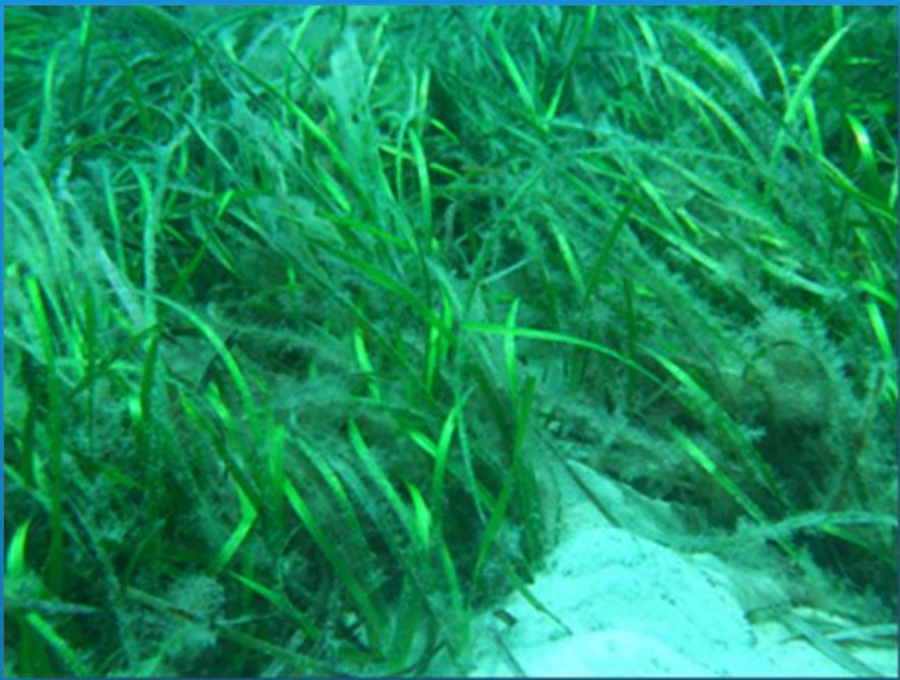
Marine Environment
and Ecology

Seagrass Condition Monitoring: Yankalilla Bay, Light River and Encounter Bay



Jason E. Tanner[1], Mandee Theil[1] and Doug Fotheringham[2]

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SARDI Aquatic Sciences
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September 2012

Final report prepared for the Adelaide and Mount Lofty Ranges Natural Resources Management Board

Government
of South Australia

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Acknowledgements

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Executive Summary

Following an earlier study to examine the condition of seagrasses in Yankalilla Bay, here we examine seagrass condition off the Light and Inman Rivers, as well as re-examining data from Yankalilla Bay to assess the abundance of seagrass epiphytes.

Yankalilla Bay epiphyte cover did not vary in response to proximity to Bungala River or Carrickalinga Creek. There were, however, strong geographic gradients, with epiphyte cover in offshore waters of the northern part of the study area much higher than elsewhere. Offshore transects around Carrickalinga Creek had greater (154%) epiphyte cover than inshore transects, and than those around Bungala River (296%). Inshore transects at Carrickalinga also had slightly higher (63%) cover than inshore transects at Bungala. Levels of epiphyte cover observed (generally <20%) were similar to those documented previously in the Adelaide metropolitan area as part of the Adelaide Coastal Waters Study, and were not considered cause for concern.

Seagrass cover in the Light River delta was very high and dominated by *Posidonia*. The seagrass condition index was generally high, with an overall mean H' of 95.9 ± 1.13 (se). The four lowest values correspond to the four transects with greatest depth (5.5-7.5 m), suggesting that they may have been towards the lower light limit for seagrasses in this relatively turbid environment. Epiphyte cover was 5.01% ± 0.53, with the overall impression from the video footage being that epiphyte loads were relatively low, and not a cause for concern. Overall, the data show the seagrasses off the Light River delta to be in very good condition, and they do not appear to be degraded due to discharges from the Light River.

The area offshore from the Inman River was comprised of a complex mixture of habitats, dominated by seagrasses and rocky reef. Areas of continuous seagrass appeared to be in good condition, with good habitat structure (mean H' = 96.2 ± 1.1), while transects with lower values (<90) were apparently randomly distributed. Transects with higher epiphyte cover (>30%) were clustered on the survey lines in close proximity to the river mouth, but with high cover only being found offshore. This pattern makes it difficult to draw any conclusions about how the river might be affecting epiphyte cover. Areas of sparse seagrass identified in aerial imagery from 2000 by the Department for Environment Water and Natural Resources (then Department for Environment and Heritage) are now classified as bare sand, suggesting that there has been some seagrass decline. However, there is need for some caution in this interpretation, as this change could be related to the different techniques used in the two studies, and thus it is recommended that further work be undertaken on the seagrasses in this area to confirm if seagrasses are in decline or not, and if so, why.

Chapter 1: Introduction

Declines in seagrass habitat have been a major concern worldwide, with 29% of known seagrass area being lost since 1879 (Waycott et al. 2009). South Australia has not been immune to this loss and its flow on effects. At Bolivar, just south of the Light River, extensive loss of seagrass has led to a changed wave climate, and contributed to a die-off of mangroves (Mifsud et al. 2004). Similarly, extensive areas of seagrass have been lost off Beachport, and this has led to substantial shore-line erosion, with the need for costly remediation works to protect the town (Seddon et al. 2003). The largest area of seagrass loss in South Australia, however, has been off the Adelaide metropolitan coast, where over 5200 ha has been lost (e.g. Westphalen et al. 2004), leading to the need for an extensive sand carting operation along the metropolitan beaches.

In 2009, the Department for Environment and Heritage (DEH, now Department for Environment Water and Natural Resources - DEWNR) and the South Australian Research and Development Institute (SARDI) undertook a joint program to assess the condition of seagrasses in Yankalilla Bay (Murray-Jones et al. 2009). In that project, a standardised methodology was developed to assess seagrass condition from data that can be collected using a remote video camera. The technique was then applied to a series of video transects running offshore in the vicinity of the Bungala River and Carrickalinga Creek. Seagrasses were found to be in good condition in these areas, and additionally, recruitment of *Amphibolis* juveniles to recruitment units was high.

To extend the baseline data collected from Yankalilla Bay to other areas of the Adelaide & Mount Lofty Ranges Natural Resources Management (AMLR NRM) jurisdiction which have not been formally surveyed previously, this project assesses the condition of seagrasses off the Inman River and the Light River Delta in Gulf St Vincent, as well as reassessing existing video footage from Yankalilla Bay to map epiphyte cover. This will provide important baseline information for future monitoring of the condition of these sites.

Baseline surveys off the Light and Inman rivers were recommended by Murray-Jones et al. (2009), on the basis that they have some of the largest seagrass areas in the AMLR NRM region and are heavily impacted catchments with growing populations. Consequently, both of these areas are at risk of losing seagrasses, with potential flow-on implications for mangrove and saltmarsh habitats immediately inshore. These surveys will allow the status of existing seagrasses to be assessed to determine if there are any potential problems associated with terrestrial inputs, and to provide a baseline for further monitoring to detect any declines associated with increasing human populations in the catchments of these waterways. Additionally, Murray-Jones et al. (2009) identified a potential increase in epiphyte loads on seagrasses close to the river mouths in Yankalilla Bay, potentially indicating the presence of anthropogenic nutrient inputs which may lead to seagrass decline, but did not formally analyse this. Hence we re-examine their data to see if this perceived increase does occur.

This project contributes to addressing NRM priorities identified in the AMLR NRM Plan 2008-11 and articulated through Regional Targets and Management Action Targets in the Plan. This project aims to contribute to the following NRM outcomes:

- NRM Plan Target 11 - Seagrass, reef and other coast, estuarine and marine habitats - Halt in the decline of habitat and a trend towards restoration

- NRM Plan Theme ***Care for Seascapes***
  - Strategy SS2 - *Mitigate Impacts on Reef and Seagrass Ecosystems*
    - Seascapes Action SS2.2 *Investigations to support seagrasses and reefs recovery*

- NRM Plan Theme ***Monitor and Evaluate the Organisation and Program Outcomes***.
  - Strategy *Monitor natural resource condition / management action target indicators*
    - *ME2.4-4 Implement seagrass monitoring program*
  - Strategy *ME5 Report natural resource condition to the Community*
    - *ME 5.3.2.2 Develop and publish report card(s) for environmental indicators for region*

In addition, the project contributes to several Management Action Targets (MATs) in the AMLR NRM Plan, as detailed in Table 1.1 below.

Table 1.1: Contribution to Management Action Targets

MAT	How will this project contribute to the MAT?
MAT42 Regular report cards on the state of the region produced	Seagrass condition information will contribute to baselines for Coastal Waters Report Cards
MAT17 Water quality objectives set for watershed, groundwater and coastal water resources in the region	Development of seagrass condition indices and establishment of seagrass condition monitoring baselines will assist in long term monitoring of coastal water quality objectives
MAT16 3 estuary management plans developed and being implemented	Development of seagrass condition indices and establishment of seagrass condition monitoring baselines will assist in long term monitoring of estuaries plan effectiveness.
MAT20 Action underway to protect migratory shorebirds and other threatened marine and coastal species	Detecting any loss of seagrass will enable remedial action to be initiated and assist in mitigation of threats to seagrass habitat dependant biodiversity

Chapter 2: Assessment of epiphyte cover on seagrasses in Yankalilla Bay

2.1 Introduction

Three main watercourses discharge into Yankalilla Bay in the vicinity of Yankalilla: Carrickalinga Creek, Bungala River and Yankalilla River (from north to south, see Figure 2.1). In 2009, Murray-Jones et al. (2009) conducted a series of video surveys offshore from the first two of these, to assess seagrass condition. Seagrasses along these transects 'appeared lush, with tall fronds at high density, and with relatively few epiphytes'. The dominant seagrass documented was *Amphibolis antarctica*, and no effect of the river discharges could be discerned on the seagrasses themselves. However, observations suggested that there was an increase in epiphyte load on seagrasses directly offshore from both discharge points. Following up on this observation, we reanalyse the video footage collected by Murray-Jones et al. (2009) to formally document patterns in epiphyte abundance in relation to proximity to the discharges. As we are reliant on video footage for this, the epiphytes recorded are all macro-epiphytes, and do not include groups such as encrusting coralline algae or turf-forming algae.

2.2 Methods

Field work

Sampling of seagrass beds was conducted at two sites in the region of Yankalilla Bay, South Australia in late March, 2009, as described in Murray-Jones et al. (2009). These sites were adjacent to the mouths of Bungala River and Carrickalinga Creek. A grid pattern was projected out from the mouths of these two freshwater sources. For each site, six survey lines perpendicular to the shore were sampled (see Figure 2.1). Each of the survey lines ran from approximately 1300 m offshore towards the inshore region to ~300 m from shore. In addition, one longer survey line running parallel to the coastline and about 650 m offshore was run from the south of the Bungala site to the north of the Carrickalinga site (transect coded 625100, Figure 2.1). The parallel survey line was approximately 3.7 km in length, and allowed replication at approximately the same depth.

For each survey line, the Department for Environment & Heritage's (DEH, now Department for Environment Water and Natural Resources - DEWNR) boat *Rapid* towed a Morphvision camera at ~1.3 ms^{-1}, which recorded continuous video transects of the seafloor. At ~30 second intervals, the elapsed time on the video recorder was noted, along with the distance along the ground in metres, recorded by a Leica GPS. For analysis, this allowed distance along the survey line to be converted into seconds on the videotape.

From the videotape data of each survey line shown in Figure 2.1, subsets of 50 m in length (subsequently referred to as transects) were randomly selected to provide replication. For each of the perpendicular survey lines, six separate 50 m transects were randomly selected between 300-1200 m offshore, three offshore of the long survey line shown in Figure 2.1 (625100), and three inshore. This enabled comparisons between inshore and offshore sites. In addition, 11 × 50 m transects were randomly selected from the long survey line (625100), referred to as the along-shore data. Six were selected within the Bungala grid, and six within the Carrickalinga grid, with three on either side of the perpendicular survey line closest to the river mouth for each site. The area between the two site grids was not sampled. Random distances were selected with at least 80 m distance between each replicate transect, to allow for reef sections to be skipped over when necessary. All transects are the same as those analysed in Murray-Jones et al. (2009).

At the same time as seagrass variables were recorded for calculation of the seagrass habitat index, epiphyte cover was also recorded. For each transect, the video was paused approximately every 1 m (=0.77 seconds), and a transparent grid of 25 squares overlying the screen used to facilitate estimation of percent epiphyte cover. As there was some minor variation in boat speed, there was some variation in the number of quadrats scored for each transect.

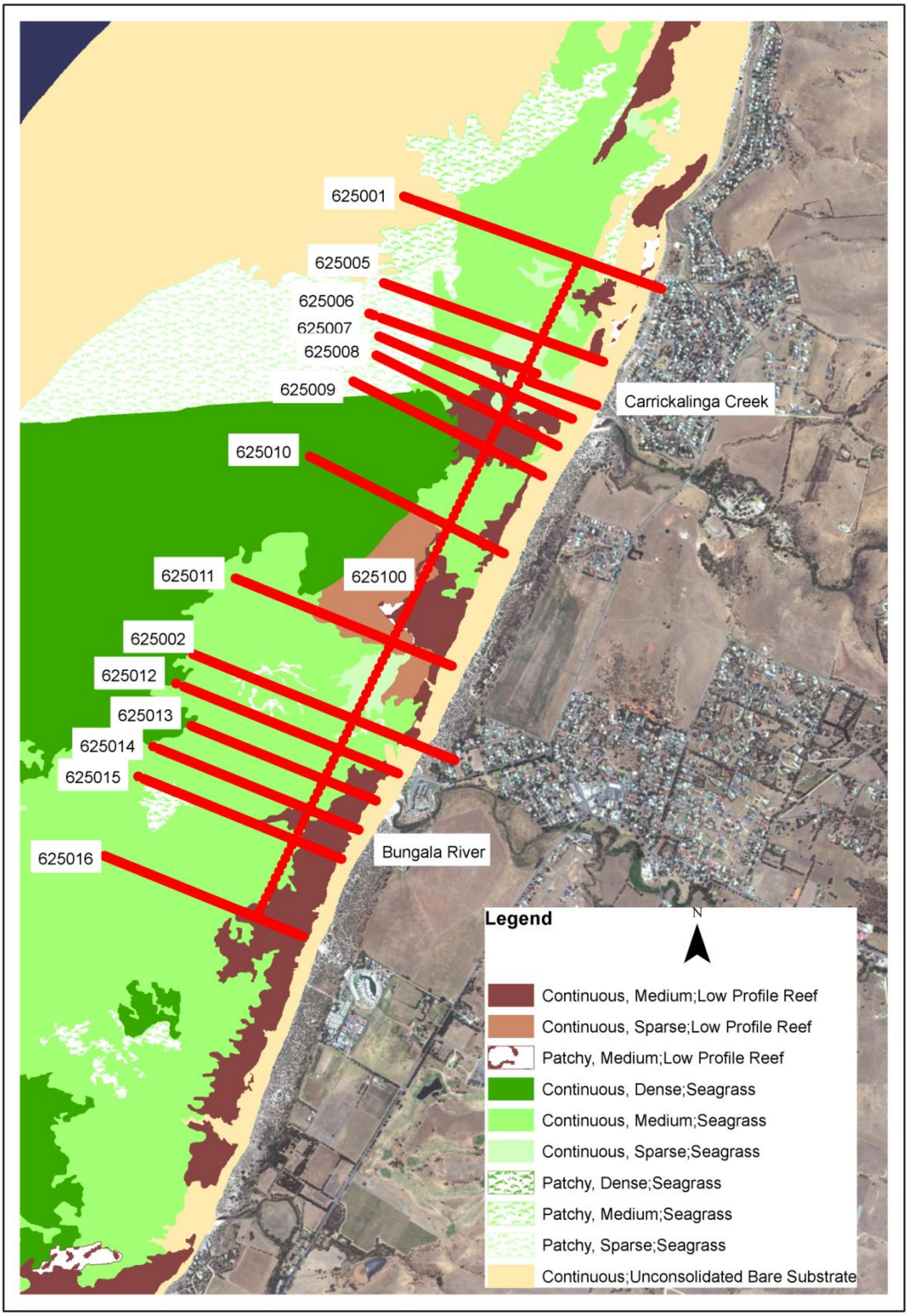

Figure 2.1: Habitat map of Yankallilla Bay showing survey lines profiled and videotaped in March 2009. The northern site is centred at the mouth of Carrickalinga Creek, while the southern site is centred at the mouth of the Bungala River (adapted from Murray-Jones et al. 2009).

Analysis of data

Following Murray-Jones et al. (2009), the data were divided into two components for analysis. In the first component, data from the transects perpendicular to shore were analysed to examine effects of 'River' (Bungala River vs Carrickalinga Creek) crossed with 'Distance from shore' (Inshore vs Offshore) and 'Survey line' (625016 vs 625015 vs 625014 etc.). The 50 m transects within each survey line were treated as nested within the combination of all other factors, and the individual quadrats were considered replicates. Quadrats were only included if they contained some seagrass cover, so that only seagrass habitat was included in the analysis, and epiphyte cover was expressed as a percentage of seagrass cover. Univariate Analysis of Variance (ANOVA) was used in PASW Statistics (ver 18). To further investigate the roles of distance along the shore, and distance offshore, as well as cover of each of *Posidonia* and *Amphibolis*, in determining epiphyte cover, non-parametric smooth curves were fit to each of these variables using generalised additive models (GAM) with the software R (ver 2.11.1). For all variables, the default thin plate regression splines were used. The along-shore data were also analysed using GAM with the same model, except that distance from shore was not used, as it was approximately constant along the length of the transect.

2.3 Results

Epiphyte cover was relatively low at Bungala, where it did not vary with distance from shore (Figure 2.2). At Carrickalinga, cover offshore was 154% higher than inshore, and 296% higher than at Bungala. These differences were significant, as indicated by the interaction term in the ANOVA (Table 2.1). There were also significant differences between individual transects within each combination of Survey line, River and Distance from shore (see also Figure 2.3). There was also a higher degree of patchiness within a 50 m transect at Carrickalinga as opposed to Bungala, as indicated by the larger standard error bars in Figure 2.3.

Table 2.1: Results of ANOVA testing the effects of River (Bungala R. vs Carrickalinga Ck), Distance from shore (inshore vs offshore), Survey line (adjacent, north, and south of each river) and Transect on epiphyte cover of seagrasses. Significant values are shown in bold type.

Source	df	MS	F	P
River	1	47042	23.97	**<0.001**
Survey line	6	2439	1.19	0.325
Distance	1	12247	6.24	**0.015**
River × Survey line	6	2278	1.11	0.367
River × Distance	1	9454	4.81	**0.032**
Survey line × Distance	6	2130	1.039	0.41
River × Survey line × Distance	6	1786	0.87	0.52
Transect(River × Survey line × Distance)	55	2187	6.26	**<0.001**
Residual	3692	349		

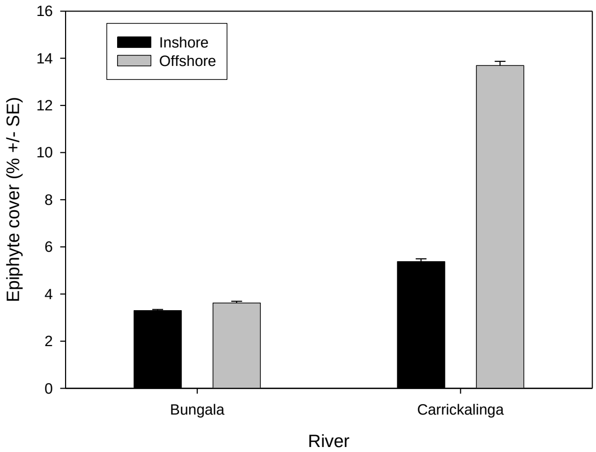

Figure 2.2: Seagrass epiphyte cover in proximity to freshwater inputs in Yankalilla Bay.

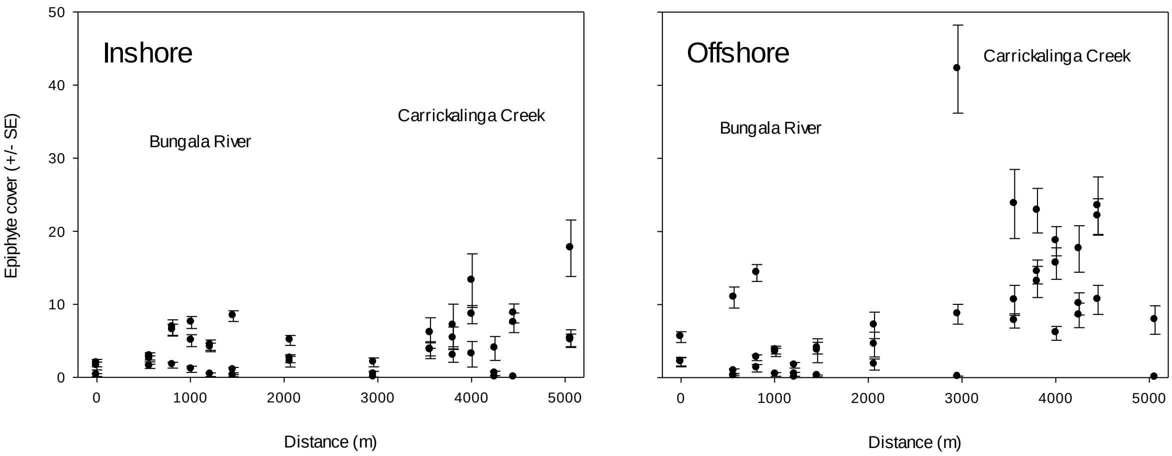

Figure 2.3: Mean epiphyte cover on 50 m transects at inshore and offshore locations as a function of distance from the southernmost survey line.

The generalised additive model indicated that all four variables (Distance along-shore, Distance from shore, Cover of *Amphibolis*, and Cover of *Posidonia*) were significant (Table 2.2), however, together they only accounted for 11.2% of the variance. Undertaking the analysis with each variable individually showed the distance along-shore explained 6.3% of the variance, distance from shore 3.4%, and cover of *Posidonia* and *Amphibolis* both explained 1.8%.

Table 2.2: Results of GAM analysis for epiphyte cover.

Term	F	P
Distance along-shore	29.47	<0.001
Distance from shore	13.86	<0.001
Cover of *Amphibolis*	5.53	<0.001
Cover of *Posidonia*	3.43	0.009

For the along-shore data, the original GAM showed that cover of *Posidonia* was not significant in explaining epiphyte cover, and suggested that cover of *Amphibolis* was a linear predictor. Following parsimony, the model was refit with a smooth fit for Distance along shore, a linear fit for *Amphibolis* cover, and excluding *Posidonia*. This model explained 15% of the variance in epiphyte cover (P<0.001), with epiphyte cover increasing at 0.015 times the rate of *Amphibolis* cover. Epiphyte cover peaked in the section of the transect just south of Bungala River (Figure 2.4), with cover at Bungala (2.05 ± 0.19 (SE)%) being approximately one third higher than off Carrickalinga (1.54 ± 0.31 %) on average. These values are clearly atypical when compared to epiphyte cover found on the cross-shore survey lines, especially for Carrickalinga. Note that while 12 transects were scored, one transect north of Carrickalinga Creek was reef, and therefore not included in the analysis.

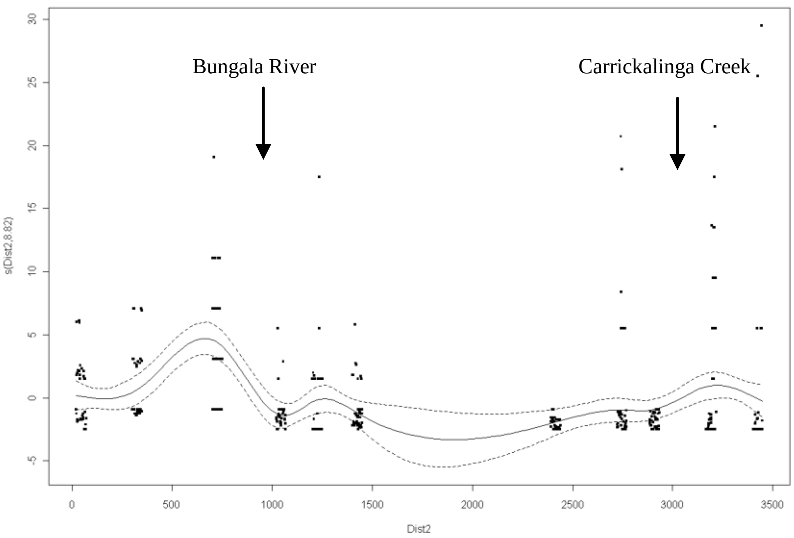

Figure 2.1: GAM fit for distance against epiphyte cover for the along-shore transect. The y-axis is epiphyte cover standardised to a mean of zero.

2.4 Discussion

Despite the suggestion by Murray-Jones et al. (2009) that the video footage analysed here showed an indication of increased epiphyte cover around the mouth of both the Bungala River and Carrickalinga Creek, this was not observable in the data. Indeed, the highest epiphyte cover occurred at one of the furthest sites from either river. There was, however, a clear relationship between position along the shore and position offshore. Offshore transects around Carrickalinga Creek had much higher (154%) epiphyte cover than inshore transects, and than transects around Bungala River (296%). Inshore transects at Carrickalinga also had slightly higher (63%) cover than inshore transects at Bungala.

The values for epiphyte cover found here are similar to those found by Bryars et al. (2006) along the Adelaide metropolitan coast during the Adelaide Coastal Waters Study. While they found total epiphyte cover was generally 40-60%, foliaceous epiphytes, which would be approximately equivalent to the epiphytes scored from the video footage, ranged between 0.5-42%, with most records <10%. Bryars et al. (2006) concluded that epiphyte cover in Holdfast Bay was not indicative of elevated nutrient loads, although other surveys closer to specific sources of nutrients did show elevated epiphyte loads.

Chapter 3: Assessment of seagrass condition and epiphyte cover off the Light River delta

3.1 Introduction

The Light River enters Gulf St Vincent to the north of Adelaide (Figure 3.1), in an area with extensive shallow-water seagrasses, and has a total catchment of ~200,000 ha. While flows are intermittent, the river catchment is predominantly used for dry-land agriculture (cropping and grazing), and thus there is the potential for negative impacts on the marine fauna and flora in the Light River delta. Descriptions of the sub-catchments can be found in Harding et al. (2003, 2005) and Henschke et al. (2008). While flow in the river is not monitored, modelling indicates a mean natural outflow of 22,900 ML yr^{-1} (http://www.anra.gov.au/topics/water/availability/sa/swma-light-river.html).

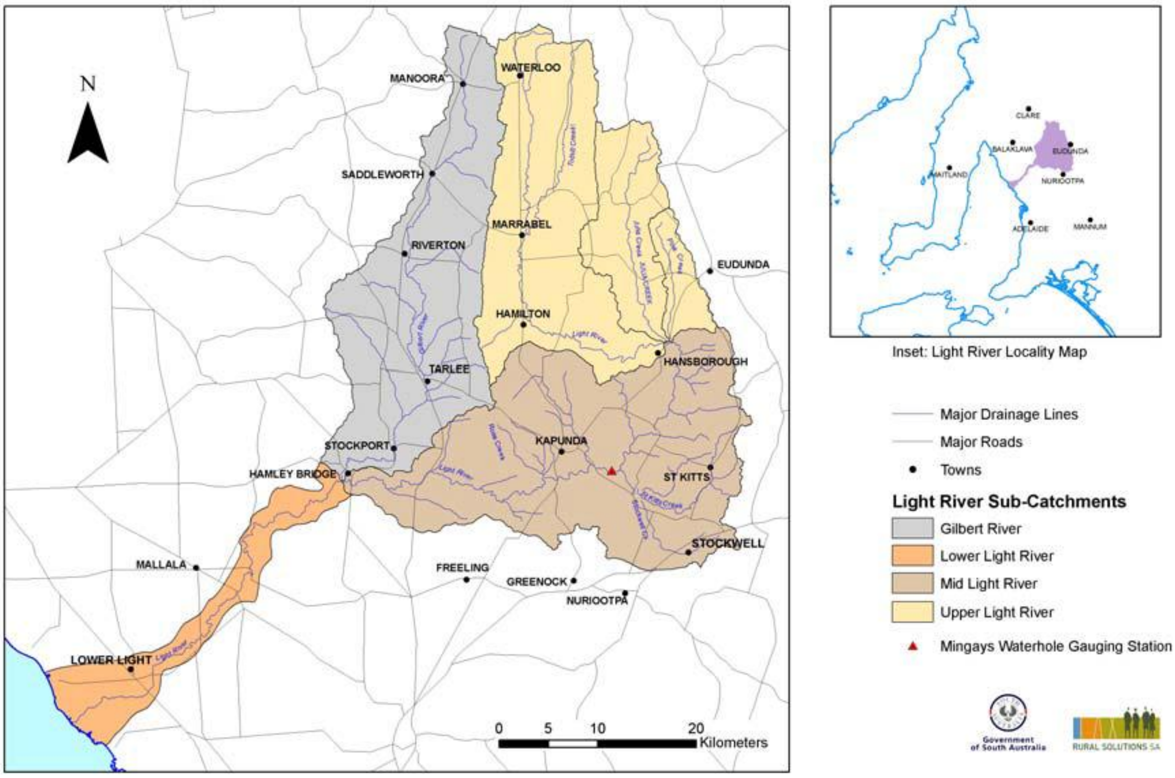

Figure 3.1: Map of the Light River catchment (from Harding et al. 2003).

The seagrasses in northern Gulf St Vincent, including those off the Light River delta, have received very little formal attention, and thus not much is known about their condition, or how it might change with increasing development of the catchment. There has been some broad-scale habitat mapping of the region, using satellite imagery (Edyvane 1999) and satellite imagery ground-truthed with in situ video transects (DEH 2008 – see Figure 3.2). The latter work is the most comprehensive, and has resulted in a series of 5 km x 5 km maps of habitat, but only has a resolution of 1:20,000, and seagrass species are not distinguished. Therefore, while providing a useful broad-scale indicator of the status of seagrasses in the region, it does not provide detailed information that can be used to assess the condition of seagrasses in a specific area. As a result, the AMLR NRM Board has identified this region as a priority for establishing a baseline of ecosystem health, focussing on seagrasses.

In this chapter, we document the baseline seagrass habitat condition index monitoring undertaken off the Light River delta, following the methods used for Yankalilla Bay (Murray-Jones et al. 2009). We also examine the distribution and abundance of seagrass epiphytes, which are a potential early warning indicator of excessive nutrient enrichment, which can lead to seagrass decline.

3.2 Methods

Field work

Sampling of seagrass beds was conducted off the Light River delta, South Australia on 6 April 2011, following the methods described in Murray-Jones et al. (2009). Six survey lines perpendicular to the shore were sampled (Figures 3.2, 3.3). Each of the survey lines ran from ~1100-1600 m offshore towards the inshore region to the shallowest point that the boat could operate (generally ~0.8 – 1 m in depth). In addition, one longer (~5000 m) survey line running parallel to the coastline connecting the offshore end of each transect was run (transect coded 520010, Figure 3.2).

For each survey line, DENR's (now DEWNR) boat *Rapid* towed a Morphvision camera at ~1.3 ms^{-1}, which recorded continuous video transects of the seafloor. At ~30 second intervals, the elapsed time on the video recorder was noted, along with the distance along the ground in metres, recorded by a Leica GPS. For analysis, this allowed distance along the survey line to be converted into seconds on the videotape.

From the videotape data of each survey line shown in Figure 3.2, subsets of 50 m in length (subsequently referred to as transects) were randomly selected, to provide replication. For each of the perpendicular survey lines, three separate 50 m transects were randomly selected from each of the inshore and offshore halves of the line. This enabled comparisons between inshore and offshore sites. In addition, 12 × 50 m transects were randomly selected from the along-shore survey line (520010), referred to as the along-shore data.

As an initial estimate of seagrass condition, enough data were recorded to calculate the habitat structure index, H′, which ranks the sampled seagrass on a scale of 0-100 (100 being excellent, 0 being poor) (for further description of the rationale and methods for calculating H' see Murray-Jones et al. 2009). Five variables (seagrass area, continuity, proximity, percentage cover and species identity) were recorded for 50 sequential 1 m^2 quadrats along each replicate transect from the video, hence covering an entire 50 m transect, and integrated to calculate H'. Information on habitat type (e.g. seagrass, sand, rock, macroalgae) was also collected and epiphyte load determined.

To obtain the above data, for each transect, the video was paused approximately every 1 m, and a transparent grid of 55 squares overlying the screen used to facilitate estimation of both percent seagrass and percent epiphyte cover. As there was some minor variation in boat speed, the time interval equating to 1 m was calculated for each transect based on the GPS records for the distance points closest to the start and end of each transect. Seagrass was scored according to type (note that low light and the difficulty of identification from video meant that seagrass was only identified to genus) and density. Percentage cover was estimated for all seagrass visible. Density was scored and grouped into one of the following classes: dense (90-100% cover), medium (40-89%), or sparse (0-39%). Other substrate types were scored (e.g. areas of sand, rock and algae) and grouped together for analysis. Epiphyte cover was recorded following the methods described in Chapter 2.

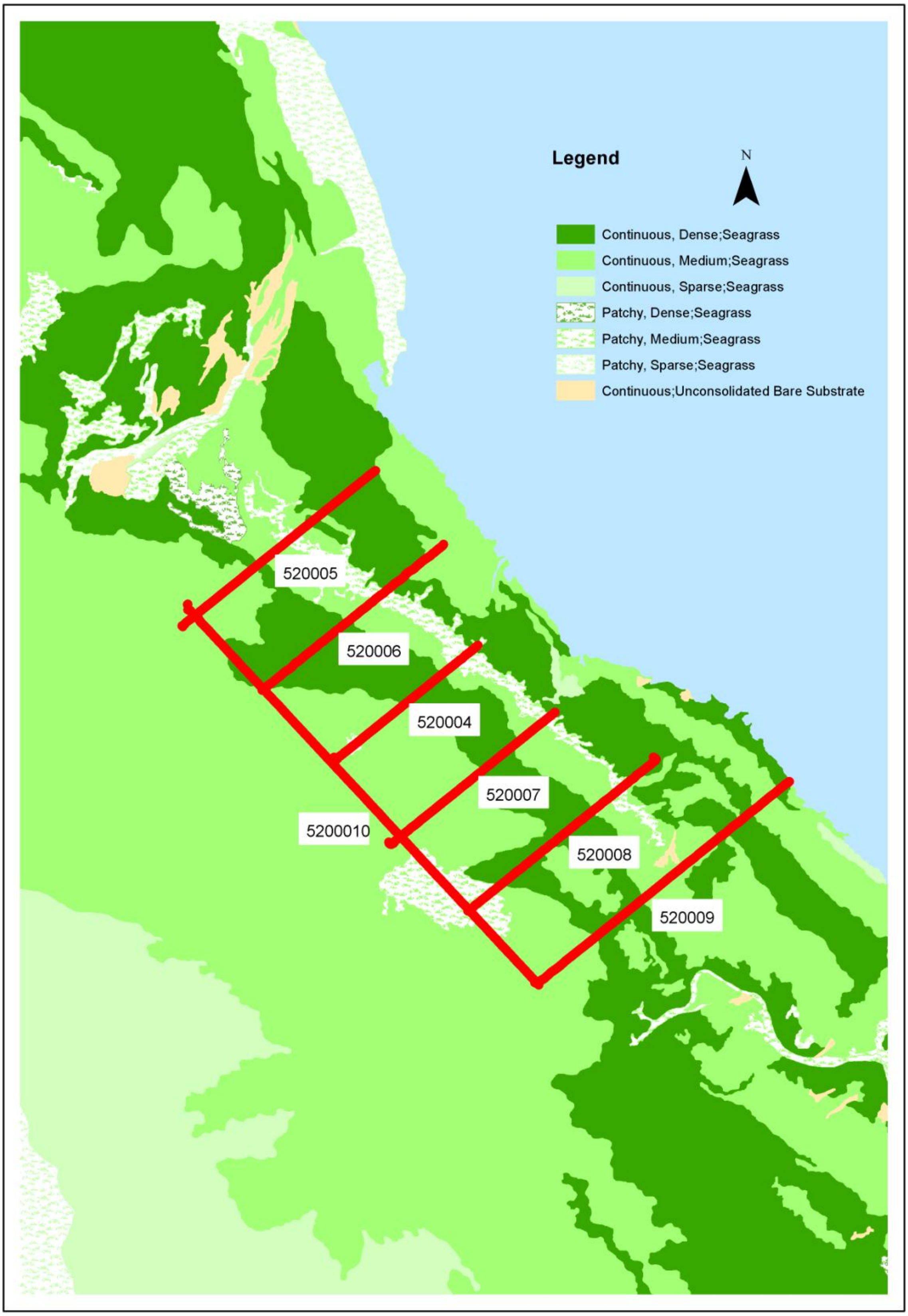

Figure 3.2: Habitat map of the Light River delta showing survey lines profiled and videotaped in April 2011.

Figure 3.3: Aerial photograph of the Light River delta showing survey lines profiled and videotaped in April 2011.

Analysis of data

Seagrass Condition Index

Following Murray-Jones et al. (2009), the data were divided into two components for analysis. In the first component, data from the transects perpendicular to shore were analysed to examine effects of 'Distance from shore' (Inshore vs Offshore) crossed with 'Survey line' (520004 vs 520005 vs 520006 etc.). With this design, the three 50 m long transects within each survey line (520004, etc) × 'Distance from shore' combination were used as replicates.

The second analysis component tested for 'along-shore' differences in H'. Here, data from the single long survey line (520010) that ran parallel to the shore were used. These data were plotted, but the nature of the patterns revealed did not lend themselves to meaningful statistical analysis.

Epiphytes

The analysis was performed as described above, except that the 50 m transects within each survey line were treated as nested within the combination of Distance and Survey Line, and the individual quadrats were considered replicates. Quadrats were only included if they contained some seagrass cover, so that only seagrass habitat was included in the analysis, and epiphyte cover was expressed as a percentage of seagrass cover. Univariate ANOVA was used in PASW Statistics (ver 18). To further investigate the roles of distance along the shore, and distance offshore, as well as cover of each of *Posidonia*, *Amphibolis* and *Zostera*/*Heterozostera*, in determining epiphyte cover, non-parametric smooth curves were fit to each of these variables using generalised additive models (GAM) with the software R (ver 2.11.1). For all variables, the default thin plate regression splines were used. The along-shore data were also analysed using GAM with the same model, except that distance from shore was not used, as it was approximately constant along the length of the survey line, and *Zostera/Heterozostera* were not included as they did not occur along this line.

3.3 Results

General habitat description

Seagrass cover was high, with 94.9% of the substrate covered by seagrass. Of this, *Posidonia* accounted for 81.4% cover, *Amphibolis* 5.9% and *Zostera/Heterozostera* 7.5%. Only 5% of the seagrass was covered in epiphytes. No hard substrate was recorded in the video footage analysed, with the 5% of the area not covered by seagrass being a mix of bare sand (3.2%), detritus, red algae and unidentifiable.

Seagrass Condition Index

'Across-shore' patterns

The calculated values of H' were very high across the area of study (mean 97.1 ± 0.6 (se)), indicating very good structure of seagrass meadows in the region overall (i.e. extensive and continuous meadows with species of high value; Figure 3.4). There was no significant variation in H' with either survey line or distance from shore (Table 3.1).

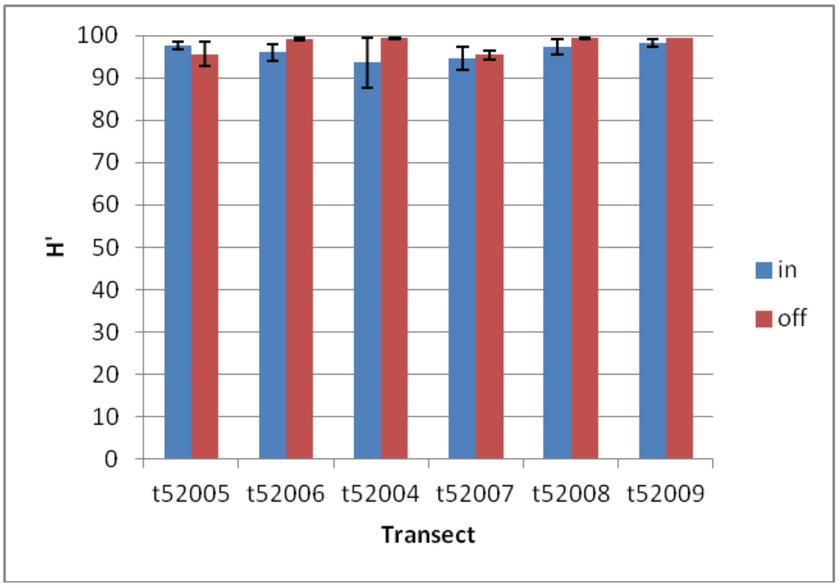

Figure 3.4: Mean (± SE) calculated H' values for inshore and offshore replicate transects off the Light River delta.

Table 3.3: Results of two-way ANOVA testing the effects of Distance from shore (inshore vs offshore), and Survey line on calculated values of H'.

Source	**df**	**MS**	***F***	***P***
Survey line	5	11.63	0.76	0.59
Distance	1	30.43	2.00	0.17
Survey line × Distance	5	9.94	0.65	0.66
Residual	24	15.23		

'Along-shore' patterns

Analysis of calculated H' values from the longshore survey line showed that the northern end of the survey line had uniformly high H' values (>99), while values varied erratically around the middle of the line and particularly towards the south (Figure 3.5). Seagrass condition was lowest ~ 4500 m from the northern end of the line.

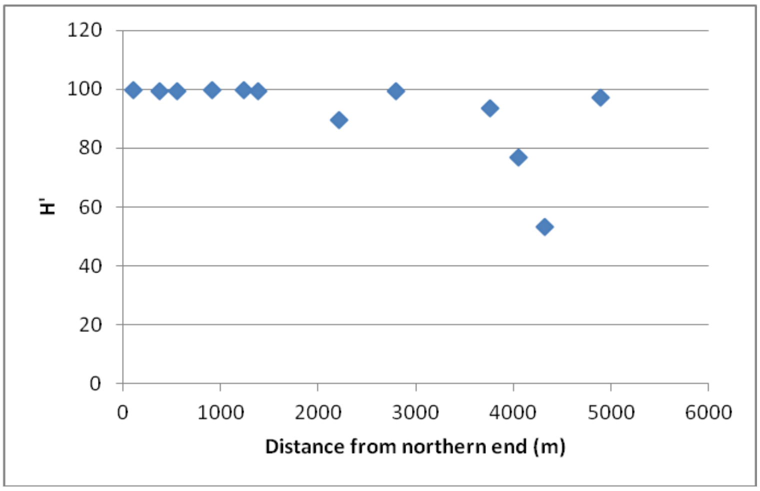

Figure 3.5: H' values for the along-shore data (survey line 520010 running parallel to the shore).

Epiphytes

Mean epiphyte cover over the entire study area was 5.01% (± 0.53 se).

'Across-shore' patterns

Epiphyte cover was highly variable between survey lines, and between distances within a survey line, ranging from 0 for the offshore transects on 520008 to 26.4% (± 2.4) for the offshore transects on 520005 (Figure 3.6). The small-scale variability (transect) was highly significant, but epiphyte cover did not vary with either survey line or distance from shore (Table 3.2).

Table 3.4: Results of ANOVA testing the effects of Distance from shore (inshore vs offshore), Survey line and Transect on epiphyte cover of seagrasses. Significant values are shown in bold type.

Source	**df**	**MS**	**F**	**P**
Survey line	5	12653	1.96	0.12
Distance	1	4482	0.69	0.41
Survey line × Distance	5	14304	2.21	0.086
Transect (Survey line × Distance)	24	6472	27.25	**<0.001**
Residual	1753	237.5		

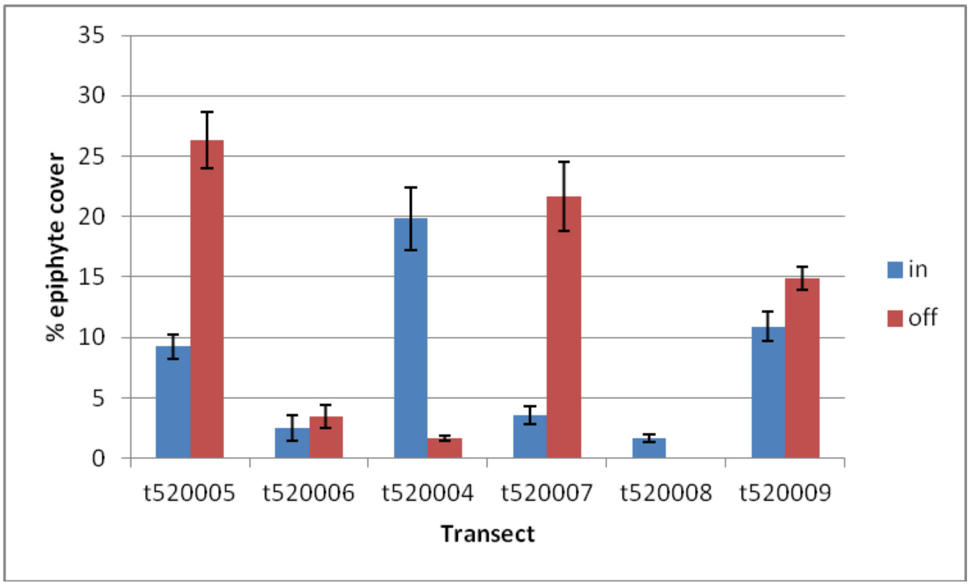

Figure 3.6: Seagrass epiphyte cover (± se) for inshore and offshore transects off the Light River delta.

The GAM indicated that the best fit involved treating survey line as a factor, and indicated that all variables apart from Cover of *Amphibolis* (i.e. Survey line, Distance from shore, Cover of *Posidonia* and Cover of *Zostera/Heterozostera*) were significant (Table 3.3), and accounted for 35.6% of the variance. Undertaking the analysis with each variable individually showed the Survey line explained 8.8% of the variance, Distance from shore 7.5%, Cover of *Amphibolis* 8.8%, Cover of *Posidonia* 6.8% and Cover of *Zostera/Heterozostera* 1.1%.

Table 3.5: Results of GAM analysis for epiphyte cover in the cross-shore data.

Term	**F**	**P**
Survey line	34.6	<0.001
Distance from shore	32.3	<0.001
Cover of *Amphibolis*	1.55	0.16
Cover of *Posidonia*	14.9	<0.001
Cover of *Zostera*	4.58	<0.001

'Along-shore' patterns

For the along-shore data, the GAM showed that cover of *Posidonia* was not significant in explaining epiphyte cover (Table 3.4). This model explained 52.2% of the variance in epiphyte cover (P<0.001), with epiphyte cover increasing smoothly with *Amphibolis* cover. However, the latter pattern is driven by the high number of stops with no *Amphibolis*, and the high proportion of stops with *Amphibolis* that were 100% *Amphibolis*. The Distance effect was driven primarily by the high cover of epiphytes at the ends of the survey line (Figure 3.7). Individually, Distance explained 32.7%, *Amphibolis* 36.7%, and *Posidonia* 16.5%, of the variation in epiphyte cover.

Table 3.6: Results of GAM analysis for epiphyte cover in the along-shore data.

Term	F	P
Distance along line	20.7	<0.001
Cover of *Amphibolis*	49.3	<0.001
Cover of *Posidonia*	1.16	0.33

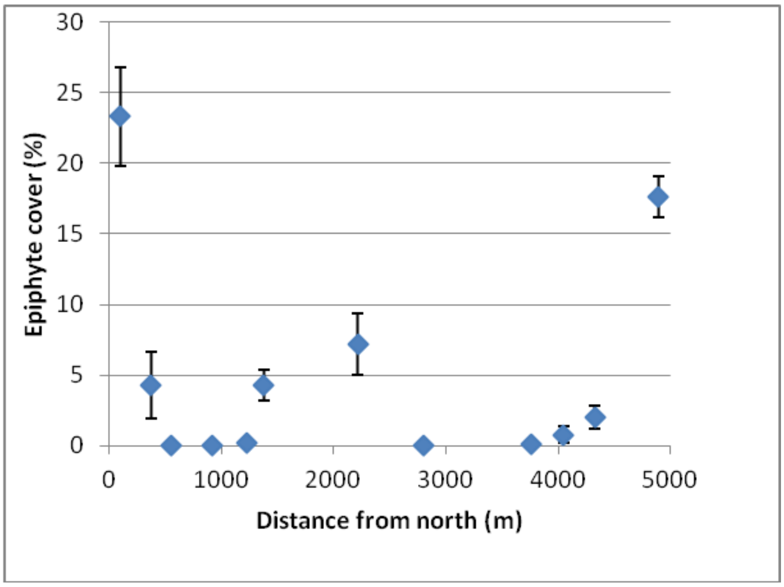

Figure 3.7: Change in mean epiphyte cover (± se) along the along-shore survey line (520010**)**.

3.4 Discussion

Seagrass cover was very high over most of the study area, comprising mostly *Posidonia*, with a small amount of *Amphibolis*, and some *Zostera*/*Heterozostera* in shallower water. The entire system appears to be based on soft sediments, with no hard substrates documented in the video footage. As a consequence of the high seagrass cover, and the predominance of larger species, the habitat condition index (H') was also high, being >99 for 25 of the 48 50 m transects scored, and >90 for another 18. Three of the five transects with scores <90 were on the southern-end of the along-shore survey line, with the other two being at the inshore and offshore ends of two northern cross-shore survey lines. The overall mean H' was 95.9 ± 1.13 (se), which compares favourably to Yankalilla Bay, where H' on the along-shore transect was found to be 96.3 (± 1.64) and 81.7 (± 4.32) off Bungala and Carrickalinga Rivers, respectively (Murray-Jones et al 2009). This is the only area for which published values of H' are currently available for comparison.

The low values of H' found at the southern end of the along-shore survey line are not necessarily cause for concern. The four lowest values correspond to the four transects with greatest depth (5.5-7.5 m), suggesting that they may have been towards the lower light limit for seagrasses in this relatively turbid environment, although transects on the cross-shore survey lines up to 9.5 m depth had H'>99.

Epiphyte cover at Light River (5.01% ± 0.53) fell within the general range seen at Yankalilla Bay (3.3-13.7% - Chapter 2). While a number of factors were found to be correlated with epiphyte cover, there were no obvious potential causative links found. The overall impression from the video footage was that epiphyte loads were relatively low, and not a cause for concern.

Overall, the data presented show the seagrasses off the Light River delta to be in very good condition, and they do not appear to be degraded due to discharges from the Light River. There were no losses of seagrasses observed around the mouth of the river, as has been seen around drain discharges in the south-east of South Australia (Wear et al. 2006). This may be due to the intermittent and low flows experienced by the Light River. Additionally, the Light River discharges through a mangrove delta and across intertidal mudflats (see Figure 3.3), and thus does not present a concentrated point source like many other rivers and drains in South Australia, but rather is a more diffuse source of freshwater and any accompanying pollutants. Thus it may simply be that inputs are sufficiently diluted before they reach the seagrass as to not cause any detectable impacts.

Chapter 4: Assessment of seagrass condition and epiphyte cover off Inman River

4.1 Introduction

The Inman River enters Encounter Bay at Victor Harbor, in an area with shallow-water seagrasses and extensive low platform rocky reef. The river predominantly flows through agricultural land upstream, with the estuary located within the city of Victor Harbor (SKM 2010). Recent studies have shown that water quality within the estuary is lower than in other nearby estuaries, and hence that there is a risk of negative impacts on seagrasses within the receiving environment. This degraded water quality is due to several pollution issues, including agricultural runoff, chemical inputs, trash and continued nutrient efflux from sediments due to the old waste water treatment plant, which discharged into the estuary (SKM 2010). Current mean flows at the mouth are 1877 ML month^{-1}, although most rainfall occurs in winter (http://www.anra.gov.au/topics/water/availability/swms/swms-501003dd.html).

Like many areas of South Australia outside the Adelaide metropolitan area, the seagrasses in Encounter Bay have received very little formal attention, and thus not much is known about their condition, or how it might change with increasing development of the catchment. There has been some broad-scale habitat mapping of the region, using satellite imagery (Edyvane 1999) and satellite imagery ground-truthed with in situ video transects (DEH 2008 – see Figure 4.1). The latter work is the most comprehensive, and has resulted in a series of 5 km x 5 km maps of habitat, but only has a resolution of 1:20,000, and seagrass species are not distinguished. Therefore, while providing a useful broad-scale indicator of the status of seagrasses in the region, it does not provide detailed information that can be used to assess the condition of seagrasses in a specific area. As a result, the AMLR NRM Board has identified this region as a priority for establishing a baseline of ecosystem health, focussing on seagrasses.

In this chapter, we document the baseline seagrass habitat condition index monitoring undertaken off the Inman River, following the methods used for Yankalilla Bay (Murray-Jones et al. 2009). We also examine the distribution and abundance of seagrass epiphytes, which are a potential early warning indicator of excessive nutrient enrichment, which may then lead to seagrass decline.

4.2 Methods

Field work

Sampling of seagrass beds was conducted off the Inman River, South Australia on 28 September 2011, following the methods described in Murray-Jones et al. (2009). Nine survey lines perpendicular to the shore were sampled (Figure 4.1). Each of the survey lines ran from approximately 600-1000 m offshore towards the inshore region to the shallowest point that the boat could operate (generally ~0.8 – 1 m in depth).

For each survey line, DENR's (now DEWNR) boat *Rapid* towed a Morphvision camera at ~1.3 ms^{-1}, which recorded continuous video transects of the seafloor. At ~30 second intervals, the elapsed time on the video recorder was noted, along with the distance along the ground in metres, recorded by a Leica GPS. For analysis, this allowed distance along the survey line to be converted into seconds on the videotape.

The videotape from each survey line was used to locate the position of distinct habitat boundaries. Subsets of 50 m in length within seagrass habitat (subsequently referred to as transects) were randomly selected, to provide replication. For each section of continuous seagrass habitat longer than 50 m, one transect was scored, with additional transects scored for every additional 100 m of seagrass habitat. Due to the patchy nature of the habitat in the survey area, with large areas of bare sand and rocky reef in addition to seagrasses, there was no stratified sampling undertaken, unlike for Yankalilla and Light River. Calculation of H’ and epiphyte cover followed the methods described in Chapter 3.

Analysis of data

Seagrass Condition Index

Due to the complex nature of the habitat, the seagrass condition index data did not lend themselves to statistical analysis of spatial pattern. Instead, a simple visual presentation is provided, with sites differentiated on a map according to whether their H’ scores were greater or less than 90.

Epiphytes

Again because of the complex nature of the habitat, the epiphyte data did not lend themselves to statistical analysis to assess spatial patterns. Instead, sites were differentiated on a map based on percent cover classes. All epiphyte data are expressed as a percentage of seagrass cover.

4.3 Results

General habitat description

Of the 6833 m of video transect recorded, 48.9% was seagrass, 15.9% sand, 14.5% reef, 12.7% mixed seagrass and reef, and 0.8% mixed reef and sand, with the remaining 7.2% not categorised due to poor image quality. The seagrass habitat was 33.4 ± 1.2 (se)% *Posidonia*, and 60.7 ± 1.2% *Amphibolis*, with only a small amount of sand (4.4 ± 0.4%) and algae (1.4 ± 0.2%).

Seagrass Condition Index

The calculated values of H' were generally high across the area of study (mean 96.2 ± 1.1 (se)), indicating very good structure of seagrass meadows in the region overall. The lowest individual measure of H’ was 80.5 for transect 3 (2nd from shore) on survey line 620007 (southwestern-most). While the spatial variation in H’ was not analysed statistically, Figure 4.1 shows that transects with H’<90 appear to be randomly distributed within the survey area.

Epiphytes

Mean epiphyte cover on seagrasses over the entire study area was 8.2% (± 0.63 se). Although epiphyte cover was generally low, some transects had up to 83%, with higher levels of cover occurring just offshore from the mouth of the Inman River, although the most inshore sites had low epiphyte loads (Figure 4.2).

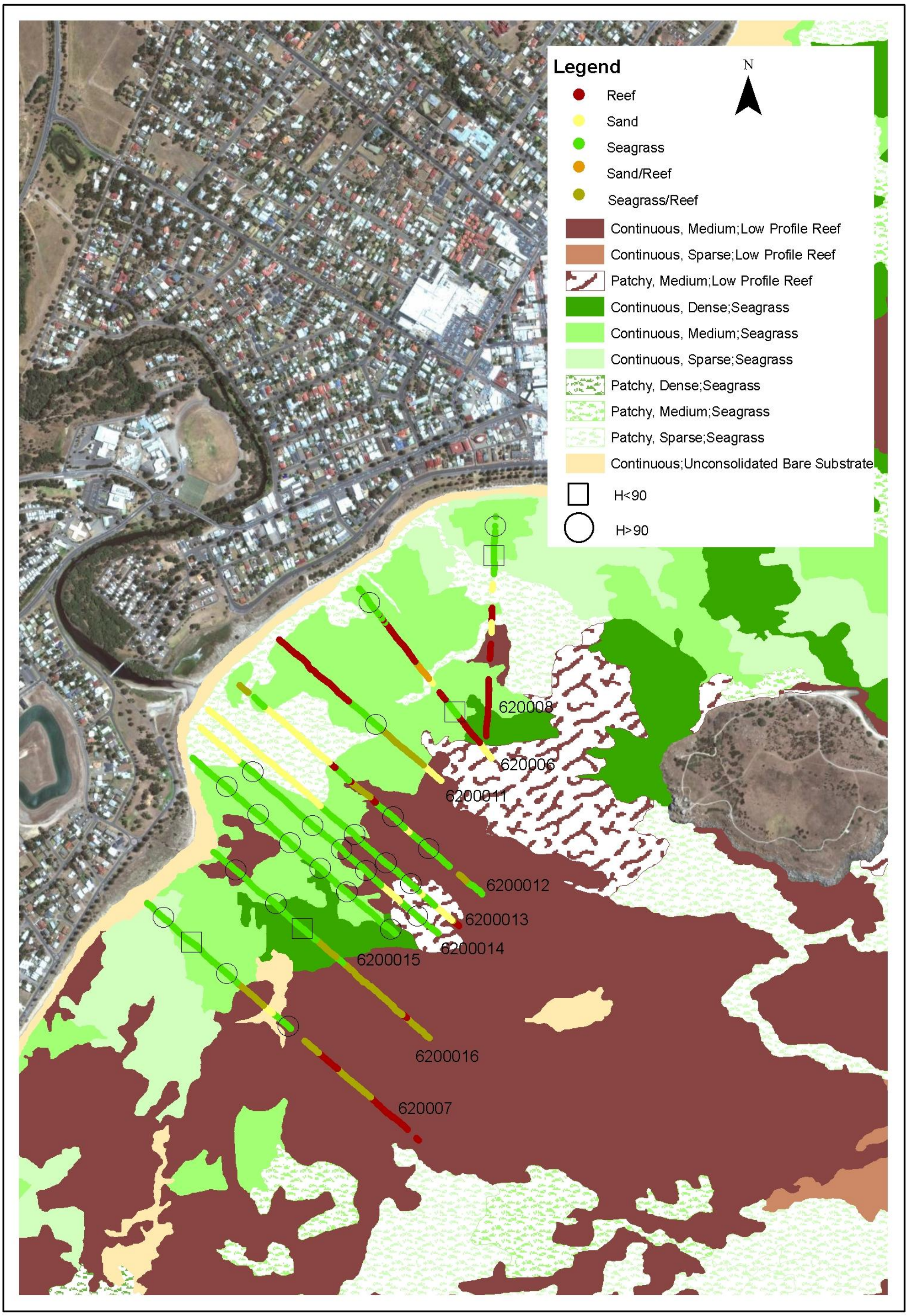

Figure 4.1: Habitat classifications offshore from the Inman River mouth from the video transects, and from broader scale DENR (now DEWNR) habitat mapping.

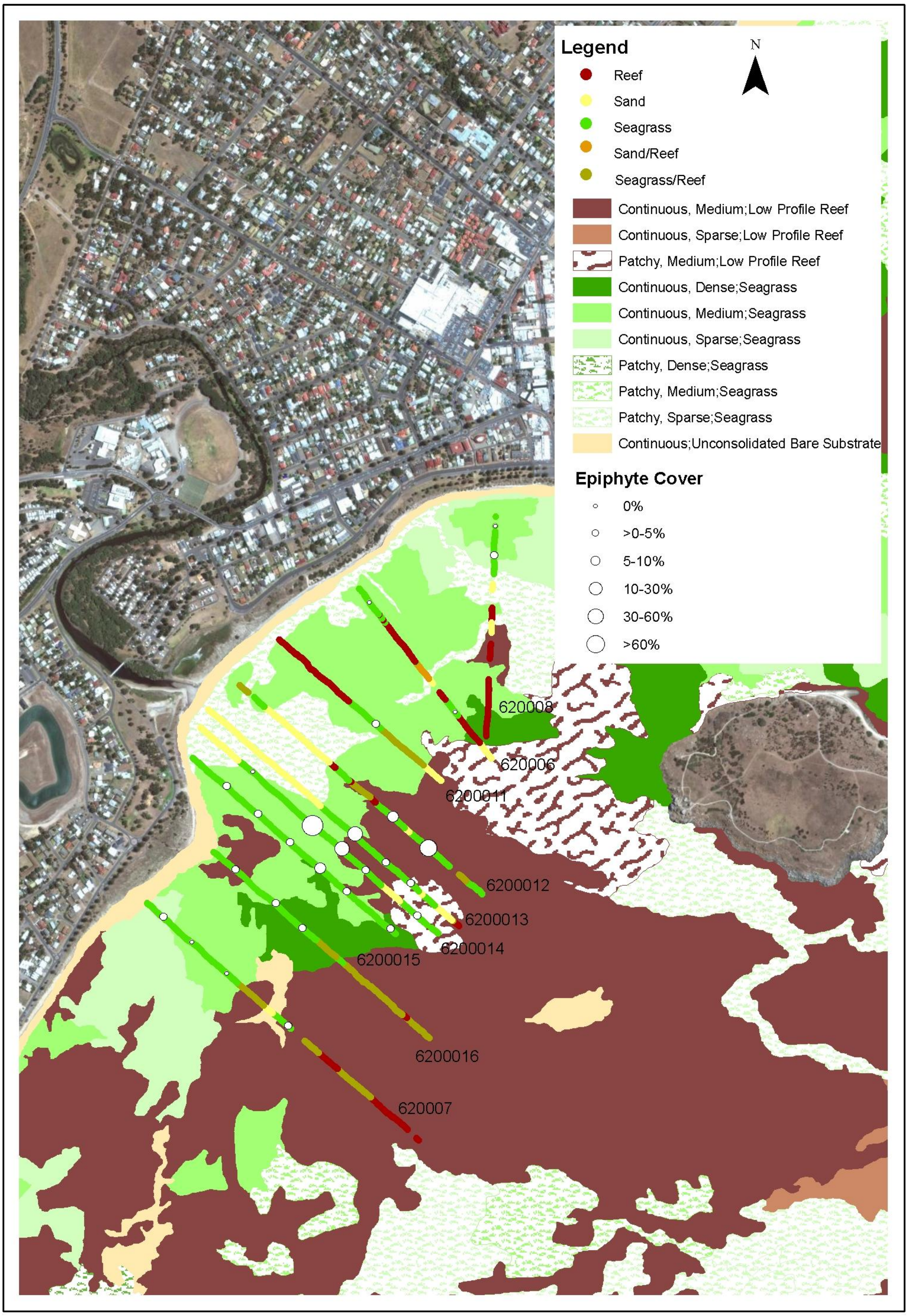

Figure 4.2: Seagrass epiphyte cover off the Inman River mouth.

4.4 Discussion

The study area was a complex mixture of habitats, dominated by seagrasses and rocky reef. The habitat classification derived from the video surveys undertaken in 2011 did not match well with that from the prior broad-scale habitat mapping. The latter was based on aerial photography collected in 2000, backed up by subsequent undated acoustic and towed video surveys (DEH 2008), both of which would have been relatively sparse in comparison to the sampling intensity used here due to the much larger extent covered. These differences are likely to be due to a combination of errors in the interpretation of the original aerial photography (which probably accounts for areas which were originally classified as seagrass and that we classified as reef), along with changes in habitat distribution and/or differences in habitat definitions (areas that were sparse seagrass and are now sand). The area that has changed classification from sparse seagrass to sand directly off the Inman River mouth needs to be interpreted cautiously, as individual operators may differ in their classification of these habitats. If the changes are real, they suggest that discharges from the river may be causing seagrass loss. Imagery available on Google Earth for 31/12/2004 and 20/11/2010 seems to show that these areas are bare sand, indicating that the majority of loss must have occurred between 2000 and 2004.

Areas that were classified as continuous seagrass appeared to be in good condition, with most transects surveyed have a high H'. The spatial arrangement of transects with a lower H' appeared to be random, with no obvious clustering or relationship to known environmental drivers. High epiphyte cover on the other hand, while occurring at a relatively low number of sites, appeared to be clustered directly offshore from the mouth of the Inman River. However, there was a transect of zero epiphyte cover between these medium to high sites and the river mouth, making it difficult to ascribe this spatial pattern to discharges from the river.

Chapter 5: General Conclusions

Based on the observations presented here, seagrasses in Yankalilla Bay and off the Light River delta appear to be in good condition. Despite being subjected to the outflows from rivers with high nutrient loads and other pollutants, there was no observed loss of seagrass off Light River, and epiphyte levels at both locations were not elevated. These results could be due to three different (non-exclusive) reasons. Firstly, nutrient loads in the waters discharged by these rivers are not high enough to cause seagrass loss. Secondly, nutrient levels may be diluted sufficiently before reaching the seagrasses that they don't cause a problem. This may be particularly relevant for the Light River, which discharges through a mangrove delta (see Figure 3.3), leading to both dilution and potential nutrient stripping before the waters reach the seagrass bed. The Bungala River and Carrickalinga Creek, however, flow across a sandy beach almost directly into the seagrass bed (see Figure 2.1), reducing the opportunities for dilution and especially nutrient stripping. Finally, all three rivers only flow intermittently, and periods of no flow may be sufficiently long for seagrasses to recover from degradation experienced during flow periods. There was no flow into Yankalilla Bay when the video was taken there, although it is not known how long this situation had persisted (Murray-Jones et al. 2009). Unfortunately, data on nutrient loads, discharge rates, and dispersion in the marine environment are lacking for all three waterways, and thus it is not possible to distinguish between these alternatives.

In contrast to Yankalilla Bay and the Light River, there is some suggestion of seagrass decline off the Inman River. Immediately offshore from the river mouth was classified as sand in this study, and as sparse seagrass in 2000 by DEH (now DEWNR). There is no historical information prior to 2000, so it is not known if this area has always been bare sand and/or sparse seagrass, or if seagrasses have been lost due to degraded water quality in the Inman River. The high epiphyte loads offshore of the river mouth are also suggestive of degradation, although the complex pattern of high and low epiphyte cover means that this interpretation is not conclusive.

Given the potential degradation observed off the Inman River mouth, this area should be given priority for further monitoring and research. Monitoring every 1-2 years will allow detection of any short-term trends in seagrass condition. As well as video monitoring, consideration should be given to looking for markers that might help to determine if seagrasses are being negatively impacted by anthropogenic influences. Given that the pollutants present include nutrients from the decommissioned wastewater treatment plant and agricultural runoff (SKM 2010), stable isotopes may be useful indicators of anthropogenic impacts (e.g Fernandes et al. 2009a, b), while direct tests for other chemical pollutants may also be warranted. However, the recent development of an estuary action plan for this river (SKM 2010) may lead to improved water quality and an increase in seagrass condition over time. For Yankalilla Bay and the Light River delta, which both appear to be in good condition, monitoring can occur less frequently, on the order of every 3-5 years, and along fewer survey lines. If subsequent declines are detected, however, then increased sampling intensity and targeted research to identify their causes, will be required, if these aren't evident based on known events.

The likelihood of future declines in Yankalilla Bay is decreased by the recent development of an estuary action plan for the Bungala River (AECOM 2010), but no such plans currently exist for Carrickalinga Creek or the Light River (although salinity action plans have been developed for the latter – Harding et al. 2003, Henschke et al. 2008). However, the AMLR NRM Board are currently developing an estuary action plan for the Light River, and in conjunction with the District Council of Yankalilla, are developing a Yankalilla, Normanville and Carrickalinga Stormwater Management Plan. These plans should result in improved water quality in their respective catchments, thus reducing the potential for negative impacts from runoff occurring on what are currently healthy seagrass systems.

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