Baywide Seagrass Monitoring Program

Milestone Report No. 2 (2008).

No. 29
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Victoria
The Place To Be

Baywide Seagrass Monitoring Program

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Executive Summary

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, thereby protecting adjacent coastal shorelines from erosion.

The Baywide Seagrass Monitoring Program comprises 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 large-scale seagrass mapping from aerial photography flown in autumn 2008, and the second small-scale field-sampling event in winter (July/August) 2008. It includes a detailed assessment of 1) seagrass area at the regional level, 2) seagrass cover, stem/shoot density and length for intertidal and subtidal seagrass plots at six regions, and 3) factors that are known to influence seagrass health (light, turbidity, and epiphyte cover).

Seagrass area in 2008 was compared with mapping from aerial photography flown between 2000 and 2007. Comparisons of seagrass cover, length and density were also made against previous data collected between 2004 and 2007 at three of the six shallow subtidal plots, and two of the four intertidal plots.

Aerial mapping

Total seagrass area declined at Blairgowrie, Point Richards and Mud Islands between 2000 and 2008. During the same period seagrass area remained stable at Swan Bay. Kirk Point displayed the greatest change in total area with an overall increase in seagrass area since 2000, although inshore seagrass declined between 2007 and 2008. Seagrass area at St Leonards displayed the greatest variability with seagrass area fluctuating between 2000 and 2008.

Regions where seagrass has declined since 2000 are exposed to greater levels of wave energy and longshore sand drift, and these may be important determinants of seagrass cover in PPB. Kirk Point is located adjacent to the Murtcaim Drain outlet. Seagrass in this region is likely to be impacted by the discharge of freshwater and nutrients from the drain. It is possible that the increase in seagrass area in this region observed between 2000 and 2007 corresponds with a large reduction in flows from the drain over this period.

The observed changes in shallow seagrass area from aerial mapping at Blairgowrie between 2007 and 2008 were within statistical criteria for expected variability.

Small-scale assessment of seagrass health

Seagrass cover, density and length varied between regions and depths. Subtidal seagrass beds monitored in this study consisted entirely of a single seagrass species *Heterozostera nigricaulis*. Intertidal seagrass beds usually comprised *Zostera muelleri*, although the aquatic macrophyte *Lepilaena marina* was also present at two of the intertidal plots monitored.

Seagrass cover, length and stem density were highest at plots in the southern part of PPB (Blairgowrie, Mud Islands and Swan Bay). Seagrass cover was low, by comparison, at Kirk Point, Point Richards and St Leonards. In autumn 2008 (first field sampling event), shallow plots at these regions were dominated by stems without leaf shoots. In winter 2008, these stems had almost completely disappeared, leaving a very sparse cover of shooting stems. Seagrass cover has been declining over the past 2 years at the Point Richards seagrass health assessment plots.

There were few consistent changes in seagrass health observed between autumn and winter 2008 at the scale of individual plots. Subtidal *H. nigricaulis* cover, length and density either increased or were unchanged, in winter relative to autumn, for Blairgowrie, Mud Islands and Swan Bay. Seagrass cover remained low at St Leonards and Kirk Point and disappeared completely at Point Richards during the same period.

Factors that influence seagrass health

Benthic light availability met or exceeded conservative environmental requirements for seagrasses in southern PPB at all regions.

Epiphytic algae were more abundant on subtidal than intertidal seagrass plants. Epiphytic algal loads on subtidal seagrasses were patchy in distribution. Where epiphytic algal loads were high, and past information was available, current levels were similar to those previously observed. No consistent change in epiphytic algal cover was observed between autumn and winter sampling events.

Conclusions

The large variations in seagrass area observed at the regional scale since 2000 are not unprecedented in PPB. At a smaller spatial scale, seagrass displayed high variability between regions and plots and exhibited few consistent patterns between autumn and winter. Seagrass health in winter 2008 and seagrass area mapped during autumn 2008 from aerial photography conformed to expected variability for seagrasses in PPB.

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Introduction

Seagrass is an important habitat in Port Phillip Bay (PPB). Seagrasses are highly productive ecosystems, supporting diverse faunal assemblages, many of commercial importance. Seagrass plants filter and retain nutrients, stabilise sediments and baffle wave energy, protecting adjacent coastal shorelines from erosion.

More than 95% of the seagrass in PPB is *Heterozostera nigricaulis* and *Zostera muelleri* (eelgrasses belonging to the family Zosteraceae). The total area of Zosteraceae in PPB was estimated to be approximately 59 km^2 in 2000 (Blake and Ball 2001). As PPB has a restricted tidal range (approximately 1 m) and a relatively small intertidal zone, most of this seagrass is the subtidal *H. nigricaulis*.

Seagrass 'health' is affected by a range of natural and human influences that occur at a range of spatial and temporal scales. These factors include:

- Habitat availability – substratum type and stability
- Water quality – nutrients, turbidity and temperature
- Hydrodynamics and coastal processes - tides, currents and sediment transport
- Trophic interactions - between epiphytes, grazers and associated predators.

The breadth of factors and various scales of influence result in seagrass beds being highly dynamic in both space and time.

The Baywide Seagrass Monitoring Program in PPB consists of three main elements:

- Annual large-scale monitoring of seagrass coverage at nine regions using aerial mapping and periodic video ground-truthing
- Small-scale monitoring of seagrass health for six of the nine regions at representative field assessment plots sampled quarterly (frequency of sampling to be reviewed after two years)
- Monitoring of key parameters that are known to affect seagrass health (including light and epiphyte abundance).

This program is described in the Port of Melbourne Corporation (PoMC) Channel Deepening Baywide Monitoring Programs (CDBMP) Seagrass Monitoring Detailed Design Rev2 (PoMC 2008a).

The objective of this program is to detect changes in seagrass health in PPB outside expected variability.

Previous results from this program were reported in Ball and Heislers (2008) and Hirst *et al*. (2008).

Purpose of This Report

This milestone report presents:

- A summary of large-scale monitoring of seagrass beds with aerial mapping and underwater video ground-truthing undertaken in autumn (April/May) 2008
- A summary of results for the small-scale monitoring of seagrass health undertaken in winter (July/August) 2008
- 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 comparisons against historical aerial photography (2000–08) and seagrass monitoring (2004–07) where available
- Discussion of QA/QC issues and any peculiarities, along with any associated implications for the data.

Project Design and Methods

Project design and methods for this study are described in PoMC (2008a). Additional methods presented in this report, and not otherwise described by PoMC (2008a), are summarised below and in Appendices 1-2.

Sampling Regions

Seagrass in PPB is being monitored at several spatial scales. Aerial photography of broad stretches of the coastline is flown annually during April/May to allow characterisation of large areas of seagrass in PPB through qualitative assessment. More detailed assessments are undertaken through mapping seagrass distribution from aerial photography in approximately 1 km^2 mega-quadrats at nine intertidal/shallow regions in the Bay (Table 1, Figure 1).

Measurement of seagrass health at a smaller spatial scale began in autumn (April/May) 2008 (Table 1, Figure 1) at six of the nine detailed field assessment regions (i.e. Kirk Point, Point Richards, St Leonards, Swan Bay, Mud Islands and Blairgowrie). These six regions will be monitored quarterly for the first two years of the program, with the frequency of monitoring to then be reviewed.

Light attenuation, turbidity (PoMC) and water quality (EPA) monitoring sites are shown in Figure 2.

Characterisation of broad areas of seagrass

The total extent of aerial photography flown in April 2008 for the detailed seagrass mapping and qualitative assessment of broad areas of seagrass is shown in Figure 1. The overall aerial photography will be compared to future photography to be flown in each year of the monitoring program. This comparison will assess whether any changes quantified in the aerial assessment regions are indicative of the broader areas they represent.

Aerial assessment regions

The water clarity at the Kirk Point aerial assessment region was partially affected by what appeared to be high algal loads in the 2008 aerial photography. This prevented mapping of the seagrass habitat near the offshore boundary at this region (see also Exceptions). As an alternative the Kirk Point mapping region was split into an inner and outer zone and only the inner zone was mapped in 2008. In order to allow comparison with existing mapping at this region for 2000-07, the past mapping was also split into the inner and outer zones in the GIS and the habitat areas for the inner zone were extracted for the time series analysis.

Small-scale monitoring plots

Seagrass health was measured at the six seagrass field-assessment regions in three, fixed, 10 m diameter plots, located in intertidal, shallow subtidal (1–2 m) and deep subtidal (3–5 m) seagrass. Differences in bathymetry and seagrass distribution meant that seagrass was not found at all depths at each region. Consequently, not all plot types were established at each region (Table 1). Intertidal seagrass was only present at Point Richards (Bellarine Bank), St Leonards, Swan Bay and Mud Islands.

The original St Leonards deep plot (denoted St Leonards 1 deep) had limited seagrass, including stems without leaves, and extensive macroalgae in April/May. An alternative deep plot (denoted St Leonards 2) was established in April/May approximately 2.5 km to the south as a contingency until after the July/August sampling, when the most suitable plot will be selected for ongoing monitoring. The St Leonards 2 deep plot was located at the sampling area used by the Fish Stock and Recruitment Sub-program 4 - Monitoring Key Fishery Species in Seagrass Beds (PoMC 2008b).

The fixed quadrat markers at the St Leonards 2 deep plot could not be found during the July/August sampling, and appeared to have been “swept out” by seabed sand movement. The quadrat markers were re-established in seagrass adjacent to the original plot. As the plot and quadrats were moved, no data from the April/May quadrats are presented in this report.

The Swan Bay shallow subtidal plot (denoted Swan Bay 1) was incorrectly sited in April/May due to a GPS datum error (see also ER2008#13). A second subtidal plot (denoted Swan Bay 2) was sampled in July/August at the correct position to allow comparisons with historical seagrass data. Swan Bay 1 was retained for the July/August sampling and observations from both Swan Bay 1 and 2 shallow plots are presented in this report.

Analysis of seagrass health

Seagrass health (cover, length and density) and epiphyte cover were compared statistically between regions and sampling dates using 2-way factorial analysis of variance (ANOVA). Region and sampling date were treated as fixed factors. Comparisons between plots within different depths were not possible because some regions were not represented at all depths (i.e. an unbalanced statistical design). Nor was it appropriate to compare intertidal *Z. muelleri* dominated seagrass plots with subtidal *H. nigricaulis* plots. Assumptions of linearity, normality and heterogeneity were assessed through examination of residuals and length and density measures were transformed using $\log_{10}$ transformations where appropriate before analysis.

Differences between regions, where detected, were identified using Tukey's HSD (Honestly Significant Difference) *post-hoc* tests. *A priori* contrasts between autumn and winter sampling dates were undertaken at each region using Fisher's LSD (Least Significant Difference) pairwise tests. All hypothesis tests were conducted at the 0.05 significance level.

Light

The percentage of surface irradiance at the depths of the shallow (2 m) and deep (5 m) plots were calculated from the mean daily light attenuation K_d coefficients by transposing Beer's Law. The calculation of light attenuation did not account for changes in tidal height.

Background light attenuation in clear seawater in PPB rarely falls below 0.1 m^{-1} (Longmore *et al.* 1996). Attenuation coefficient values that were <0.1 m^{-1} were treated as data anomalies and excluded from the calculations.

Nutrients

Nutrient data are collected by the EPA near some of the seagrass regions for the CDBMP Water Quality program. Relationships between nutrients and seagrass, if present, will be difficult to detect until changes in time series of both have been detected (at least two years of data). Nutrient impacts are most likely to be expressed as epiphytic growth. No data on nutrients are reported here.

Other factors

A range of other factors that may influence seagrass health are recorded as field-notes (PoMC 2008a). Some of these factors have little influence on seagrass health during winter (e.g. swan grazing, desiccation stress and spadices) and are not reported here.

Data Management

QA/QC.

Data Quality Assurance and Quality Control issues associated with the seagrass habitat mapping and operation of the light loggers are presented in Appendices 3 and 4 respectively.

Exceptions to Detailed Design

Exceptions to the Detailed Design (PoMC 2008a) for the reporting period are documented in Exception Report ER2008#20, and summarised as follows:

- The number of video ground-truthing sites within the Kirk Point, Curlewis Bank and St Leonards aerial assessment regions was <10
- The 0.0625 m^2 (0.25 x 0.25 m) fixed quadrats established at the field-assessment plots to measure shoot density were sub-sampled at some plots
- The full extent of the Kirk Point aerial assessment region was unable to be mapped due to poor water clarity
- Upper intertidal limit measurements were not recorded at Swan Bay due to seagrass wrack on the shore
- Outer (deeper) edge measurements were not recorded at any region
- This milestone report was not delivered according to specified timelines.

Table 1. Monitoring regions and assessment methods for the different components of the CDBMP Seagrass Monitoring Program.

Region	Assessment Method		Field Assessment Plots		
	Aerial (Annual)	Field (Quarterly)	Intertidal	Shallow (1–2 m)	Deep (2–5 m)
Altona	√				
Kirk Point	√	√		√	
Point Henry West	√				
Curlewis Bank	√				
Point Richards	√	√	√	√	√
St Leonards 1	√	√	√	√	√
St Leonards 2*		√			√
Swan Bay 1	√	√	√	√	
Swan Bay 2#		√		√	
Mud Islands	√	√	√	√	√
Blairgowrie	√	√		√	√

* Contingency deep plot for St Leonards 1 deep plot.

Extra field-assessment plot established beyond the requirements of the Detailed Design (PoMC 2008a) – see ER2008#13.

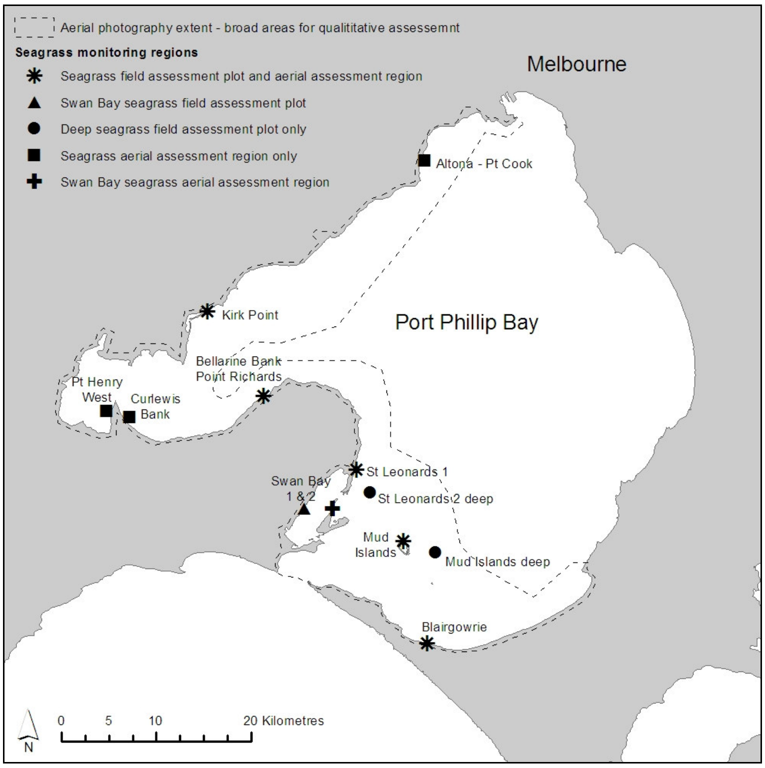


Figure 1. Locations of large-scale monitoring (aerial assessment) regions and small-scale field assessment plots in Port Phillip Bay.

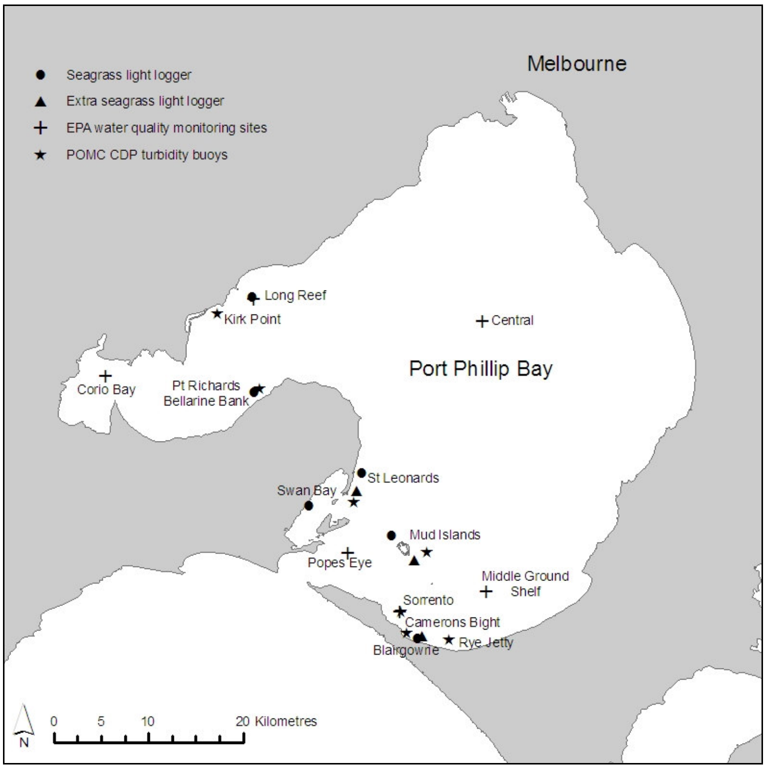


Figure 2. Locations of light loggers, EPA water quality monitoring sites and PoMC turbidity monitoring stations.

Note: The closest pile for deployment of light loggers at the Kirk Point region was located at Long Reef.

Results

Seagrass mapping

The percentage cover of seagrass habitat categories at the aerial assessment regions in autumn (April) 2008 is shown in Figure 3. Aerial photography of the aerial assessment regions overlayed with ground-truthing sites classified by habitat categories is shown in Figures 4–12. Example images of seagrass habitat categories at each region from the video ground-truthing are shown in Figure 13.

Altona

Total vegetation cover at Altona was 31%, and consisted of predominantly medium-dense and medium-dense patchy macroalgae (Figures 3 and 4). Sparse and sparse-patchy seagrass was present growing amongst medium-dense macroalgae at depths <1.5 m. *Caulerpa remotifolia* was widespread amongst the vegetation at this region, typically growing with sparse seagrass (Figure 13A). Seagrass length was 5–10 cm, and epiphytic macroalgal cover was <20%.

Video ground-truthing of the deeper areas (>2 m) at Altona showed that the vegetation visible in the aerial photography was predominantly medium-dense macroalgae (Figure 4).

Blairgowrie

Total seagrass cover at Blairgowrie was 6%, and was predominantly medium-dense *H. nigricaulis* (Figure 13B) separated by expanses of bare sediment (Figures 3 and 5). Seagrass length was 5–30 cm, and epiphytic macroalgal cover was <20%.

Curlewis Bank

Total seagrass cover at Curlewis Bank was 94% (Figure 3), and consisted of predominantly medium-dense seagrass (Figure 13C). The seagrass formed a continuous band that extended approximately 1 km offshore to a depth of approximately 5 m (Figure 6). Seagrass length was 30–50 cm, and epiphytic macroalgal cover was <20%.

Kirk Point

The offshore water clarity at Kirk Point was partially affected by apparent high algal loads in the 2008 aerial photography, and only the inner zone of this aerial assessment region was mapped (Figure 7, see Exceptions, ER2008#20).

Total seagrass cover at the Kirk Point inner-zone was 78%, and consisted of predominantly medium-dense (Figure 13D) and sparse patchy seagrass (Figure 3). Seagrass length was 20–50 cm, and epiphytic macroalgae cover was absent.

Mud Islands

Total seagrass cover at Mud Islands was 42%, and was predominantly medium-dense seagrass (Figure 3, Figure 13E). A band of seagrass extended from the intertidal zone to a distance of approximately 300 m along the northern shore and 100 m along the eastern shore, reaching depths of approximately 1.5 m (Figure 8). Seagrass length was 10–30 cm in the subtidal zone, and epiphytic macroalgal cover was mostly <20%.

Point Henry West

Total seagrass cover at Point Henry West was 88%, and was predominantly medium-dense seagrass (Figure 3). The medium-dense seagrass (Figure 13F) formed a continuous band extending for a distance of approximately 800 m offshore to a depth of approximately 3 m (Figure 9). The vegetation changed to medium-dense patchy macroalgae with seagrass beyond depths of approximately 3 m, covering 11% of the region. The seagrass *Halophila australis* was also present at video sites 2 & 3 growing with *H. nigricaulis* at depths >3 m (Figure 9). Seagrass length was 10–40 cm in the subtidal zone, and epiphytic macroalgal cover was >20% at depths >1 m and <20% at depths <1 m.

Point Richards

Total seagrass cover at Point Richards (Bellarine Bank) was 8%, and comprised fragmented beds of medium-dense seagrass (Figure 3) close to shore at depths <1.5 m (Figure 10). Seagrass, below the density detectable by aerial photography interpretation, was observed between the medium-dense beds. The seagrass beds at this region also included stands of *H. nigricaulis* stems without leaves (Figure 13G). The seagrass with shoots was 5–10 cm in length, and epiphytic macroalgal cover was mostly <20%.

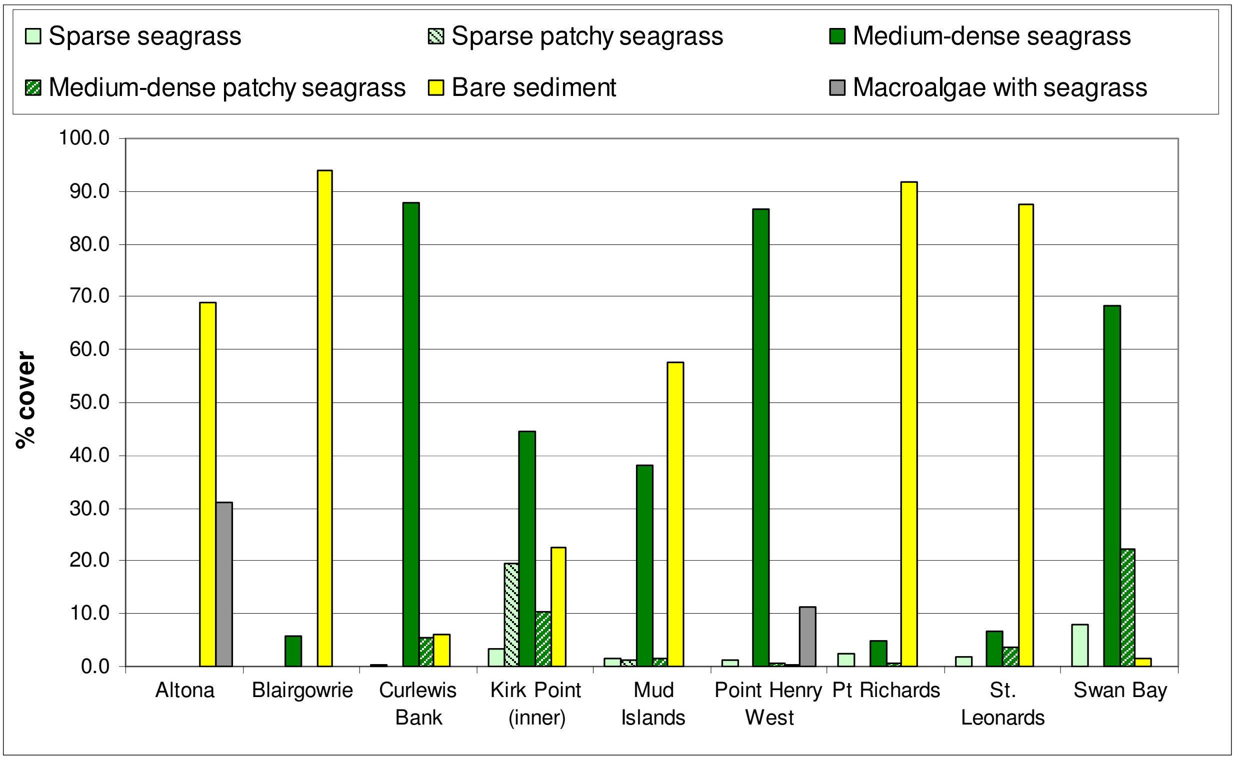


Figure 3. Percentage cover of seagrass habitat categories at the nine aerial assessment regions in Port Phillip Bay in April 2008.
Note: vegetation cover at Altona was predominantly macroalgae with sparse seagrass.

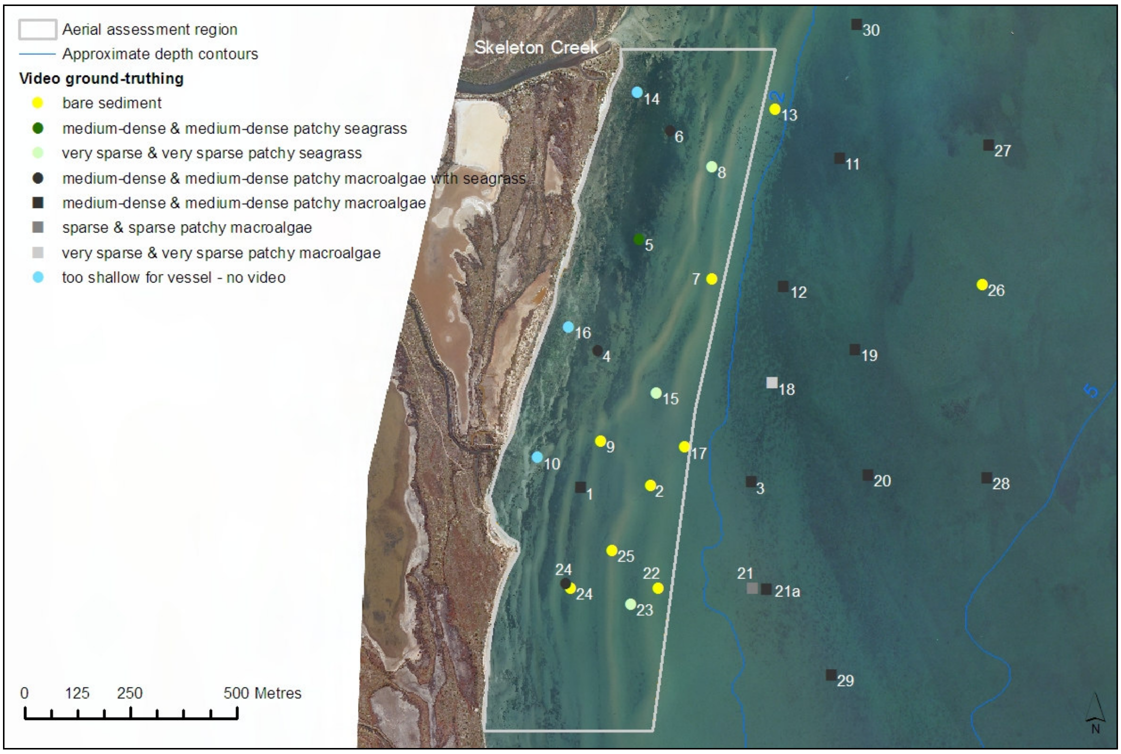


Figure 4. Aerial photography at Altona aerial assessment region flown 20 April 2008, overlayed with ground-truthing sites (1–30) classified by habitat.

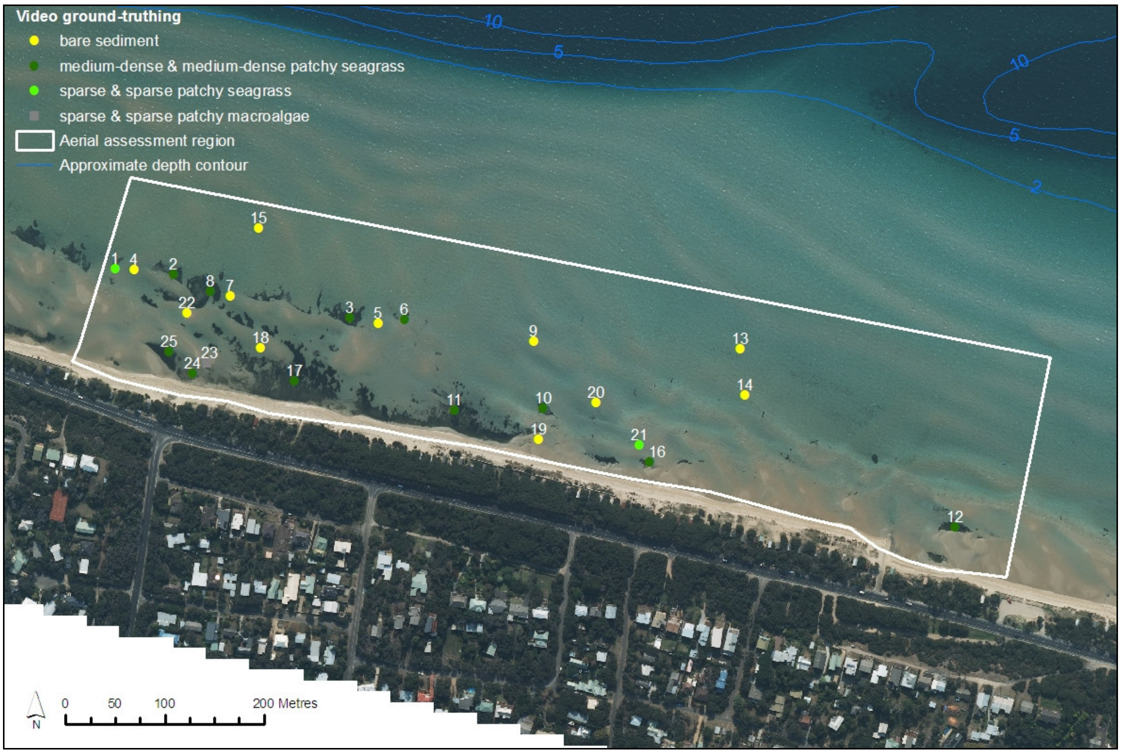


Figure 5. Aerial photography at Blairgowrie aerial assessment region flown 24 April 2008, overlayed with ground-truthing sites (1–25) classified by habitat.

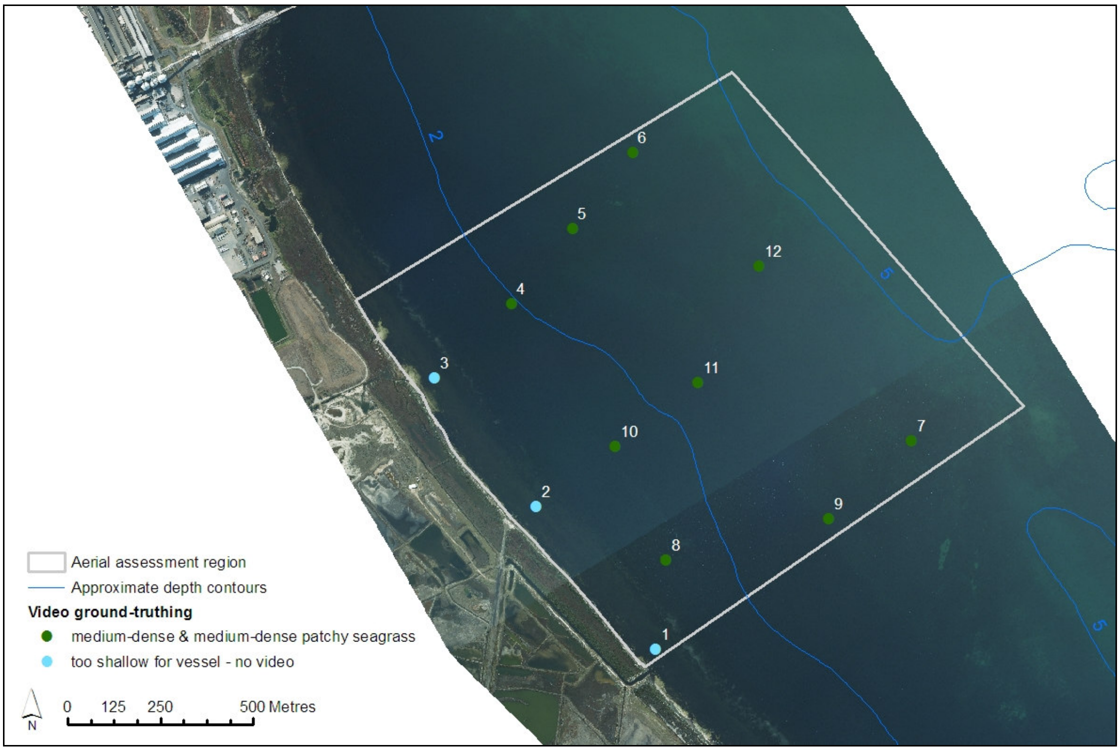


Figure 6. Aerial photography at Curlewis Bank aerial assessment region flown 23 April 2008, overlayed with ground-truthing sites (1–12) classified by habitat.

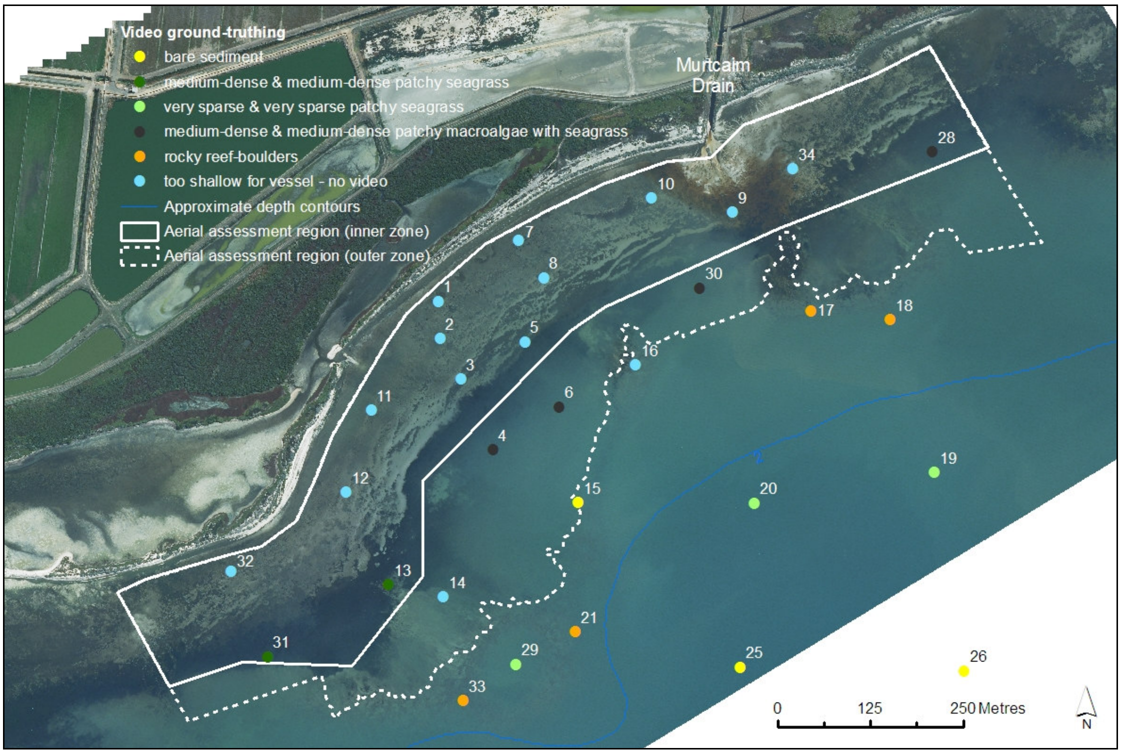


Figure 7. Aerial photography at Kirk Point aerial assessment region flown 20 April 2008, overlayed with ground-truthing sites (1–34) classified by habitat.

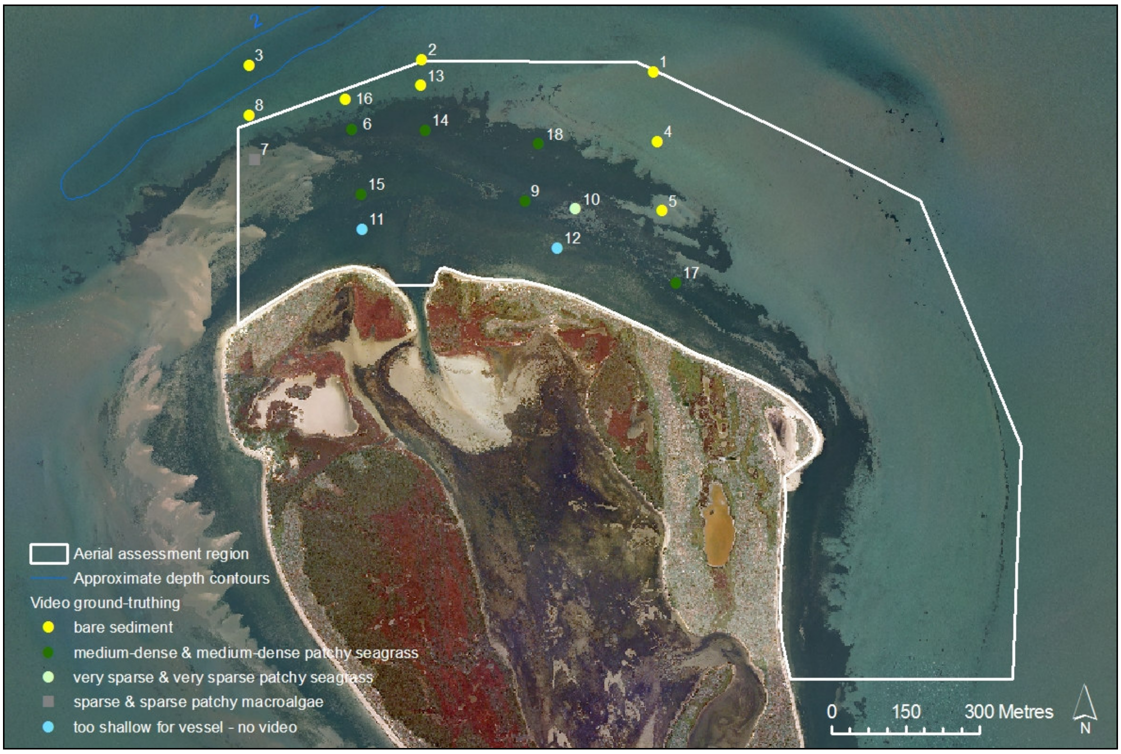


Figure 8. Aerial photography at Mud Islands aerial assessment region flown 24 April 2008, overlayed with ground-truthing sites (1–18) classified by habitat.

Figure 9. Aerial photography at Point Henry West aerial assessment region flown 23 April 2008, overlayed with ground-truthing sites (1–13) classified by habitat.

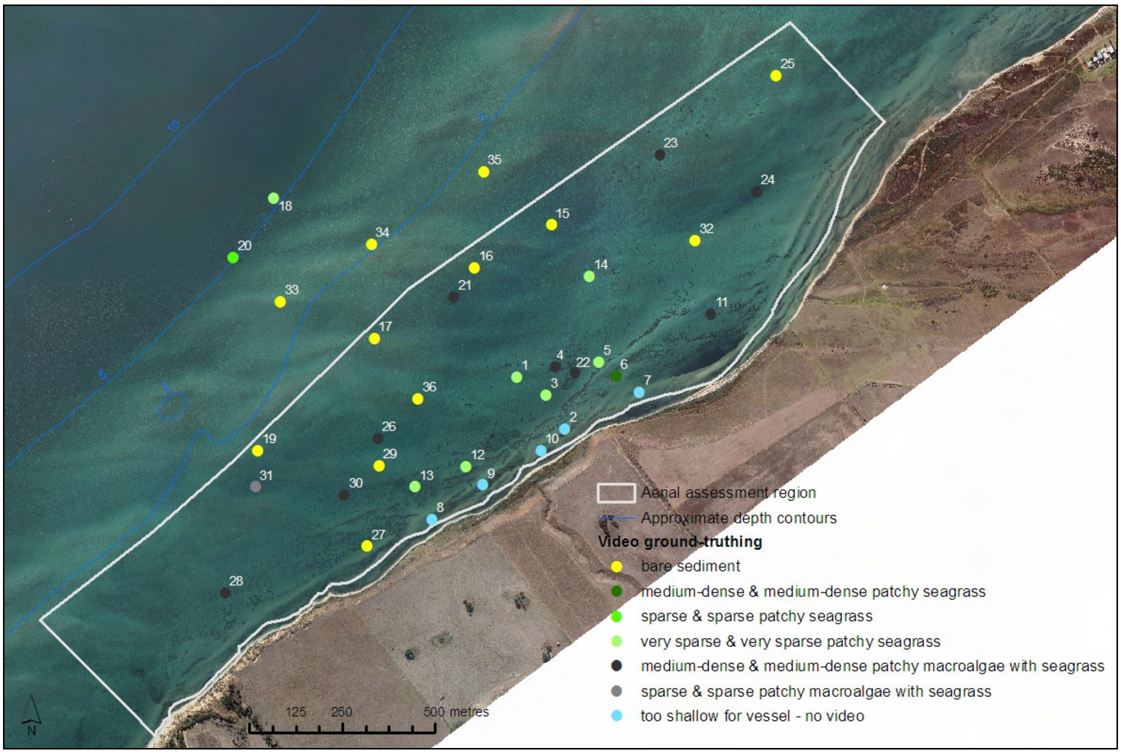


Figure 10. Aerial photography at Point Richards aerial assessment region flown 23 April 2008, overlayed with ground-truthing sites (1–36) classified by habitat.

St Leonards

Total seagrass cover at St Leonards was 12%, consisting of narrow bands of medium-dense (Figure 13H) and sparse seagrass within 50 m of the shoreline (Figures 3 and 11). The seagrass at video sites 2 and 11 consisted of stems without leaves. Smaller fragmented medium-dense and medium-dense patchy seagrass beds extended out to approximately 100 m from the shore to depths of approximately 1 m (Figure 11). Seagrass length was 5–20 cm, with <20% epiphytic macroalgal cover.

Stands of sparse patchy *H. nigricaulis* stems without leaves were present at depths of approximately 4 m adjacent to the aerial assessment region (video sites 12–14, Figure 11) Further stands of sparse patchy *H. nigricaulis* (shoots and stems without leaves) were present on the opposite side of Coles Channel at depths of approximately 5 m. The depth and low densities of seagrass prevented accurate mapping in this area.

Swan Bay

The Swan Bay aerial assessment region was mostly intertidal. Total seagrass cover was 98%, consisting of predominantly medium-dense and medium-dense patchy seagrass (Figure 3). In the intertidal areas, *Z. muelleri* intermixed with *Lepilaena marina* formed extensive beds with a medium-dense and medium-dense patchy cover (Figure 13I). In the shallow subtidal areas, medium-dense stands of *H. nigricaulis* were present (Figure 12). Seagrass lengths were up to 5 cm in the intertidal zone and approximately 5–30 cm in the shallow subtidal, with epiphytic macroalgal cover mostly <20% in the intertidal zone and >20% in the shallow subtidal.

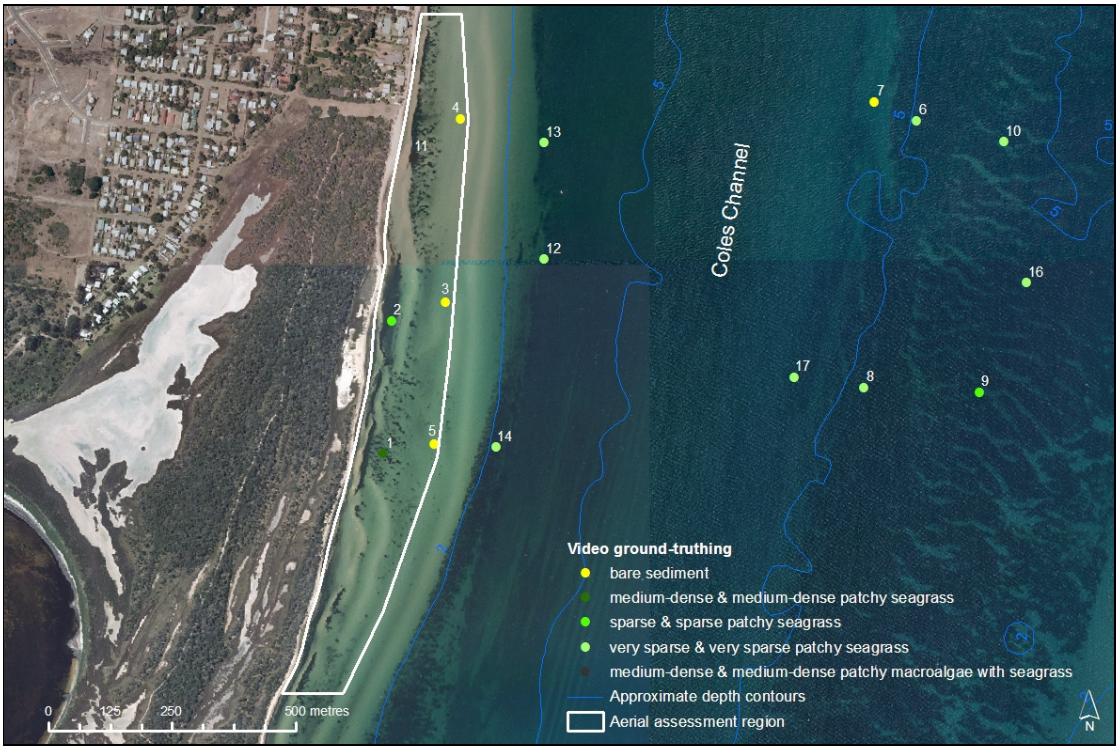


Figure 11. Aerial photography at St Leonards aerial assessment region flown 24 April 2008, overlayed with ground-truthing sites (1–17) classified by habitat.

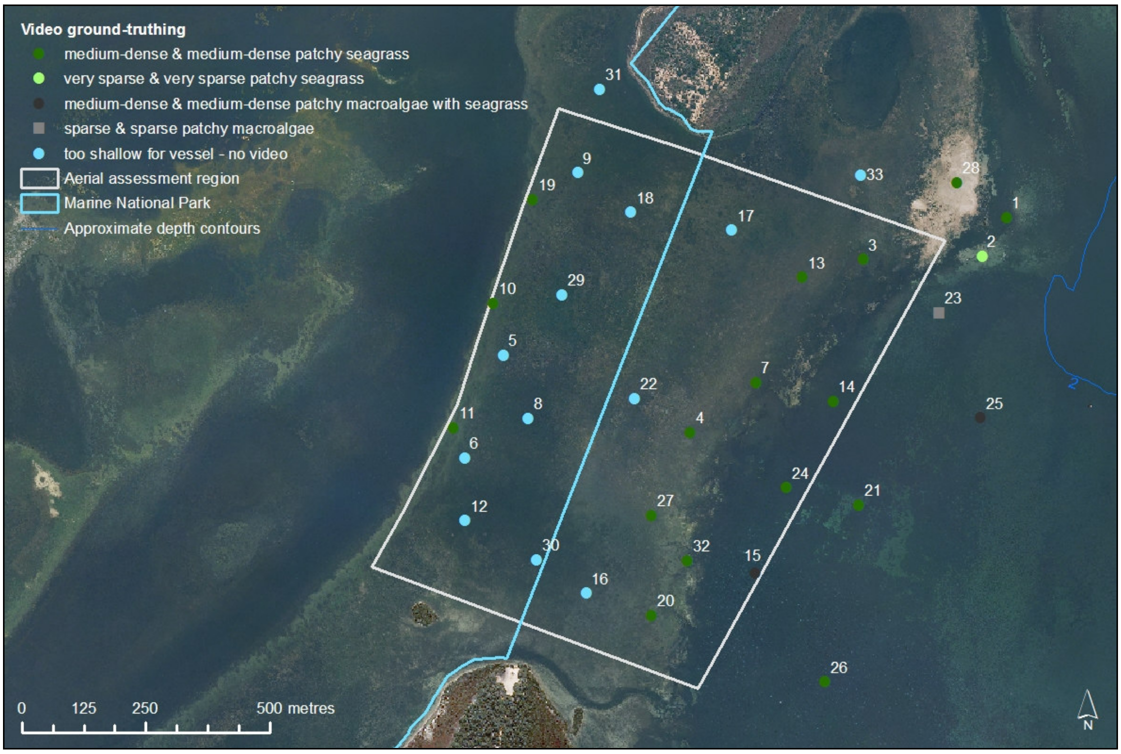
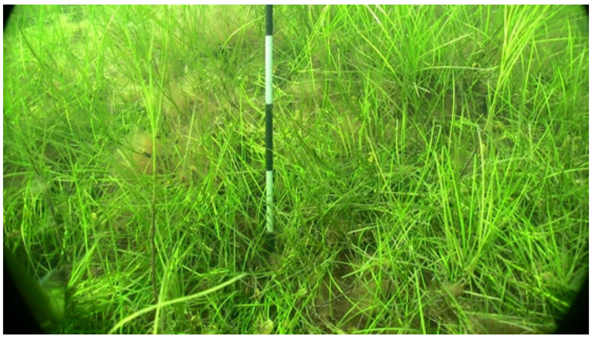


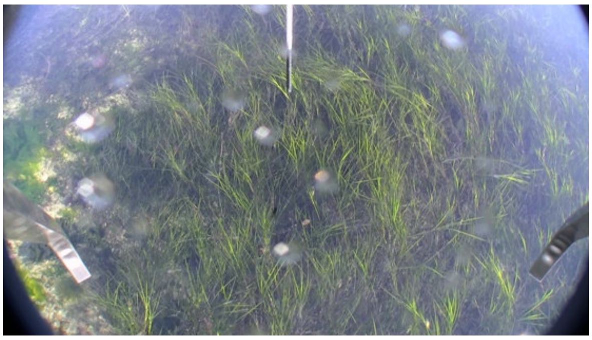
Figure 12. Aerial photography at Swan Bay aerial assessment region flown 24 April 2008, overlayed with ground-truthing sites (1–33) classified by habitat.

A. Altona video site 4: medium-dense macroalgae (includes *C. remotifolia*) with sparse *H. nigricaulis*.

B. Blairgowrie video site 11: medium-dense *H. nigricaulis.*



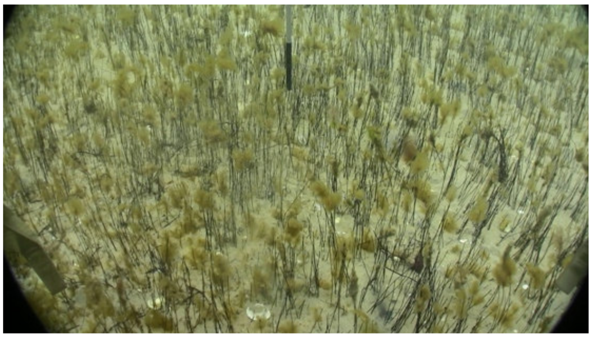
C. Curlewis Bank video site 9: medium-dense *H. nigricaulis*.



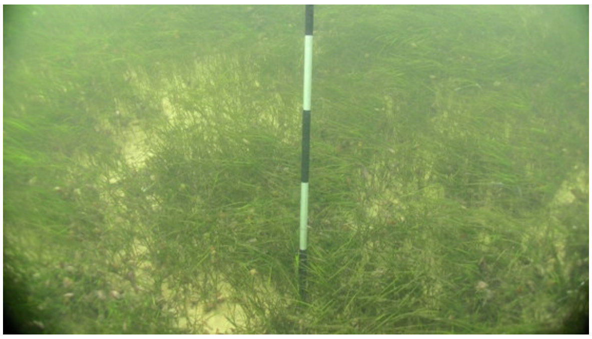
D. Kirk Point video site 13: medium-dense H. nigricaulis.

E. Mud Islands video site 14: medium-dense *H. nigricaulis*.

F. Point Henry West video site 6: medium-dense *H. nigricaulis*.

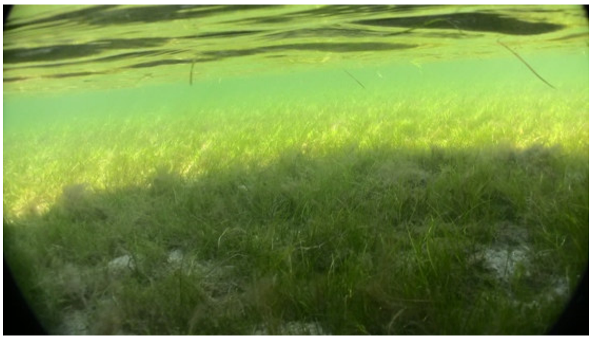


G. Point Richards video site 6: medium-dense *H. nigricaulis* stems.



H. St Leonards video site 1: medium-dense *H. nigricaulis.*

Figure 13. Video ground-truthing still images.



I. Swan Bay video site 4: medium-dense *Z. muelleri* and *L. marina*.

Figure 13 cont. Video ground-truthing still images.

Mapping accuracy

Error matrices comparing the classification of ground-truthing and aerial mapping data for the aerial assessment regions are presented in Appendix 1. A summary of the overall mapping accuracies for each region is presented in Table 2. Mapping accuracies were >90%, except for Swan Bay, Point Richards and St Leonards, where accuracy ranged from 50% to 77%.

There is no defined minimum standard of accuracy for marine benthic habitat mapping. The Coastal Services Center (2005) of the US National Ocean Service suggested that overall mapping accuracies of 80–85% are an upper limit for benthic habitat data derived from remote sensing. Overall mapping accuracy at the nine aerial assessment regions was >85% apart from Point Richards, St Leonards and Swan Bay. The causes of the reduced mapping accuracy at these regions are outlined in Appendix 1 and consisted of:

- Misclassification of seagrass densities due to physical conditions (e.g. dark sediments underlying seagrass at Swan Bay) or presence of seagrass beds with non-shooting stems (e.g. Point Richards)
- Ground-truthing sites that did not match the mapping classification, but were positioned near the boundary of two habitat features and the distance to the closest matching mapping category was less than the spatial accuracy of the mapping (±2 m).

The mapping ground-truthing in future years will seek to address these issues by increasing the range of habitat categories ground-truthed at some regions (e.g. Point Richards) and locating ground-truthing sites at distances >2 m from the boundary between different habitat types.

Table 2. Summary of overall mapping accuracy (see Appendix 1 for error matrices).

Aerial assessment region	Ground-truthing sites correctly classified in mapping	Total ground-truthing sites	Overall mapping accuracy (%)
Altona	15	15	100
Blairgowrie	23	25	92
Curlewis Bank	9	9	100
Kirk Point (inner)	3	3	100
Mud Islands	13	13	100
Point Henry West	12	12	100
Point Richards	15	26	58
St Leonards	3	6	50
Swan Bay	10	13	77

Historical seagrass mapping comparison

Blairgowrie

The total percent seagrass cover at Blairgowrie in April 2008 (6%) was above the criteria for expected variability in percent cover for both the decadal and year to year scales (Ball and Heislers 2008). The percent seagrass cover in 2008 compared with historical data since 1956 is shown in Figure 14.

The logit transformed value for percent seagrass cover at Blairgowrie in 2008 was -2.757. This was also above the criteria for expected variability in percent cover on both the decadal and year to year scale (Ball and Heislers 2008)). The logit transformed trends in percent seagrass cover are shown in Figure 15.

On the basis of these results the changes in shallow seagrass cover observed at the Blairgowrie region during the reporting period for 2008 were within expected variability.

Other regions

Total percentage seagrass cover at six of the nine aerial assessment regions since 2000 is shown in Table 3. Seagrass cover varied temporally across the regions.

Seagrass cover at:

- Swan Bay remained above 90%
- Mud Island declined from 54% in 2000 to 42% in 2006 and then remained stable
- St Leonards fluctuated between 24% and11%
- Kirk Point overall region and inner zone fluctuated with an overall increase. Seagrass cover for the overall region and inner zone followed a similar pattern between 2000 and 2007.
- Blairgowrie and Point Richards declined.

Table 3. Percentage of total seagrass cover at the nine aerial assessment regions in Port Phillip Bay for 2000–08; NA, not available.

	Total seagrass cover (%)[1]									
Year	**Altona[2]**	**Blairgowrie[3]**	**Curlewis Bank**	**Kirk Point (all)[3]**	**Kirk Point (inner)[3]**	**Mud Islands**	**Point Henry West[4]**	**Pt Richards[3]**	**St. Leonards**	**Swan Bay[3]**
2000		30		46	19	54		63	24	97
2001									24	95
2002										
2003		12							17	94
2004						46			11	95
2005		8		84	74			20		
2006		7		72	57	42		15	23	95
2007		7		95	92	44		14		99
2008	NA	6	94		78	42	88	8	12	98

[1]total seagrass cover includes patchy seagrass categories

[2]total vegetation cover at Altona in 2008 was 31%, consisting of predominantly medium-dense macroalgae mixed with spare and sparse patchy seagrass. The proportion of seagrass as a percentage of total vegetation cover could not be determined.

[3]2000–07 data from Ball *et al.* (in prep.)

[4]Approximately 11% of the Point Henry West region consisted of dense-medium patchy macroalgae with seagrass.

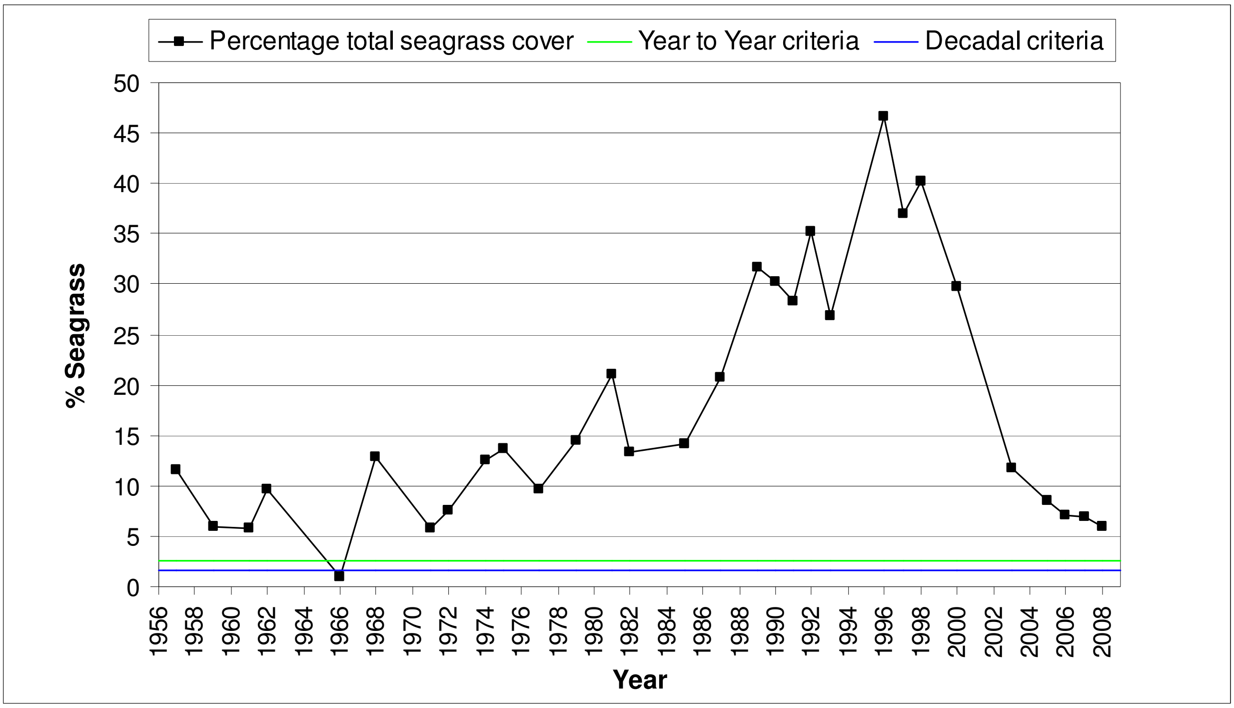


Figure 14. Percentage seagrass cover at Blairgowrie aerial assessment region 1957–2008 (1957–99 data from Jenkins *et al.* (2000); 2000–07 data from Ball *et al.* (in prep)); decadal and year to year criteria values for 2008 shown as blue and green lines respectively.

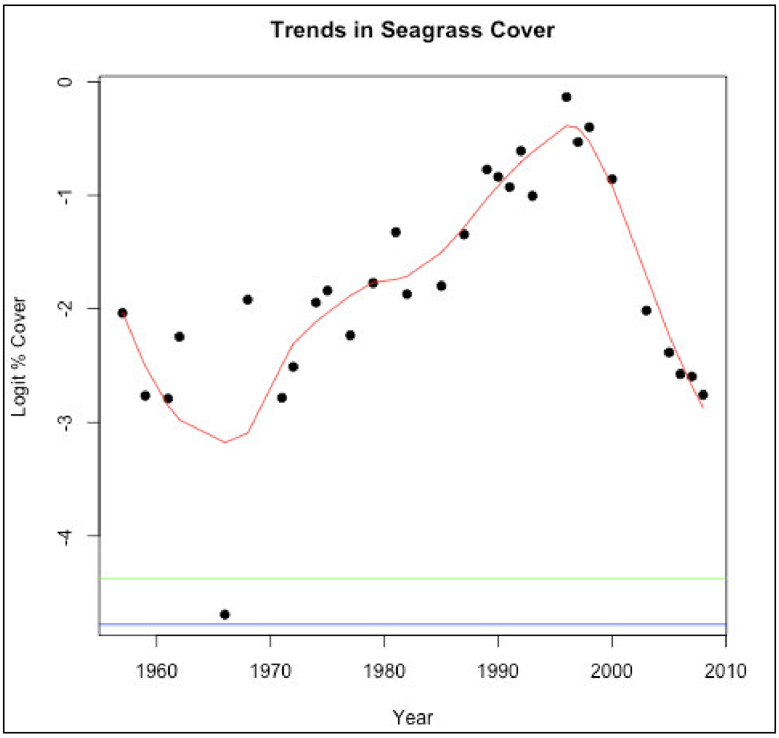


Figure 15. Trends in seagrass cover (logit transformed % cover) at Blairgowrie aerial assessment region; decadal and year to year criteria values for 2008 shown as blue and green lines respectively (graph produced by Emphron Informatics Pty Ltd).

Seagrass Health

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

Subtidal

Seagrass cover

Heterozostera nigricaulis seagrass cover varied significantly between regions for shallow (ANOVA; $F_{5,133}$=270; P<0.001) and deep ($F_{3,88}$=212; P<0.001) subtidal plots (Figure 16). There were strong statistical interactions between time and region for both the shallow ($F_{5,133}$=22.5; P<0.001) and deep ($F_{3,88}$=35.4; P<0.001) plots. This indicates that temporal differences in cover between autumn and winter 2008 varied between regions.

Tukey's HSD *post-hoc* statistical comparisons showed that seagrass cover in the shallow subtidal plots at the Blairgowrie, Mud Islands and Swan Bay 1 was significantly greater (P<0.05) than that recorded at Kirk Point, Point Richards and St Leonards.

Seagrass cover in the shallow plots increased significantly at Blairgowrie, Mud Islands and Swan Bay 1 between autumn and winter 2008 (Figure 16). *Heterozostera nigricaulis* cover remained low at St Leonards and Kirk Point, and disappeared at Point Richards. *Heterozostera nigricaulis* cover in the deep plots increased at Mud Islands.

Seagrass length

Heterozostera nigricaulis seagrass length varied between regions within shallow (ANOVA; $F_{5,133}$ = 218; P<0.001) and deep ($F_{3,88}$=32.3; P<0.001) plots (Figure 17).

Seagrass length at the shallow plots was significantly greater at Blairgowrie, Mud Islands and Swan Bay 1 in comparison with Kirk Point, Point Richards and St Leonards (Tukey's HSD *post-hoc* test). There were statistical interactions between time and region for shallow ($F_{5,133}$=67; P<0.001), but not deep ($F_{3,88}$=1.6; P>0.05) plots. This indicates that the magnitude of temporal differences in length varied between regions amongst shallow plots.

Seagrass length in the shallow plots increased significantly at Blairgowrie between autumn and winter 2008, but decreased significantly at Kirk Point, Point Richards and St Leonards. The reduction in seagrass length at Point Richards was due to the loss of seagrass in this plot.

Stem density

Shooting stem density varied significantly between regions within shallow (ANOVA; $F_{5,133}$ = 459; P<0.001) and deep ($F_{3,88}$=230; P<0.001) subtidal plots (Figure 18). There were statistical interactions between time and region for both the shallow ($F_{5,133}$=6.3; P<0.001) and deep ($F_{3,88}$=15.9; P<0.001) plots. This indicates that regional differences in shooting stem density varied between sampling times.

There were no statistically significant changes in shooting-stem counts between autumn and winter 2008 within the shallow plots. Significant reductions in shooting-stem counts were recorded within the deep plots at Point Richards between autumn and winter. Where non-shooting stems had previously dominated in autumn at the Point Richards shallow plot and St Leonards shallow and deep plots, few were present in winter.

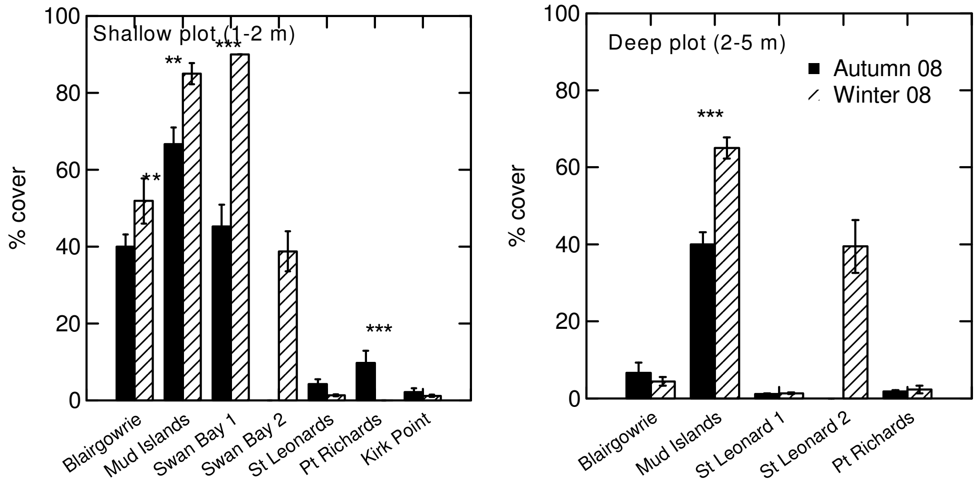


Figure 16. Mean (± se) seagrass cover (%) for *H. nigricaulis* at shallow and deep subtidal plots sampled in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), ***P*<0.01 and ****P*<0.001.

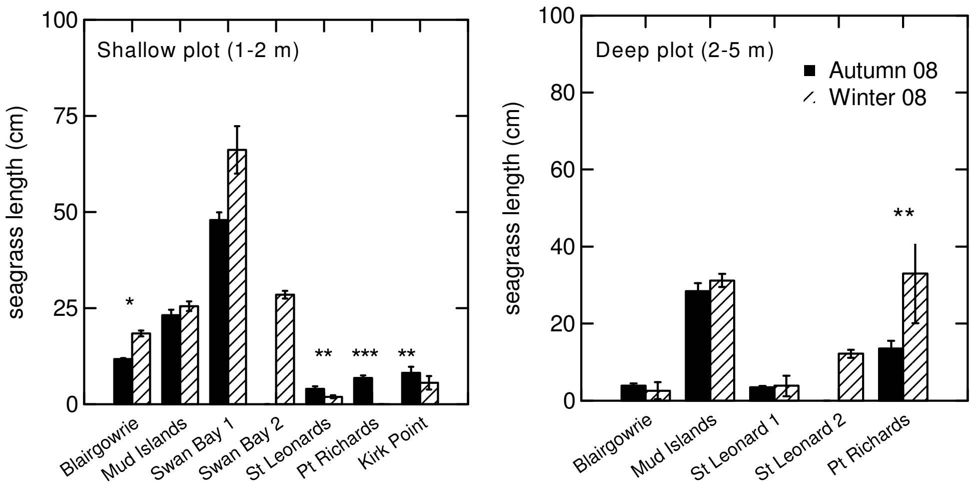


Figure 17. Mean (± se) seagrass length (cm) for *H. nigricaulis* at shallow and deep subtidal plots sampled in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), **P*<0.05, ***P*<0.01 and ****P*<0.001.

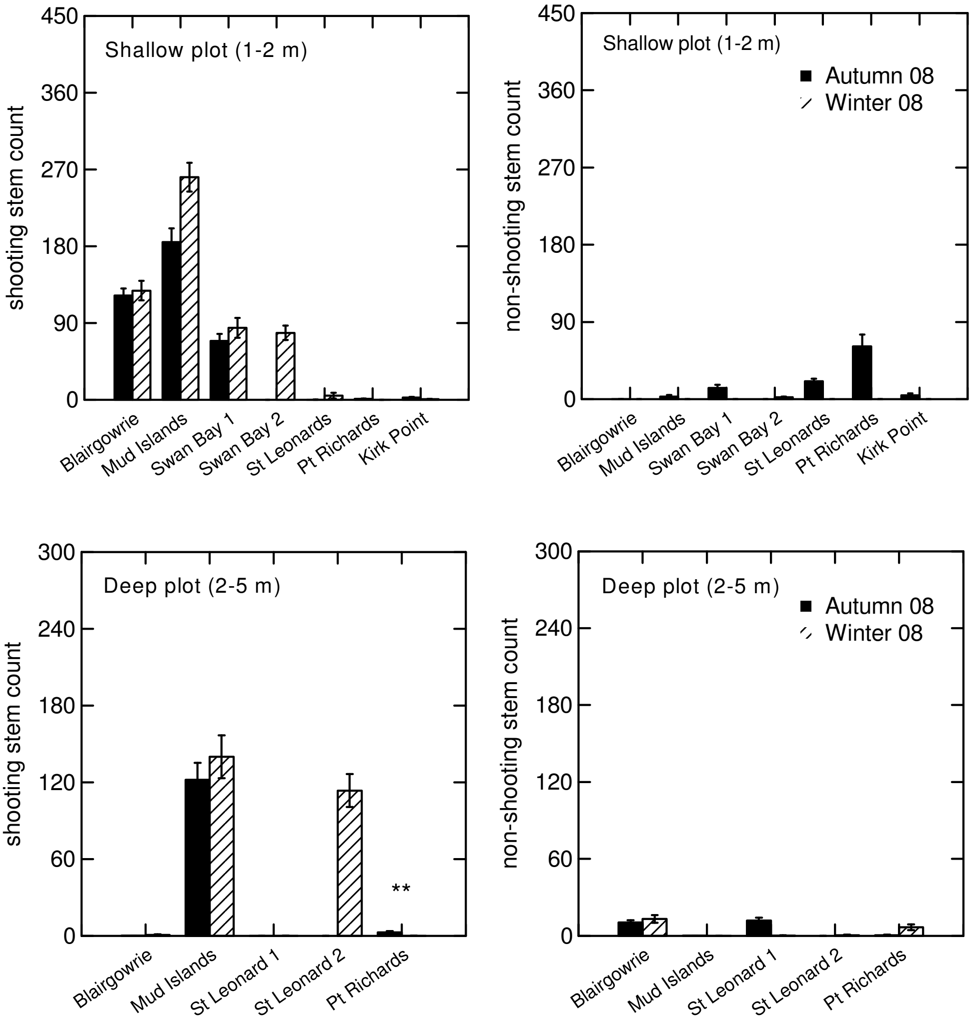


Figure 18. Mean (± se) shooting and non-shooting stem density per 0.0625 m^{-2} for *H. nigricaulis* at shallow and deep subtidal plots sampled in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), ***P*<0.01.

Intertidal

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 *L. marina*. *Zostera muelleri* was more abundant in the Mud Islands plot, whereas the Swan Bay plot was dominated by *L. marina* (Figure 19A). *Zostera muelleri* was the only seagrass species present at Point Richards and St Leonards.

Seagrass cover (*Z. muelleri* and *L. marina* combined) varied significantly between regions (ANOVA; $F_{3,88}$=58.9; P<0.001) (Figure 19B). There were statistical interactions between time and region for seagrass cover ($F_{3,88}$=4.9; P=0.002) and shoot density ($F_{3,88}$=6.2; P<0.001) but not length ($F_{3,88}$=0.9; P>0.05). This indicated that where autumn and winter samples varied for these variables this pattern varied between regions.

Intertidal seagrass cover did not change significantly between autumn and winter 2008, except for Point Richards where cover declined by 50%. Seagrass length did not vary significantly between autumn and winter (Figure 19C). Shoot density decreased significantly at St Leonards and Point Richards, and increased significantly at Mud Islands between autumn and winter (Figure 19D).

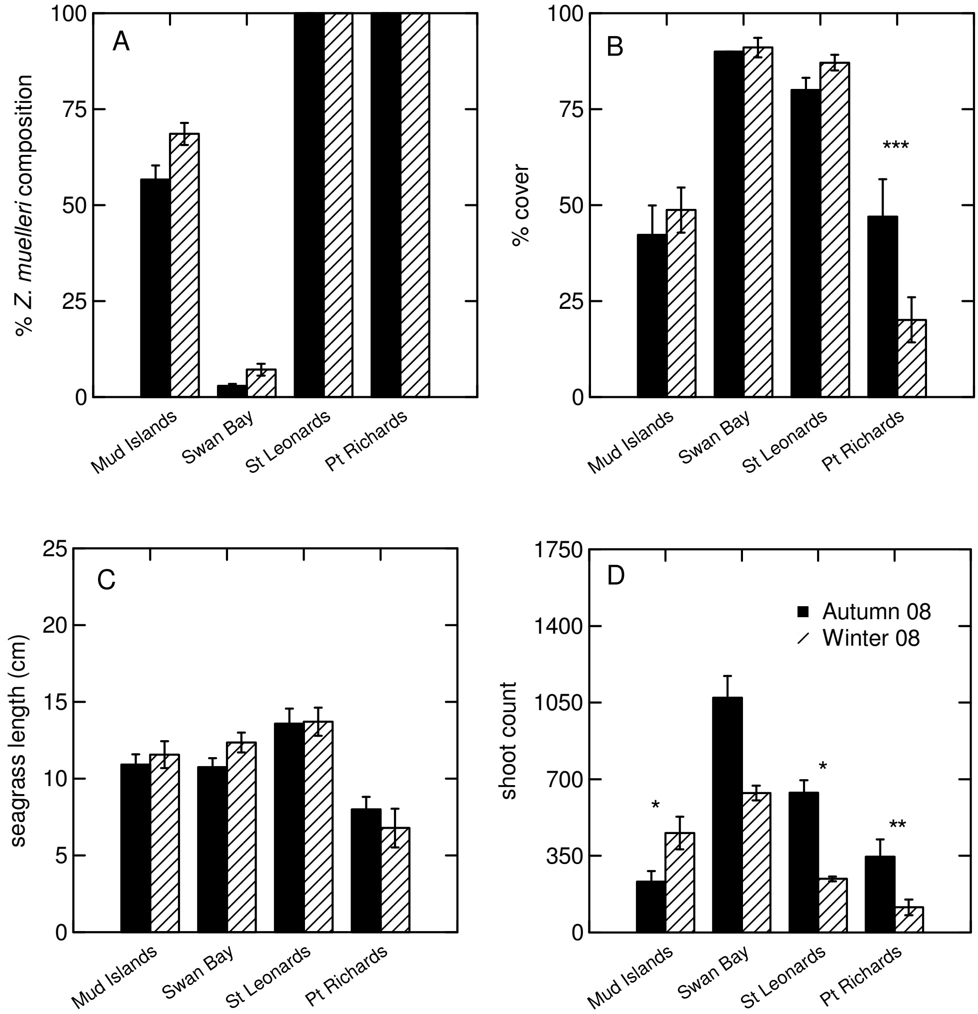


Figure 19. Mean (± se) A) *Z. muelleri* composition (%), B) seagrass cover (%), C) length, and D) shoot density 0.0625 m^{-2} for intertidal plots sampled in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), *$P<0.05$, **$P<0.01$ and ***$P<0.001$.

Intertidal seagrass upper limits

Spatial changes in the upper boundaries of the intertidal seagrass monitoring lines at St Leonards were <1 m between the autumn and winter 2008 sampling events. Spatial changes in the upper boundaries of the intertidal seagrass monitoring lines at Mud Islands were mostly <2 m, with a maximum change of 2.6 m on line 1. Differences in spatial position and orientation of the intertidal upper seagrass boundaries at St Leonards and Mud Islands were mostly less than the spatial accuracy of the Thales mobile mapper (±2 m).

At Point Richards, the change in the upper boundaries between autumn and winter was a maximum distance of 2.4 m on line 1. On Line 2, seagrass moved offshore by 1.5–5 m. Seagrass changes on Line 3 were <1 m. The western end of the line was buried by sand reducing its length from approximately 21 m to 7 m. The western end of the backup monitoring line 4 was also subject to sand burial reducing its length from approximately 22 m to 8 m, and the upper limit of the remaining intertidal seagrass also moved offshore by distances of up to 5 m.

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 20–25. 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 atttentuation data.

Turbidity data were available for Blairgowrie, Mud Islands, St Leonards, Kirk Point and Point Richards. Turbidity levels at these regions were <5 NTU at 12 noon throughout the winter 2008 deployment period (July-September), except for Point Richards, where two spikes in turbidity to about 15 NTU in late June–early July coincided with peaks in light attenuation.

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 data excluded from the analysis due to problems with the operation of the light logger or associated wiper systems. The perfomance of the light loggers is discussed in Appendix 2.

Mean attenutation coefficients for regions in the southern part of PPB were typically in the range 0.2–0.4 m^{-1}. With the exception of Swan Bay, attenuation coefficients at most regions rarely exceeded 0.5 m^{-1}. The mean daily K_d for Swan Bay between July and September 2008 was 1.1 m^{-1} (Table 4), and ranged between 0.6–2.2 (Figure 23).

Table 4. Mean daily light attenuation coefficients (K_d) and % surface irradiance at depths of shallow (2 m) and deep plots (5 m) from 10am–2pm calculated for each region for the period July-September, 2008.

Region (Light logger)	Lower logger depth (m)	Distance to shallow plot (km)	Distance to deep plot (km)	Mean Kd (m^{-1}) Apr-Jun	Mean Kd (m^{-1}) Jul-Sep	Mean daily % irradiance at 2 m Jul-Sep	Mean daily % irradiance at 5 m Jul-Sep	Total days Jul-Sep	Notes
Point Richards (Aquaculture zone pile)	4.0	1.3	0.07	0.2	0.4	48	18	72	Jul-Sep data excludes 7 Sep onwards due to fouling of lower logger sensors.
Kirk Point (Long Reef)	3.0	4.5	NA	0.3	0.3	53	NA	75	Jul-Sep data excludes 4 Sep onwards due to possible fouling of logger sensors.
Blairgowrie (speed restriction pile)	2.7	0.7	0.08	0.2	0.2	67	38	67	
Blairgowrie (Sorrento Channel No. 10)	5.4	0.7	0.5	0.2	0.3	58	28	78	
Mud Islands (North West MNP pile)	3.2	1.2	5	0.2	0.2	69	40	31	Apr-Jun mean Kd excludes 9-25 June due to possible fouling of light sensors. Jul-Sep data excludes 5 August onwards due to fouling of light sensors.
Mud Islands (South East MNP pile)	2.0	2.5	2.4	0.2	0.2	77	52	46	Apr-Jun data excludes 1 June onwards due to bad data (possible fouling) Jul-Sep data excludes 23 Aug onwards due to lower wiper failure.
St. Leonards (Coles Channel No. 5)	5.0	0.8	0.4	0.4	0.3	53	23	55	Jul-Sep: no data was recorded 8–23 Aug while logger/wipers were repaired
St. Leonards (Coles Channel No. 3)	4.2	2.1	2.3	NA	0.3	55	24	30	Apr-Jun mean Kd excludes 11 June onwards due to unreliable data Jul-Sep data excludes 14 Aug onwards due to failure of upper logger.
Swan Bay (MNP pile south east of jetty)	1.3	0.5	NA	2.3	1.1	15	NA	75	Apr-Jun Kd values were unreliable (see Milestone Report No. 1)

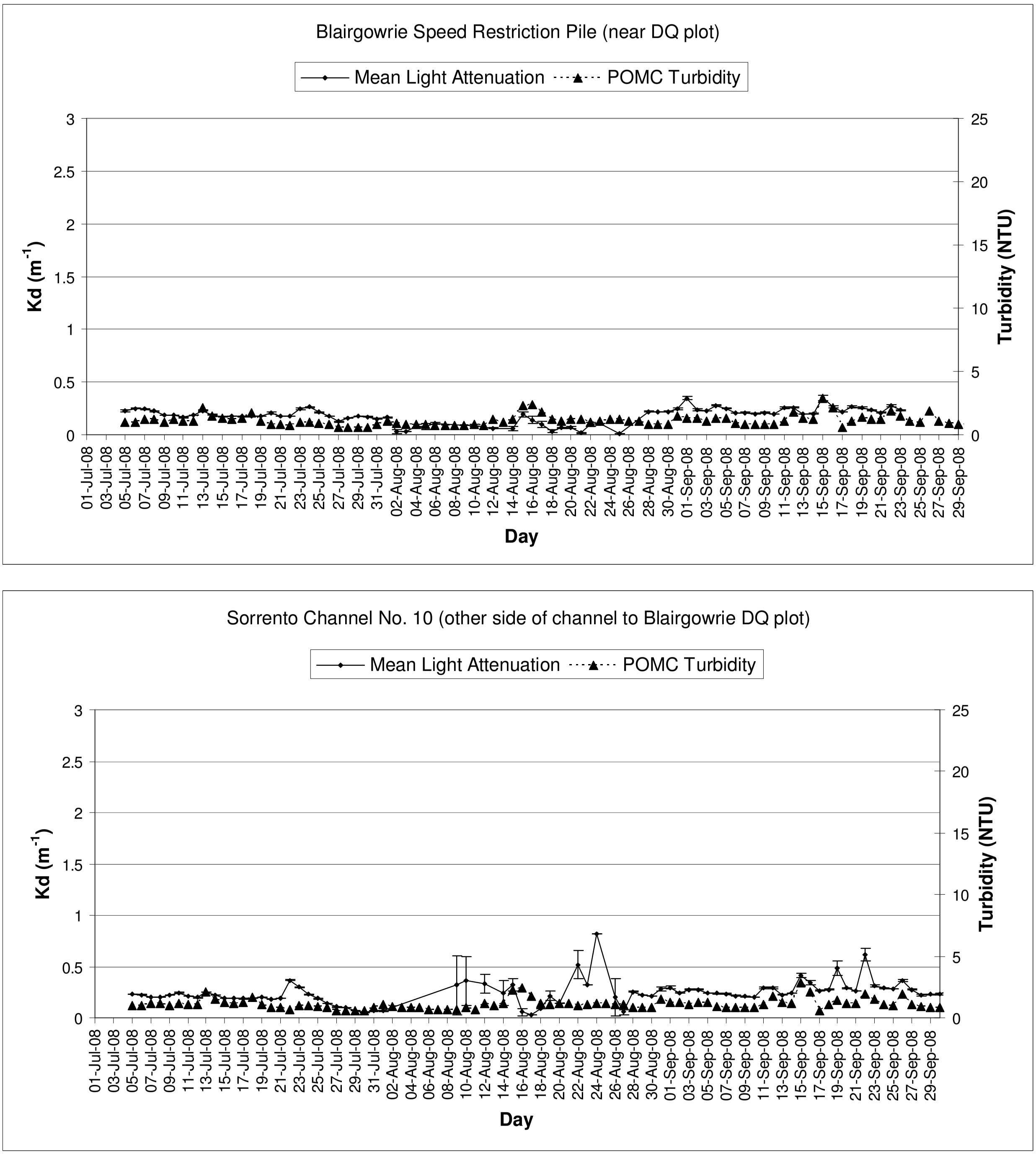


Figure 20. Mean (± se) light attenuation coefficients (m^{-1}), calculated daily between 10am and 2pm, and turbidity at Blairgowrie (two sites) for the period July-Sept., 2008; PoMC turbidity data from Camerons Bight monitoring station.

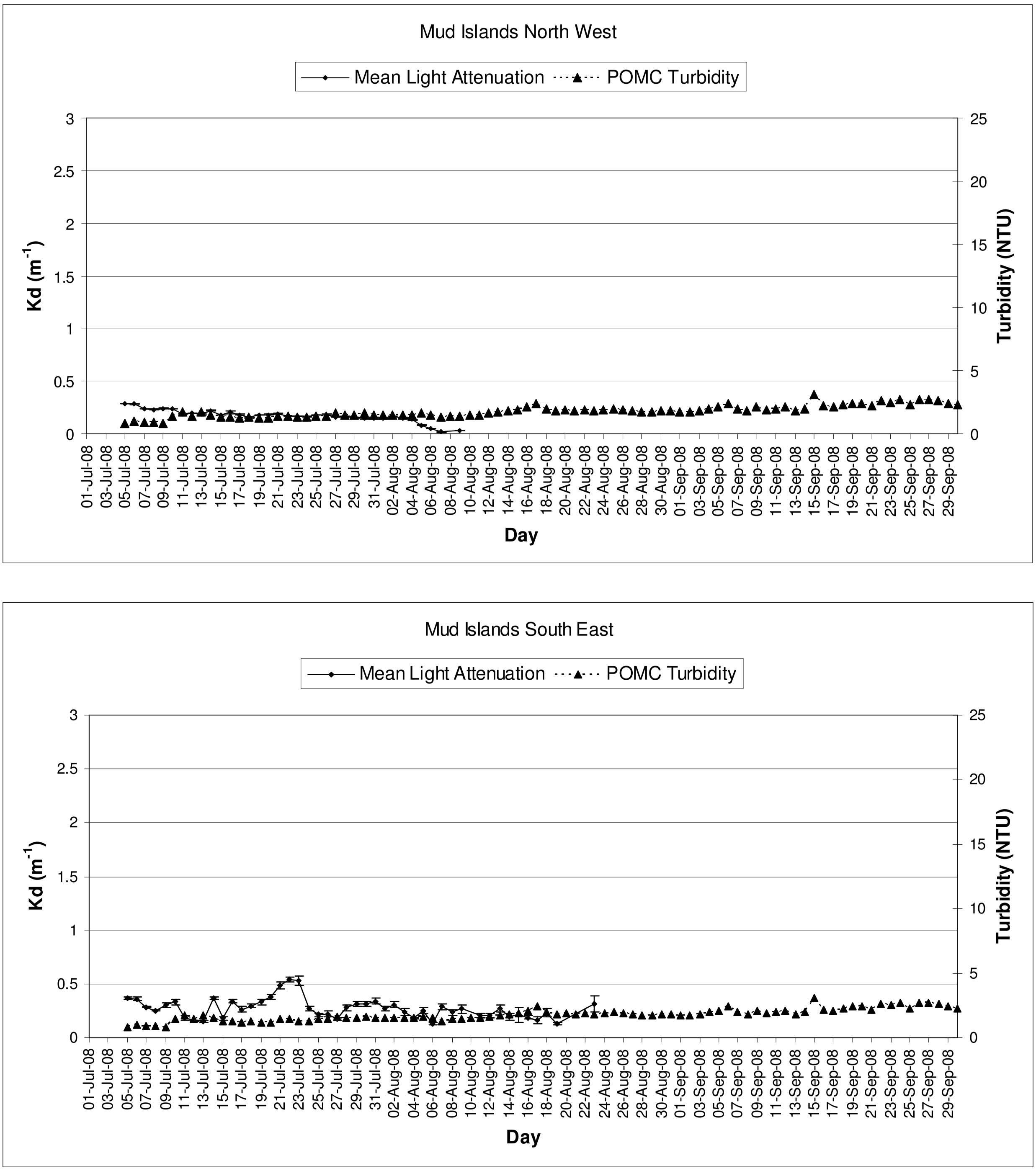
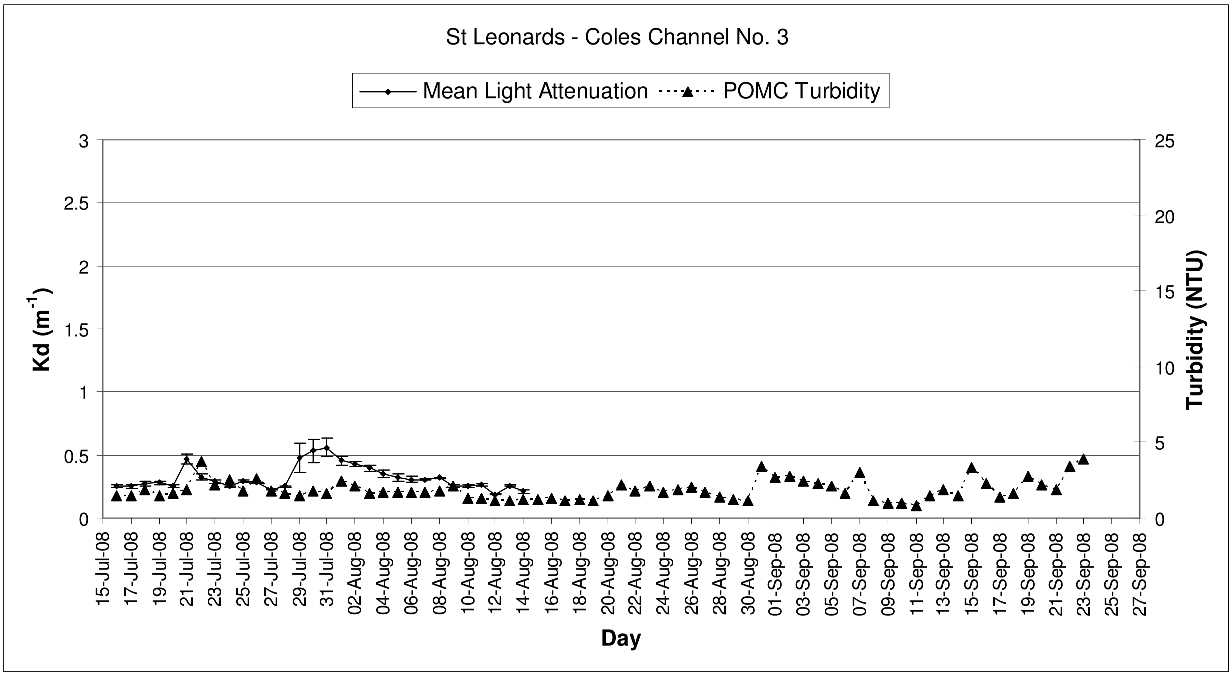


Figure 21. Mean (± se) light attenuation coefficients (m^{-1}), calculated daily between 10am and 2pm, and turbidity at Mud Islands (two sites), for the period July-Sept., 2008; data after 23 August at south east MNP pile excluded, and no usable data recorded at north west pile after 5 August (see Appendix 2); PoMC turbidity data from Mud Islands monitoring station.



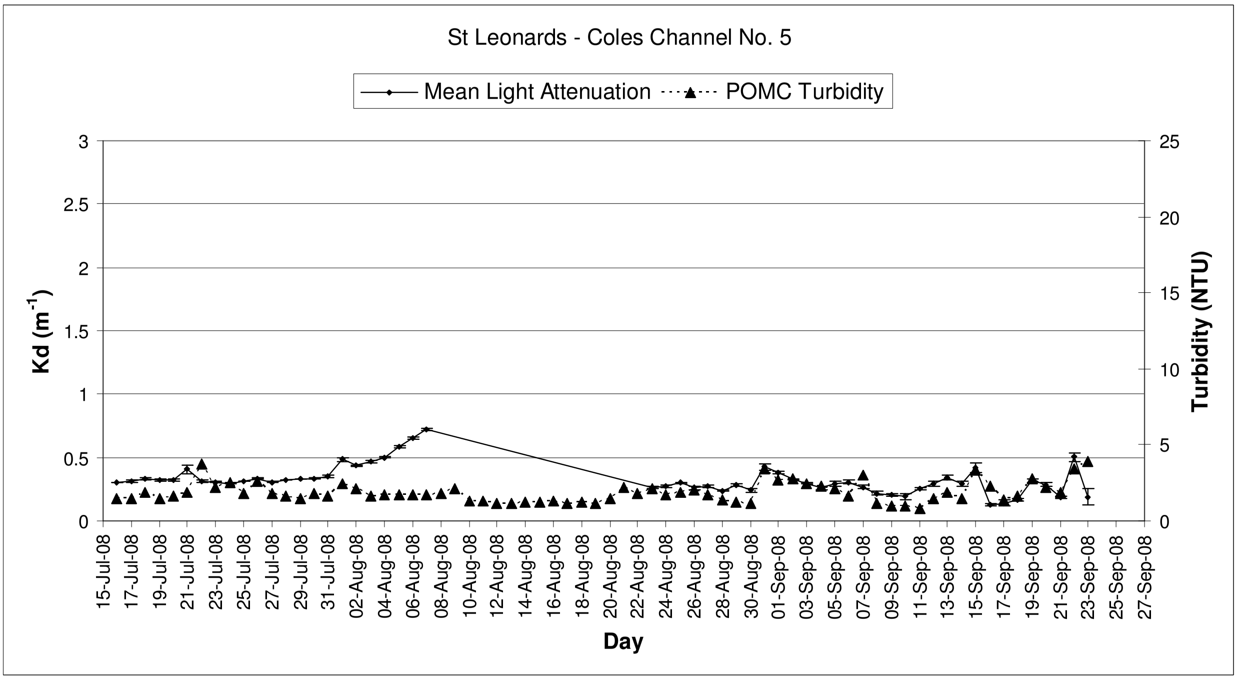


Figure 22. Mean (± se) light attenuation coefficients (m^{-1}), calculated daily between 10am and 2pm, and turbidity at St Leonards (two sites) for the period July-Sept., 2008; no loggers were deployed at Coles Channel No. 5 during 8–23 August (see Appendix 2); PoMC turbidity data from Swan Bay (Coles Channel) monitoring station.

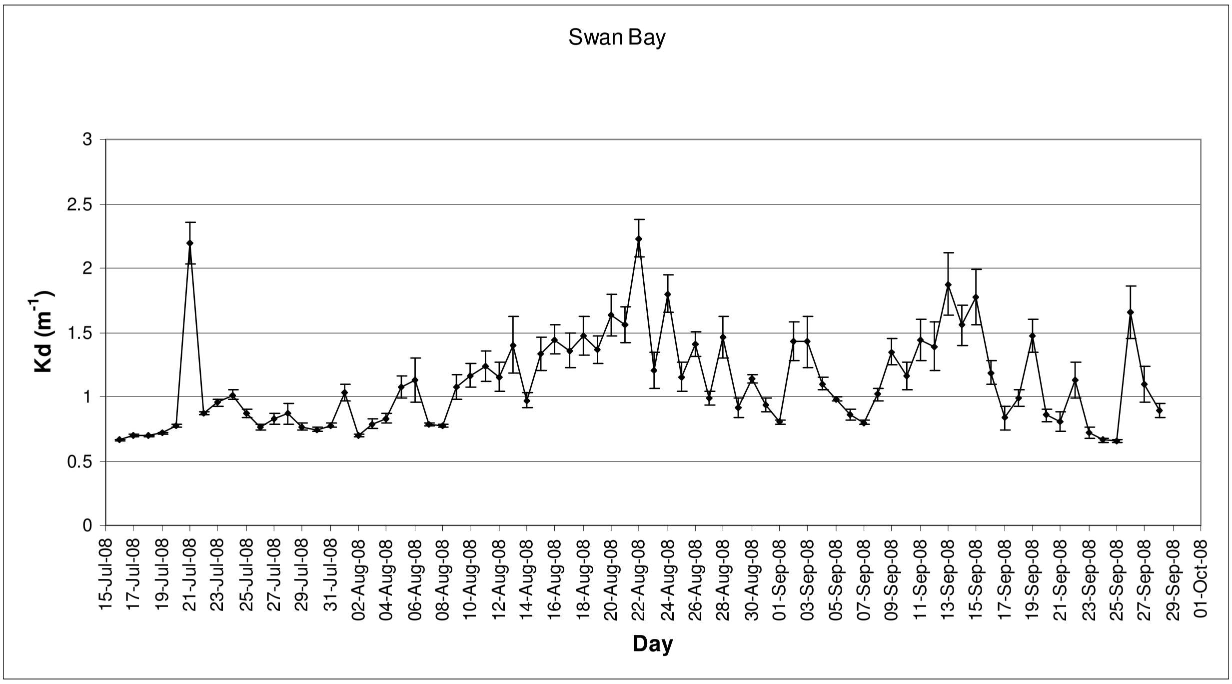


Figure 23. Mean (± se) light attenuation coefficients (m^{-1}), calculated daily between 10am and 2pm, at Swan Bay for the period July-Sept., 2008.

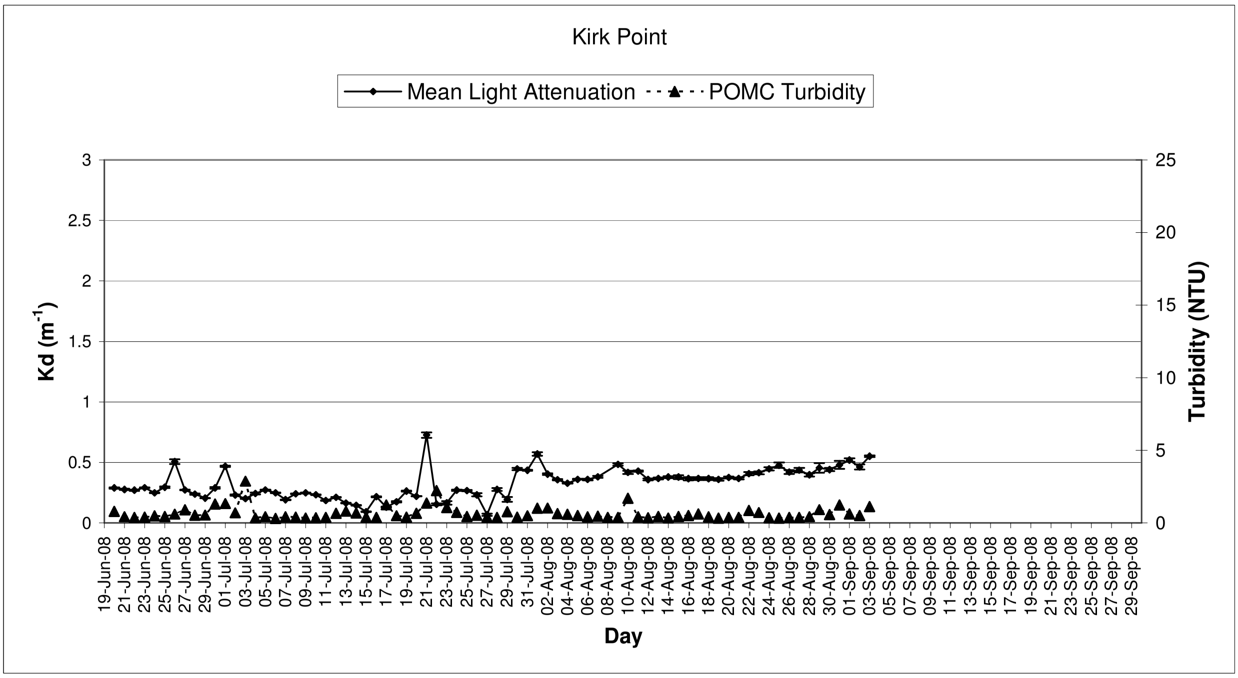


Figure 24. Mean (± se) light attenuation coefficients (m^{-1}), calculated daily between 10am and 2pm, and turbidity at Kirk Point for the period June-Sept., 2008; data after 3 September excluded (see Appendix 2); POMC turbidity data from Kirk Point monitoring station.

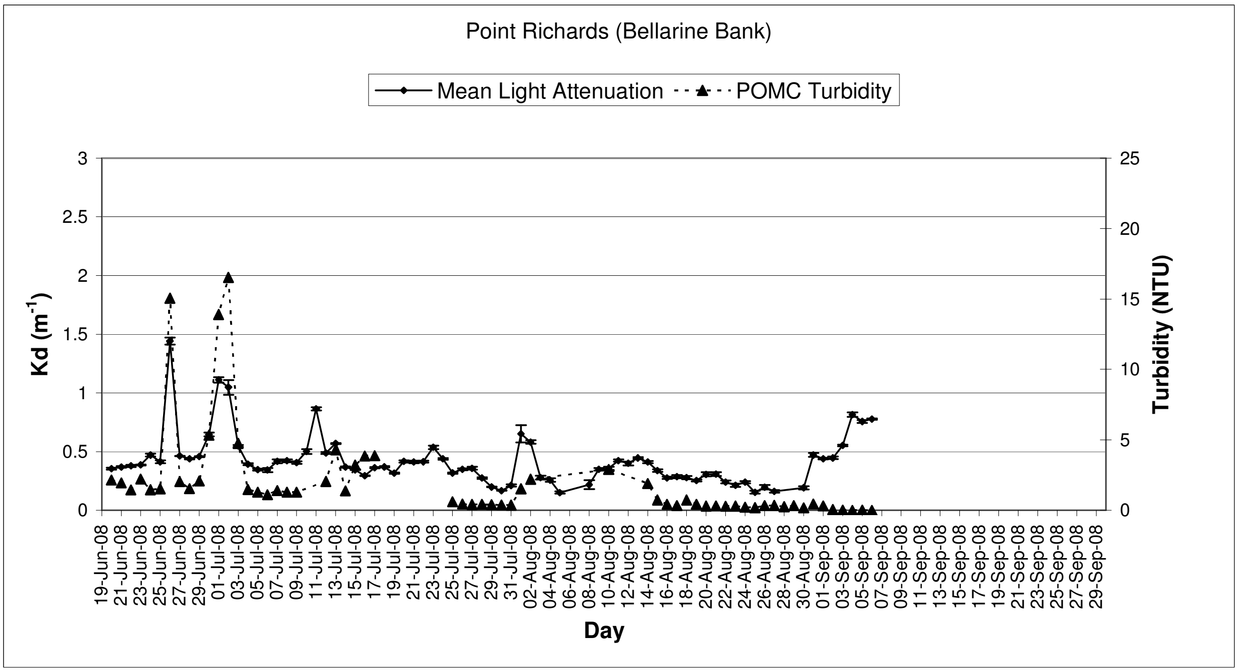


Figure 25. Mean (± se) light attenuation coefficients (m^{-1}), calculated daily between 10am and 2pm, and turbidity at Point Richards for the period June-Sept., 2008; data after 6 September excluded (see Appendix 2); POMC turbidity data from Point Richards monitoring station.

Epiphytes

Epiphytic turfing algal cover on *H. nigricaulis* leaves varied significantly between regions amongst shallow (ANOVA; $F_{5,133}$=9.5, P<0.001) and deep ($F_{3,88}$=353.7, P<0.001) subtidal plots (Figure 26). At Mud Islands, turfing algae increased significantly to cover >50% of leaf area at the deep plot, and decreased significantly at the shallow plot between autumn and winter 2008. Over the same period turfing algal cover increased significantly at the Blairgowrie shallow plot. Turfing algal cover was low amongst the other plots surveyed with the exception of the St Leonards 2 deep plot, where turfing algae covered 40% of the leaf area in winter.

Encrusting epiphytic algae cover of *H. nigricaulis* leaf area varied significantly between regions amongst shallow (ANOVA; $F_{5,133}$=45.5, P<0.001) and deep ($F_{3,88}$=13.0, P<0.001) subtidal plots (Figure 27). Encrusting algal cover decreased significantly at the shallow Mud Islands and Swan Bay 1 plots, and increased significantly at the shallow Blairgowrie plot between autumn and winter 2008. During the same period encrusting algae decreased in cover at the deep Mud Islands plot (Figure 27).

No consistent temporal pattern in epiphytic macroalgal cover was observed between autumn and winter 2008 (Figure 28). Epiphytic macroalgal cover increased significantly at the shallow Swan Bay 1 and deep Blairgowrie subtidal plots between autumn and winter, and decreased at Mud Islands. Low macroalgal cover at St Leonards, Point Richards and Kirk Point shallow plots in winter coincided with low seagrass cover at these regions (Figure 16).

Epiphytic turfing and encrusting algae covered <3% of *Z. muelleri* leaf area in the intertidal plots (Figure 29). Epiphytic macroalgal cover increased significantly at Mud Islands and Swan Bay between autumn and winter 2008. It covered <15% of the quadrat area in these regions (Figure 30).

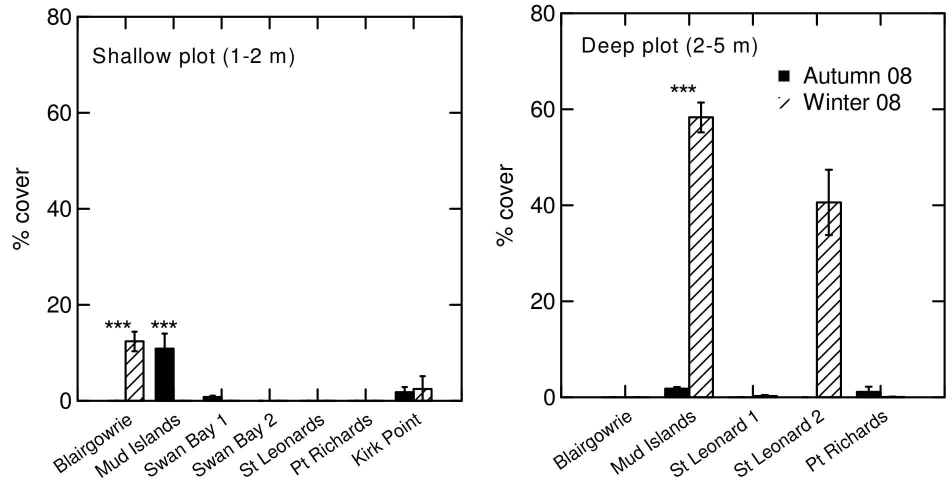


Figure 26. Mean (± se) epiphytic turfing algae cover (%) of *H. nigricaulis* leaf area at shallow and deep subtidal plots in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), ****P*<0.001.

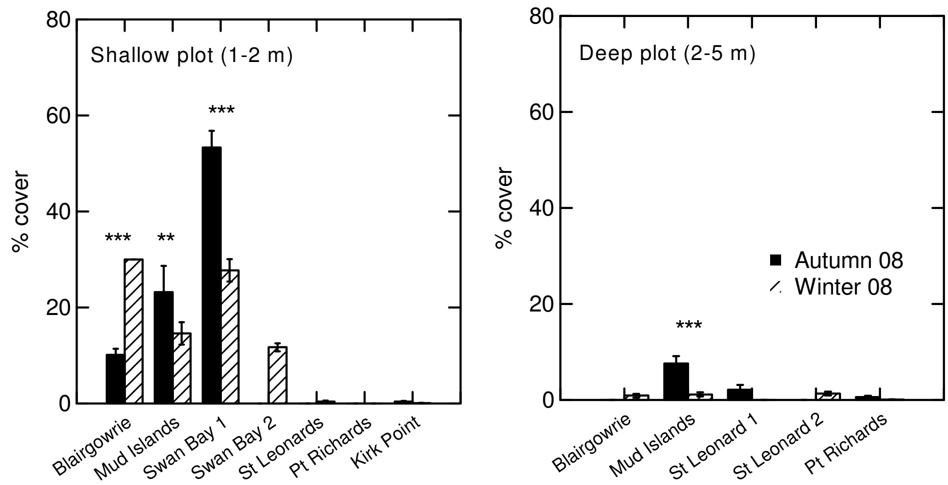


Figure 27. Mean (± se) epiphytic encrusting algal cover (%) of *H. nigricaulis* leaf area at shallow and deep subtidal plots in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), ** *P*<0.01 and ****P*<0.001.

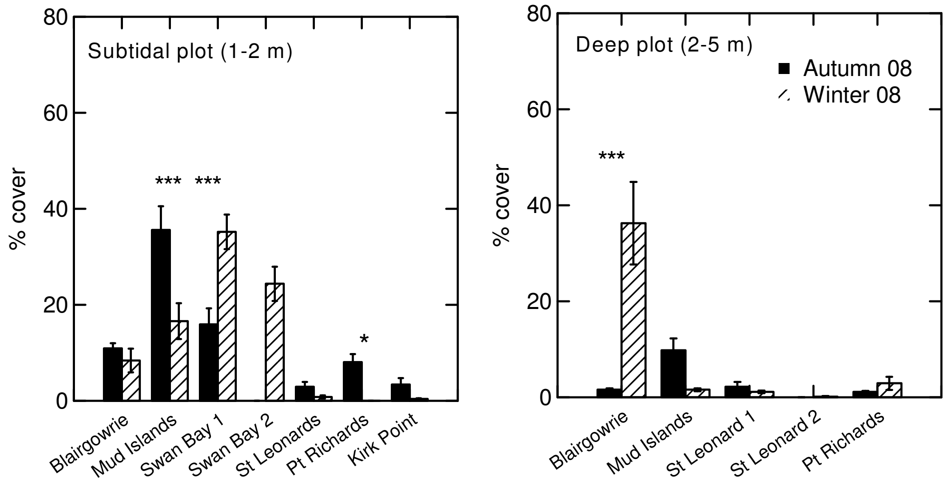


Figure 28. Mean (± se) epiphytic macroalgal cover (%) of shallow and deep subtidal seagrass plots in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), *P<0.05 and ***P<0.001.

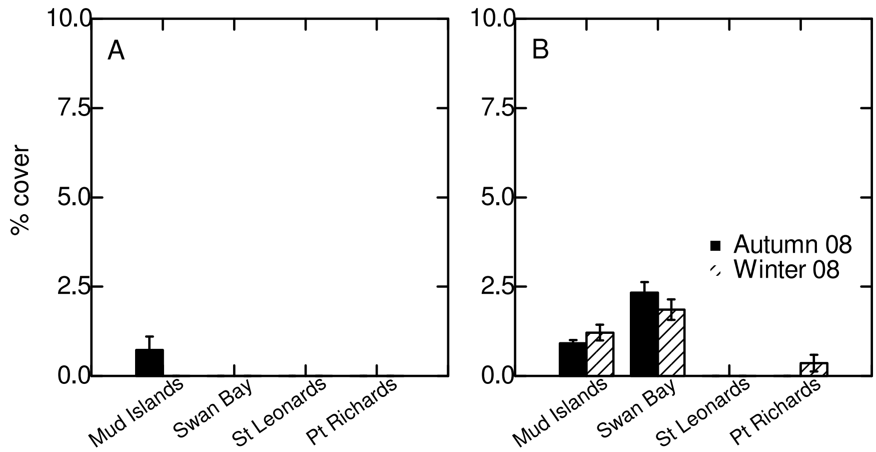


Figure 29. Mean (± se) A) turfing, and B) encrusting epiphytic algal cover (%) of *Z. muelleri* leaf area at intertidal plots in autumn (bold) and winter (hatched) 2008.

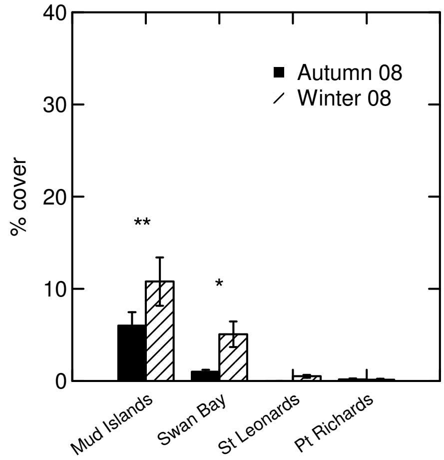


Figure 30. Mean (± se) epiphytic macroalgal cover (%) of intertidal seagrass plots in autumn (bold) and winter (hatched) 2008; significant differences between sampling dates (LSD pairwise tests), **P*<0.05.

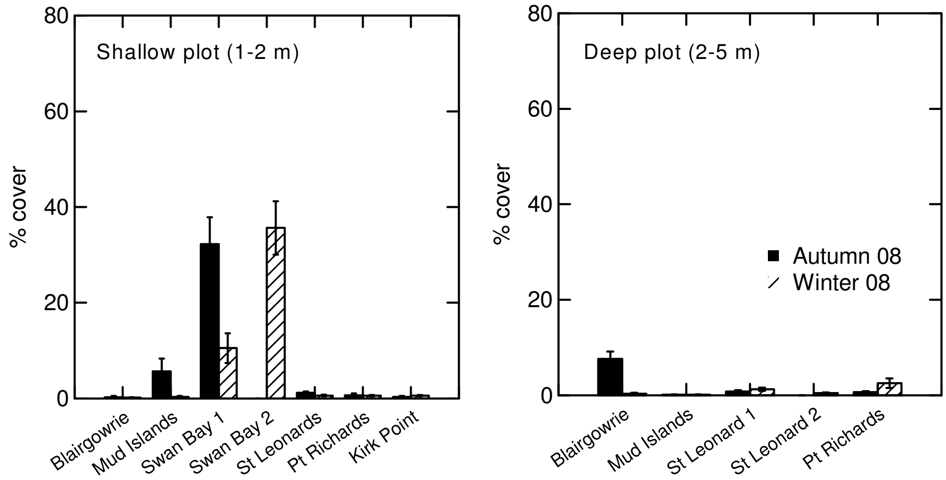


Figure 31. Mean (± se) cover (%) of drift macroalgae at subtidal plots in autumn (bold) and winter (hatched) 2008.

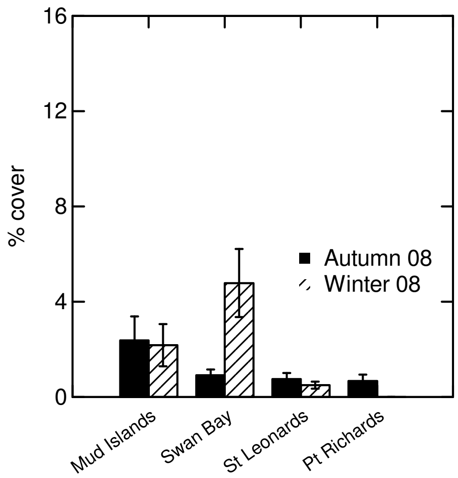


Figure 32. Mean (± se) cover (%) of drift macroalgae at intertidal plots in autumn (bold) and winter (hatched) 2008.

Other factors

Drift Algae

Drift macroalgae was abundant at the shallow Swan Bay 2 plot in winter, covering >30% of the quadrat area. Cover declined at Swan Bay 1 between autumn and winter 2008 (Figure 31). At other plots drift macroalgae comprised <10% of subtidal and intertidal plots (Figure 32).

Other Epiphytic biota

Biota such as the encrusting bivalve *E. georgiana* were patchily distributed, and accounted for 50% of the total epiphytic cover in some quadrats (e.g. St Leonards 1 deep). Overall, *E. georgiana* contributed a small percentage of the epiphytic biota on seagrass in PPB (data not shown).

Comparisons Against Historical Data

There were a number of differences between the methods used in the present study and Ball *et al.* (in prep.), the latter from which historical data (2000-07) have been sourced. These differences included the use of random rather than fixed quadrats, fewer replicates (n = 5 versus 12) and the use of destructive core sampling to count shoot/stem densities in the previous study. These differences are likely to influence the variances to a greater extent than the means (and hence the trends observed).

Seagrass health

Historical data (Ball *et al.* in prep.) showed that shallow subtidal seagrass cover, seagrass length and stem density were higher at Kirk Point and Point Richards in the recent past (Figure 33). In April 2005 seagrass covered >80% of the benthos at both regions. In August 2008 no seagrass was present at Point Richards and seagrass at Kirk Point covered <2% of the benthos. Coincident with changes in seagrass cover were reductions in seagrass length and stem density.

Shallow subtidal seagrass between April 2005 and April 2006 covered approximately 100% of the Swan Bay 2 plot (Figure 33). In April 2007 cover was 12%, and in August 2008 seagrass covered 37% of the benthos. No information was available for April 2008 (see ER2008#13).

Intertidal seagrass was present at only two of the regions where historical data was available: Point Richards and Swan Bay (Figure 34).

Intertidal seagrass cover, length and density in May and August 2008 at Point Richards were similar to past levels encountered at this plot.

Zostera muelleri dominated the Swan Bay intertidal plot in April 2005. In August 2008 the dominant seagrass species was *L. marina* (Figure 34). In May 2008 *L. marina* shoot counts were >1000 quadrat^{-1}, and in July 2008 were approximately >600 shoots quadrat^{-1}. *Zostera muelleri* length was similar to the more abundant *L. marina* between November 2005 and July 2008.

Seagrass epiphyte cover

The extent of epiphytic algal cover varied over time in shallow subtidal seagrass plots sampled on seven occasions between April 2005 and winter 2008 (Figure 35). As seagrass is now absent at the Point Richards shallow plot, historical comparisons are of limited value at this region. Epiphytic turfing and macroalgal levels in winter 2008 were low relative to past levels recorded at Kirk Point. Encrusting and macroalgal cover at Swan Bay 2 were similar to levels encountered in the past.

Raw Data

Electronic data provided with this report are summarised in Appendix 3.

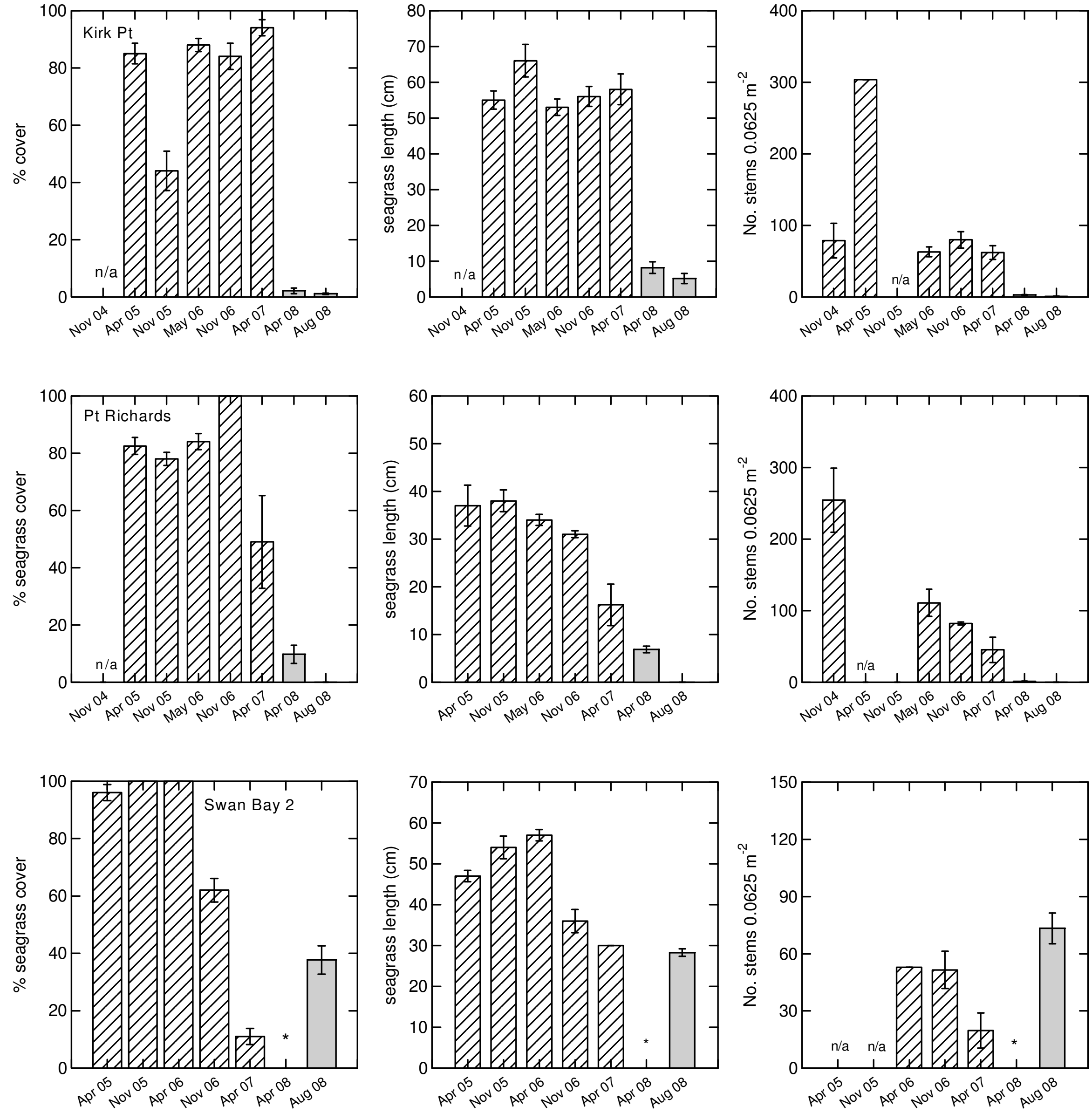


Figure 33. Mean (±se) seagrass cover (%), length and stem density for *H. nigricaulis* at Kirk Point, Point Richards and Swan Bay 2 shallow subtidal plots. Presented are data from November 2004 – April 2007 (FRB; Ball *et al.* in prep.) and the autumn and winter 2008 Baywide seagrass monitoring field assessments (depicted in grey); n/a denotes where no data were available; * denotes missing data at Swan Bay 2 in autumn 2008 (see ER2008#13).

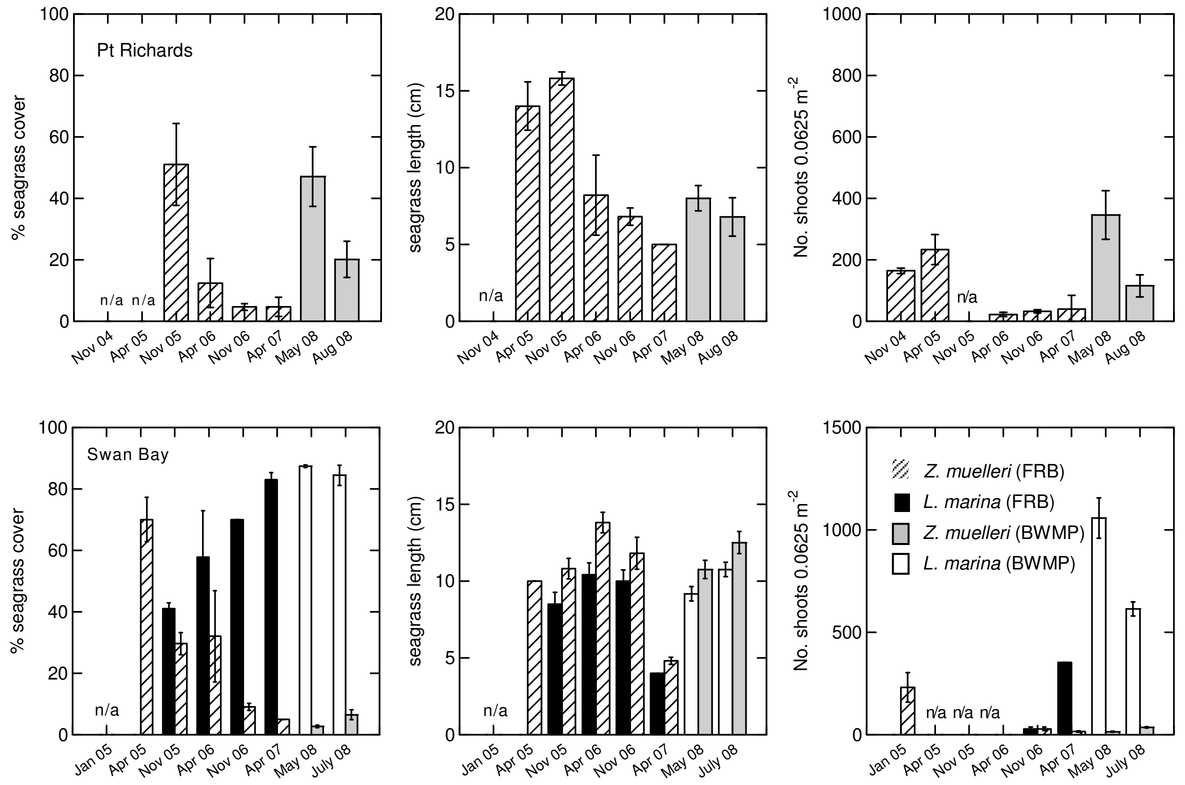


Figure 34. Mean (±se) cover (%), shoot length and density for intertidal seagrass at Point Richards and Swan Bay, November 2004 – April 2007 (FRB; Ball *et al.* in prep.) and for the autumn and winter 2008 Baywide seagrass monitoring field assessments; n/a denotes where no data were available.

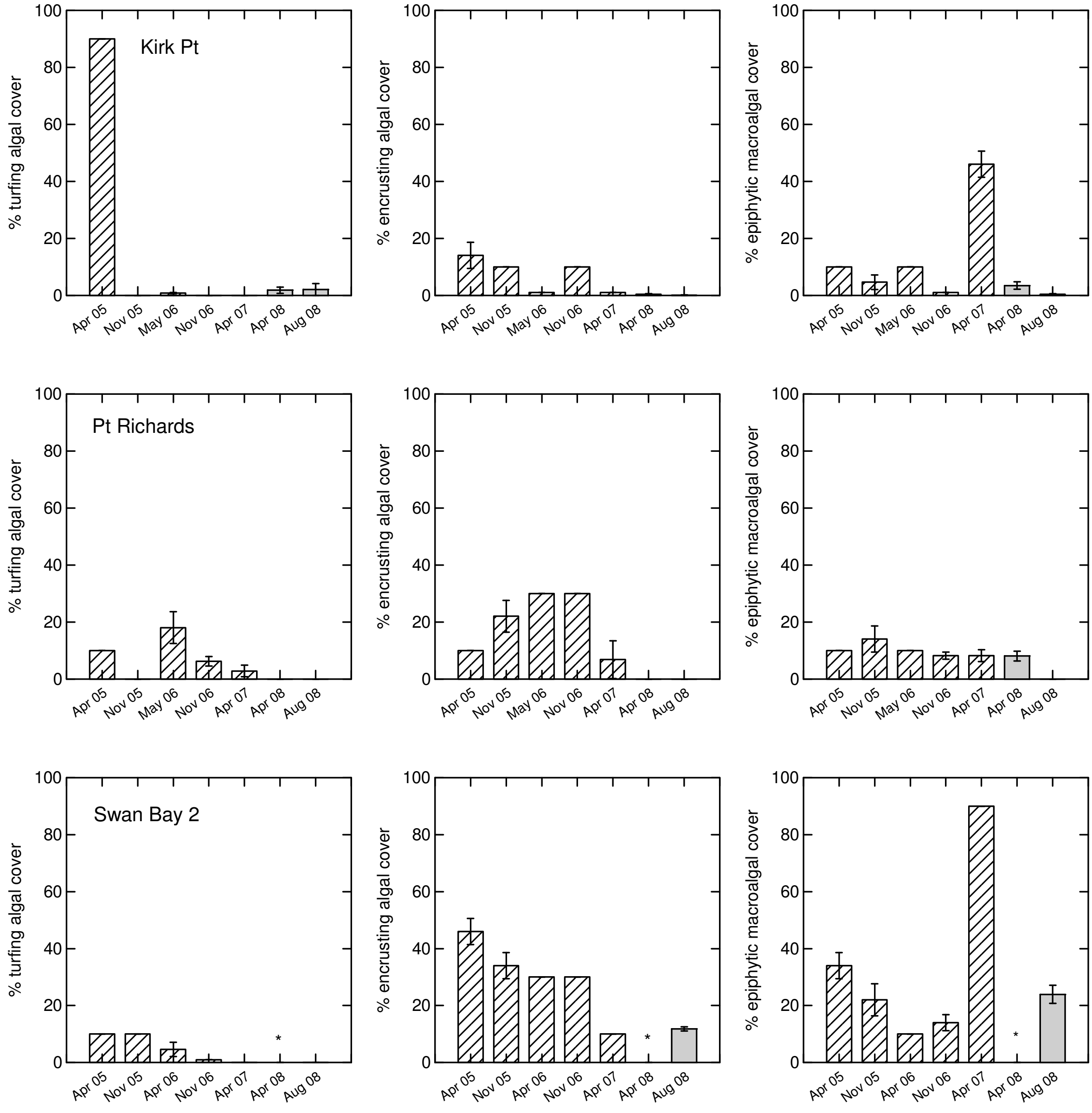


Figure 35. Mean (±se) turfing, encrusting and macroalgal epiphytic cover (%) for *H. nigricaulis* at Kirk Point, Point Richards and Swan Bay 2 shallow subtidal plots, April 2005 – April 2007 (Ball *et al*. in prep.) and for the autumn and winter 2008 Baywide seagrass monitoring field assessments (depicted in grey); *denotes missing data at Swan Bay 2 in autumn 2008 (see ER2008#13).

Discussion

This study:

1) Mapped seagrass area within regions representative of seagrass in PPB using aerial photography
2) Monitored seagrass health in autumn and winter 2008, at a finer spatial scale within each of these areas
3) Monitored the likely drivers of seagrass change (light, turbidity and epiphytes)
4) Contrasted current seagrass area and health with historical information (where available), to compare seagrass area and health with that measured in the past.

Seagrass mapping

Seagrass at Altona, Blairgowrie, Mud Islands, Point Richards and St Leonards was characterised by narrow bands of seagrass close to the shoreline at depths mostly <1.5 m. The Altona region had a higher proportion of macroalgae than the other regions. Wide expanses of bare mobile sand separated the inshore seagrass beds at these regions from sparser stands of seagrass further offshore at depths typically >5 m. Mobile sandbars fronting the inshore seagrass appeared to determine the outer boundary of shallow seagrass at these regions.

In comparison to the other regions, the Kirk Point region is partially protected by a rocky reef offshore at depths of approximately 1.5 m. This reef partly defines the outer boundary of the aerial assessment region.

Seagrass habitat at Point Henry West and Curlewis Bank was similar, forming wide and almost continuous bands of medium-dense seagrass extending from the shoreline out to depths of approximately 3–5 m.

The Swan Bay aerial assessment region had an almost total cover of seagrass of varying densities, growing over intertidal flats and in shallow depths (predominantly <1 m). Swan Bay is a shallow, protected embayment and is the only study region with extensive areas of intertidal habitat.

Total seagrass area has declined at Blairgowrie, Point Richards and Mud Islands since 2000. During the same period seagrass area remained stable at Swan Bay. Kirk Point displayed the greatest change in total cover with an overall increase in seagrass area since 2000, although the inner zone decreased between 2007 and 2008. Seagrass area at St Leonards displayed the greatest variability with seagrass area fluctuating between 2000 and 2008.

Seagrass cover at Blairgowrie increased by approximately 400% between the late 1970s and 1996 (Figure 15). By 2008 seagrass area at this region had declined to levels last seen in the 1970s. This was within statistical criteria for expected variability at decadal and year to year scales. This indicates that seagrass beds in PPB undergo periodic contraction and expansion in area.

The regions where seagrass declined since 2000 are typically exposed to greater levels of wave energy and longshore sand drift. Temporal changes in nearshore sediment transport in response to variable wind patterns (i.e. direction and intensity) may be an important influence on shallow seagrass area in southern PPB and at Point Richards (Bellarine Bank). Such climatic variability is known to influence fish recruitment at a range of temporal scales (Jenkins 2005). Seagrass beds are susceptible to smothering by sand (as observed at Point Richards) and higher sediment transport may also impede recruitment into, and colonisation of, denuded sediments adjacent to existing seagrass beds.

The Kirk Point aerial assessment region is located adjacent to the Murtcaim Drain outlet. Seagrass in this region is likely to be impacted by the discharge of freshwater and nutrients from the drain. It is possible that the increase in seagrass area in this region between 2000 and 2007 corresponds with a large reduction in flows from the Murtcaim Drain (25,372 ML annual discharge in 2000/01 reduced to 546 ML in 2006/07, Melbourne Water Western Treatment Plant discharge records).

Seagrass cover declined at the Kirk Point aerial assessment region between 2007 and 2008 without any corresponding increases in discharges from the Murtcaim Drain. The "milky" colour of the water (probably due to algal loads) visible in the April 2009 Kirk Point aerial photography (Figure 7) prevented seagrass mapping at depths >1 m. A Quickbird satellite image of the Kirk Point region captured in February 2008 also showed that the offshore region was affected by the same "milky" discolouration in the water. This indicated that poor water clarity affected the Kirk Point region over several months in early 2008 and this may have contributed to the decline in seagrass cover observed between 2007 and 2008.

Seagrass health

There were few consistent trends in seagrass health observed at the scale of individual plots. Subtidal *H. nigricaulis* cover, length and density either increased, or were unchanged, in winter relative to autumn in 2008 for locations in the southern part of PPB. Seagrass cover, length and density continued to decline at Point Richards and remained low at Kirk Point and St Leonards.

During autumn the shallow subtidal plots at St Leonards, Point Richards and Kirk Point were dominated by non-shooting stems. The video ground-truthing for the aerial mapping also showed that non-shooting stems were abundant at St Leonards and Point Richards in autumn. By winter the stems at the shallow plots had almost completely disappeared leaving a very sparse cover of shooting stems at these plots. It was unclear when monitoring began in autumn whether these stems were still alive, and whether shoots might regrow. Their subsequent disappearance indicates that these stems were dead.

Intertidal *Z. muelleri* displayed little change between autumn and winter 2008. The exception to this pattern was *Z. muelleri* at Point Richards where cover and shoot density declined significantly between autumn and winter. This pattern was also mirrored at the upper limits of intertidal seagrass at Point Richards where seagrass was buried by mobile sand bars in places.

Zostera muelleri has been almost completely replaced by *L. marina* at the Swan Bay intertidal plot between April 2005 and July 2008. It is unclear to what extent these changes in seagrass composition at the field assessment plot are representative of intertidal seagrass in Swan Bay more generally. Such changes are undetectable using aerial photography to map seagrass area, although *L. marina* was observed in the video ground-truthing at the aerial assessment region.

The aquatic macrophyte genus *Lepilaena* has a broad range of salinity tolerances and frequently occurs in estuaries, coastal lagoons and hypersaline lakes. It is unclear why *L. marina* cover has increased at the expense of *Z. muelleri* in the Swan Bay plot. *Lepilaena*'s wider salinity tolerances support a hypothesis that changes to salinity in parts of Swan Bay, coincident with drought conditions in southern Australia, may play a role.

Lepilaena marina is considered vulnerable in Victoria, due to its disjunct and poorly known distribution, and is listed as a threatened species under the Flora and Fauna Guarantee Act (1988) (DSE 2008).

Factors that affect seagrass health

Based on evidence from the literature and investigations in PPB, a light requirement of 15% of surface light appeared to be a conservative minimum annual light requirement for Zosteraceae in the south of the Bay (CEE 2007).

The percentage of surface irradiance reaching seagrass plants may be reduced by increases in water column turbidity, phytoplankton blooms and shading from epiphytic algae. Seagrasses are also subject to self-shading (Zimmerman 2006).

All regions recorded mean benthic light levels at the depth of the deep and shallow plots that either met or exceeded 15% of surface irradiance.

Turbidity levels adjacent to the seagrass assessment regions were low and within the limits outlined in the CDP Environmental Management Plan (PoMC 2008c) 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 in excess of 50% of primary productivity in seagrass meadows. In high abundance, epiphytic algae may cause excessive shading of seagrass leaves leading to reduced seagrass productivity and mortality.

No consistent change in epiphytic algal cover was observed between autumn and winter. Epiphyte cover increased at some plots in winter, but it is difficult to judge whether such increases in epiphyte loads were unusual at these regions without historical data collected in winter. Epiphytic algal cover on intertidal *Z.*

muelleri plants remained low when contrasted with subtidal *H. nigricaulis* stands.

Caution should be exercised when comparing past field observations with the current data because the historical data did not include a winter sampling event. For example, current epiphyte levels were consistent with those observed in the past at the Swan Bay 2 subtidal plot. However, it is possible that epiphyte levels may be naturally lower in winter.

Epiphytic algal cover was also low at Kirk Point and Point Richards compared with historical trends, but as seagrass cover in these plots was negligible, such historical comparisons are of limited value in assessing the current health of these seagrass beds. The decline in macroalgal cover at the shallow Point Richards subtidal plot is, at least partly, explained by the reduced cover of seagrass in this plot and the absence of any vegetative structure for attachment of epiphytic macroalgae.

Conclusions

At a large spatial scale, seagrass was observed to decline in area at a number of regions around PPB. A decrease in seagrass area was recorded at Kirk Point over the past year, while there was a net increase in seagrass cover since 2000. Seagrass area remained relatively stable at Swan Bay between 2000 and 2008. The recent historical trend at St Leonards was less certain and displayed greater variability. The large variations in seagrass area observed since 2000 are not unprecedented in PPB.

At a smaller spatial scale, seagrass displayed high variability between regions and plots and exhibited few consistent patterns between autumn and winter 2008. Seagrass health in winter 2008 and seagrass area mapped during autumn 2008 from aerial photography were within expected variability for seagrasses in PPB.

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Appendix 1

Video ground-truthing

Seagrass mapping from the aerial photography was primarily ground-truthed with underwater video. The ground-truthing sites were positioned to maximise coverage of field observations across the range of seagrass habitats present, and to target any areas of uncertain classification. Ground-truthing sites were also positioned amongst bare sediment to assist in assessing the mapping accuracy.

Some additional video sites outside the mapping regions were ground-truthed to assist with interpreting the aerial photography and where it was not possible to ground-truth the entire mapping region due to shallow depths preventing access by boat (e.g. Swan Bay, Kirk Point). Extra video sites in the deeper areas adjacent to the mapping regions at some sites also provided an indication as to whether the seagrass extended into depths beyond those able to be accurately interpreted from the aerial photography (*e.g.* Altona, Kirk Point, Point Richards and St Leonards).

Mapping error matrices

Mapping error matrices are presented in Tables 5–13. The overall accuracy of the mapping was calculated by dividing the total number of polygons correctly classified (i.e. the sum of the major diagonal), as determined by the ground-truthing, by the total number of ground-truthing sites (Congalton 1991).

The error matrices include the overall mapping accuracy, and present two methods of classifying the accuracy of individual habitat categories. In the first method, the total number of correct mapping polygons in a habitat category was divided by the total number of polygons of that category derived from the ground-truthing data (i.e. the column total). This is known as the producer's accuracy or omission error and indicates the probability of a reference polygon being correctly classified (Congalton 1991). In the second method, the total number of correct polygons in a category was divided by the total number of polygons classified in that category (i.e. the row total). This is known as the user's accuracy or commission error and indicates the probability that a polygon classified in the mapping actually represents that category on the ground (Congalton 1991).

The mapping error matrices were produced by overlaying the location of the video ground-truthing sites on the polygon mapping layers in ArcGIS. A spatial join was then used to export a table combining the video ground-truthing classification with the corresponding mapping classification at each video site. Each table was summarised in MS Excel to calculate the number of sites where the video classification matched the mapping classification.

The video ground-truthing was interpreted to identify the dominant habitat. For each seagrass site the seagrass density was recorded according to the following categories:

- Bare <1% cover
- Sparse 1–20% cover,
- Medium 21–60% cover
- Dense 61–100% cover.

For the mapping accuracy assessment, video ground-truthing sites with sparse seagrass were split into very sparse seagrass (1–10%) and sparse seagrass (11–20%) categories, as seagrass densities ≤10% are typically below the level able to be interpreted from aerial photography. Mapping polygons classified as bare sediment that intersected video ground-truthing sites classified as very sparse seagrass were treated as being correctly classified in calculating the error matrices.

Mapping accuracy assessment

Overall mapping accuracy at the nine aerial assessment regions was >85% apart from Point Richards, St Leonards and Swan Bay. The causes of the reduced mapping accuracy at these regions and limitations of accuracy assessment at Kirk Point are discussed below.

Kirk Point

While Kirk Point had a 100% overall mapping accuracy, this was based on only three ground-truthing sites (Table 8). This was due to the shallowest areas not being ground-truthed in 2008 (see Exceptions, ER2008#20). The 2008 habitat classification was consistent though with previous mapping and video ground-truthing at this region by Ball *et al.* (in prep.). The light coloured sediments at Kirk point also assisted in distinguishing bare sediment from seagrass in the aerial photography. Ball *et al*. (in prep.) reported these vegetated areas to be predominantly *H. nigricaulis* in April 2007. The medium-dense seagrass observed at video site 13 in April 2008 was unchanged from the habitat observed during the video ground-truthing undertaken in April 2007 (Figure 13D).

Point Richards

At Point Richards the overall mapping accuracy was 58%. The error matrix (Table 11) shows that the reduced overall accuracy at this region was primarily due to areas identified as medium-dense and medium-dense patchy seagrass in the ground-truthing being mapped as sparse and sparse patchy seagrass or bare sediment. Further examination of the ground-truthing showed that eight of these sites consisted of macroalgae and seagrass stems without leaves. These habitats are more difficult to distinguish in the aerial photography from bare sediment and sparse seagrass due to the absence of seagrass leaves. Four of the sites that did not match the mapping were also at the boundary between different habitats in the mapping and were within 1.5 m of a polygon with a correctly matching classification, which is within the positional error of the mapping data. These factors contributed to the low overall mapping accuracy at Point Richards.

St Leonards

St Leonards had the lowest overall mapping accuracy of 50%, although the ground-truthing consisted of six sites (Table 12) within the aerial assessment region. The three ground-truthing sites that did not match the mapping were at the boundary between different habitats in the mapping and were within 0.5 m of a polygon with a correctly matching classification, which is within the positional error of the mapping data. The overall mapping accuracy at St Leonards is therefore in reality higher than 50%.

Swan Bay

The overall mapping accuracy at Swan Bay was 77% due to some ground-truthing sites classified as sparse and sparse patchy seagrass being mapped as medium-dense and medium-dense patchy seagrass. The dark colour of underlying sediments at Swan Bay can cause areas of sparse seagrass to appear as medium-dense in the aerial photography and contributed to the misclassification of this seagrass category in places. Conversely, the error matrix (Table 13) shows that the user's accuracy for medium-dense and medium-dense patchy seagrass was 100%. This was the dominant habitat at this region and the user accuracy indicates that there was a high probability that areas mapped as medium-dense would actually be medium-dense seagrass. None of the ground-truthing sites fell within areas mapped as sparse or sparse patchy seagrass.

Table 5. Altona mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

Mapping Data	Ground-truthing Data: Medium-Dense & Medium-Dense Patchy Vegetation[1]	Ground-truthing Data: Sparse & Sparse Patchy Vegetation	Ground-truthing Data: Bare Sediment[2]	Total	User's Accuracy
Medium-Dense & Medium-Dense Patchy Vegetation	**5**	0	0	5	100%
Sparse & Sparse Patchy Vegetation	0	**0**	0	0	ND
Bare Sediment	0	0	**10**	10	100%
Total	5	0	10	**15**	
Producer's Accuracy	100%	ND	100%		**Overall accuracy 100%**

[1] consists of two ground-truthing sites with medium-dense patchy macroalgae with seagrass, one with medium-dense macroalgae with seagrass, one with medium-dense patchy seagrass and one with medium-dense continuous & patchy macroalgae.

[2] includes three ground-truthing sites with very sparse patchy seagrass.

Table 6. Blairgowrie mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.

Mapping Data	Ground-truthing Data Medium-Dense & Medium-Patchy Seagrass	Sparse & Sparse Patchy Seagrass	Bare Sediment[1]	Total	User's Accuracy
Medium-Dense Seagrass	**11**	1	0	12	92%
Sparse Seagrass	0	**0**	0	0	ND
Bare Sediment	0	1	**12**	13	92%
Total	11	2	12	**25**	
Producer's Accuracy	100%	0%	100%		**Overall accuracy 92%**

[1]includes one ground-truthing site with sparse macroalgae.

Table 7. Curlewis Bank **mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.**

Mapping Data	Ground-truthing Data Medium-Dense & Medium-Dense Patchy Seagrass	Sparse & Sparse Patchy Seagrass	Bare Sediment	Total	User's Accuracy
Medium-Dense & Medium-Dense Patchy Seagrass	**9**	0	0	9	100%
Sparse & Sparse Patchy Seagrass	0	**0**	0	0	ND
Bare Sediment	0	0	**0**	0	ND
Total	9	0	0	**9**	
Producer' Accuracy	100%	ND	ND		**Overall accuracy 100%**

Table 8. Kirk Point **mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey); ND, no data.**

Mapping Data	Ground-truthing Data Medium-Dense & Medium-Dense Patchy Seagrass[1]	Sparse & Sparse Patchy Seagrass	Bare Sediment	Total	User's accuracy
Medium-Dense & Medium-Dense Patchy Seagrass	**3**	0	0	3	100%
Sparse & Sparse Patchy Seagrass	0	**0**	0	0	ND
Bare Sediment	0	0	**0**	0	ND
Total	3	0	0	**3**	
Producer's Accuracy	100%	ND	ND		**Overall accuracy 100%**

[1] Includes one ground truthing site with medium-dense macroalgae with seagrass.

Table 9. Mud Islands mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey).

Mapping Data	Ground-truthing Data Medium-dense & Medium-dense Patchy Seagrass	Sparse & Sparse Patchy Seagrass[1]	Bare Sediment[2]	Total	User's Accuracy
Medium-Dense & Medium-Dense Patchy Seagrass	**6**	0	0	6	100%
Sparse & Sparse Patchy Seagrass	0	**1**	0	1	100%
Bare Sediment	0	0	**6**	6	100%
Total	6	1	6	**13**	
Producer's Accuracy	100%	100%	100%		**Overall accuracy 100%**

[1] Includes one ground-truthing site with very sparse patchy seagrass.

[2] Includes one ground-truthing site with sparse patchy macroalgae.

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

Mapping Data	Ground-truthing Data Medium-Dense & Medium-Dense Patchy Seagrass[1]	Sparse & Sparse Patchy Seagrass	Bare Sediment	Total	User's Accuracy
Medium-Dense & Medium-Dense Patchy Seagrass	**12**	0	0	12	100%
Sparse & Sparse Patchy Seagrass	0	**0**	0	0	ND
Bare Sediment	0	0	**0**	0	ND
Total	12	0	0	**12**	
Producer's Accuracy	100%	ND	ND		**Overall accuracy 100%**

[1] Includes two ground-truthing sites with medium-dense macroalgae with seagrass and one with medium-dense patchy macroalgae with seagrass.

Table 11. Point Richards mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey).

Mapping Data	Ground-truthing Data Medium-dense & Medium-dense Patchy Seagrass[2]	Sparse & Sparse Patchy Seagrass	Bare Sediment[1]	Total	User's accuracy
Medium-Dense & Medium-Dense Patchy Seagrass	**2**	0	2	4	50%
Sparse & Sparse Patchy Seagrass	3	**0**	0	3	0%
Bare Sediment	5	1	**13**	19	68%
Total	10	1	15	**26**	
Producer's accuracy	20%	0	87%		**Overall accuracy 58%**

[1] correctly classified data includes five sites which were very sparse continuous or patchy seagrass.

[2] includes nine video ground-truthing sites classified as medium-dense continuous and patchy macroalgae with seagrass.

Table 12. **St Leonards mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey).**

Mapping Data	Ground-truthing Data Medium-dense & Medium-dense Patchy Seagrass[1]	Sparse & Sparse Patchy Seagrass	Bare Sediment	Total	User's Accuracy
Medium-Dense & Medium-Dense Patchy Seagrass	**0**	1	0	1	0%
Sparse & Sparse Patchy Seagrass	0	**0**	0	0	ND
Bare Sediment	2	0	**3**	5	60%
Total	2	1	3	**6**	
Producer's Accuracy	0%	0%	100%		**Overall accuracy 50%**

[1] Includes one ground-truthing site with medium-dense macroalgae with seagrass.

Table 13. **Swan Bay mapping error matrix (correctly classified mapped data relative to ground-truthing sites shaded in grey).**

Mapping Data	Ground-truthing Data Medium-Dense & Medium-Dense Patchy Seagrass[1]	Sparse & Sparse Patchy Seagrass	Bare Sediment	Total	User's Accuracy
Medium-Dense & Medium-Dense Patchy Seagrass	**10**	0	0	10	100%
Sparse & Sparse Patchy Seagrass	3	**0**	0	3	0%
Bare Sediment	0	0	**0**	0	ND
Total	13	0	0	**13**	
Producer's Accuracy	77%	ND	ND		**Overall accuracy 77%**

[1] Includes one ground truthing site with medium-dense macroalgae with seagrass.

Appendix 2

Light logger assessment

The performance of the light loggers and associated wiper systems deployed during autumn-winter 2008 is summarised below.

Blairgowrie (speed restriction pile)

This pile was closest to the deep seagrass monitoring plot at Blairgowrie. The attenuation coefficients for July 2008 (Figure 20) were reasonably consistent and were similar to values from April/May 2008 (Hirst *et al.* 2008). The loggers were checked during the sampling event in late August 2008 and the upper logger at this site was found to have come loose due to faulty straps, and had swung around to the south. It appears from the data that this most likely occurred on 2 August (Figure 20). The logger was replaced in late August and the attenuation values after this period are consistent with the earlier data from July and April. Small variations in light attenuation during September appear to match variations in the PoMC turbidity data at Camerons Bight.

Blairgowrie (Sorrento Channel No. 10)

This logger site was established as a backup to the loggers at the speed restriction pile. During the July-October 2008 deployment the loggers were checked on 27 August and the upper wiper was found to have stopped working due to flooding of the housing. Heavy fouling was also present on the logger and light fouling on the light sensor. It would appear from the data (Figure 20) that the wiper stopped working around 21 July as the data prior to this showed similar attenuation coefficients to the April/May period from the earlier deployment. A new wiper and logger were deployed on 28 August and the attenuation coefficients after this show some spikes in the data which match small changes in the turbidity data.

Mud Islands (north west MNP pile)

This pile was closest to the shallow seagrass plot at Mud Islands. The July 2008 attenuation coefficients from the second deployment showed little variation and were consistent with the April/May 2008 data and corresponding PoMC turbidity data (Figure 21). The attenuation coefficients after 4 August dropped to 0 over a few days and no usable data were recorded after 9 August due to heavy fouling on the top of the logger.

Mud Islands (south east MNP pile)

The loggers at this pile were established as a backup to the loggers at the north west pile, and this site was closest to the Mud Islands deep seagrass plot. The attenuation coefficients for the July-October 2008 deployment showed small variations up til 23 August, but these were not matched by changes in turbidity. The attenuation coefficients after 23 August were erratic, with two large spikes in the data. This may have been caused by drift algae settling on the loggers. The lower wiper system also stopped working during the deployment. It appears that this may have occurred in late August as the attenuation coefficients in the final month of the deployment were consistently higher than the first half of the deployment.

St Leonards (Coles Channel No. 5)

The loggers at Coles Channel No. 5 are closest to the main St Leonards deep seagrass plot. The attenuation coefficients from July-September 2008 were relatively consistent and mostly appeared to follow a similar pattern to the PoMC turbidity data (Figure 22). A check on the logger during the August sampling event on 8 August found that the wiper arm had broken on the lower logger wiper. The logger was retrieved, but was not able to be replaced until 23 August, so there is a gap of several weeks in the data from the second deployment.

St Leonards (Coles Channel No. 3)

A secondary deep seagrass plot was set up at the deep seagrass bed being used in the CDBMP Fish in Seagrass Monitoring Program. Light loggers were deployed at Coles Channel No. 3 which is the closest pile to this site, and is also close to the location of the PoMC turbidity monitoring station. The second deployment period was from July-October 2008, but the upper logger stopped recording on the 14 August without any clear cause (Figure 22).

Swan Bay

Swan Bay is shallow (predominantly <2 m) and the maximum depth at the base of the pile for the lower logger was only 1.3 m, positioned close to the silty sediments at the seabed. While turbidity data was not available for within Swan Bay, it would be expected to become periodically turbid due to the silty sediment becoming stirred up in the water column. The dense beds of seagrass in Swan Bay also mean that the lower logger may periodically be affected by drifting rafts of dead seagrass leaves. Longmore *et al.* (2002) found an average attenuation of 0.5 m^{-1} at a 4 m deep site in southern Swan Bay over a 6-month period in 2001.

The attenuation coefficients from the July-August 2008 deployment were still relatively high (Figure 23), but were much lower than the May-July data (Hirst *et al.* 2008).

Kirk Point

The June-August 2008 Kirk Point data had small peaks in the attenuation coefficients which may have been the result of drift algae or short periods of turbid water (Figure 24). The loggers were checked during the August sampling event and the upper wiper was found to have stopped working. It was replaced with a new wiper and logger on 8 August.

The attenuation coefficients at Kirk Point after 3 September showed a continual increase, which may have been due to heavy growth of the introduced kelp *Undaria pinnatifida* on the Long Reef pile shading both loggers (Figure 36). The *U. pinnatifida* is cleaned off the pile prior to replacing the loggers during each servicing trip and when the loggers are checked during each sampling event, but this species can regrow rapidly.

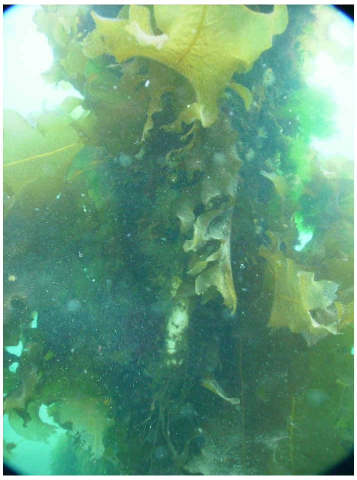

Figure 36. Dense *U. pinnatifida* growth at Long Reef (Kirk Point) navigation pile August 2008.

Point Richards (Bellarine Bank)

The June-September 2008 attenuation coefficients at Point Richards showed a continual increase after 3 September. The wiper motor was found to have stopped working on the lower logger at Point Richards when it was retrieved in late September, and this appears to be the cause of the increased attenuation coefficients in September. This data needs to be compared with the PoMC turbidity data at Point Richards when it is available, but elevated attenuation coefficients at these sites in mid to late-September appears to be due to equipment failures.

Observed Logger Problems

There were some problems or gaps in the data from the first two light logger deployment periods during autumn and winter 2008. The primary causes of the problems were:

- Excessive build up of marine fouling on the loggers and/or wiper systems
- Failure or ineffective operation of wiper systems
- Failure of straps securing the logger/wiper units to navigation piles.

To minimise problems with the light loggers and as part of continuous improvement to the seagrass monitoring program, the following actions were undertaken as part of the third logger deployment for September - November 2008:

- The effectiveness of the wipers was partly impacted by a higher lip on the top of the light logger casings in the most recent model, which inhibited the ability of the wiper to keep the sensor clean. After consulting with the manufacturer, FRB reduced the size of the lip by several millimetres
- A different type of strapping was used to secure loggers to the piles. A backup set of re-enforced straps was used to secure the loggers where the loggers are subject to strong currents at St Leonards and Blairgowrie
- The loggers were visually checked during the field-sampling events to identify potential problems with the equipment. This identified problems with the loggers at Kirk Point, Blairgowrie speed restriction pile and St Leonards Coles Channel No. 5 during the July-August sampling and these loggers were replaced
- Copper tape was added to the logger housings and wiper arms to inhibit fouling. The wiper housings are also being painted with recreational boating anti-foulant

- More powerful servo motors were installed in the wiper systems to increase the strength of the wiping action across the light sensors
- The water tight sealing system for the wiper housings was improved and the seals were replaced on all the wiper systems
- The Swan Bay loggers were moved to a deeper pile approximately 3 km to the west so that the lower logger did not have to sit at the level of the seabed to reduce impact of the bottom sediments and smothering by drifting seagrass
- Any loggers that failed to record data without explanation (e.g. July-Sep St Leonards Coles Channel No. 3, April-June Mud Islands south east) have been replaced
- The deployment of backup loggers at Blairgowrie, Mud Islands and St Leonards was continued.

The Detailed Design (PoMC 2008a) specifies that the light loggers are to be serviced every 2–3 months, and the initial two deployments were for approximately 3 months. Increasing the frequency of servicing the light logger may further improve the reliability of data collected by the loggers. This arrangement will also be assessed during the September - November 2008 deployment.

Appendix 3

Electronic data

Electronic data files are as follows:

- Seagrass health observations at plots and quadrats: CDP_Seagrass_database.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)
- Seagrass mapping GIS data: a separate shapefile exists for each region with the naming format region_name_monthyear.shp (e.g. Blairgowrie_shallow_April08.shp)
- Aerial photography mosaic for PPB: portphillip-seagrass_2008apr20_air_vis_30cm_mga55.ecw
- Underwater video ground-truthing GIS data: PPB_seagrass_video_2008_MGA55.shp
- Light logger data: Logger_data_July-Sep08.xls.