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Seagrass Condition Monitoring: Fleurieu Peninsula 2019

Jason E. Tanner and Mandee J. Theil

SARDI Publication No. F2019/000198-1
SARDI Research Report Series No. 1024

SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

July 2019

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

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This publication may be cited as:
Tanner, J.E. and Theil, M.J. (2019). Seagrass Condition Monitoring: Fleurieu Peninsula 2019. Final report prepared for the Adelaide and Mount Lofty Ranges Natural Resources Management Board. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2019/000198-1. SARDI Research Report Series No. 1024. 20pp.

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SARDI Publication No. F2019/000198-1
SARDI Research Report Series No. 1024

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Date:	9 July 2019
Distribution:	AMLRNRMB, SAASC Library, Parliamentary Library, State Library and National Library
Circulation:	Public Domain

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ACKNOWLEDGEMENTS

Fieldwork was undertaken by Ian Moody, Leo Mantilla, Mandee Theil and Paul Malthouse. Video analysis was conducted by Mandee Theil and Leo Mantilla. Comments on an earlier draft of this report from Jason Nicol and Ana Redondo Rodriguez, and the editorial oversight of Tim Ward, were appreciated. The encouragement of Kristian Peters (Adelaide and Mount Lofty Ranges Natural Resources Management Board), and the financial support of this organisation, is gratefully acknowledged.

EXECUTIVE SUMMARY

Video transects were undertaken along a number of survey lines in Yankalilla Bay in 2009 and in Encounter Bay in 2011-14, primarily to assess seagrass condition in these regions. In addition, epiphyte loads were scored from the video footage as a potential indicator of nutrient stress. Here, we undertake repeat surveys of the same lines in 2019 to assess if there have been any changes over time.

In Yankalilla Bay, there were no changes in seagrass habitat condition over time, although there was a decline in condition from south to north. Epiphyte cover decreased by around 50% over the ten year survey interval, potentially indicating decreased water column nutrients in the region. Epiphytes followed the opposite spatial pattern to habitat condition, being higher in the north. Both spatial patterns suggest that seagrasses in the north of the bay are under greater stress than those in the south. There is a small peak in epiphyte load just south of Bungala River, possibly indicating some localised nutrient input from this source. There was high variability in epiphyte cover off Carrickalinga Creek, making it difficult to discern any small-scale spatial pattern there.

In Encounter Bay, there has been a decline in seagrass habitat condition over time, which appears to be spatially consistent across the region, suggesting that it is not due to localized impacts. There was no significant change in epiphyte cover over time, although some suggestion of an increase around Hindmarsh River which warrants continued monitoring, and a possible decrease around the Inman River. Seagrasses in this region appear to be under some level of stress, and are potentially in decline.

Keywords: Seagrass, habitat condition, *Posidonia*, *Amphibolis*, Fleurieu Peninsula.

1. INTRODUCTION

Declines in seagrass habitat have been a major concern worldwide, with 29% of known seagrass area lost since 1879 (Waycott et al. 2009). South Australia has not been immune to this loss and its flow on effects. At Bolivar, 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 6200 ha has been lost (e.g. Westphalen et al. 2004), contributing to the need for an extensive sand replenishment operation along the metropolitan beaches to mitigate coastal erosion.

In 2009, the Department for Environment and Heritage (DEH, now Department for Environment and Water - DEW) 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. Subsequent surveys were undertaken off the Light River delta and off the Inman River in Encounter Bay in 2011 (Tanner et al. 2012), and around the Hindmarsh River in Encounter Bay in 2013/14 and Port Adelaide in 2014 (Tanner et al. 2014).

To determine if any changes have occurred since these original surveys, we repeated surveys at the Fleurieu Peninsula sites (Yankalilla Bay and Encounter Bay). The same methodology is utilised, allowing a direct comparison between surveys. We document both seagrass habitat condition, and epiphyte cover, and compare these to the results of the previous surveys in 2009 and 2013/14 respectively.

Understanding and maintaining or improving the condition of marine assets (e.g. seagrasses) remains a legislative requirement under the South Australian *Natural Resources Management Act (2004)*. The Adelaide and Mount Lofty Ranges (AMLR) NRM Plan identifies seagrass as an important component of regional marine ecosystems, and measuring the health and condition against its regional targets is fundamental to measuring success of the implementation of the Regional Plan. Regional Targets that this work contributes to include:

T9: Improvement in conservation prospects of native species from current levels

T10: Reduced land-based impacts on coastal, estuarine and marine processes

T11: Halt the decline of seagrass, reef and other coast, estuarine and marine habitats and a trend toward restoration.

Seagrass monitoring is an invaluable component to providing information that informs the regional Marine Health conceptual model found within the AMLR NRM Plan. Seagrass monitoring is also underpinned by guiding targets 10, 12 and 13 of the South Australia's NRM Plan (2007-2017) and respective regional NRM Plans.

2. METHODS

2.1. Field work

Sampling of seagrass beds was conducted in Yankalilla Bay on the 20th and 25th February, and in Encounter Bay on the 2nd and 3rd of April 2019. As close as was possible given the limitations of sea conditions and tides, the same transects (Figure 2.1) were surveyed as previously, following the methods described in Murray-Jones et al. (2009). In Yankalilla Bay, 14 survey lines perpendicular to shore were surveyed, along with a single longshore line. Each perpendicular line ran from ~1300m offshore, to ~300m from the beach, or as close as possible without endangering the vessel. One line was directly offshore from each of the Bungala River and Carrickalinga Creek mouths, with three lines either side of each. In Encounter Bay, 20 survey lines perpendicular to the shore were sampled, one off Basham's Beach, one in Horseshoe Bay, one off Watson's Gap with one additional line either side, four off the Hindmarsh River mouth and 9 around the Inman River mouth. Each of these survey lines ran from ~500-1300 m offshore towards the inshore region to the shallowest point that the vessel could operate (generally ~0.8–1 m in depth). Again, as close as possible, these surveys lines replicated those surveyed previously (Tanner et al. 2012, 2014).

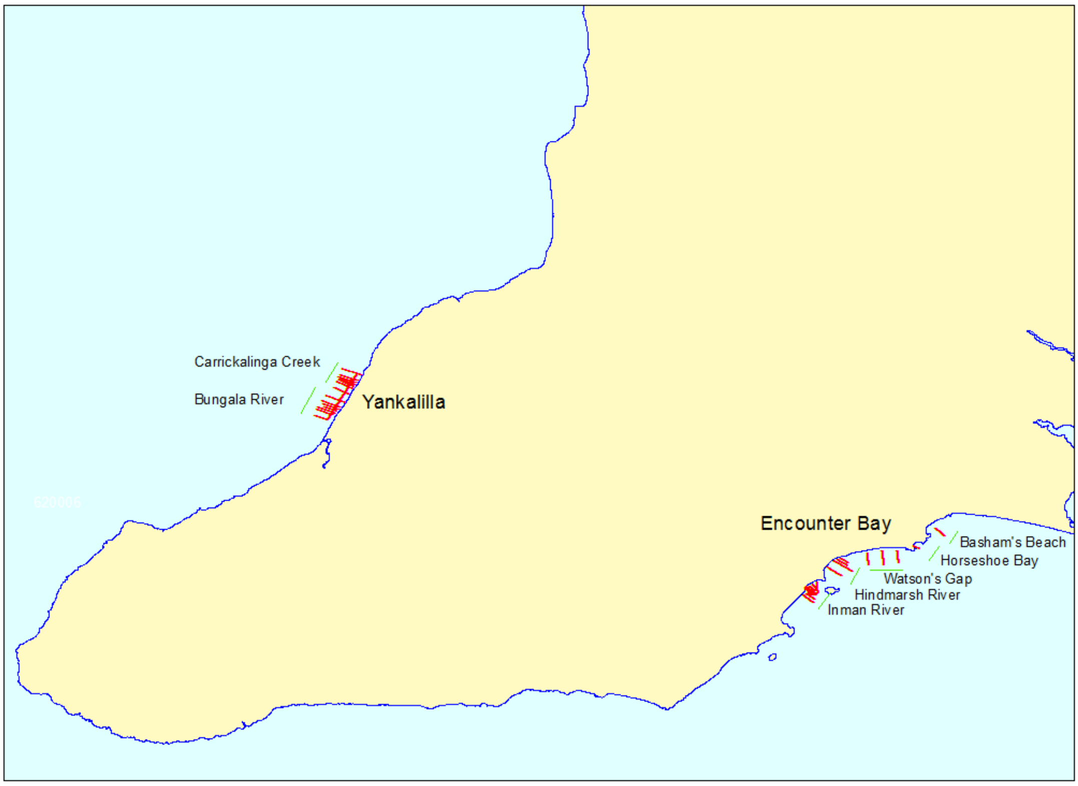

Figure 2.1: Map showing the location of the study regions on the Fleurieu Peninsula, survey lines (red) and site groupings mentioned in the text (green lines).

For each survey line, a GoPro camera attached to an analogue underwater camera with a live feed to the vessel was towed at ~1.3 ms^{-1}, which recorded continuous video of the seafloor. The analogue camera had a GPS overlay, allowing the position of habitat breaks to be accurately recorded, while the GoPro provided high quality footage for the analysis of habitat composition.

2.2. Video analysis

The videotape from each survey line was used to locate the position of distinct habitat and species boundaries. Habitats were originally scored using a fine habitat classification based on the analysts interpretation of the footage, with classifications then merged into a smaller number for mapping. Subsets of 50 m in length within seagrass habitat (subsequently referred to as transects) were randomly selected for detailed analysis of seagrass habitat condition and epiphyte cover. For Yankalilla, where seagrass habitat was extensive, three transects were selected on each survey line offshore from the longshore line, and three inshore of it. There were several instances where the habitat inshore was predominantly reef and/or bare sand, and there was thus insufficient seagrass to obtain all three transects (survey lines 625007, 625015 and 625016 only had 0, 2 and 1 inshore transects respectively). For the longshore line, three transects were surveyed either side of each river mouth. In Encounter Bay, 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 Encounter Bay, with large areas of bare sand and rocky reef in addition to seagrasses, there was no stratified sampling undertaken, unlike for Yankalilla.

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 stops an estimated 1 m apart (approximating 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 vessel 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 (low light and the difficulty of identification from video meant that seagrass was only identified to genus) and percentage cover. Other substrate types were scored (e.g. areas of sand, rock and algae) and grouped together for analysis. Epiphyte cover was expressed as a percentage of total seagrass cover.

2.3. Statistical analysis

Yankalilla

For the across-shore lines, both H' and epiphyte cover were analysed with an analysis of covariance using R v3.5.1 (R Core Team 2018). Year (2009 vs 2019) and Distance from Shore (inshore vs offshore) were included, as well as distance from the southernmost transect. Individual survey line was not included as a factor as it was aliased with distance from the southernmost transect. For the longshore line, a 2-way analysis of variance was used, with river and year as factors.

Encounter Bay

The more complex spatial arrangement of the Encounter Bay transects meant that there was no simple along-shore distance to include in the analysis, so analysis of variance was used for both H' and epiphyte cover. The data were divided into two regions – Inman River and Hindmarsh River. Instead of distance alongshore, the individual survey lines were included as a factor, nested within region. To examine broader changes in habitat structure over time, percentage habitat cover (using the coarser habitat classification) on each transect was analysed using PERMANOVA (Anderson 2001) in the PERMANOVA+ add on (Anderson et al. 2008) to Primer v7 (Clarke and Gorley 2015). Region and year were orthogonal factors, with survey line nested within region. Because there were a limited number of habitat types, Euclidean distances were used to calculate the resemblance matrix, and 9999 permutations of residuals under a reduced model were performed. This was followed up by a principal co-ordinates analysis to visualise differences.

3. RESULTS

3.1. Yankalilla

Mixed *Amphibolis* and *Posidonia* was the dominant habitat present in Yankalilla Bay, with *Amphibolis* (continuous and patchy) being the next most dominant habitats (Table 3.1). Many of the habitats present were mixed, with frequent changes between them. Overall, seagrass accounted for 63% of the survey area, mixed seagrass and reef for 17%, reef for 16% and sand 4% (Figure 3.1). Similar data for 2009 were not available for comparison.

Table 3.1: Habitat types present on the survey lines in Yankalilla Bay.

Cover type	%
Amphibolis	13.0
Amphibolis/macroalgae	8.1
Amphibolis/macroalgae/*Posidonia*	5.0
Amphibolis/macroalgae/*Posidonia*/reef	0.6
Amphibolis/macroalgae/reef	0.2
Amphibolis/*Posidonia*	24.5
Amphibolis/sand	0.4
Halophila/patchy *Posidonia*	0.1
macroalgae	7.3
macroalgae/patchy *Amphibolis*	0.8
macroalgae/patchy *Amphibolis*/*Posidonia*	0.2
macroalgae/patchy *Amphibolis*/*Posidonia*/reef	0.3
macroalgae/patchy *Amphibolis*/reef	0.2
macroalgae/*Posidonia*	0.5
macroalgae/reef	8.7
macroalgae/rock/sand	0.1
macroalgae/sand	0.3
patchy *Amphibolis*	13.0
patchy *Amphibolis*/*Posidonia*	1.6
patchy *Amphibolis*/rock/*Zostera*	0.8
patchy *Posidonia*	2.9
patchy reef	0.1
Posidonia	6.6
sand	4.1
very patchy *Amphibolis*	0.4

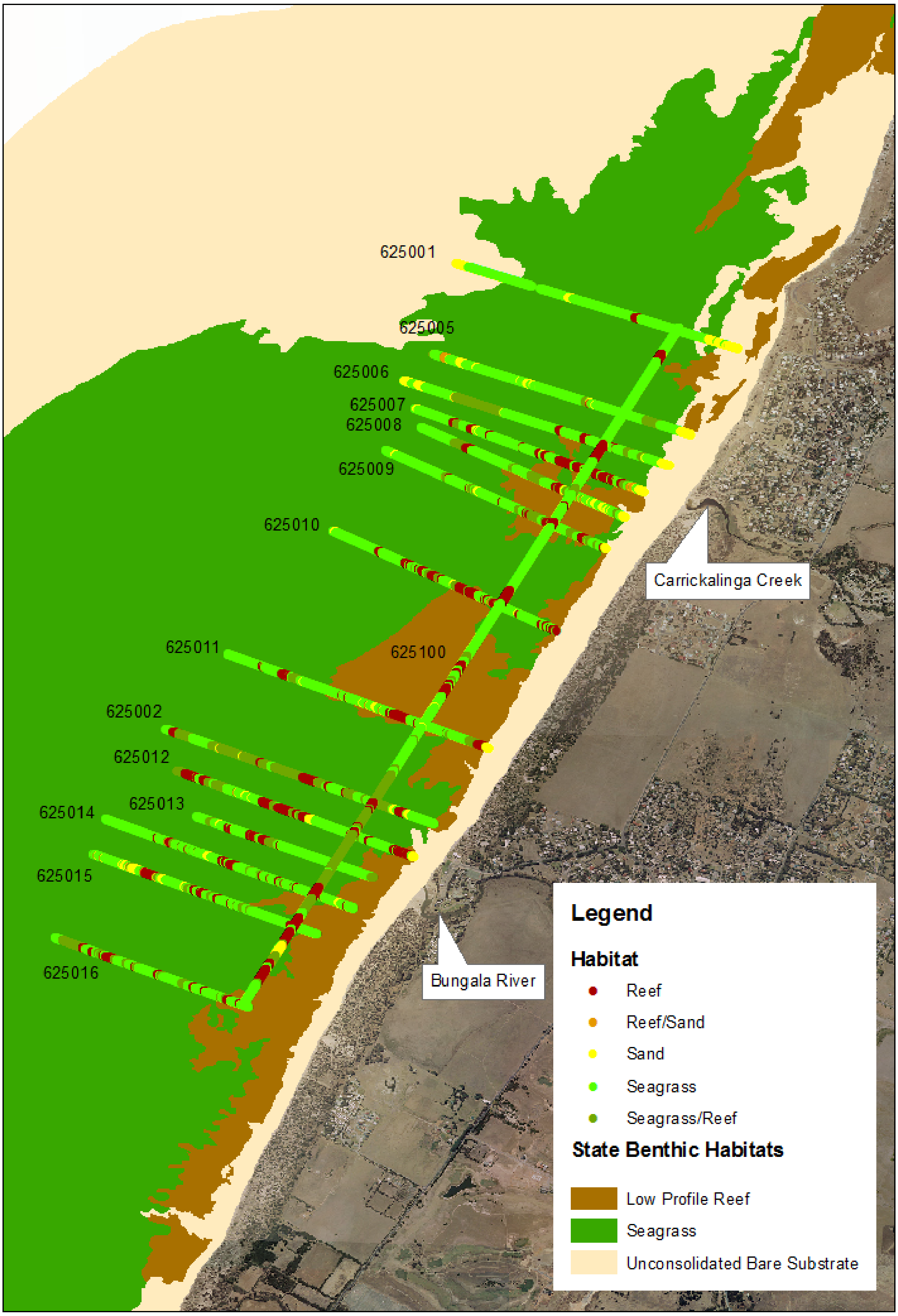

Figure 3.1: Map showing coarse level habitat classifications along the 2019 survey lines in Yankalilla Bay, with the state benthic mapping habitat classification as background. The longshore line (625100) indicates the demarcation between inshore and offshore transects.

For the across-shore data, there was an interaction between distance from the southernmost survey line and distance offshore for the habitat condition index, but no other factor was significant (Table 3.2). Importantly, year was not significant, indicating that no change occurred in seagrass habitat condition in the ten years between surveys. There is a general decreasing trend in seagrass habitat condition from south to north (Figure 3.2). Habitat condition is higher inshore in the south, but higher offshore around the mouth of Carrickalinga Creek, accounting for the significant interaction. The longshore data supported the difference between north and south (Table 3.3), and no change over time, with Carrickalinga transects having a 14% lower H' than the Bungala transects (Figure 3.3).

Table 3.2: ANCOVA results for seagrass habitat condition in Yankalilla Bay.

	df	**SS**	**F**	**P**
Distance	1	4730	51.8	**<0.0001**
Year	1	167	1.83	0.18
Inshore/Offshore	1	29	0.32	0.57
Distance x Year	1	1	0.007	0.93
Distance x Inshore/Offshore	1	700	7.67	**0.006**
Year x Inshore/Offshore	1	287	3.14	0.08
Distance x Year x Inshore/Offshore	1	99	1.09	0.30
Residuals	152	13876		

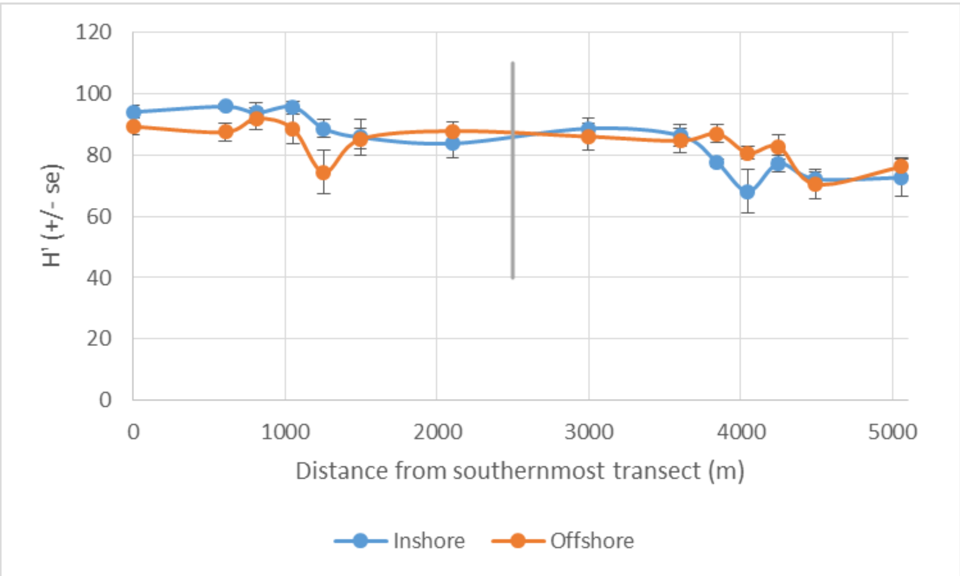

Figure 3.2: Seagrass habitat condition index in Yankalilla Bay. Grey vertical line indicates demarcation between survey lines off Bungala River (left) and those off Carrickalinga Creek (right).

Table 3.3: ANOVA results for seagrass habitat condition on the longshore survey line in Yankalilla Bay.

	df	SS	F	P
River	1	1073	19.9	**0.0003**
Year	1	18.5	0.34	0.57
River x Year	1	5	0.09	0.76
Residuals	19	1027		

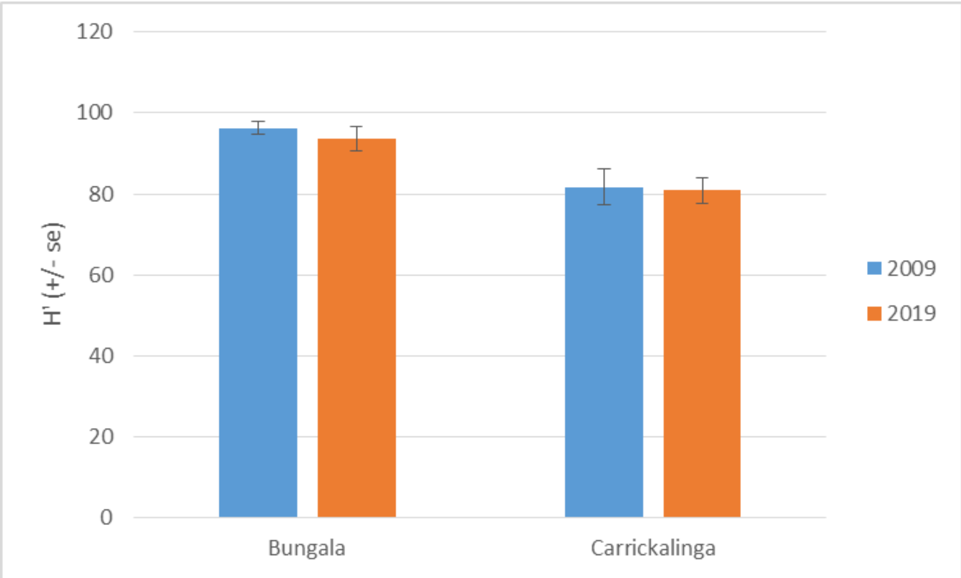

Figure 3.3: Seagrass habitat condition on the longshore survey line in Yankalilla Bay.

Epiphyte cover of seagrasses was significantly affected by distance from the southernmost survey line, year, and distance from shore (Table 3.4) in the across-shore data. Off Bungala River, epiphyte cover was relatively low, but peaked immediately offshore from the river (Figure 3.4). Cover was low inshore in 2019 compared to offshore and to 2009. Epiphyte cover was higher off Carrickalinga Creek, and much more variable, although again 2019 inshore tended to be low. Looking at year in isolation, 2009 had a mean epiphyte cover of seagrass of 7.3% (± 0.9 se), while 2019 had 5.1% (± 0.7). Inshore transects had 4.1% cover (± 0.6), while offshore had 8.1% (± 1). There was a significant river by year interaction in the longshore data (Table 3.5), with Bungala having consistently lower cover than Carrickalinga and 2019 lower than 2009 (Figure 3.5).

Table 3.4: ANCOVA results for seagrass epiphyte cover in Yankalilla Bay.

	df	SS	F	P
Distance	1	1333	29.8	**<0.0001**
Year	1	217	4.85	**0.029**
Inshore/Offshore	1	641	14.3	**0.0002**
Distance x Year	1	67	1.49	0.22
Distance x Inshore/Offshore	1	119	2.65	0.11
Year x Inshore/Offshore	1	0	0.003	0.95
Distance x Year x Inshore/Offshore	1	5	0.10	0.75
Residuals	152			

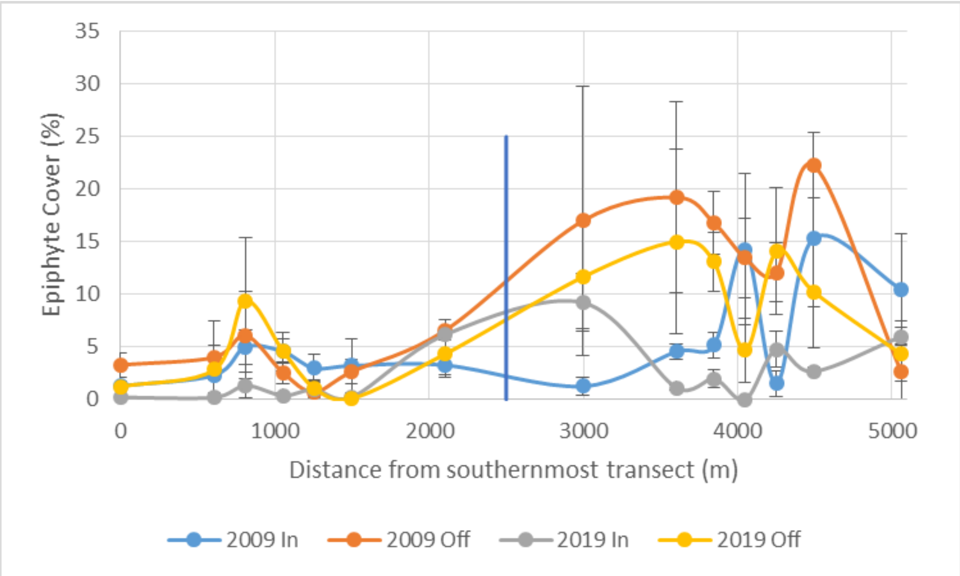

Figure 3.4: Seagrass epiphyte cover in Yankalilla Bay. Blue vertical line indicates demarcation between survey lines off Bungala River (left) and those off Carrickalinga Creek (right).

Table 3.5: ANOVA results for seagrass epiphyte cover on the longshore survey line in Yankalilla Bay.

	df	SS	F	P
River	1	170	8.76	**0.008**
Year	1	124	6.39	**0.021**
River x Year	1	95	4.87	**0.040**
Residuals	19	369		

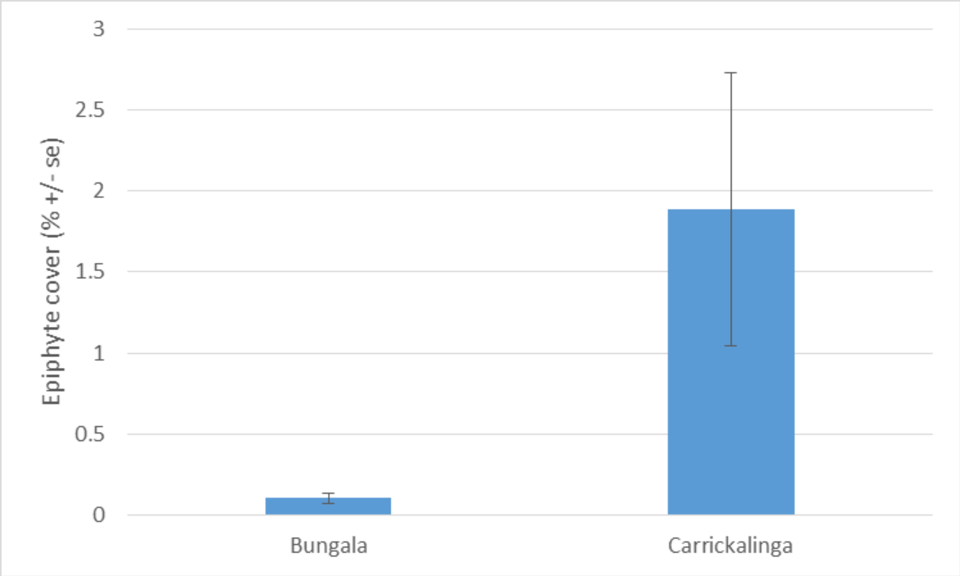

Figure 3.5: Seagrass epiphyte cover on the longshore survey line in Yankalilla Bay.

3.2. Encounter Bay

The Hindmarsh transects were dominated by reef and similar habitats (40%) and sand (40%), with only 10% seagrass, while those at Inman had a much higher cover of seagrass (47%) and mixed seagrass/reef (18%) (Table 3.6). In comparison, in 2011 there was 53% seagrass cover at Inman and 14% mixed seagrass/reef – so very little change. In 2013/14, Hindmarsh was 32% reef and 27% sand, but 20% seagrass. *Amphibolis* was again the dominant seagrass. Despite these differences, there was no overall difference in habitat structure between years in Encounter Bay, although there was between regions, and between survey lines within a region (Table 3.7). As would be expected based on Table 3.6, the principal co-ordinates analysis (Figure 3.7) shows the main differences between Hindmarsh and Inman survey lines occur on an axis defined by contrasting amounts of seagrass and reef habitat.

Table 3.6: Habitat types present on the survey lines in Encounter Bay.

	Percent Cover	
Cover type	**Hindmarsh**	**Inman**
Amphibolis	2.1	17.7
Amphibolis/macroalgae	1.4	7.9
Amphibolis/macroalgae/patchy *Posidonia*	0.0	1.9
Amphibolis/macroalgae/*Posidonia*	0.5	0.0
Amphibolis/macroalgae/*Posidonia*/reef	0.3	0.0
Amphibolis/macroalgae/*Posidonia*/reef/patchy *Zostera*	0.3	0.0
Amphibolis/macroalgae/reef	1.5	5.6
Amphibolis/macroalgae/sand	0.1	0.0
Amphibolis/*Posidonia*	1.8	12.5
Amphibolis/*Posidonia*/*Zostera*	0.0	0.8
Amphibolis/rock/macroalgae	1.1	0.0
Amphibolis/sand	0.0	0.8
Amphibolis/*Zostera*	0.0	1.7
Halophila/sand/very patchy *Posidonia*	0.3	0.0
macroalgae	0.1	0.0
macroalgae/*Posidonia*	0.0	0.2
macroalgae/reef	24.4	13.1
macroalgae/reef/patchy *Zostera*	0.5	0.0
macroalgae/reef/*Posidonia*	0.3	1.3
macroalgae/reef/*Zostera*	0.4	0.0
macroalgae/rock/sand	0.0	3.4
macroalgae/sand	1.1	0.4
macroalgae/sand/*Zostera*	0.0	0.6
macroalgae/*Zostera*	0.0	0.2
patchy *Amphibolis*/macroalgae/patchy *Posidonia*/reef	0.2	0.0
patchy *Amphibolis*/macroalgae/reef/patchy *Zostera*	0.6	0.0
patchy *Amphibolis*/macroalgae/sand	0.5	0.0
patchy *Amphibolis*/sand	0.2	0.0
Posidonia	5.5	8.7
Posidonia/*Zostera*	0.0	0.6
rock	0.0	0.1
rock/macroalgae	15.9	0.0
rock/macroalgae/*Posidonia*	0.1	0.0
rock/*Posidonia*/*Zostera*	0.0	0.6
sand	40.4	18.0
sand/rock	0.2	0.0
sand/*Zostera*	0.5	3.2
Zostera	0.0	0.7

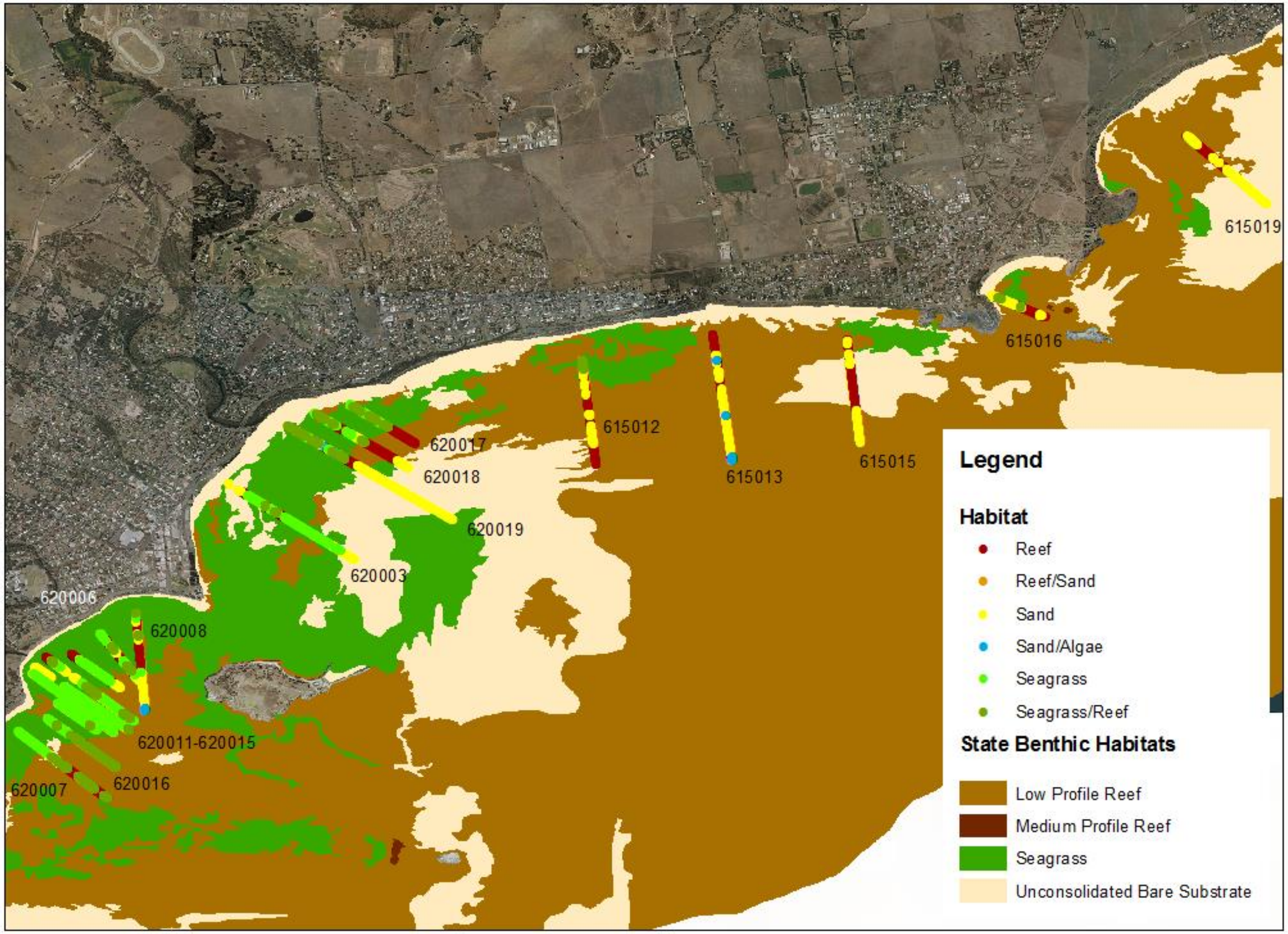

Figure 3.6: Map showing coarse level habitat classifications along the 2019 survey lines in Encounter Bay, with the state benthic mapping habitat classification as background.

Table 3.7: PERMANOVA analysis for habitat cover in Encounter Bay.

Source	df	SS	Pseudo-F	P
Year	1	1199.9	1.6855	0.1436
Region	1	15571	5.382	**0.0071**
Survey Line(Region)	16	46290	4.0642	**0.0001**
Year x Region	1	1171.1	1.6451	0.1562
Residual	16	11390		

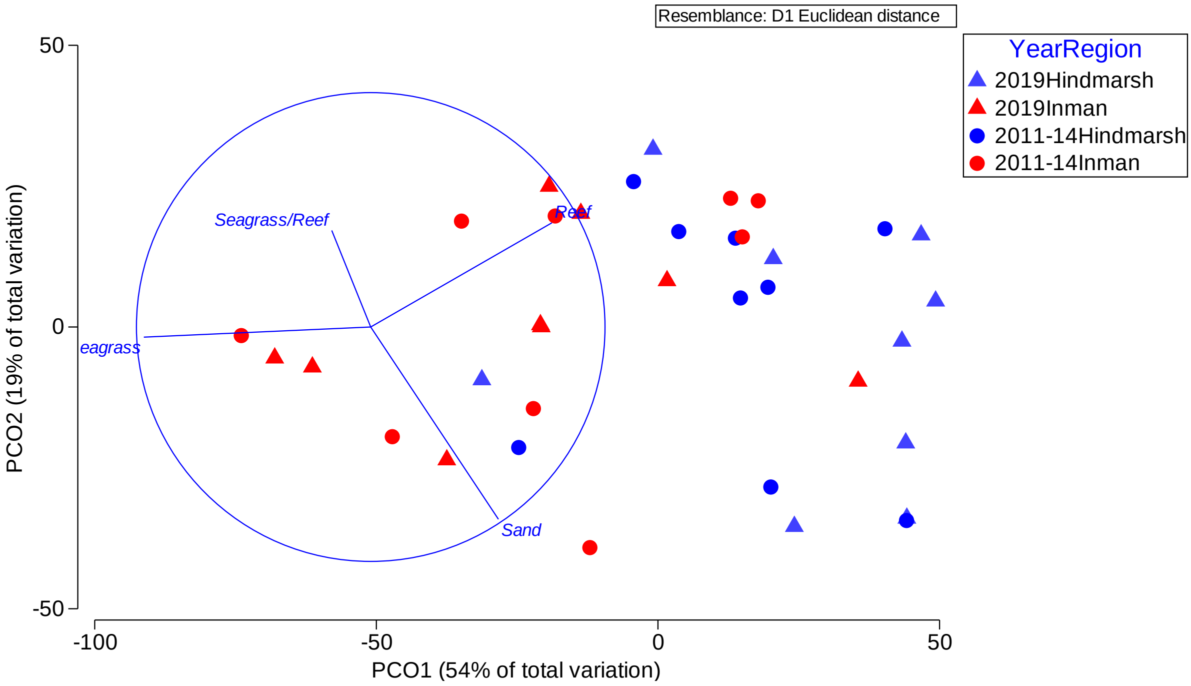

Figure 3.7: Principal co-ordinates analysis of habitat cover in Encounter Bay.

There were significant main effects of both year and region for the habitat condition index, but no interactions (Table 3.8). For both regions, the mean habitat condition index score declined by ~10% between surveys, while Hindmarsh had a ~15% lower score than Inman for both surveys (Figure 3.8).

Table 3.8: ANOVA results for seagrass habitat condition in Encounter Bay.

	df	SS	F	P
Year	1	1697	15.3	**0.0002**
Region	1	3185	28.7	**<0.0001**
Year x Region	1	0	0.001	0.98
Survey Line (Region)	14	2185	1.4	0.17
Survey Line (Region) x Year	9	984	0.99	0.46
Residuals	68	7536		

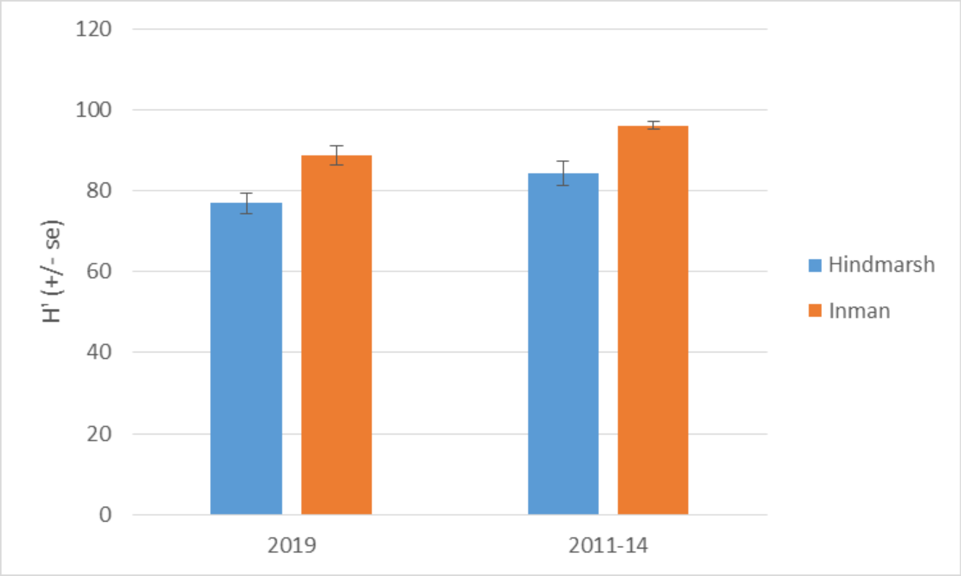

Figure 3.8: Seagrass habitat condition index in Encounter Bay.

Epiphyte cover of seagrasses did not vary with any of the factors examined (Table 3.9). There was, however, high variability, especially at Inman in 2011 (Figure 3.9). The general trend, however, was for epiphyte cover to increase at Hindmarsh and decrease at Inman over time.

Table 3.9: ANOVA results for seagrass epiphyte cover in Encounter Bay.

	df	SS	F	P
Year	1	0	0.004	0.95
Region	1	92	0.82	0.37
Year x Region	1	365	3.28	0.07
Survey Line (Region)	14	2411	1.55	0.12
Survey Line (Region) x Year	9	1368	1.37	0.22
Residuals	68	7574		

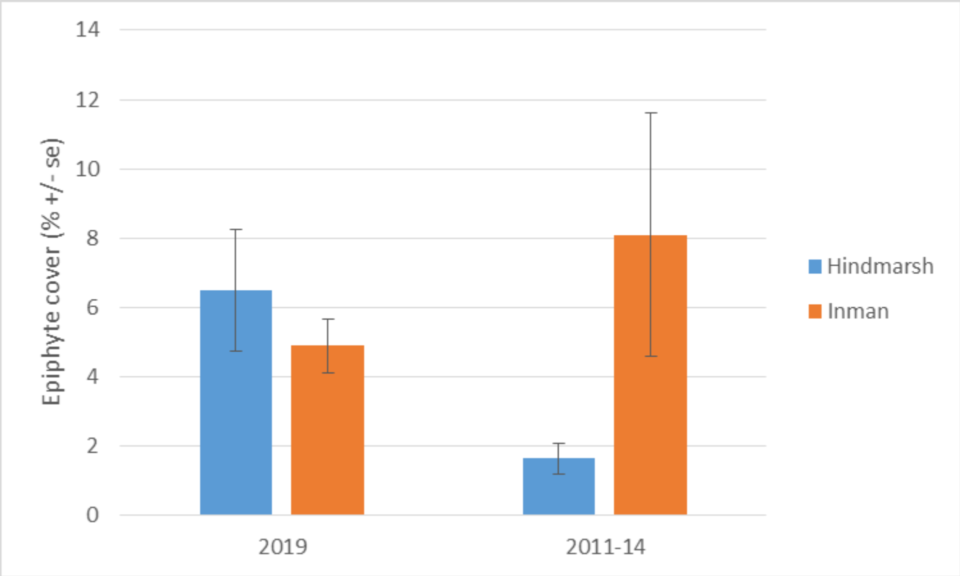

Figure 3.9: Seagrass epiphyte cover in Encounter Bay.

4. DISCUSSION

In Yankalilla Bay, there is a gradient in seagrass habitat condition from south to north, with condition being the best in the south in the vicinity of Bungala River. There were also differences between inshore and offshore, although these changed along the coast, with condition being better inshore in the south, but offshore off Carrickalinga Creek. Importantly, there were no differences detected between 2009 and 2019. In both years, there was a decline in habitat condition inshore in the vicinity of Carrickalinga Creek, which may indicate a localized decline in water quality due to discharge from the creek, although it could also be a result of natural variation in the substrate present (Murray-Jones et al. 2009).

Epiphyte cover in Yankalilla Bay varied as a function of location along the shore, distance from shore and year. There was approximately a 50% decline in cover between 2009 and 2019. This should be interpreted somewhat cautiously, as epiphytes are fast growing, and can potentially vary substantially over short time periods. With only 2 surveys ten years apart, it is not possible to determine if this is a sustained decline, or if the surveys just happened to be during a short-term peak in 2009 and trough in 2019. For longer-lived seagrasses, changes between two time points are of greater concern, as under natural conditions, change occurs slowly from year to year. There was a clear indication of a peak in epiphyte load on the survey line just south of Bungala River, which would be expected if the river is discharging nutrients which then move south. This peak occurred in both years, and both inshore and offshore. Off Carrickalinga Creek, epiphyte loads were much higher, but also a lot more variable. The high level of epiphytes present may indicate increased nutrient levels in this part of the bay, with local factors leading to variability within and between survey lines. If this is the case, and the decline in epiphyte load is a real long-term trend, then this suggests that nutrient loads are declining. However, additional surveys will be required to confirm this.

In Encounter Bay, there is some suggestion that the extent of seagrass cover has declined around Hindmarsh River, but not Inman River. However, the overall analysis of habitat change only showed spatial variation, and no temporal change. The transects around Inman River had substantially higher seagrass cover than those around Hindmarsh River, while reef cover showed the opposite pattern. Seagrass habitat condition, however, did decline over time around both rivers, by about 10%. There was no variation between survey lines within a region, indicating that the decline was region wide rather than along particular lines. It thus appears that whatever has led to this decline has occurred at the scale of the entire survey area, and is not a localised impact.

The lower habitat condition score for Hindmarsh River compared to Inman River is not surprising given the greater proportion of reef in this area, as the index is designed for use in shallow soft-sediment habitats where seagrasses are expected to dominate. It does not work so well in areas that are a mosaic of seagrass and reef, and should not be used for spatial comparison, although temporal comparisons are still valid. To properly understand overall habitat condition off Hindmarsh River would require the development of a similar index for macroalgae, perhaps with a focus on robust brown species (Turner et al. 2006) using methodology such as photoquadrats and indices such as community structure and percent cover of canopy forming macroalgae (Brook and Bryars 2014; Brock et al. 2018), although this also would suffer from the mosaic of habitat types present.

While there were no significant differences in epiphyte cover in Encounter Bay, there is some suggestion that it may have declined off Inman River and increased off Hindmarsh River. Again, the same caveats apply as for Yankalilla Bay, in that with only two surveys, it is not possible to determine if this is a long-term trend or simply short-term variation. It does, however, suggest that the potential for nutrient enrichment off Hindmarsh River needs to be considered.

The longshore survey line showed broadly similar patterns to the across-shore survey lines in Yankalilla Bay, although as there was only a single line, replication was less, making it potentially more difficult to detect patterns. Whilst it was repeated here for the purpose of historical comparison, it does not improve resolution for comparison of the overall condition seagrass in the region, and is essentially redundant. Consideration should thus be given to whether the resources used to survey this line would be better used elsewhere.

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