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Baywide Seagrass Monitoring Program


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Baywide Seagrass Monitoring Program


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Executive Summary

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

This milestone report presents the results of small-scale monitoring of seagrass health for autumn (April-May) 2009. It includes a detailed assessment of 1) seagrass cover, stem/shoot density and length for subtidal and intertidal seagrass plots at six regions, and 2) factors that are known to influence seagrass health (light, turbidity, and epiphyte cover). Subtidal seagrass was monitored at two depths: shallow (1–2 m) and deep (3–5 m) plots at six and four of the regions, respectively.

Seagrass cover, length and stem/shoot density in autumn 2009 were compared with the previous sampling dates in summer 2009, and with measurements in autumn 2008. Seagrass health was also compared with historical data collected between 2004 and 2007 for plots at three of six shallow subtidal plots, and two of four intertidal plots.

Seagrass health

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

Subtidal seagrass beds monitored in this study consisted of a single seagrass species *Heterozostera nigricaulis*. Intertidal seagrass beds comprised *Zostera muelleri*, although the aquatic macrophyte *Lepilaena marina* was also present at the Swan Bay and Mud Islands intertidal plots.

Subtidal

Plots at Blairgowrie (shallow), Mud Islands (shallow and deep), Swan Bay 1 and 2 (shallow), and St Leonards 2 (deep) continued to be characterised by high overall seagrass cover and were dominated by high densities of shooting stems in autumn 2009. Many of these plots exhibited evidence of seasonal decline between summer and autumn 2009, consistent with observed growth patterns for *H. nigricaulis* in PPB.

Shallow subtidal plots at St Leonards, Point Richards and Kirk Point, and deep plots at Blairgowrie, St Leonards 1 and Point Richards were characterised by a very low cover of seagrass dominated by non-shooting stems. There was little evidence of seagrass growth at these plots between autumn 2008 and autumn 2009, and the overall trend was one of declining stem length and density over the course of this study. The one exception to this pattern was at the deep St Leonards 1, and to a lesser extent Point Richards, plots where new shooting stems were recorded in autumn 2009.

Video transects showed that seagrass maximum depth was shallower in autumn 2009, than recorded in summer 2009, at Blairgowrie and Point Richards. This change in maximum depth coincides with a seasonal decline in day length, and hence total available light, during autumn. Day length has been shown to be an important determinant of maximum seagrass depth elsewhere.

Intertidal

Intertidal seagrass cover decreased at Mud Islands and St Leonards, but remained unchanged at Swan Bay and Point Richards between summer and autumn 2009. No corresponding reduction in length or shoot density was observed. Reductions in intertidal seagrass cover during autumn are consistent with the pattern of reduced growth in late summer/early autumn observed for northern hemisphere species of *Zostera*.

Seagrass cover, length and shoot density at Point Richards were much lower in autumn 2009 when compared with autumn 2008 as a consequence of sand accretion in the intertidal zone. Approximately 75% of the intertidal plots and >50% of the intertidal zone at Point Richards was buried under sand between autumn 2008 and autumn 2009.

Factors that affect seagrass health

Benthic light availability exceeded conservative environmental requirements for seagrasses in southern PPB at all regions.
Epiphyte algae were patchy in space and time and often characterised by high variation in abundance. In general epiphytic algae were less abundant on 1) intertidal than subtidal seagrass plants, and 2) subtidal plots dominated by non-shooting stems. No consistent change in epiphytic algal cover was observed between summer and autumn 2009. There was also no correlation between decreases in subtidal seagrass cover, length and stem density and epiphytic algal cover in autumn 2009.

Conclusions
The health of subtidal seagrass varied depending upon the initial condition of the plot in autumn 2008. Where field assessment plots were dominated by an initial dense cover of shooting stems in autumn 2008, changes in subtidal seagrass health between summer and autumn 2009 were consistent with seasonal declines in *H. nigricaulis* biomass and shoot density observed in other studies. Generalised physiological growth models also indicate that seagrass growth is expected to decline in autumn corresponding with reduced net photosynthesis.

Subtidal seagrass cover, length and stem density remained low at all plots where seagrass cover was initially low and dominated by non-shooting stems in autumn 2008. In some cases this seagrass is indicative of previously healthy seagrass at these locations. With the exception of the deep plot at St Leonards 1, and to a lesser extent Point Richards, subtidal seagrass at these plots displayed little evidence of regrowth between summer and autumn 2009.

Intertidal seagrass health varied as expected based on previous studies of *Zostera* species elsewhere. Intertidal seagrass at Point Richards continued to disappear and only a fraction of the original plot remained by autumn 2009 due to sand accretion in the intertidal zone.

The health of seagrasses in PPB between summer and autumn 2009 varied as expected based on comparisons with studies of Zosteraceae seagrass species in PPB and elsewhere.
Table of Contents

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

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

Materials and Methods.............................................................................................................................................. 2
Data Management.......................................................................................................................................................... 2
  QA/QC..................................................................................................................................................................... 2
Exceptions to Detailed Design .................................................................................................................................... 2

Results............................................................................................................................................................................... 4
Seagrass health............................................................................................................................................................... 4
  Intertidal seagrass upper limits ................................................................................................................................. 5
  Subtidal seagrass lower limits ..................................................................................................................................... 5
Light, turbidity and epiphytes ....................................................................................................................................... 5
  Light attenuation (Kd), % surface irradiance and turbidity ...................................................................................... 5
  Epiphytes.................................................................................................................................................................. 5
Comparisons against historical data ......................................................................................................................... 6
  Seagrass health........................................................................................................................................................ 6
  Seagrass epiphyte cover ......................................................................................................................................... 6

Discussion......................................................................................................................................................................... 7
Seagrass health............................................................................................................................................................... 7
  Subtidal............................................................................................................................................................... 7
  Intertidal............................................................................................................................................................. 8
Factors that affect seagrass health............................................................................................................................ 9
Conclusions....................................................................................................................................................................... 10

Acknowledgements....................................................................................................................................................... 11

References..................................................................................................................................................................... 12
List of Tables

Table 1. Summary of small-scale seagrass monitoring plots within regions......................................................... 2

Table 2. Summary of linear mixed effects model analysis testing for differences between all regions and sampling dates for seagrass cover, length and shooting stem density counts at shallow and deep subtidal plots. Planned statistical comparisons within each subtidal plot: C1 - autumn 2009 versus summer 2009, and C2 - autumn 2009 versus autumn 2008.................................................. 17

Table 3. Summary of 2-way ANOVA testing for differences between all regions and sampling dates for seagrass cover, length and shoot density counts at intertidal plots. Planned statistical comparisons within each intertidal plot: C1 - autumn 2009 versus summer 2009, and C2 - autumn 2009 versus autumn 2008. .................................................................................................................................................... 22

Table 4. Mean daily light attenuation coefficients (Kd) and % surface irradiance at depths of shallow (2 m) and deep plots (5 m) from 10 am–2 pm calculated for each region for March-May 2009. ................. 28

Table 5. Summary of linear mixed effects models testing for differences between all regions and sampling dates (seasons) for arcsin transformed epiphytic algae at shallow and deep subtidal plots. Planned statistical comparisons within each subtidal plot: C1 - autumn 2009 versus summer 2009, and C2 - autumn 2009 versus autumn 2008.......................... ............................................................................................ 36

List of Figures

Figure 1. Locations of monitoring regions and small-scale field assessment plots in Port Phillip Bay................. 3

Figure 2. Locations of light loggers, EPA water quality monitoring sites and PoMC turbidity monitoring stations in Port Phillip Bay. ..................................................................................................................................................... 3

Figure 3. Mean (± se) seagrass cover (%) for H. nigricaulis at shallow subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the Swan Bay 2 shallow plot in autumn 2008....... 15

Figure 4. Mean (± se) seagrass cover (%) for H. nigricaulis at deep subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data available was available for the St Leonards 2 deep plot in autumn 2008. ..................................................................................................................................................... 15

Figure 5. Mean (± se) seagrass length (cm) for H. nigricaulis at shallow subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the Swan Bay 2 shallow plot in autumn 2008....... 16

Figure 6. Mean (± se) seagrass length (cm) for H. nigricaulis at deep subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the St Leonards 2 deep plot in autumn 2008. ..................................................................................................................................................... 16

Figure 7. Mean (± se) A) shooting and B) non-shooting stem density count per 0.0625 m² quadrat for H. nigricaulis at shallow subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the Swan Bay 2 shallow plot in autumn 2008. ..................................................................................................................................................... 19

Figure 8. Mean (± se) A) shooting and B) non-shooting stem density count per 0.0625 m² quadrat for H. nigricaulis at deep subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the St Leonards 2 deep plot in autumn 2008. ..................................................................................................................................................... 19

Figure 9. Mean (± se) A) Z. muelleri composition (%), combined seagrass B) cover (%), C) length, and D) shoot density count 0.0625 m² for intertidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009. ..................................................................................................................................................... 21
Figure 10. Mud Islands intertidal seagrass monitoring line positions autumn 2008, summer and autumn 2009. .......................................................... 23

Figure 11. St Leonards intertidal seagrass monitoring line positions autumn 2008, summer and autumn 2009. Line 4 is an extra monitoring contingency line established as a backup for the three principal monitoring lines. ..................................................................................................................... 24

Figure 12. Point Richards (Bellarine Bank) intertidal seagrass monitoring line positions autumn 2008, summer and autumn 2009. Note seagrass at line 3 and backup line 4 were buried with sand by spring 2008 and no seagrass is currently present at these lines. ..................................................................................................................... 25

Figure 13. Aerial photography of intertidal seagrass monitoring area at Point Richards April 2008 (top) and April 2009 (bottom) highlighting expansion of sand beach. Note lines 3 and 4 were buried by spring 2008 and intertidal seagrass was not present at these positions in autumn 2009. ................. 25

Figure 14. Mean (± se) maximum depth (m) of shooting H. nigricaulis stems observed on video transects run offshore at Blairgowrie and Point Richards in spring 2008 (black), summer 2009 (hatched) and autumn 2009 (grey). NB. Shooting stems were recorded on only a single transect at Blairgowrie in spring 2008. ..................................................................................................................... 26

Figure 15. Mean (± se) light attenuation coefficients (m-1), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) at Blairgowrie (two sites) from 12 noon, for January–February 2009 (see also Appendix 3). PoMC turbidity data is from Camerons Bight monitoring station. Red arrows indicate when loggers were serviced........................................... 27

Figure 16. Mean (± se) light attenuation coefficients (m-1), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) at Mud Islands (two sites) from 12 noon, for January–February 2009 (see also Appendix 3). PoMC turbidity data is from Mud Islands monitoring station. Red arrows indicate when loggers were serviced........................................... 28

Figure 17. Mean (± se) light attenuation coefficients (m-1), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) at St Leonards (two sites) from 12 noon, for January–February 2009 (see also Appendix 3). PoMC turbidity data from Swan Bay (Coles Channel) monitoring station. Red arrows indicate when loggers were serviced................................. 30

Figure 18. Mean (± se) light attenuation coefficients (m-1), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) at Kirk Point from 12 noon, for January–February 2009 (see also Appendix 3). PoMC turbidity data from Long Reef monitoring station. Red arrows indicate when loggers were serviced................................. 31

Figure 19. Mean (± se) light attenuation coefficients (m-1), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) from 12 noon, at Point Richards for January–February 2009. Red arrows indicate when loggers were serviced................................. 32

Figure 20. Mean (± se) light attenuation coefficients (m-1), calculated daily between 10am and 2pm, at Swan Bay for January–February 2009 (see also Appendix 3). No turbidity data was available for this region. Red arrows indicate when loggers were serviced................................. 33

Figure 21. Mean (± se) epiphytic turfing algae cover (%) of H. nigricaulis leaf area at A) shallow and B) deep subtidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates no data available for autumn 2008................................. 35

Figure 22. Mean (± se) encrusting epiphytic algal cover (%) of H. nigricaulis leaf area at A) shallow and B) deep subtidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates no data available for autumn 2008................................. 36

Figure 23. Mean (± se) epiphytic macroalgal cover (%) of A) shallow and B) deep subtidal seagrass plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) 2009 and autumn (hatched); n indicates where no data available for autumn 2008................................. 38

Figure 24. Mean (± se) A) turfing, and B) encrusting epiphytic algal cover (%) of Z. muelleri leaf area at intertidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009... 39
Figure 25. Mean (± se) epiphytic macroalgal cover (%) of intertidal seagrass plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009. 

Figure 26. Mean (± se) cover (%) of drift macroalgae at A) shallow and B) deep subtidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009. n indicates where no data were available. 

Figure 27. Mean (± se) cover (%) of drift macroalgae at intertidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009. 

Figure 28. Mean (± se) seagrass cover (%), length (cm) and shooting-stem density (counts 0.0625 m$^{-2}$) for H. nigricaulis at Kirk Point, Point Richards and Swan Bay 2 shallow subtidal plots. Historical data collected from November 2004 – April 2007 (hatched) proceeds Baywide seagrass monitoring field data collected between autumn 2008 and autumn 2009 (depicted in grey); n/a denotes where no data were available; * denotes missing data at Swan Bay 2 in autumn 2008. 

Figure 29. Mean (± se) cover (%), shoot length (cm) and shoot density (counts 0.0625 m$^{-2}$) for intertidal seagrass at Point Richards and Swan Bay, November 2004–April 2007 (FRB) and May 2008–April 2008 (Baywide Seagrass Monitoring Program, BSMP), n/a denotes where no data were available. 

Figure 30. Mean (± se) turfing, encrusting and macroalgal epiphytic cover (%) for H. nigricaulis at Kirk Point, Point Richards and Swan Bay 2 shallow subtidal plots, April 2005–April 2007 (hatched) and between April 2008–April 2009 (grey); * denotes missing data at Swan Bay 2 in autumn 2008.
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 2009a).

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

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

Purpose of this Report

This milestone report covers the reporting period April–May 2009, and presents:

- A summary of results for the small-scale monitoring of seagrass health undertaken in autumn (April–May) 2009
- A summary of measurements for primary factors influencing seagrass health (i.e. light, turbidity and epiphytes)
- A 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 variables between summer and autumn 2009, and autumn 2009 and autumn 2008
- Comparisons with historical seagrass monitoring (2004–07), where possible
- Discussion of QA/QC issues and any irregularities, along with any associated implications for the data.

The results of large-scale aerial imagery from April/May 2009 are currently being processed and will be reported in a future Milestone Report.

Previous results from this program were reported in Hirst et al. (2008a, b, 2009a, b).
Materials and Methods

Project design and methods for this program are described in PoMC (2009a). Methods presented in this report and not described by the previous Detailed Design (PoMC 2008), and not otherwise described by Hirst *et al.* (2008a, b, 2009a, b) are summarised in Appendix 1.

This report comprises two main elements:

- Small-scale monitoring of seagrass health for six regions (Table 1)
- Monitoring of key parameters that are known to affect seagrass health (including light and epiphyte abundance).

The location of field-assessment plots for small-scale seagrass monitoring, light loggers and PoMC turbidity monitoring stations in PPB are shown in Figures 1 and 2.

Data Management

**QA/QC.**

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

Exceptions to Detailed Design

Exceptions to the Detailed Design as applied for the reporting period (PoMC 2008), have been previously documented in Hirst *et al.* (2009b) and Exception Report ER2009#30, and are summarised as follows:

- Upper intertidal limit measurements were not recorded at Swan Bay due to seagrass wrack on the shore
- Deeper boundary of subtidal seagrass was not monitored at Mud Islands and St Leonards.

The Detailed Design has since been revised to account for these issues (PoMC 2009a)

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

<table>
<thead>
<tr>
<th>Region</th>
<th>Field Assessment Plots</th>
<th>Intertidal</th>
<th>Shallow (1–2 m)</th>
<th>Deep (2–5 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirk Point</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point Richards</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>St Leonards 1</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>St Leonards 2*</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Swan Bay 1</td>
<td>✓</td>
<td>✓ #</td>
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</tr>
<tr>
<td>Swan Bay 2</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Mud Islands</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
</tr>
<tr>
<td>Blairgowrie</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

* Contingency deep plot for St Leonards 1 deep.

# Extra field-assessment plot established in July/Aug 2008 due to positional error in location of original Swan Bay shallow plot established in April/May 2008 (renamed to Swan Bay 2) relative to position of historic sampling plot (see Hirst *et al.* 2008b and ER2008#13).
Figure 1. Locations of monitoring regions and small-scale field assessment plots in Port Phillip Bay.

Figure 2. Locations of light loggers, EPA water quality monitoring sites and PoMC turbidity monitoring stations in Port Phillip Bay.
Note: The closest pile for deployment of light loggers at the Kirk Point region was located at Long Reef.
Results

The results for this program for the reporting period April-May (autumn) 2009 are provided in Appendix 2 and summarised below.

Seagrass health

Seagrass health was assessed in terms of temporal changes across regions and depth plots using linear mixed-effects statistical models. The magnitude and direction of temporal change in cover, length and stem/shoot density varied between regions and seasons for all seagrass health variables, as indicated by strong statistical interactions between regions and sampling dates. Statistically significant changes in seagrass variables between summer and autumn 2009, and autumn 2009 and autumn 2008 are summarized below.

Seagrass cover between summer and autumn 2009:

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

Seagrass length between summer and autumn 2009:

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

Seagrass cover in autumn 2009 compared with autumn 2008:

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

Seagrass length in autumn 2009 compared with autumn 2008:

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

Shooting stem/shoot density between spring 2008 and summer 2009:

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

Shallow subtidal plots at Point Richards (0 shooting stems quadrat$^{-1}$), Kirk Point (0) and St Leonards (1), and deep plots at Blairgowrie (1.5) and Point Richards (3) contained very little seagrass in autumn 2009. When this program began in autumn 2008 these plots were dominated by non-shooting stems of _Heterozostera nigricaulis_ (>70% of total stems recorded), but by autumn 2009 >65% of the fixed quadrats in these plots did not contain any shooting or non-shooting seagrass stems.

Seagrass cover in autumn 2009 compared with autumn 2008:

- In shallow subtidal plots, was higher at Blairgowrie and Mud Islands, lower at Swan Bay 1, and unchanged at St Leonards, Point Richards and Kirk Point
- In deep subtidal plots, was lower at Mud Islands, and unchanged at Blairgowrie, St Leonards 1 and Point Richards
- In intertidal plots, was lower at St Leonards and Point Richards, and unchanged at Mud Islands and Swan Bay.
Shooting stem/shoot density in autumn 2009 compared to autumn 2008:

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

**Intertidal seagrass upper limits**
The upper extent of intertidal seagrass at St Leonards has remained relatively stable since autumn 2008. At Point Richards two monitoring lines that were buried by sand during 2008 had not been recolonised with seagrass by autumn 2009, and the remaining two lines showed little movement between summer and autumn 2009. The monitoring lines at Mud Islands moved predominantly seaward between summer and autumn 2009, but remain mostly landward of their position in autumn 2008.

**Subtidal seagrass lower limits**
The maximum depths at which shooting *H. nigricaulis* stems were observed decreased significantly between summer and autumn 2009 at Blairgowrie and Point Richards. Maximum depth declined from 7.2 m to 5.9 m at Blairgowrie, and from 10.1 to 6.7 m at Point Richards, between summer and autumn 2009.

**Light, turbidity and epiphytes**

**Light attenuation (Kd), % surface irradiance and turbidity**
Benthic light availability exceeded conservative environmental requirements for seagrasses in southern PPB at all regions during April-May 2009. Turbidity levels monitored by the PoMC in southern PPB were <5 NTU on all days at Camerons Bight (Blairgowrie), Mud Islands and St Leonards and >90% of days at Long Reef (Kirk Point) and Point Richards.

**Epiphytes**
Temporal changes in epiphyte cover were assessed across regions and depth plots.

**Turfing algal cover between summer and autumn 2009:**
- At shallow subtidal plots, decreased at Blairgowrie, Mud Islands and Swan Bay 2, and was unchanged at Swan Bay 1, St Leonards, Point Richards and Kirk Point. Turfing algae covered <15% of leaf area at all shallow plots in autumn 2009
- At deep subtidal plots, decreased at Mud Islands and St Leonards, and was unchanged at Blairgowrie, St Leonards 1 and Point Richards. Turfing algae covered <10% of leaf area at all deep plots in autumn 2009.

**Encrusting algal cover between summer and autumn 2009:**
- At shallow subtidal plots, decreased at Blairgowrie, increased at Swan Bay 1 and 2, was unchanged at Mud Islands, Point Richards, St Leonards and Kirk Point. Encrusting algae covered 41% of leaf area at Blairgowrie, 20% at Mud Islands, 18% at Swan Bay 1 and 15% at Swan Bay 2 and 0% at St Leonards, Point Richards and Kirk Point in autumn 2009
- At deep subtidal plots, decreased at Mud Islands, St Leonards 2 and Point Richards, and was unchanged at Blairgowrie and St Leonards 1. Encrusting algae covered <2% of leaf area at all deep subtidal plots in autumn 2009.

**Epiphytic macroalgal cover between summer and autumn 2009:**
- At shallow subtidal plots, increased at Swan Bay 1 and Point Richards, decreased at Swan Bay 2, and was unchanged at Blairgowrie, Mud Islands, St Leonards and Kirk Point. Macroalgae covered 99% of the shallow plot at Swan Bay 1, 32% at Swan Bay 2, 30% at Point Richards, 8% at Blairgowrie and Mud Islands and 0% at Kirk Point in autumn 2009
- At deep subtidal plots was unchanged. Macroalgae covered <3% of deep plots in autumn 2009
- At intertidal plots, increased at Mud Islands and Swan Bay, and was unchanged at St Leonards and Point Richards.

**Epiphytic turfing algal cover in autumn 2009 compared to autumn 2008:**
- At shallow subtidal plots, was higher at Blairgowrie, Swan Bay 1, and was unchanged at Mud Islands, St Leonards, Point Richards and Kirk Point
- At deep subtidal plots was unchanged.
Epiphytic encrusting algal cover in autumn 2009 compared to autumn 2008:

- At shallow subtidal plots, was higher at Blairgowrie, lower at Swan Bay 1, and unchanged at Mud Islands, St Leonards, Point Richards and Kirk Point
- At deep subtidal plots was, lower at Mud Islands, and unchanged at Blairgowrie, St Leonards 1 and Point Richards.

Epiphytic macroalgal cover in autumn 2009 compared to autumn 2008:

- At shallow subtidal plots, was higher at Swan Bay 1 and Point Richards, lower at Mud Islands, and unchanged at Blairgowrie, St Leonards and Kirk Point
- At deep subtidal plots was, lower at Mud Islands, and unchanged at Blairgowrie, St Leonards 1 and Point Richards.

Comparisons against historical data

Seagrass health
Historical data indicated that seagrass cover, length and stem density were higher at the shallow subtidal Kirk Point and Point Richards plots between 2005 and 2007 when compared with recent monitoring in 2008/09. Most of the seagrass at these plots disappeared between April 2007 and April 2008.

Seagrass covered >95% of the Swan Bay 2 shallow subtidal plot between April 2005 and April 2006. By April 2007, seagrass cover had declined to 12% (Figure 28). By April 2009 seagrass cover and length had recovered to levels observed in November 2006.

Intertidal seagrass cover and shoot density at Point Richards in April 2009 were similar to past levels observed at this plot between April 2005 and April 2007. Seagrass length in April 2009 was at its lowest recorded level at Point Richards.

*Zostera muelleri* dominated the intertidal plot at Swan Bay when it was established in April 2005, but by November 2006 this plot was dominated by *Lepilaena marina*. Although now dominated by *L. marina*, seagrass cover and length were similar to past levels.

Seagrass epiphyte cover
Epiphytic algal cover varied over time in shallow seagrass plots sampled between April 2005 and April 2009.

Epiphytic algal cover at Kirk Point and Swan Bay 2 were low relative to past levels observed at these plots. Turfing and encrusting algal cover at Point Richards in April 2009 was lower, but epiphytic macroalgal cover in April 2009 was higher than recorded in the past at this shallow subtidal plot.
Discussion

Seagrass health

Subtidal

The subtidal seagrass plots monitored in this study can be split into two discrete groups, regardless of depth: 1) plots characterised by high overall seagrass cover and dominated by high densities of shooting *H. nigricaulis* stems, and 2) plots containing little living seagrass and dominated by non-shooting stems. The first group includes shallow plots at Blairgowrie, Mud Islands, Swan Bay 1 and 2, and deep plots at Mud Islands and St Leonards 2 (see Figure 7 and 8 respectively). The second group comprises shallow plots at St Leonards, Point Richards and Kirk Point, and deep plots at Blairgowrie, St Leonards 1 and Point Richards (see Figure 7 and 8 respectively). Further details on the make-up and behaviour these two groups can be found in Hirst et al. (2009b).

The first group tracks changes in subtidal seagrass condition at locations with dense, ‘healthy’ seagrass, whereas, the second group represents locations formerly occupied by healthy seagrass, but now largely dominated by remnant non-shooting stems. In terms of understanding the health of seagrass in PPB the former is more informative and the discussion below is largely restricted to these plots.

Seagrass cover, length and shooting-stem density generally decreased or remained unchanged between summer and autumn 2009 at ‘healthy’ seagrass sites. Seagrass cover and stem density at the deep Mud Islands and St Leonards plots decreased between summer and autumn 2009. During the same period seagrass cover decreased at the Mud Islands (shallow), seagrass length and stem density decreased at Swan Bay 1 (shallow), whereas seagrass cover, length and stem density remained unchanged at Blairgowrie (shallow). Only two parameters – cover at Swan Bay 2 and length at Mud Islands – increased between summer and autumn 2009. Prior to autumn 2009 seagrass cover, length or stem density had increased between autumn 2008 and summer 2009 at all of these plots, except Swan Bay 1 where cover declined between spring 2008 and summer 2009 (see Hirst et al. 2009b).

A reduction in seagrass variables in autumn is consistent with observed growth patterns for *H. nigricaulis* in PPB (Bulthuis and Woelkerling 1983). During autumn *H. nigricaulis* leaf productivity and turn-over drop off sharply as net photosynthesis declines (Bulthuis 1987). The irradiance at which photosynthesis exceeds respiration is called the compensation point. At higher water temperatures, greater irradiance is required to reach the compensation point, as the metabolic demands of cellular respiration are higher. Bulthuis (1987) suggested that the beginning of the ‘growth minimum’ for *H. nigricaulis* may correspond with a reduction in total irradiance as day length shortens. In PPB, though daylength shortens from late summer to mid autumn water, temperatures and respiration remain high.

The extent to which changes in seagrass cover, length and shoot/stem density are a reflection of growth patterns is unknown. These variables are intended as proxies of seagrass health, but may only imperfectly measure changes in seagrass growth under conditions of physiological stress; and may be difficult to distinguish from other impacts such as those caused by wave turbulence.

The absence of a clear, generalised seasonal pattern across plots is also consistent with the findings of previous studies. Bulthuis and Woelkerling (1983) found that leaf productivity rates varied considerably between sites located within PPB and Western Port (WP). Campbell and Miller (2002) estimated that variation between sites explained >80% of total variance in *H. nigricaulis* shoot density and above-ground biomass in WP, whilst temporal (including seasonal) variation explained <20% of total variance. Seasonal patterns were evident at some sites, but not others (Campbell and Miller 2002). The authors attributed this high spatial, relative to lower temporal, variability to a range of factors known to influence seagrass productivity including differences in light and nutrient availability between locations.

*Heterozostera nigricaulis* shooting stems were observed at significantly shallower maximum depths at Blairgowrie and Point Richards in autumn compared with summer 2009. During summer, shooting stems were recorded to a mean maximum depth of 10.1 m along video transects at Point Richards, and to a depth of 7.2
m at Blairgowrie (see Figure 14). By autumn 2009, shooting stems were limited to mean maximum depths of 6.7 and 5.9 m for Point Richards and Blairgowrie, respectively. In North American estuaries the maximum depth distribution of Z. marina is determined principally by daily light period rather than light attenuation (Dennison and Alberte 1985). It is possible that longer day lengths in spring and summer may promote the growth of H. nigricaulis at greater depths at these locations.

Non-shooting stems were recorded at greater depths than live seagrass at Blairgowrie (i.e. to a mean maximum depth 10.1 m). This implies that suitable environmental conditions do exist to support the growth of seagrass at depths exceeding those recorded in this study at Blairgowrie. Whether these conditions coincide with greater photoperiod over the summer months is yet to be established. It is not possible to conclude, at this point, whether the change in the maximum seagrass depth between spring 2008 and autumn 2009 conform to expected variability as there is no comparable data for H. nigricaulis communities elsewhere.

The disappearance of shooting stems at greater depths is unlikely to have a major impact on the productivity of benthic habitats offshore at Blairgowrie and Point Richards as H. nigricaulis tends to be very sparsely distributed throughout its depth range at these locations. In the case of Blairgowrie the difference in depth between summer and autumn 2009 was not large. Video footage showed that Point Richards supports extensive beds of the fast growing seagrass species Halophila australis at depths >10 m. This species of seagrass presumably has lower light requirements.

There was no clear trend in seagrass health between the start of the study in autumn 2008 and autumn 2009. Seagrass cover, length and stem density were higher at Blairgowrie and Mud Islands shallow plots, but lower at Swan Bay 1 shallow plot and the Mud Islands deep plot in autumn 2009 compared with autumn 2008. No data were available for Swan Bay 2 and St Leonards 2 in autumn 2008, precluding similar analysis of trends at these plots. The lack of similar values from year-to-year within seagrass plots is consistent with the findings of Ball et al. (in prep.), who found that inter-annual differences were often greater than differences observed between seasons for variables such as cover and stem density.

There was some level of congruence between the seagrass sampling undertaken by the “Baywide Monitoring of Key Fishery Species in Segrass Beds Sub Program” (Hutchinson et al. 2009) and the sampling undertaken in this study. Temporal trends in seagrass biomass between autumn 2008 and autumn 2009 at the shallow Blairgowrie and Mud Islands and deep Blairgowrie and St Leonards fish sampling stations were similar to those observed for cover and stem density measurements in this study. This study measured a large (>50%) decrease in seagrass cover, length and stem density at Mud Islands deep plot, but this was not matched by a similar decrease in biomass at fish sampling stations (Hutchinson et al. 2009). Overall these comparisons imply that the results presented in these reports may have some greater generality beyond the plots sampled.

No shooting stems were recorded at the shallow plots at Point Richards and Kirk Point, whilst <1 shooting stem quadrat\(^{-1}\) were recorded at the shallow St Leonards and deep Blairgowrie plots in autumn 2009. There was little evidence of seagrass growth at these plots between autumn 2008 and autumn 2009. The trend was one of declining stem length and density over the course of this study (see also Hirist et al. 2009b). One clear exception to this pattern at plots with low overall seagrass cover was the increase in shooting stem densities observed at St Leonards 1 and Point Richards deep plots between summer and autumn 2009. In autumn 2009 a mean of 11 shooting stems quadrat\(^{-1}\) was recorded at St Leonards 1, but prior to autumn 2009 shooting stem densities were <1 stems quadrat\(^{-1}\). A statistically significant, but slight, increase in shooting stem density was also recorded at the Point Richards deep plot between summer and autumn 2009 (i.e. 2.8 versus 1.3 shooting stems quadrat\(^{-1}\)).

**Intertidal**

Intertidal seagrass cover decreased at Mud Islands and St Leonards, but remained unchanged at Swan Bay and Point Richards between summer and autumn 2009. No corresponding reduction in either length or shoot density was observed at Mud Islands or St Leonards during the same period. Seagrass cover at St Leonards was lower in autumn 2009 in comparison with autumn 2008, but no different at Mud Islands between autumn 2008 and 2009. Reductions in intertidal seagrass cover during autumn are consistent with 1) the pattern of reduced growth resulting from lower net
photosynthesis in late summer/early autumn observed for northern hemisphere species of Zostera (Dennison 1987) and 2) higher thermal/desiccation stress experienced during summer/early autumn.

The greatest changes in seagrass cover, length and shoot density were observed at Point Richards between autumn 2008 and autumn 2009. Intertidal seagrass cover, length and shoot density were much lower in autumn 2009 than autumn 2008. This pattern is not due to a decline in the health of seagrass at this plot per se – as seagrass cover and length remained relatively high for the small number of quadrats which contained seagrass in autumn 2009 - but the physical disappearance of seagrass as the plot became buried under sand. Approximately 75% of the intertidal plot was buried under sand between autumn 2008 and autumn 2009, to the extent that only two of the twelve randomly sampled quadrats contained seagrass in autumn 2009. The two most easterly upper intertidal monitoring lines established in autumn 2008 had also completely disappeared by autumn 2009 (Figure 13). Onshore sand accretion at this location is a natural phenomenon caused by longshore sand drift along this coastline (Bird 1993).

Factors that affect seagrass health

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

Light attenuation data was available for all dates and sites, except the period 17-26 March at St Leonards (see Figure 17). As turbidity was <2 NTU the risk of failing to detect a period of higher light attenuation for this week was likely to be low, therefore, the data gap does not impact ability of program to meet its objectives.

Turbidity levels adjacent to the seagrass assessment regions were low and within the limits outlined in the CDP Environmental Management Plan (POMC 2009b) for the Blairgowrie, Mud Islands and St Leonards regions.

Seagrasses are important sites for attachment of biota, including epiphytic algae and encrusting sessile invertebrates. Epiphytic algae often contribute >50% of total primary productivity within seagrass meadows (Borowitza et al. 2006). In high abundance, epiphytic algae may cause excessive shading of seagrass leaves leading to reduced seagrass productivity and eventually mortality.

Epiphyte algae were patchy in space and time and often characterised by fluctuating peaks in abundance. In general, epiphytic algae were more abundant 1) on subtidal than intertidal seagrass plants, and 2) in subtidal plots dominated by a high cover of shooting stems. The latter provide substantially more substrate for the attachment of epiphytic and encrusting algae.

Even amongst plots with similar seagrass cover and length (and hence available substrate), epiphyte cover varied considerably. For example, epiphytic macroalgal covered >70% of the plot at Swan Bay 1, but <10% of the plot at Blairgowrie (shallow) between spring 2008 and autumn 2009 during a period when comparable levels of seagrass cover were recorded at these shallow subtidal plots. It is difficult to explain these differences, other than to attribute them to location effects. Epiphytic and drift macroalgal levels were consistently higher at all Swan Bay plots throughout this study.

Few consistent trends in epiphytic algal cover were observed between summer and autumn 2009, and between autumn 2008 and autumn 2009, at subtidal plots characterised by high overall seagrass cover. With the exception of Swan Bay 1, turfing algal leaf cover decreased between summer and autumn 2009. Turfing algal levels recorded in autumn 2009 were either higher or no different from the corresponding levels recorded in autumn 2008.

Encrusting and macroalgal epiphytic cover displayed varying trends between summer and autumn 2009. Encrusting algal cover increased at some sites, whilst decreasing at others (see Table 5). Epiphytic macroalgal cover increased at Swan Bay 1, decreased at Swan Bay 2 and remained low at other plots between summer and autumn 2009.

Similarly, encrusting algal levels in autumn 2009 were higher, lower or no different than the same plots in autumn 2008. Epiphytic algal cover at Swan Bay 1 was substantially higher in autumn 2009 compared with autumn 2008, but the levels were either lower or remain unchanged at the other plots.
There was no correlation between epiphytic macroalgal cover and decreases in cover, length and shooting stem density at subtidal plots observed between autumn and summer 2009. Decreases in seagrass length and shooting stem density at Swan Bay 1 coincided with macroalgal cover >90%, but similar decreases in cover, length and stem density were observed at the deep Mud Islands and St Leonards 2 plots where epiphytic macroalgal cover was <5%.

**Conclusions**

Subtidal seagrass health in autumn 2009 was dependent upon the initial condition of the plot in autumn 2008. Where field assessment plots were dominated by an initial dense cover of shooting stems in autumn 2008, changes in subtidal seagrass health between summer and autumn 2009 were consistent with seasonal declines in *H. nigricaulis* biomass and shoot density observed in other studies. Generalised physiological growth models also indicate that seagrass growth is expected to decline in autumn corresponding with reduced net photosynthesis.

Subtidal seagrass cover, length and stem density remained low at all plots where seagrass cover was initially low and dominated by non-shooting stems in autumn 2008. In some cases this seagrass is indicative of previously healthy seagrass at these locations. With the exception of the deep plot at St Leonards 1, and to a lesser extent Point Richards, subtidal seagrass at these plots displayed little evidence of regrowth between summer and autumn 2009.

Intertidal seagrass health varied as expected based on previous studies of *Zostera* species elsewhere. Intertidal seagrass at Point Richards continued to disappear and only a fraction of the original plot remained by autumn 2009 due to sand accretion in the intertidal zone.

The health of seagrasses in PPB between summer and autumn 2009 varied as expected based on comparisons with studies of Zosteraceae seagrass species in PPB and elsewhere.
Acknowledgements

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References


Appendix 1. Materials and Methods

The following describes materials and methods utilised for this program and not specified in the previous Detailed Design (PoMC 2008) or earlier reports (Hirst et al. 2008a, b, 2009a, b).

Data analysis
Temporal trends in subtidal seagrass health (% cover, length and stem density) and epiphyte cover were examined using a linear mixed-effects model (see Hirst et al. 2009a). The model chosen to describe the response of each dependent variable included the terms ‘region’ and ‘date’ as fixed effects, and variance within quadrats over time analysed as a random effect. To account for temporal correlation within quadrats, models were fitted alternatively with compound, unstructured and AR1 covariance matrices. The optimum model fit was chosen using Akaike’s Information Criteria (AIC).

Two planned statistical comparisons between sampling events were undertaken in this report: C1 – a contrast between the current season and the previous season (summer 2009), and C2 – a contrast between the current season and the same season in the preceding year (2008). The latter allowed comparison with similar seasonal conditions. Linear mixed effects modelling and planned comparisons were performed using the R statistical software package.
Appendix 2. Results

Seagrass Health

Results are reported separately for subtidal plots (shallow and deep) containing *H. nigricaulis* (Figures 3–8), and intertidal plots, typically dominated by *Z. muelleri* (Figure 9).

Subtidal

**Seagrass cover**

Seagrass cover at shallow subtidal plots varied significantly between regions and sampling dates (season) (Table 2). Seagrass cover at Blairgowrie, Swan Bay 1 and 2, and lowest at St Leonards, Point Richards and Kirk Point (Tukeys post-hoc test, Table 2, Figure 3).

Seagrass cover at shallow subtidal plots decreased significantly at Mud Islands between summer and autumn 2009, but remained significantly higher than autumn 2008 (Table 2, Figure 3). Seagrass cover increased at Swan Bay 2 between summer and autumn 2009, but remained unchanged at Blairgowrie, Swan Bay 1, St Leonards, Point Richards and Kirk Point.

Seagrass cover was significantly higher in autumn 2009 compared with autumn 2008 at Blairgowrie and Mud Islands, but lower at Swan Bay 1 (note there is no data for Swan Bay 2 for this period) (Figure 3). Cover remained low at St Leonards, Point Richards and Kirk Point throughout the survey and was unchanged between autumn 2008 and 2009 at these plots (Table 2, Figure 3).

Seagrass cover at deep subtidal plots varied significantly between regions and sampling dates (season) (Table 2, Figure 4). Seagrass cover at Mud Islands and St Leonards 2 deep plots was significantly higher than that at the Blairgowrie, St Leonards 1 and Point Richards plots (Tukeys post-hoc test, Table 2).

Seagrass cover decreased significantly at the Mud Islands and St Leonards 2 deep plots between summer and autumn 2009 (Table 2, Figure 4). At Mud Islands seagrass cover declined from 83% to 17% between summer and autumn 2009 and was significantly lower in this plot than autumn 2008. At St Leonards 2, seagrass cover decreased from 69% to 47% between summer and autumn 2009, but no data was available for autumn 2008. Seagrass cover at Blairgowrie, St Leonards 1 and Point Richards deep plots did not change between summer and autumn 2009, and between autumn 2008 and 2009.

There were strong statistical interactions between region and date for both shallow and deep plots, implying that the magnitude and direction of temporal change in cover varied between regions (Table 2). This is reflected in the varied pattern of temporal change between plots observed amongst the planned statistical comparisons.

**Seagrass length**

Seagrass length at the shallow subtidal plots varied significantly between regions and sampling dates (Table 2). Seagrass length was greatest at Swan Bay 1 and 2 and lowest at St Leonards and Point Richards (Tukeys post-hoc test, Table 2, Figure 5).

Seagrass length at shallow plots increased significantly at Mud Islands, decreased at Swan Bay 1, and was unchanged at Swan Bay 2, St Leonards, Point Richards and Kirk Point between summer and autumn 2009 (Table 2, Figure 5).

Seagrass length at Blairgowrie and Mud Islands was significantly higher in autumn 2009 in comparison to autumn 2008, but lower at Swan Bay 1, St Leonards, Point Richards and Kirk Point in autumn 2009 in comparison to autumn 2008.

Seagrass length at the deep subtidal plots varied significantly between regions and sampling dates (Table 2, Figure 6). Seagrass length was greatest at Mud Islands and lowest at Blairgowrie and St Leonards 1 (Tukeys post-hoc test, Table 2).

Seagrass length at deep plots decreased significantly at Mud Islands, increased significantly at St Leonards 1 and Point Richards, and was unchanged at Blairgowrie and St Leonards 2 between summer and autumn 2009 (Table 2, Figure 6). Seagrass length was greater at St Leonards 1 and lower at Mud Islands in autumn 2009 in comparison to autumn 2008.

Seagrass length at Blairgowrie and Point Richards in autumn 2009 was unchanged in comparison to autumn 2008.

There was a strong statistical interaction between time and region for both shallow and deep subtidal plots (Table 2).
Figure 3. Mean (± se) seagrass cover (%) for *H. nigricaulis* at shallow subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the Swan Bay 2 shallow plot in autumn 2008.

Figure 4. Mean (± se) seagrass cover (%) for *H. nigricaulis* at deep subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data available was available for the St Leonards 2 deep plot in autumn 2008.
Figure 5. Mean (± se) seagrass length (cm) for *H. nigricaulis* at shallow subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the Swan Bay 2 shallow plot in autumn 2008.

Figure 6. Mean (± se) seagrass length (cm) for *H. nigricaulis* at deep subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the St Leonards 2 deep plot in autumn 2008.
Table 2. Summary of linear mixed effects model analysis testing for differences between all regions and sampling dates for seagrass cover, length and shooting stem density counts at shallow and deep subtidal plots. Planned statistical comparisons within each subtidal plot: C1 - autumn 2009 versus summer 2009, and C2 - autumn 2009 versus autumn 2008.

<table>
<thead>
<tr>
<th>Region</th>
<th>Date</th>
<th>Region*Date</th>
<th>Tukeys post-hoc test</th>
<th>Planned contrast</th>
<th>Blairgowrie (B)</th>
<th>Mud Islands (MI)</th>
<th>Swan Bay 1 (SB1)</th>
<th>Swan Bay 2 (SB2)1</th>
<th>St Leonards (SL)</th>
<th>Point Richards (PR)</th>
<th>Kirk Point (KP)</th>
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NS (or blank) *P>0.05, **P<0.05, ***P<0.01 and ****P<0.001
1 only C1 contrasts performed (NB. no autumn 2008 data indicated by black cells)
+ 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
F: F-ratio; P: probability that null hypothesis is true
Stem density
Shooting stem density counts at the shallow subtidal plots varied significantly between regions and not sampling dates (season) (Table 2, Figure 7A). There was also a significant interaction between region and date. Shooting stem density was highest at Mud Islands and lowest at Point Richards shallow plots (Tukey’s post-hoc test, Table 2). In autumn 2009 there were no shooting stems recorded at the Point Richards plot.

Shooting stem densities decreased significantly between summer and autumn 2009 at Swan Bay 1, but were unchanged at Blairgowrie, Mud Islands, Swan Bay 2, St Leonards, Point Richard and Kirk Point shallow subtidal plots (Table 2, Figure 7A). Shooting stem densities at Blairgowrie and Mud Islands were significantly higher in autumn 2009 compared with autumn 2008, and lower at Swan Bay 1, Point Richards and Kirk Point in autumn 2009 compared with autumn 2008. During autumn 2009 there were no shooting stems recorded at Point Richards and Kirk Point, although a small number (<5 quadrat^-1) were recorded in autumn 2008.

Shooting stem densities at the deep subtidal plots varied significantly between regions, but not between sampling dates (season) (Table 2, Figure 8A). There was also a significant interaction between region and date (Table 2). Shooting stem counts were significantly higher at Mud Islands and St Leonards 2 than at the Blairgowrie, St Leonards 1 and Point Richards deep plots (Tukey’s post-hoc test, Table 2).

Shooting stem densities decreased significantly at Mud Islands and St Leonards 2 between summer and autumn 2009, and increased at St Leonards 1 and Point Richards between summer and autumn 2009 (Table 2, Figure 8A). No change was observed at Blairgowrie. Shooting stem densities at Mud Islands were significantly lower in autumn 2009 compared with autumn 2008, but higher at St Leonards 1. There was no detected change between autumn 2009 and autumn 2008 at Blairgowrie and Point Richards.

One deep (Figure 8) and three shallow (Figure 7) plot/s were dominated by quadrats that contained no seagrass (either shooting or non-shooting stems) during autumn 2009. Where seagrass was present it was almost entirely composed of non-shooting stems. Plots dominated by quadrats without seagrass included: Point Richards shallow (8/12 quadrats without seagrass), Kirk Point shallow (11/12), St Leonards shallow (11/12) and Blairgowrie deep (10/12). Low numbers of shooting H. nigricaulis stems were recorded at St Leonards (mean = 11.4 quadrat^-1) and Point Richards (mean = 2.8) deep plots in autumn 2009. Shooting stems were largely absent from these plots in the past (Figure 8A) (see Hirst et al. 2009a, b).
Figure 7. Mean (± se) A) shooting and B) non-shooting stem density count per 0.0625 m² quadrat for *H. nigricaulis* at shallow subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the Swan Bay 2 shallow plot in autumn 2008.

Figure 8. Mean (± se) A) shooting and B) non-shooting stem density count per 0.0625 m² quadrat for *H. nigricaulis* at deep subtidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates where no data was available for the St Leonards 2 deep plot in autumn 2008.
Intertidal seagrass beds were present at four of the six regions: Mud Islands, Point Richards, Swan Bay and St Leonards. Intertidal plots at Mud Islands and Swan Bay comprised a mixture of *Z. muelleri* and the aquatic macrophyte *Lepilaena marina* (Figure 9A). *Lepilaena marina* dominated the plot at Swan Bay in autumn 2009, with *Z. muelleri* covering <10% of the plot. *Lepilaena marina* comprised a small proportion of the seagrass present at Mud Islands in autumn 2009. *Z. muelleri* was the only intertidal seagrass species present at the Point Richards and St Leonards plots.

Total seagrass cover (*Z. muelleri* and *L. marina* combined) varied significantly between regions and sampling dates (season) (Table 3). There was a strong statistical interaction between region and date for seagrass cover indicating inconsistent temporal change across regions. Intertidal seagrass cover was greatest at Swan Bay and lowest at Point Richards (Tukeys post-hoc test, Table 3). Only two of the quadrats sampled at Point Richards contained intertidal seagrass, the remainder of the plot was buried under sand (see Intertidal seagrass upper limits below).

Seagrass cover decreased significantly at Mud Islands and St Leonards between summer and autumn 2009, but was unchanged at Swan Bay and Point Richards (Table 3, Figure 9B). Seagrass cover at St Leonards and Point Richards in autumn 2009 was significantly lower than autumn 2008. By comparison, seagrass cover at Mud Islands and Swan Bay in autumn 2009 did not differ significantly from cover in autumn 2008 (Table 3, Figure 9B).

Seagrass length varied significantly between regions and sampling dates (season) (Table 3). A statistical interaction between region and sampling date was also detected. Seagrass at Mud Islands, Swan Bay and St Leonards was significantly longer than at Point Richards (Tukeys post-hoc test, Table 3).

Seagrass length was unchanged between summer and autumn 2009 at all intertidal plots (Table 3, Figure 9C). Seagrass length at St Leonards and Point Richards in autumn 2009 was significantly lower than autumn 2008, whereas seagrass length was unchanged at Mud Islands and Swan Bay in autumn 2009 compared with autumn 2008.

Shoot densities varied significantly between regions and sampling dates (season) (Table 3). A significant statistical interaction was also detected between region and sampling date. Shoot densities were highest at Swan Bay and lowest at Point Richards (Tukeys post-hoc test, Table 3).

Shoot densities were unchanged at all intertidal plots between summer and autumn 2009 (Table 3). Shoot density counts in autumn 2009 were not significantly different from counts recorded in autumn 2008 at Mud Islands, Swan Bay and St Leonards. Shoot density counts at Point Richards were significantly lower in autumn 2009 compared with autumn 2008 (Table 3, Figure 9D). The latter is consistent with the long-term decline observed at this plots since autumn 2008 (see Hirst *et al.* 2009a, b).
Figure 9. Mean (± se) A) *Z. muelleri* composition (%), combined seagrass B) cover (%), C) length, and D) shoot density count 0.0625 m$^{-2}$ for intertidal plots sampled in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009.
Table 3. Summary of 2-way ANOVA testing for differences between all regions and sampling dates for seagrass cover, length and shoot density counts at intertidal plots. Planned statistical comparisons within each intertidal plot: C1 - autumn 2009 versus summer 2009, and C2 - autumn 2009 versus autumn 2008.

<table>
<thead>
<tr>
<th></th>
<th>arcsin (% total cover)</th>
<th>loge (length)</th>
<th>loge (count)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Region</strong></td>
<td>F3,220=108.5; P&lt;0.001</td>
<td>F3,220=112.0; P&lt;0.001</td>
<td>F3,220=103.1; P&lt;0.001</td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td>F4,220=8.3; P&lt;0.001</td>
<td>F4,220=14.8; P&lt;0.001</td>
<td>F4,220=11.7; P&lt;0.001</td>
</tr>
<tr>
<td><strong>Region*Date</strong></td>
<td>F12,220=4.4; P&lt;0.001</td>
<td>F12,220=7.1; P&lt;0.001</td>
<td>F12,220=6.0; P&lt;0.001</td>
</tr>
<tr>
<td>Tukeys test</td>
<td>SB&gt;SL&gt;MI&gt;PR</td>
<td>SB,SL,MI&gt;PR</td>
<td>SB&gt;MI,SL&gt;PR</td>
</tr>
<tr>
<td>Planned contrast</td>
<td>C1</td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>Mud Islands (MI)</td>
<td>-3.7***</td>
<td>-0.4</td>
<td>+1.1</td>
</tr>
<tr>
<td>Swan Bay (SB)</td>
<td>-0.9</td>
<td>-0.8</td>
<td>-0.5</td>
</tr>
<tr>
<td>St Leonards (SL)</td>
<td>-2.4*</td>
<td>-3.5***</td>
<td>-0.2</td>
</tr>
<tr>
<td>Point Richards (PR)</td>
<td>-1.0</td>
<td>-4.1***</td>
<td>-1.1</td>
</tr>
</tbody>
</table>

NS (or blank) P>0.05, *P<0.05, **P<0.01 and ***P<0.001
+ 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
F: F-ratio; P: probability that null hypothesis is true
**Intertidal seagrass upper limits**

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

The upper intertidal monitoring lines at Mud Islands moved in a predominantly seaward direction between summer and autumn 2009. The maximum overall change in position since summer 2009 was 2.5 m on lines 1 and 2, and 5 m at the eastern end of line 3. The position of all three monitoring lines in autumn 2009 remained mostly landward of their position in autumn 2008.

The positions of the intertidal monitoring lines at St Leonards have shown the least movement, remaining relatively stable since autumn 2008. Changes in the monitoring lines between summer and autumn 2009, and also since autumn 2008, were mostly less than the spatial accuracy of the Thales mobile mapper (±2 m).

Lines 1 and 2 at Point Richards showed little change in their position between summer and autumn 2009. Line 1 was mostly seaward of its position in autumn 2008 by up to 4 m. Line 2 was also seaward of its position in autumn 2008 by 10 m. The intertidal seagrass at lines 3 and 4 was buried by sand accretion in spring 2008, and had not re-colonised at these positions by autumn 2009 (Figure 13).

**Figure 10.** Mud Islands intertidal seagrass monitoring line positions autumn 2008, summer and autumn 2009.
Figure 11. St Leonards intertidal seagrass monitoring line positions autumn 2008, summer and autumn 2009. 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 autumn 2008, summer and autumn 2009. Note seagrass at line 3 and backup line 4 were buried with sand by spring 2008 and no seagrass is currently present at these lines.

Figure 13. Aerial photography of intertidal seagrass monitoring area at Point Richards April 2008 (top) and April 2009 (bottom) highlighting expansion of sand beach. Note lines 3 and 4 were buried by spring 2008 and intertidal seagrass was not present at these positions in autumn 2009.
Subtidal seagrass lower limits

Video surveys of maximum seagrass depth were conducted at Blairgowrie and Point Richards in May (autumn) 2009. Depths were corrected to the Australian Height Datum (AHD).

The maximum depth at which shooting *H. nigricaulis* stems were observed decreased significantly between summer and autumn 2009 at Blairgowrie and Point Richards (2 way-ANOVA; $F_{2,44} = 24.2$, $P<0.001$). Maximum depth declined from 7.2 to 5.9 m at Blairgowrie, and from 10.1 to 6.7 m at Point Richards, between summer and autumn 2009 (Figure 14). Non-shooting stems were recorded to a mean maximum depth of 10.1 m at Blairgowrie in autumn 2009.

Figure 14. Mean ($\pm$ se) maximum depth (m) of shooting *H. nigricaulis* stems observed on video transects run offshore at Blairgowrie and Point Richards in spring 2008 (black), summer 2009 (hatched) and autumn 2009 (grey). NB. Shooting stems were recorded on only a single transect at Blairgowrie in spring 2008.
Light, turbidity and epiphytes

Light attenuation (\(K_d\)), % surface irradiance and turbidity

Mean daily light attenuation (\(K_d\)) coefficients recorded between 10 am and 2 pm are presented in Figures 15–20. Where turbidity data presented as 6-hourly exponentially weighted moving averages (EWMAs) were available from a nearby PoMC monitoring station, the EWMA value from 12 noon was overlayed on the light attenuation data.

Percentage surface irradiance calculated at the depths of the shallow (2 m) and deep (5 m) plots is summarised in Table 4. Table 4 also identifies any data excluded from the analysis due to problems with the operation of the light logger or wiper systems (Appendix 3).

Mean daily attenuation coefficients for regions in the southern part of PPB during March-May 2009 were in the range 0.2–0.4 m\(^{-1}\) (Table 4).

Turbidity levels (6-hourly EWMA) at monitoring stations in southern PPB were <5 NTU around 12 noon during March to May 2009. Turbidity at Kirk Point and Point Richards was more variable, reaching maximum values of 12.4 and 12.8 NTU respectively (Figures 18 and 19). These spikes in turbidity were coincident with spikes in the attenuation values.

The mean daily attenuation coefficients at Blairgowrie (Sorrento Channel No. 10) (Figure 15), Mud Islands South East (Figure 16) and St Leonards Coles Channel No. 5 (Figure 17) had a small increase in March-May 2009 compared with January-February 2009 (Table 4). At Kirk Point (Figure 18) and Swan Bay (Figure 20) the mean daily attenuation coefficients were lower in March-May than January-February 2009 (Table 4).

Mean daily attenuation coefficients at the backup Blairgowrie loggers (Sorrento Channel No. 10, Figure 15) were higher from 2 April to 18 May 2009 (\(K_d\) approximately 0.5) than the rest of April-May 2009 when attenuation coefficients were typically 0.3. The increased attenuation coefficients at this site were not matched at the main Blairgowrie light monitoring site (Speed Restriction Pile, Figure 15) located approximately 600 m away, although some data were lost from this site due to loggers flooding (see Appendix 3). Turbidity at the Camerons Bight monitoring site did not reflect the increased attenuation coefficients, although this site is approximately 1.7 km to the west. The mean daily PAR values for the upper and lower loggers also followed a similar overall pattern at both Blairgowrie sites. There was no obvious malfunction of the logger/wiper or fouling of the sensors to account for the increased attenuation coefficients at Sorrento Channel No. 10.
Table 4. Mean daily light attenuation coefficients ($K_d$) and % surface irradiance at depths of shallow (2 m) and deep plots (5 m) from 10 am–2 pm calculated for each region for March-May 2009.

<table>
<thead>
<tr>
<th>Region (Light logger)</th>
<th>Lower logger depth (m)$^a$</th>
<th>Distance to shallow plot (km)</th>
<th>Distance to deep plot (km)</th>
<th>Mean daily $K_d$ (m$^{-1}$) Jan-Feb$^b$</th>
<th>Mean daily $K_d$ (m$^{-1}$) Mar-May</th>
<th>Mean daily % irradiance at 2 m Mar-May</th>
<th>Mean daily % irradiance at 5 m Mar-May</th>
<th>Total data days Mar-May</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blairgowrie (speed restriction pile)</td>
<td>1.8</td>
<td>0.7</td>
<td>0.08</td>
<td>0.3</td>
<td>0.3</td>
<td>56</td>
<td>25</td>
<td>41</td>
<td>Mar-May data excluded 1–26 March and 6–31 May due to loggers flooding</td>
</tr>
<tr>
<td>Blairgowrie (Sorrento Channel No. 10)</td>
<td>3.2 &amp; 3.4</td>
<td>0.7</td>
<td>0.5</td>
<td>0.2</td>
<td>0.4</td>
<td>51</td>
<td>21</td>
<td>92</td>
<td>No errors/gaps</td>
</tr>
<tr>
<td>Mud Islands (North West MNP pile)</td>
<td>2.2 &amp; 2.7</td>
<td>1.2</td>
<td>5</td>
<td>0.3</td>
<td>0.3</td>
<td>54</td>
<td>21</td>
<td>92</td>
<td>No errors/gaps</td>
</tr>
<tr>
<td>Mud Islands (South East MNP pile)</td>
<td>1.9 &amp; 2.5</td>
<td>2.5</td>
<td>2.4</td>
<td>0.2</td>
<td>0.3</td>
<td>55</td>
<td>23</td>
<td>83</td>
<td>Mar-May data excluded 22–31 May due to logger flooding</td>
</tr>
<tr>
<td>St. Leonards (Coles Channel No. 5)</td>
<td>2.8 &amp; 3.0</td>
<td>0.8</td>
<td>0.4</td>
<td>0.1</td>
<td>0.2</td>
<td>64</td>
<td>34</td>
<td>67</td>
<td>Mar-May data excluded 1–26 March due to unreliable $K_d$ values (&lt; 0.1)</td>
</tr>
<tr>
<td>St. Leonards (Coles Channel No. 3)</td>
<td>3.0 &amp; 3.2</td>
<td>2.1</td>
<td>2.3</td>
<td>0.3</td>
<td>0.3</td>
<td>59</td>
<td>28</td>
<td>82</td>
<td>Mar-May data excluded 17–26 March due to fouling of loggers</td>
</tr>
<tr>
<td>Kirk Point (Long Reef)</td>
<td>2.5 &amp; 3.1</td>
<td>4.5</td>
<td>NA</td>
<td>0.6</td>
<td>0.4</td>
<td>49</td>
<td>NA</td>
<td>87</td>
<td>Mar-May data excluded 6–7 &amp; 9–12 May 2009 due to unreliable $K_d$ values (&lt;0.1).</td>
</tr>
<tr>
<td>Point Richards (Aquaculture zone pile)</td>
<td>2.2 &amp; 2.6</td>
<td>1.3</td>
<td>0.07</td>
<td>0.4</td>
<td>0.4</td>
<td>52</td>
<td>22</td>
<td>92</td>
<td>No errors/gaps</td>
</tr>
<tr>
<td>Swan Bay (Channel Marker No. 3)$^#$</td>
<td>2.3 &amp; 2.4</td>
<td>3.5</td>
<td>NA</td>
<td>0.4</td>
<td>0.3</td>
<td>56</td>
<td>NA</td>
<td>79</td>
<td>Mar-May data excluded 3–15 March due to unreliable data.</td>
</tr>
</tbody>
</table>

$^a$ Depth of lower logger on first & second deployment

$^b$ Source: Hirst et al. (2009b)
indicate when light loggers were serviced.

Also Appendix 3. POMC turbidity data from Camerons Bight monitoring station. Red arrows
indicate (6-hourly EWMA) at Blairgowrie (two sites), from 12 noon for January–February 2009 (see
Figure 15). Mean (± SE) light attenuation coefficients (m−1), calculated daily between 10am and 2pm, and
turbidity (6-hourly EWMA) at Blairgowrie (two sites) from 12 noon for January–February 2009 (see
Appendix 3). POMC turbidity data is from Camerons Bight monitoring station. Red arrows
indicate when light loggers were serviced.

Figure 15. Mean (± SE) light attenuation coefficients (m−1), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) at Blairgowrie (two sites) from 12 noon for January–February 2009 (see Appendix 3). POMC turbidity data is from Camerons Bight monitoring station. Red arrows indicate when light loggers were serviced.
Figure 16. Mean (± se) light attenuation coefficients (m⁻¹) calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) at Mud Islands (two sites) from 12 noon, for January–February 2009 (see also Appendix 3). Red arrows indicate when light loggers were serviced.
Figure 17. Mean (± se) light attenuation coefficients ($m^{-1}$), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) at St Leonards (two sites) from 12 noon, for January–February 2009 (see also Appendix 3). Red arrows indicate when light loggers were serviced.
Indicate when light loggers were serviced. In Figure 18, mean (± se) light attenuation coefficients (m\(^{-1}\)), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) for January-February 2009. Red arrows indicate when light loggers were serviced. PoMC turbidity data from Long Reef monitoring station.

Figure 19. Mean (± se) light attenuation coefficients (m\(^{-1}\)), calculated daily between 10am and 2pm, and turbidity (6-hourly EWMA) for January-February 2009. Red arrows indicate when light loggers were serviced.
Figure 20. Mean (± se) light attenuation coefficients (m⁻¹), calculated daily between 10am and 2pm, at Swan Bay for January–February 2009 (see also Appendix 3). No turbidity data was available for this region. Red arrows indicate when light loggers were serviced.

Epiphytes

Epiphytic turfing algal cover on *H. nigricaulis* leaves in shallow subtidal plots varied significantly between regions and sampling dates (season) (Table 5, Figure 21A). Turfing algae covered 12% of leaf area at Blairgowrie, 9% at Swan Bay 1, 8% at Mud Islands and 2% at Swan Bay 2 in autumn 2009. No turfing algae was present at the other shallow plots sampled in autumn 2009 (Figure 21A). Turfing algal cover decreased significantly at Blairgowrie, Mud Islands and Swan Bay 2, and was unchanged at Swan Bay 1, St Leonards, Point Richards and Kirk Point between summer and autumn 2009 (Table 5). Turfing algal cover was significantly higher at Blairgowrie and Swan Bay 1 in autumn 2008 compared with autumn 2008, but did not vary at Mud Islands, St Leonards, Point Richards and Kirk Point.

Turfing algal cover at deep plots varied significantly between regions and sampling dates (season) (Table 5; Figure 21B). Turfing algae covered 6% of leaf area at Point Richards, 1% at St Leonards 1 and 2, and 0% at Blairgowrie and Mud Islands deep plots in autumn 2009.

Turfing algal cover decreased significantly at Mud Islands and St Leonards 2 between summer and autumn 2009 (Table 5). Turfing algae covered >30% of leaf area at Mud Islands in summer 2009, but by autumn 2009 had fallen to 0%. Similarly, turfing algae covered >10% of leaf area in summer 2009, but covered 1% by autumn 2009 at St Leonards 2. Turfing algal cover was unchanged between summer and autumn 2009 at Blairgowrie, St Leonards 1 and Point Richards. Turfing algae levels for all deep plots in autumn 2009 were unchanged compared with levels recorded in autumn 2008.

Encrusting epiphytic algal cover of *H. nigricaulis* leaf area in shallow subtidal plots varied significantly between regions and sampling dates (season) (Table 5, Figure 22A). Encrusting algae covered 41% of leaf area at Blairgowrie, 20% at Mud Islands, 18% at Swan Bay 1 and 15% at Swan Bay 2 and 0% at St Leonards, Point Richards and Kirk Point in autumn 2009 (Figure 22A). Encrusting epiphytic algal cover increased significantly at the Swan Bay 1 and 2, decreased at Blairgowrie and was unchanged at Mud Islands, St Leonards, Point Richards and Kirk Point shallow subtidal plots between summer and autumn 2009 (Table 5). Encrusting algal cover was higher at Blairgowrie and lower at Swan Bay 1 in autumn 2009 compared with
Encrusting epiphytic algal cover in deep plots varied significantly between regions and sampling dates (season) (Table 5; Figure 22B). Encrusting algae covered <2% of leaf area at all deep subtidal plots in autumn 2009. Encrusting epiphytic algal cover decreased significantly at Mud Islands, St Leonards 2 and Point Richards deep plots between summer and autumn 2009 (Table 5), but was unchanged at Blairgowrie and St Leonards 1. Encrusting algal cover at Mud Islands decreased significantly between autumn 2009 and autumn 2008 but did not vary at Blairgowrie, St Leonards 1 and Point Richards.

Epiphytic macroalgal cover at shallow subtidal plots varied significantly between regions and sampling dates (season) (Table 5; Figure 23A). Macroalgae covered 99% of the plot at Swan Bay 1, 32% at Swan Bay 2, 30% at Point Richards, 8% at Blairgowrie and Mud Islands and 0% at Kirk Point and St Leonards in autumn 2009 (Figure 23A). Macroalgal cover increased significantly at Swan Bay 1 and Point Richards, decreased at Swan Bay 2, between summer and autumn 2009, and was unchanged at Blairgowrie, Mud Islands, St Leonards and Kirk Point between summer and autumn 2009 (Table 5). Macroalgal cover was significantly higher in autumn 2009 compared with autumn 2008 at Swan Bay 1 and Point Richards, lower at Mud Islands and unchanged at Blairgowrie, St Leonards and Kirk Point (Table 5).

Epiphytic macroalgal cover at deep subtidal plots varied significantly between regions and sampling dates (season) (Table 5). Macroalgae covered <3% of deep plots in autumn 2009 (Figure 23B). Macroalgal cover remained low and was unchanged between summer and autumn 2009 at all deep subtidal plots (Table 5). Macroalgal cover was significantly lower at Mud Islands, but unchanged at Blairgowrie, St Leonards and Point Richards, in autumn 2009 compared with autumn 2008 (Figure 23B).
Figure 21. Mean (± se) epiphytic turfing algae cover (%) of *H. nigricaulis* leaf area at A) shallow and B) deep subtidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates no data available for autumn 2008.
Table 5. Summary of linear mixed effects models testing for differences between all regions and sampling dates (seasons) for arcsin transformed epiphytic algae at shallow and deep subtidal plots. Planned statistical comparisons within each subtidal plot: C1 - autumn 2009 versus summer 2009, and C2 - autumn 2009 versus autumn 2008.

<table>
<thead>
<tr>
<th></th>
<th>Turfing algae</th>
<th>Encrusting algae</th>
<th>Epiphytic macroalgae</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shallow plots</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region*Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrast</td>
<td>C1</td>
<td>C2</td>
<td></td>
</tr>
<tr>
<td>Blairgowrie</td>
<td>-23.3***</td>
<td>+4.4***</td>
<td>+11.3***</td>
</tr>
<tr>
<td>Mud Islands</td>
<td>-2.7***</td>
<td>-0.9</td>
<td>-1.2</td>
</tr>
<tr>
<td>Swan Bay 1</td>
<td>+1</td>
<td>+2.9**</td>
<td>-13.2***</td>
</tr>
<tr>
<td>Swan Bay 21</td>
<td>-4.0***</td>
<td>-6.5***</td>
<td></td>
</tr>
<tr>
<td>St Leonards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point Richards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirk Point</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Deep plots</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region*Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrast</td>
<td>C1</td>
<td>C2</td>
<td></td>
</tr>
<tr>
<td>Mud Islands</td>
<td>-17***</td>
<td>-0.8</td>
<td>-7.8***</td>
</tr>
<tr>
<td>St Leonards 21</td>
<td>-4.3***</td>
<td>-5.0***</td>
<td></td>
</tr>
<tr>
<td>Blairgowrie</td>
<td>-0.5</td>
<td>0</td>
<td>+1.1</td>
</tr>
<tr>
<td>St Leonards 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point Richards</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NS (or blank) P>0.05, *P<0.05, **P<0.01 and ***P<0.001. 
1 only C1 contrasts performed (NB. no autumn 2008 data indicated by black cells) 
+ 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 
F: F-ratio; P: probability that null hypothesis is true
Figure 22. Mean (± se) encrusting epiphytic algal cover (%) of *H. nigricaulis* leaf area at A) shallow and B) deep subtidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009; n indicates no data available for autumn 2008.
Figure 23. Mean (± se) epiphytic macroalgal cover (%) of A) shallow and B) deep subtidal seagrass plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) 2009 and autumn (hatched); n indicates where no data available for autumn 2008.

**Intertidal plots**
Epiphytic turfing algae covered <1% of leaf area at the intertidal plots in autumn 2009 (Figure 24A). Encrusting algae covered 3% of leaf area at Swan Bay, 1% at Mud Islands and 0% at St Leonards and Point Richards intertidal plots in autumn 2009 (Figure 25). Note that the “real” cover of epiphytic macroalgae at Point Richards is 20% because only two quadrats contained seagrass in this plot (see above). Mac railalgal cover increased significantly at Mud Islands (Linear Mixed Effects analysis; t=+2.0, P=0.044) and Swan Bay (LME analysis; t=+3.8, P<0.001) between summer and autumn 2009. Mac railalgal cover was higher in autumn 2009 compared with autumn 2008 at Swan Bay (LME analysis; t=+6.5, P<0.001), but no different at Mud Islands (LME analysis; t=+1.2, P>0.05).

**Other factors**

**Drift algae**
Drift macroalgae was abundant at Swan Bay 1 (99% cover) and covered 30% of the plot at Swan Bay 2 in autumn 2009 (Figure 26A). Drift algae covered <10% of the other plots sampled (Figure 26 and 27).

**Other epiphytic biota**
The encrusting bivalve *Electroma georgiana* was patchily distributed. *Electroma georgiana* covered 75% of the deep plot at Mud Islands and 60% of the deep plot at St Leonards 2 in autumn 2009 (data not shown). *Electroma georgiana* was not recorded at intertidal plots and comprised <2% of total cover at the other subtidal plots.
Figure 24. Mean (± se) A) turfing, and B) encrusting epiphytic algal cover (%) of *Z. muelleri* leaf area at intertidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009.

Figure 25. Mean (± se) epiphytic macroalgal cover (%) of intertidal seagrass plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009.
Figure 26. Mean (± se) cover (%) of drift macroalgae at A) shallow and B) deep subtidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009. n indicates where no data were available.

Figure 27. Mean (± se) cover (%) of drift macroalgae at intertidal plots in autumn (black), winter (hatched), spring (grey) 2008 and summer (cross-hatched) and autumn (hatched) 2009.
Comparisons against historical data

Seagrass health
Historical data (2004-07) collected as part of a previous study were available for shallow subtidal plots at Kirk Point, Point Richards and Swan Bay 2, and for intertidal plots at Point Richards and Swan Bay. Inevitably, some difficulties are encountered when comparing data from different studies. The data collected between 2004 and 2007 (Ball et al. in prep.) used random rather than fixed quadrats, fewer replicates (n = 5 versus 12) and destructive cores to estimate shoot/stem densities.

Historical data indicated that seagrass cover, length and stem density were higher at Kirk Point and Point Richards shallow subtidal plots in the past (Figure 28). When these plots were established in April 2005, seagrass covered >80% of the benthos. By April 2008, when the first season’s sampling was undertaken for the Seagrass Baywide Monitoring Program, seagrass covered <10% of the benthos. Seagrass cover, length and stem densities remained low throughout 2008 and early 2009, and had not returned to pre-April 2007 levels by April 2009.

Seagrass covered >95% of the Swan Bay 2 shallow subtidal plot between April 2005 and April 2006. By April 2007, seagrass cover had declined to 12%, but began to increase in August 2008 (Figure 28). By April 2009 seagrass cover and length had recovered to levels observed in November 2006.

Intertidal seagrass cover and shoot density at Point Richards in April 2009 were similar to levels observed at this plot between April 2005 and April 2007 (Figure 29). Seagrass length in April 2009 was at its lowest recorded level for this plot.

Zostera muelleri dominated the Swan Bay intertidal plot when it was established in April 2005. From November 2006 this plot was dominated by L. marina (Figure 29). Zostera muelleri and L. marina shoot lengths were similar between November 2005 and April 2009.

Seagrass epiphyte cover
Epiphytic algal cover varied over time in shallow subtidal seagrass plots between April 2005 and April 2009 (Figure 30). Epiphytic algal cover at Kirk Point and Swan Bay 2 were low relative to past levels observed at these plots. Epiphytic turfing and encrusting algal cover at Point Richards shallow plot in April 2009 was lower than levels recorded in the past, but epiphytic macroalgal cover in April 2009 exceeded levels recorded in the past (Figure 30).
Figure 28. Mean (±se) seagrass cover (%), length (cm) and shooting-stem density (counts 0.0625m⁻²) for *H. nigricaulis* at Kirk Point, Point Richards and Swan Bay 2 shallow subtidal plots. Historical data collected from November 2004 – April 2007 (hatched) proceeds Baywide seagrass monitoring field data collected between autumn 2008 and autumn 2009 (depicted in grey); n/a denotes where no data were available; * denotes missing data at Swan Bay 2 in autumn 2008.
Figure 29. Mean (±se) cover (%), shoot length (cm) and shoot density (counts 0.0625m$^{-2}$) for intertidal seagrass at Point Richards and Swan Bay, November 2004–April 2007 (FRB) and May 2008-April 2008 (Baywide Seagrass Monitoring Program, BSMP), n/a denotes where no data were available.
Figure 30. Mean (±se) turfing, encrusting and macroalgal epiphytic cover (%) for *H. nigricaulis* at Kirk Point, Point Richards and Swan Bay 2 shallow subtidal plots, April 2005–April 2007 (hatched) and between April 2008–April 2009 (grey); *denotes missing data at Swan Bay 2 in autumn 2008.
Appendix 3. Light Logger Performance

The performance of the light loggers and wiper systems deployed during March-May 2009 are summarised below (see also Table 4).

Blairgowrie (speed restriction pile)
The upper logger flooded during the deployment from 2 February to 26 March 2009 and no data was recovered (Figure 15). The flooding was caused by a hairline crack in the logger housing. The lower logger functioned correctly during this deployment. The upper logger also flooded during the 6 May to 11 June 2009 deployment. This was a new logger and there were no visible problems with the housing to explain the failure. The logger has been returned to the manufacturer for assessment.

Mud Islands South East
The top light logger flooded during the 22 May to 7 July 2009 deployment. Consequently no data was recovered for the period 23–30 May (Figure 16). This was a new logger purchased at the same time as the logger which also flooded at the Blairgowrie speed restriction pile (see above) and there were no visible problems with the logger housing. This logger has also been returned to the manufacturer for assessment. The lower logger functioned correctly. The backup loggers at Mud Islands North West functioned correctly and provided attenuation data for the missing period at the south east pile for the end of May (Figure 16).

St. Leonards (Coles Channel No. 3)
Data for the period 17–26 May 2009 had a large spike in attenuation values (>5). The wiper on the lower logger had jammed when it was retrieved and there was heavy fouling on the light logger. This appeared to be the cause of the spike in attenuation and this data was excluded from the analysis (Figure 17). It is possible that the higher attenuation values in early March (up to 0.5) were also influenced by fouling of the sensor as the turbidity was relatively stable, although there was a small increase in turbidity on 15 March. There was no alternative light data for this period from the backup logger (see below).

St. Leonards (Coles Channel No. 5)
The data from 19 February to 25 March 2009 had unreliable Kd values (<0.1) and was excluded from the analysis (Figure 17).

Kirk Point
The data at the end of the 17 March to 12 May deployment (i.e. 6–7 and 9–12 May 2009) had unreliable Kd values (<0.1) and was excluded from the analysis (Figure 18).

Swan Bay
A large spike in the attenuation values occurred at Swan Bay in the first half of March 2009 (Figure 20). Swan Bay has large amounts of drifting dead seagrass, and smothering of the light loggers may have caused the spike in attenuation. Alternatively, the wiper motors on both loggers needed to be replaced at the end of this deployment and it is possible that one or both wipers became stuck on the sensors during this period.
Appendix 4 Data

Electronic data files are as follows:

- Seagrass health observations at plots and quadrats: CDP_seagrass_database_MR5.xls
- Intertidal seagrass upper limit boundaries: a separate shapefile exists for each region with the naming format Regioncode_UL_date_projection (e.g. MI_UL_12May08_MGA55.shp)
- Light logger data: Logger_data_March-May09.xls.