>
<td>Producer's Accuracy</td>
<td>100%</td>
<td>ND</td>
<td>ND</td>
<td>Overall accuracy 100%</td>
<td></td>
</tr>
</tbody>
</table>

1Correctly classified data includes two ground-truthing sites with medium-dense seagrass and stems

Table 16. Point Richards 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Mapping Data</th>
<th>Medium-dense &amp; medium-dense patchy seagrass or macroalgae with seagrass or stems</th>
<th>Sparse &amp; Sparse patchy seagrass</th>
<th>Bare sediment</th>
<th>Total</th>
<th>User's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Seagrass</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>3</td>
<td>0</td>
<td>17</td>
<td>20</td>
<td>85%</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>0</td>
<td>17</td>
<td>35</td>
<td>Overall accuracy 91%</td>
</tr>
<tr>
<td>Producer's Accuracy</td>
<td>83%</td>
<td>ND</td>
<td>100%</td>
<td>Overall accuracy 91%</td>
<td></td>
</tr>
</tbody>
</table>

1Includes one ground-truthing site with medium-dense macroalgae with seagrass.
2Includes three ground-truthing sites with medium-dense macroalgae with seagrass/stems
3Includes two ground-truthing sites with very sparse macroalgae and one ground-truthing site with very sparse seagrass.

Table 17. St Leonards 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Mapping Data</th>
<th>Medium-dense &amp; medium-dense patchy seagrass</th>
<th>Sparse &amp; Sparse patchy seagrass</th>
<th>Bare sediment1</th>
<th>Total</th>
<th>User's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-Dense &amp; Medium-Dense Patchy Seagrass</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>100%</td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>ND</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>7</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>1</td>
<td>7</td>
<td>17</td>
<td>Overall accuracy 100%</td>
</tr>
<tr>
<td>Producer's Accuracy</td>
<td>100%</td>
<td>ND</td>
<td>100%</td>
<td>Overall accuracy 100%</td>
<td></td>
</tr>
</tbody>
</table>

1Correctly classified data includes one ground-truthing site with very sparse patchy macroalgae
Table 18. Swan Bay 2011 mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

<table>
<thead>
<tr>
<th>Mapping Data</th>
<th>Ground-truthing Data</th>
<th>Total</th>
<th>User’s Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medium-Dense &amp;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium-Dense Patchy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seagrass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-Dense &amp; Medium-Dense</td>
<td>10</td>
<td>10</td>
<td>100%</td>
</tr>
<tr>
<td>Patchy Seagrass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sparse &amp; Sparse Patchy Seagrass</td>
<td>0</td>
<td>3</td>
<td>0%</td>
</tr>
<tr>
<td>Bare Sediment</td>
<td>0</td>
<td>0</td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Producer’s Accuracy</td>
<td>100%</td>
<td>ND</td>
<td>0%</td>
</tr>
<tr>
<td>Overall accuracy</td>
<td>100%</td>
<td>ND</td>
<td>0%</td>
</tr>
</tbody>
</table>

1Incorrectly classified data includes one ground-truthing site with very sparse seagrass and two ground-truthing sites with very sparse macroalgae.
Appendix 5. 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)
- Seagrass mapping GIS data: a separate shapefile exists for each region with the naming format region_name_monthyear.shp (e.g. Blairgowrie_shallow_April11.shp)
- Aerial photography mosaic for PPB: Seagrass_2011april06-07_air_RGB_30cm_mga55.ecw
- Underwater video ground-truthing GIS data: PPB_seagrass_video_2011_MGA55.shp