Mackay-Whitsunday-Isaac Seagrass Monitoring 2017-2023

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Mackay-Whitsunday-Isaac Seagrass Monitoring

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Pictured are from left to right : Mick Eden (Townsville Helicopters), Michael Rasheed (JCU), Jaime Newborn (Healthy Rivers 2 Reef Partnership), Tim Ffrost, Grant Jones and Carmen Vele (Dalrymple Bay Infrastructure).

CONTENTS

1 KEY FINDINGS

VERY GOOD

Seagrass Condition 2023

1. This is the seventh year of annual seagrass monitoring for the southern marine zone in Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership (HR2RP).
2. The overall condition of seagrasses across the three monitoring meadows was rated as very good in 2023 with all three indicators (biomass, meadow area and species composition) scoring good or very good against the baseline (Figure 1).
3. This year is the third year that scores can be generated for inclusion in the HR2RP Report Card, now that the requirement of 5 years of baseline data has been surpassed.
4. There were favourable conditions for seagrass growth leading up to the 2023 survey, with no noteworthy natural or anthropogenic impacts in the region since the previous survey.
5. The seagrasses in the region continued to have a high level of utilisation by dugongs with dugong feeding trails recorded in the two inshore meadows as well as the presence of a numerous green turtles observed during the survey.

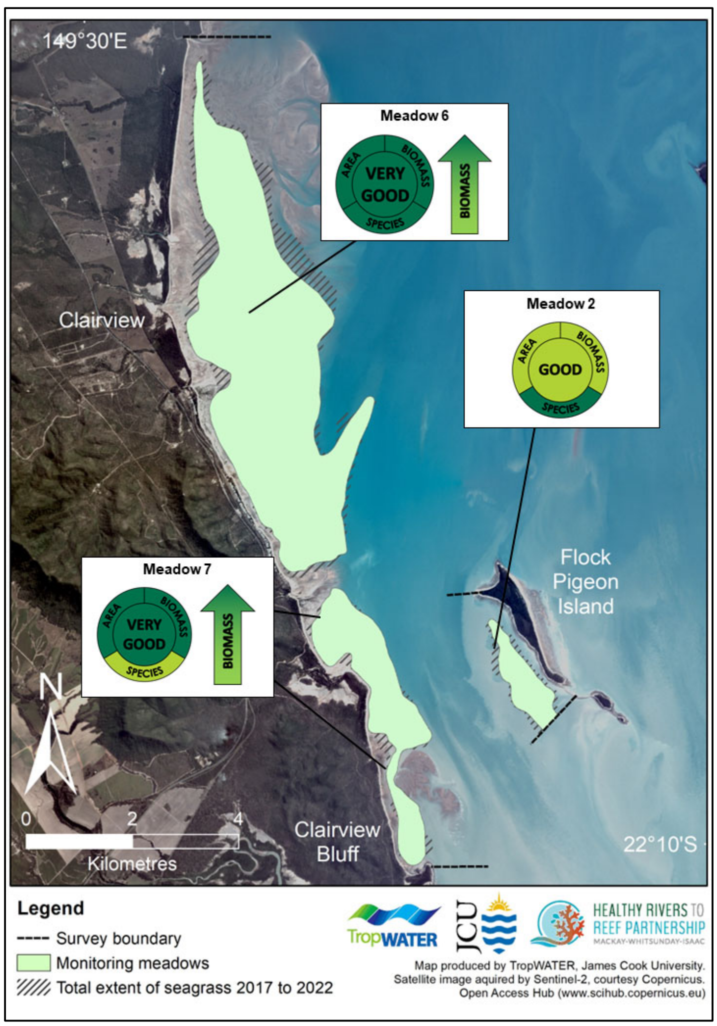

Figure 1. Seagrass condition for HR2R partnership southern zone seagrass monitoring areas 2023

2 INTRODUCTION

Seagrass habitats are immensely productive and provide a range of ecosystem services with substantial economic value (Costanza et al. 2014, Scott et al. 2018). These services include coastal protection, support of fisheries production, nutrient cycling, particle trapping, removal of bacterial pathogens, and acting as a carbon sink (Hemminga and Duarte 2000, Fourqurean et al. 2012, Lamb et al. 2017). Seagrasses provide food for herbivores like dugongs (*Dugong dugon*) and green turtles (*Chelonia mydas*) (Heck et al. 2008, Unsworth and Cullen 2010, Scott et al. 2018, Scott et al. 2020).

Natural and anthropogenic factors have contributed to global declines in seagrass (Waycott et al. 2009). Natural disturbances include tropical cyclones, floods, disease, and overgrazing by herbivores (Robblee et al. 1991, Fourqurean et al. 2010, McKenna et al. 2015). Anthropogenic activities that threaten seagrass habitat in the tropical Indo-Pacific region include industrial and urban run-off, port and coastal development, and dredging (Grech et al. 2012, York et al. 2015).

The sensitivity of seagrass to disturbance and environmental change make it an excellent indicator of marine environmental health (Dennison et al. 1993, Abal and Dennison 1996, Orth et al. 2006). Seagrass condition assessments require adequate baseline information on seagrass presence/absence, biomass, species composition, and meadow area, plus ongoing monitoring to understand and detect change. Long-term monitoring and condition reporting on Queensland's seagrass is largely undertaken by the Queensland Ports Seagrass Monitoring Program (QPSMP) that occurs in the majority of commercial ports (www.jcu.edu.au/portseagrassqld), and the Marine Monitoring Program (MMP) that focusses on the inshore Great Barrier Reef (GBR) (http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/reef-2050-marine-monitoring-program) and reports seagrass condition as part of the Reef Water Quality Protection Plan (https://www.reefplan.qld.gov.au/measuring-success/report-cards/).

The QPSMP and MMP contribute their seagrass condition assessments to a variety of regional Report Cards. These include the Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership (HR2RP; http://healthyriverstoreef.org.au/), the Wet Tropics Healthy Waterways Partnership (WTHWP; http://wettropicswaterways.org.au/report-card/), the Dry Tropics Partnership for Healthy Waters (DTPHW; https://drytropicshealthywaters.org/report-cards-1), and the Gladstone Healthy Harbour Partnership (GHHP; http://ghhp.org.au/report-cards/2020). Regional Report Cards at the Natural Resource Management (NRM) scale are divided into zones defined largely by habitat and latitude (Figure 1a). Attempts to report zone-scale seagrass condition revealed a number of gaps with no long-term monitoring data available to inform Report Card scores. For the HR2RP Report Card, the southern inshore marine zone was identified as a major data and knowledge gap for seagrass condition (http://healthyriverstoreef.org.au/southern-inshore-monitoring-project/).

James Cook University's TropWATER Centre were contracted in 2017 by the HR2RP to address the knowledge gaps in environmental condition, including seagrass, for the southern inshore marine zone. Data from the SIP monitoring is currently used to provide Report Card scores in this zone. TropWATER have conducted seagrass surveys previously in this zone: (1) in 1987, as part of large-scale seagrass assessments along the Queensland coast (Coles et al. 1987); (2) in 1997, during GBR-wide deep water surveys (Coles et al. 2009); (3) in 1999, during assessments for Dugong Protection Areas (Coles et al. 2002); and (4) in 2003-2004, during GBR-wide seabed biodiversity surveys led by CSIRO (Pitcher et al. 2007). These surveys revealed substantial intertidal seagrass meadows along the coast, but sparse and patchy subtidal seagrass. The largest intertidal meadows were located in the Clairview Dugong Protection Area (DPA) between Carmila and Clairview Bluff (Figure 1b). These meadows were mapped in 1987 (Coles et al. 1987), and revisited in 1999 (Roder et al. 2002), and were the focus for TropWATER's seagrass baseline survey in 2017.

The 2017 survey was an important first step in addressing seagrass knowledge gaps in the southern inshore zone of the HR2RP Report Card (Carter and Rasheed 2018). The 2017 and 1999 surveys revealed similar seagrass distribution, biomass, and species composition to the original 1987 survey, indicating these seagrass areas are likely to be relatively permanent features and ideal for monitoring. Three meadows were selected for long-term monitoring: two large intertidal meadows between Clairview and Clairview Bluff (Meadows 6 and 7), and the intertidal meadow at Flock Pigeon Island (Meadow 2).

This report presents findings from the 2023 seagrass monitoring survey of the HR2RP southern inshore marine zone. Our objectives were to:

- Map seagrass distribution, density and community composition in monitoring meadows;
- Compare results with previous seagrass monitoring results of these meadows;
- Incorporate results into a Geographic Information System (GIS) database for the zone.
- Develop seagrass meadow scores for the southern inshore marine zone for incorporation into the HR2RP Report Card.

3 METHODS

3.1 Survey Approach

The survey was conducted in September 2023 to coincide with the peak seagrass growing season, when meadows are likely to contain maximum biomass and area. Survey methods and the seagrass metrics recorded followed the established methods for Queensland seagrass monitoring which also occur at Townsville (McKenna et al. 2024b), Gladstone (Reason and Rasheed 2024), Cairns (Reason et al. 2024a), Mourilyan (Shepherd et al. 2024), Mackay-Hay Point (Rasheed et al. 2024), Abbot Point (McKenna et al. 2024a), Thursday Island (Scott et al. 2023), Weipa (Reason et al. 2024b), and Karumba (Scott and Rasheed 2024). Using standardised methods ensures seagrass data is comparable with that used to report seagrass condition for other marine inshore zones in the HR2RP Report Card, and in the WTHWP, DTPHW, GHHP, and QPSMP Report Cards. Standardisation also allows for comparisons with historical data sets collected previously in the same area.

3.2 Field Surveys

Intertidal meadows were sampled at low tide using a helicopter. Monitoring meadows are all intertidal because: (1) the large tidal range (up to 8.5m) means that intertidal seagrasses are exposed during spring low tides so helicopter surveys are likely to capture the majority of seagrasses in the region; and (2) subtidal meadows form a relatively minor component of seagrass area and are restricted to very shallow subtidal water, with the same species composition as the much larger adjacent/adjoining intertidal meadows (Carter and Rasheed 2018).

At each site the helicopter came to a low hover (within a metre of the ground). Within a 10m^2 circular area seagrass biomass was ranked, and the percent contribution of each species to that biomass was estimated, from three 0.25 m^2 randomly placed quadrats. Within the larger 10m^2 circular area the percent cover of seagrass, algae, and other benthic macro-invertebrates (BMI) were recorded. GPS was used to record the position of each site, and also intertidal meadow boundaries when visible.

3.3 Biomass and Species Composition

Seagrass above-ground biomass was determined using a "visual estimates of biomass" technique (Kirkman 1978, Mellors 1991). For each 0.25 m^2 quadrat an observer assigned a biomass rank, made in reference to a series of 12 quadrat photographs of similar seagrass habitats for which the above-ground biomass had previously been measured. At the completion of ranking, the observer also ranked a series of at least five photographs of calibration quadrats that represented the range of seagrass observed during the survey. These calibration quadrats had previously been harvested and the actual biomass determined in the laboratory. A separate regression of ranks and biomass from the calibration quadrats were generated for each observer and applied to the biomass ranks given in the field. Field biomass ranks were converted into above-ground biomass estimates in grams dry weight per square metre (g DWm^{-2}; total and for each species).

4.4 Seagrass Meadow Mapping and Geographic Information System (GIS)

All survey data were entered into a Geographic Information System (GIS) developed for the HR2RP southern inshore zone using ArcGIS 10.8.2. Three GIS layers were created to describe seagrass features in the region: a seagrass site layer, seagrass meadow layer, and seagrass biomass interpolation layer.

Site layer

The site layer contains data collected at each site, including:

- Temporal details – survey date.
- Spatial details – latitude and longitude.
- Habitat information – sediment type; seagrass information including presence/absence, above-ground biomass (total and for each species) and biomass standard error (SE); percent cover of seagrass, algae, and open substrate; presence/absence of dugong feeding trails (DFTs).
- Sampling method and any relevant comments.

Interpolation layer

The interpolation layer describes spatial variation in seagrass biomass across each meadow and was created using an inverse distance weighted (IDW) interpolation of seagrass site data within each meadow using ArcGIS®.

Meadow layer

The meadow (polygon) layer provides summary information for all sites within each of the three monitoring meadows, including:

- Temporal details – survey date.
- Habitat information – mean meadow biomass ± standard error (SE), meadow area (hectares) ± reliability estimate (R), number of sites within each meadow, seagrass species present, meadow density and community type, meadow landscape category (Figure 2).
- Meadow identification number – A unique number assigned to each monitoring meadow to allow comparisons over time.
- Sampling method and any relevant comments.

Meadow boundaries were constructed using seagrass presence/absence site data, field notes, GPS marked meadow boundaries, colour satellite imagery of the survey region (Source: ESRI, HERE, Garmin © Open Street Map contributors, and the GIS user community), and aerial photographs taken during helicopter surveys.

Meadow area was determined using the calculate geometry function in ArcGIS®. Meadows were also assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow. The mapping precision for coastal seagrass meadows ranged from ±20 m for intertidal seagrass meadows with boundaries mapped by helicopter, to ±50 m for boundaries mapped by distance between sites with and without seagrass. The mapping precision estimate was used to calculate a buffer around each meadow representing error; the area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Meadows were described using a standard nomenclature system. Seagrass community type is defined using the dominant species' percent contribution to mean meadow biomass (for all sites within a meadow) (Table 1). Meadow density is based on mean biomass and the dominant species within the meadow (Table 2).

Isolated seagrass patches

The majority of area within the meadow consists of unvegetated sediment interspersed with isolated patches of seagrass.

Aggregated seagrass patches

The meadow consists of numerous seagrass patches but still features substantial gaps of unvegetated sediment within the boundary.

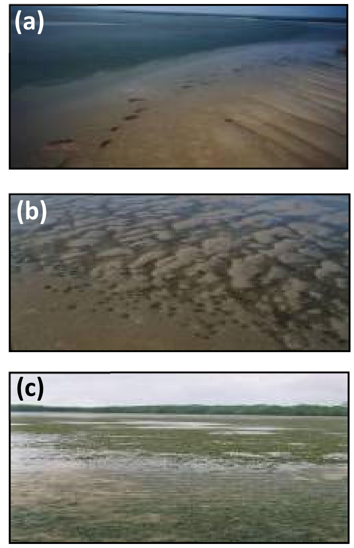

Figure 2. Seagrass meadow landscape categories: (a) Isolated seagrass patches, (b) aggregated seagrass patches, (c) continuous seagrass cover.

Table 1. Seagrass meadow community types.

Community type	Species composition
Species A	Species A is 90-100% of composition
Species A with Species B	Species A is 60-90% of composition
Species A with Species B/Species C	Species A is 50% of composition
Species A/Species B	Species A is 40-60% of composition

Table 2. Seagrass meadow density categories.

	Mean above-ground biomass (g DW m^{-2})	
Density	*H. uninervis* (thin) / *Z. muelleri* subsp. *capricorni* (thin)	*H. ovalis* / *H. decipiens*
Light	< 1	< 1
Moderate	1 - 4	1 - 5
Dense	> 4	> 5

3.4 Seagrass Meadow Condition Index

A condition index was developed for seagrass monitoring meadows based on changes in mean above-ground biomass, total meadow area and species composition relative to a baseline (see Carter et al. 2023 for full details). Seagrass condition for each indicator in the HR2RP southern inshore marine zone was scored from 0 to 1 and assigned one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor). Overall meadow condition is the lowest indicator score where this is driven by biomass or area. Where species composition is the lowest score, it contributes 50% of the overall meadow score, and the next lowest indicator (area or biomass) contributes the remaining 50% (Carter et al. 2023). This is the second year that we have had the minimum of 5 years of baseline data to generate seagrass grades with confidence to be presented for the HR2RP Report Card.

4 RESULTS

Four seagrass species were recorded during the 2023 survey of the monitoring meadows: *Zostera muelleri* subsp. *capricorni* (abbreviated to *Z. capricorni* throughout this report), *Halodule uninervis*, *Halophila decipiens* and *Halophila ovalis* (Figure 3). Only thin leaf morphologies of *Z. capricorni* and *H. uninervis* are found in the survey area. These variants of the two species have very similar above ground characteristics and are difficult to differentiate as part of rapid visual surveys.

Seagrass was present at 79% of the 145 intertidal survey sites (Figure 4). The mainland coastal Meadows 6 and 7 were characterised by a largely continuous cover of seagrass, while Meadow 2 at Flock Pigeon Island had aggregated patches of seagrass cover (Figure 5).

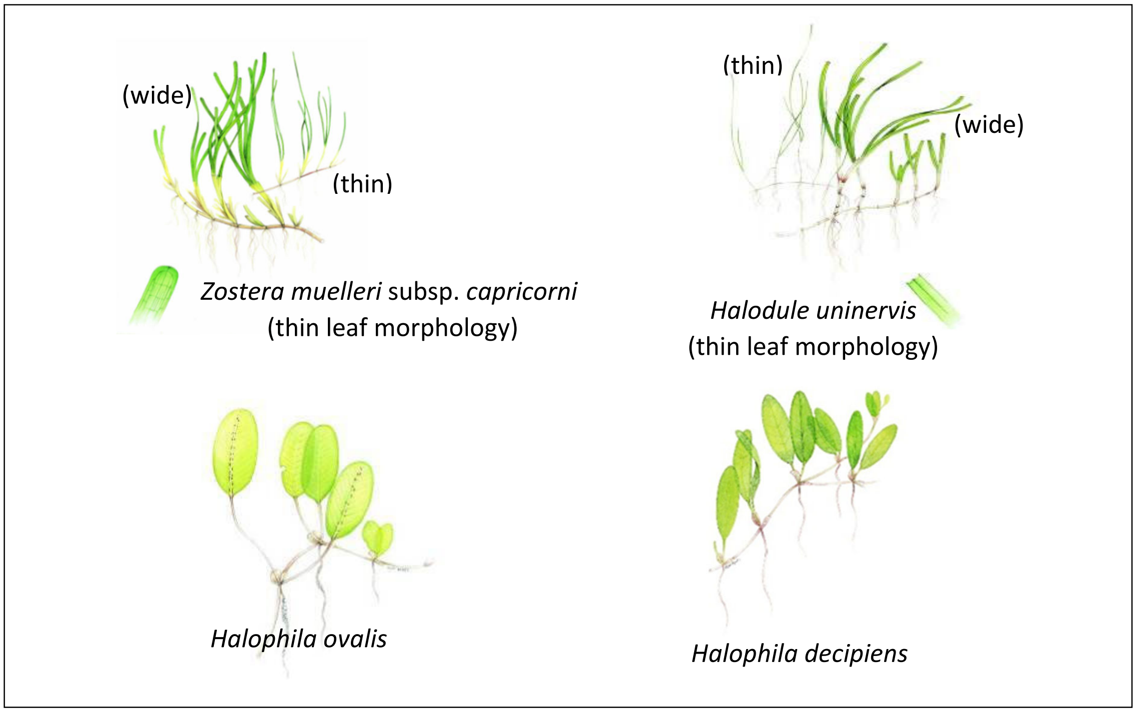

Figure 3. Seagrass species present in the HR2RP southern inshore marine zone during the 2023 survey.

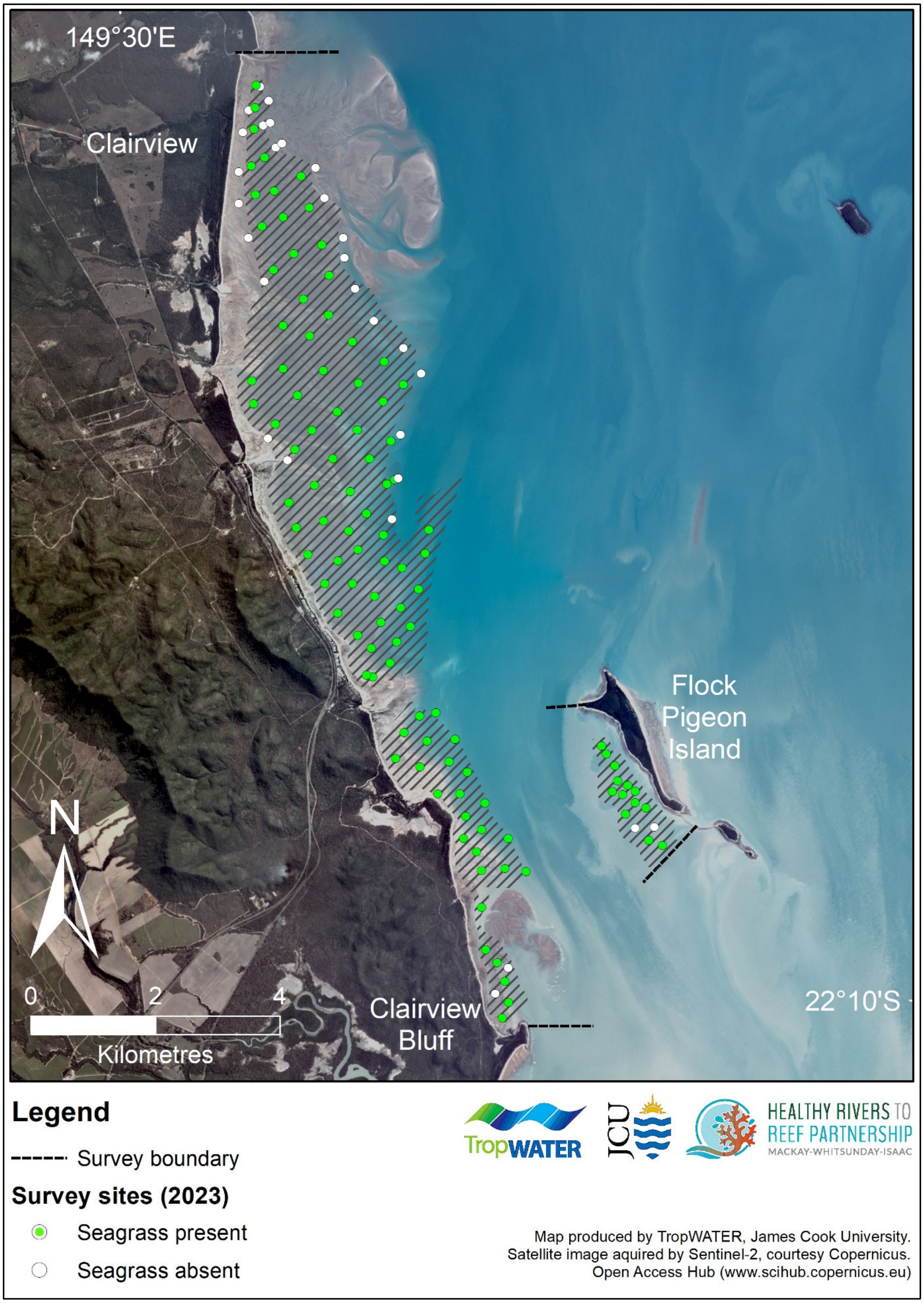

Figure 4. Location of intertidal survey sites in the southern inshore marine zone with seagrass presence/absence in 2023.

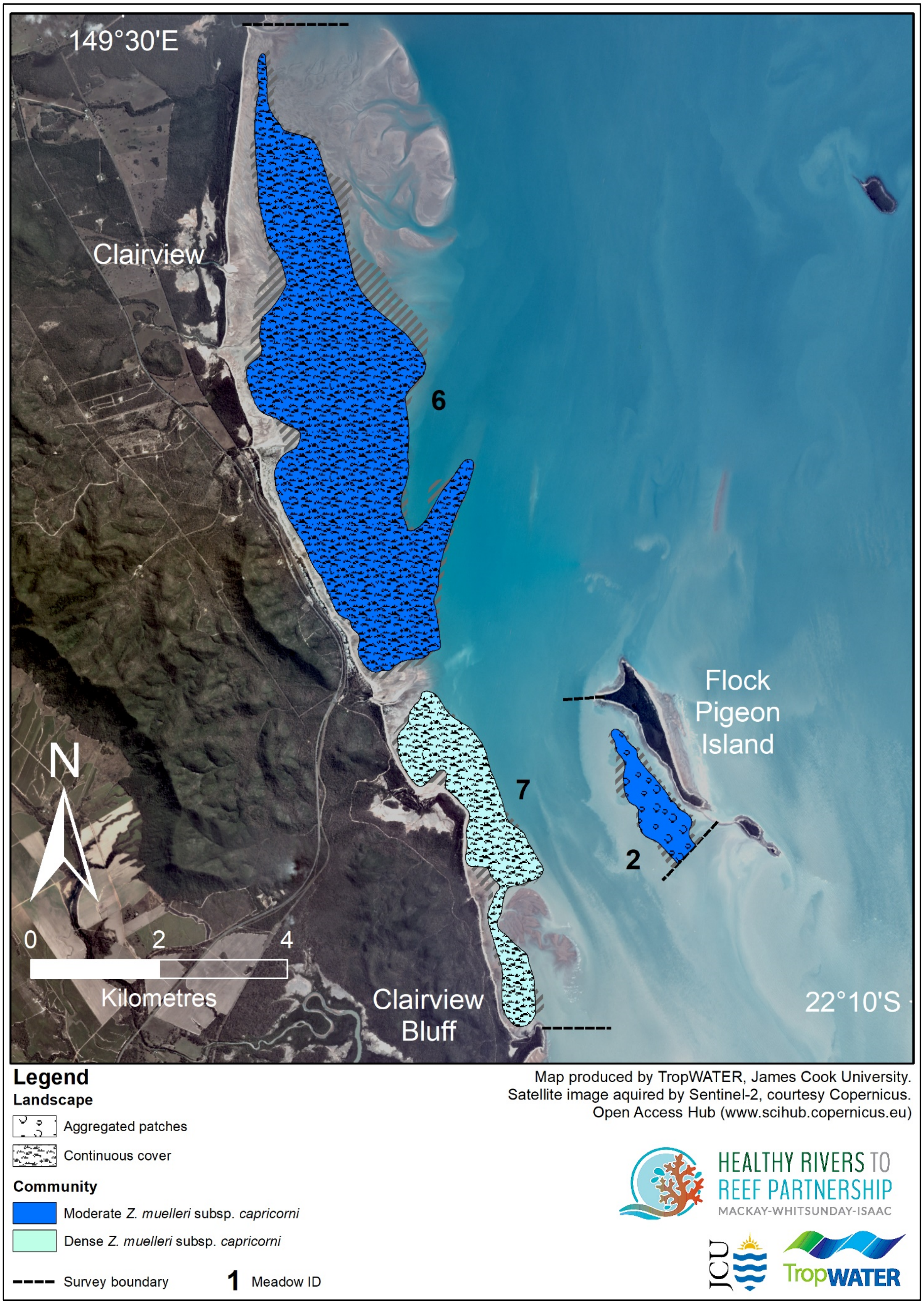

Figure 5. Seagrass monitoring meadow landscape categories and community types in 2023.

4.1 Seagrass condition for annual monitoring meadows

All three of the seagrass monitoring meadows scored an overall good condition assessed against their baseline (currently 7-year baseline). All the individual indicators (seagrass above-ground biomass, meadow area and species composition) were scored as either good or very good condition across the three meadows in 2023 (Table 3).

Within each monitoring meadow seagrass biomass (density) was not distributed evenly throughout the meadow footprints but rather varied as a mosaic of biomass hot spots and low spots ranging from 0 to 8.4 g DWm^{-2} (Figures 6-8). Biomass was greatest throughout Meadow 7 and in the southern end of Meadow 6. These areas of high biomass coincide with where the majority of dugong feeding trails were recorded (Figure 9). Dugong feeding trails were recorded in Meadow 2 once again after being absent in 2022 (Figure 9).

Table 3. Grades and scores for condition indicators (biomass, area, and species composition) for Clairview monitoring meadows, 2022.

Meadow	Biomass	Area	Species Composition	Overall Meadow Score
2 – Flock Pidgeon	0.75	0.83	1.00	0.75
6 – Clairview North	0.96	0.94	0.95	0.94
7 – Clairview South	0.99	1	0.80	0.90
Clairview Overall Score				0.86

The Flock Pidgeon Island Meadow 2 had a mean biomass of 1.59 ± 0.44 g DWm^{-2} demonstrating further recovery from 2020 when the meadow had the lowest value recorded throughout the project (Figure 7). There was minimal change in area of this small meadow, from 99.6 ± 2.8 ha in 2022 to 99.4 ± 5.3 ha (Figure 7). Meadow 2 is dominated by the narrow leaf forms of *Z. capricorni* and *H. uninervis* and maintained a very good species score in 2023 (Figure 7).

The Clairview North Meadow 6 is the largest monitoring meadow in the southern inshore zone and covered a total area of 1459 ± 25.5 ha in 2023 achieving a very good grade for this indicator. Meadow area has been fairly stable over the last five years with slightly positive trend leading towards the largest area on record in 2023 (Figure 8). Since the program began in 2017 the meadow biomass has been relatively low, with a very good grade recorded in 2023 providing the highest biomass since monitoring began (3.4 ± 0.31 g DWm^{-2}). This meadow remains dominated by *H. uninervis*, and *Z. capricorni*, producing a very good species composition score (Figure 9).

The Clairview South Meadow 7 had an increase in biomass to very good condition in 2023 with the highest biomass on record (4.1 ± 0.62 g DWm^{-2}). The area of Meadow 7 has been consistently growing since 2017, with 2023 producing the highest area (341.8 ± 13.6 ha) recorded for the program to date achieving very good grades (Figure 9). The meadow remains dominated by *H. uninervis* and *Z. capricorni* resulting in a good grade for this indicator (Figure 9).

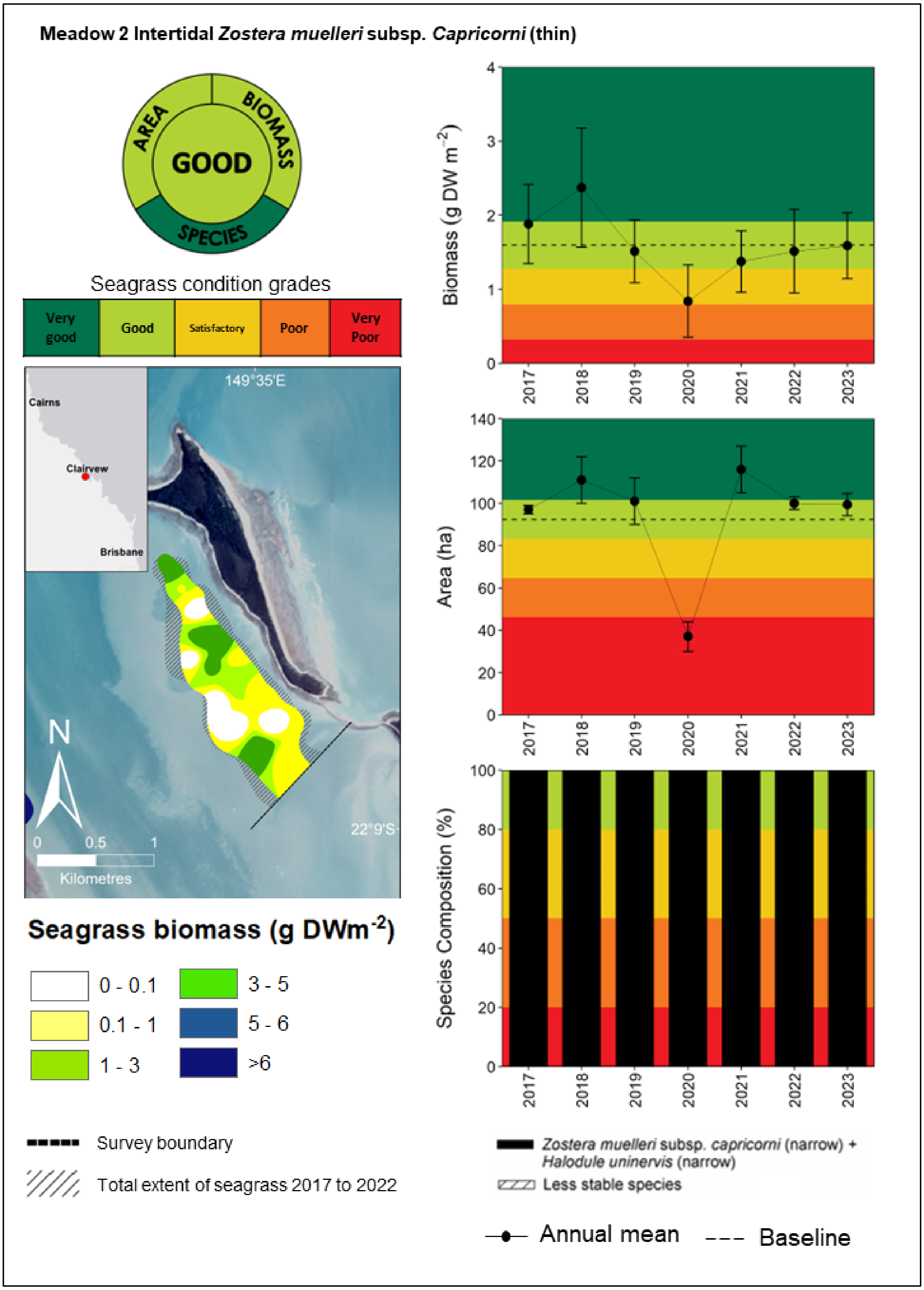

Figure 6. Changes in biomass, area and species composition for Meadow 2, 2017 - 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

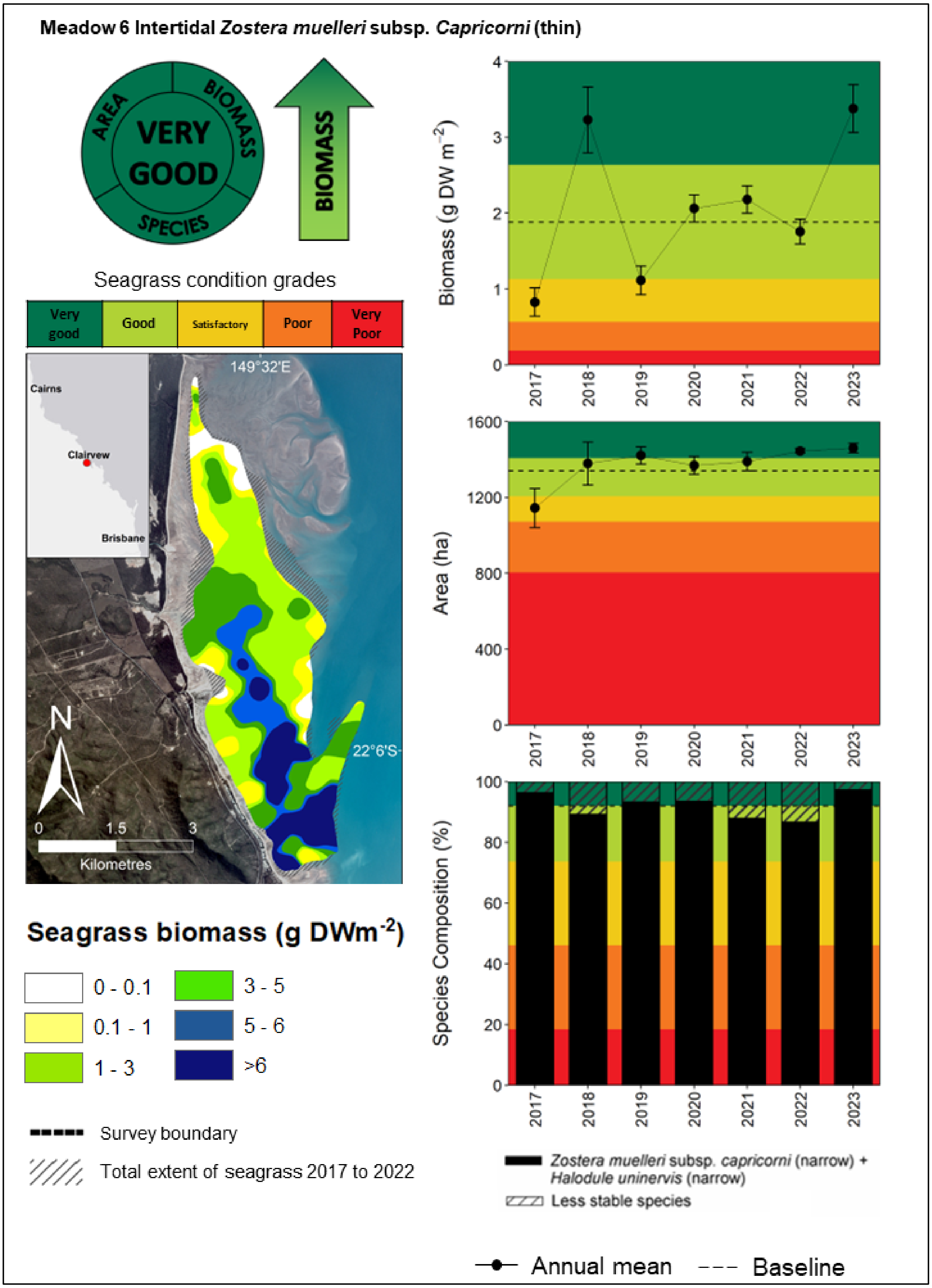

Figure 7. Changes in biomass, area and species composition for Meadow 6, 2017 - 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

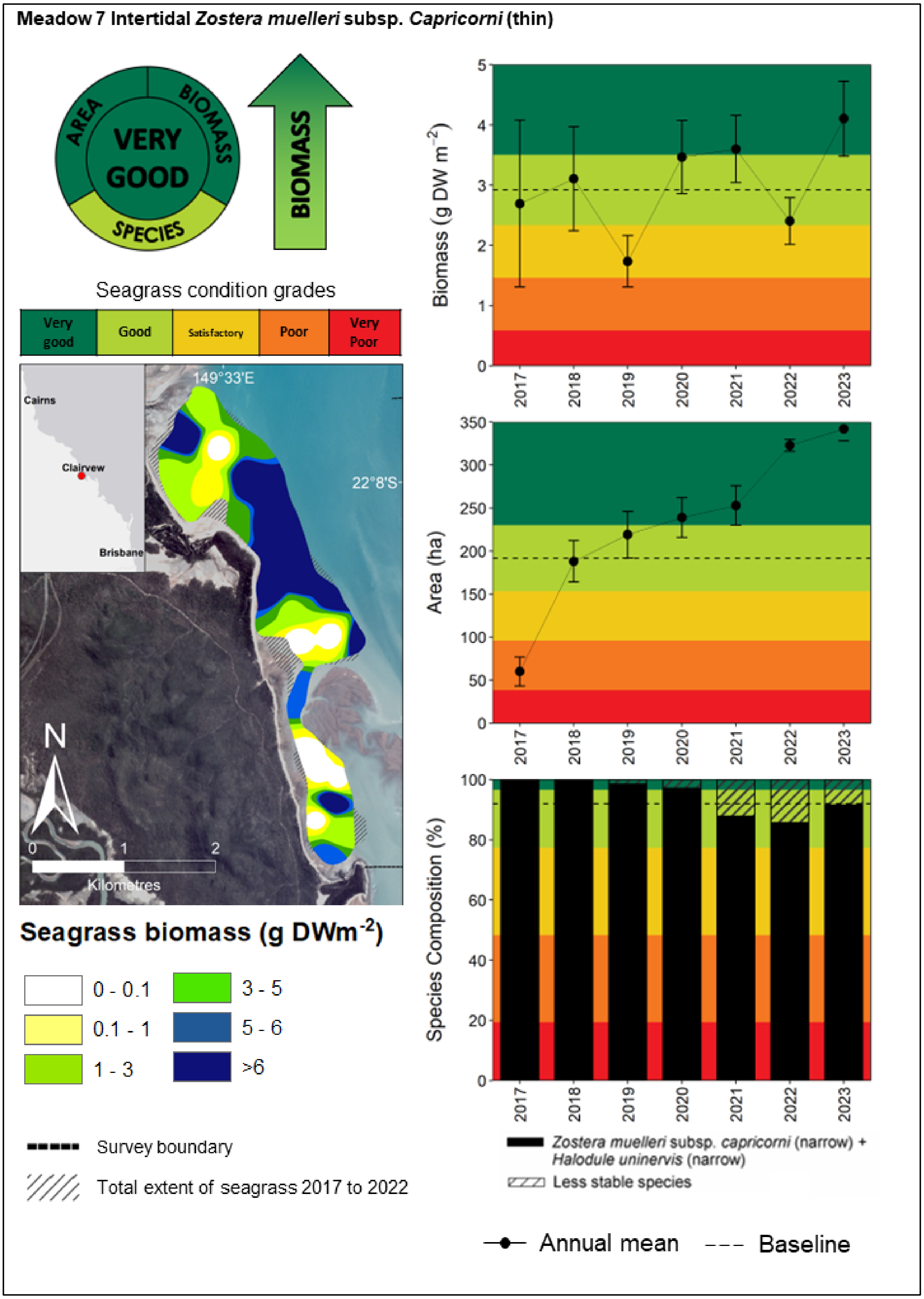

Figure 8. Changes in biomass, area and species composition for Meadow 7, 2017 - 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

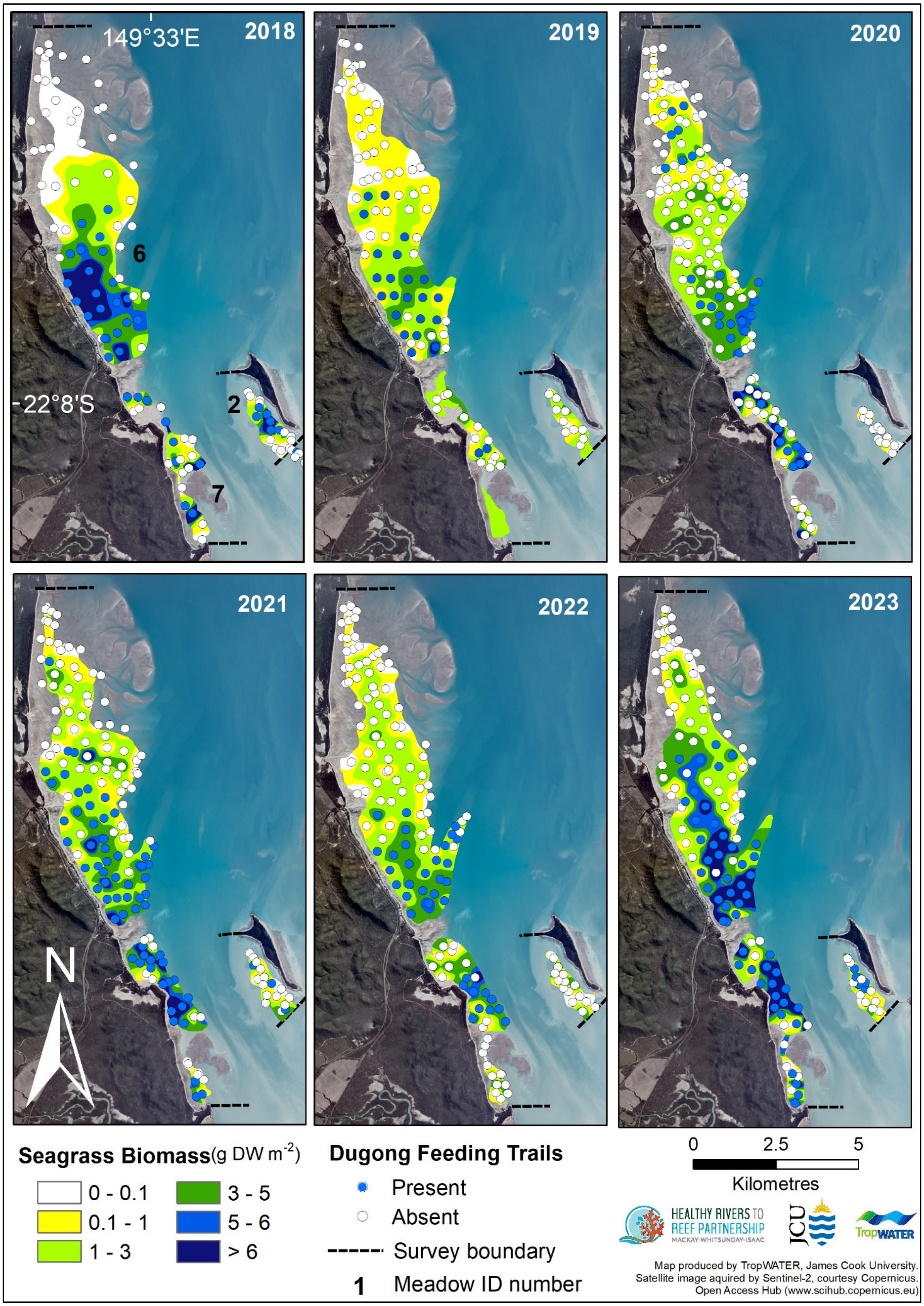

Figure 9. Variation in intertidal seagrass biomass within monitoring meadows, and presence of dugong feeding trails, 2018-2023.

5 DISCUSSION

In 2023, the seventh annual seagrass monitoring survey in the southern inshore marine zone of the Mackay-Whitsunday-Isaac HR2RP provided valuable insights into the condition and dynamics of the seagrass meadows. Overall, seagrasses in the region received a very good condition score when compared to their seven-year baseline average, with the individual monitoring meadows receiving either very good (Meadow 6 & 7) or good (Meadow 2) scores. Each of the individual indicators, including seagrass above-ground biomass, meadow area, and species composition, received good or very good condition scores across the board in 2023 (Figure 7, 8, 9). However, seagrass biomass was not distributed evenly throughout the meadows. As with previous years the meadows had a mosaic of high and low biomass regions within their boundaries, which vary in their location from year to year. In 2023 the highest biomass was concentrated in the central region of Meadow 7 and the southern end of Meadow 6, which coincided with the locations where most dugong feeding trails were recorded (Figure 9). While the monitoring program is still in its early days, there appears to be an overall positive trend for seagrass indicators over the seven years, indicating that the conditions in the region have been generally favourable for seagrass.

The Flock Pigeon Island seagrass meadow has continued to show signs of recovery since the substantive declines in biomass and area in 2020. Coinciding with the recovery of seagrass in 2023 was a return of substantial dugong feeding trails to the meadow for the first time since 2018 (Figure 9). The two mainland seagrass meadows (6 & 7) had very good biomass values resulting in the highest biomass recorded in the 7-year monitoring program. However, these values were relatively low compared with some meadows of these species elsewhere in Queensland. This seemingly low biomass in Clairview is typical for similar meadows in the greater region (Reason et al. 2023b, York et al. 2023), and likely to be locally driven by a combination of large tidal movements, high grazing pressure and low light conditions preventing seagrasses from reaching higher abundances. The area of the northern mainland meadow (6) has remained relatively consistent with its spatial footprint since 2018, while southernmost monitoring meadow (7) has shown a continuous year on year expansion in area since 2017. Both meadows (6 & 7) had their highest recorded area in 2023 since the program begun. The positive trends for these meadows, is reflected in near by monitoring programs in Mackay / Hay Point, indicating favourable seagrass growing conditions in the past 12 months throughout the greater region (Rasheed et al. 2024).

The distribution of seagrass biomass within the meadows has shown a constantly-changing mosaic of hot spots and low spots between years. It underscores the importance of adopting a comprehensive monitoring approach that captures the entire meadow (Figure 9) to allow for a more representative assessment of changes in the regional seagrass resource, as particular sub-sections of the meadows may exhibit dramatic shifts in biomass from year to year but not on their own reflect the health of the greater meadow. The correlation between biomass hot spots and dugong feeding efforts suggests a potential role of herbivory in shaping the location of seagrass biomass concentrations within the meadows.

The findings of the 2023 survey contribute to our understanding of the seagrass communities within the southern inshore zone and their ecological importance, particularly for dugongs and green sea turtles. These monitoring efforts provide valuable data for the Mackay-Whitsunday-Isaac HR2RP Report Card, enabling the assessment of seagrass health in the region. The continued monitoring and analysis of the meadows will further refine the understanding of their dynamics and assist in defining their baseline condition for future monitoring efforts. It is worth noting that seagrass meadows can exhibit spatial and temporal variability, even in the absence of major natural or anthropogenic impacts, and continued monitoring can help capture these localised fluctuations and will help establish a more robust baseline as we approach the required 10-year mark for fixing the baseline as per the methods outlined in Carter et al. (2023). In 2023 after seven years of the annual monitoring program, seagrasses were in some of the best condition to date, indicating a healthy marine environment, with water quality and environmental conditions favourable for seagrass growth and a positive outlook for seagrasses and their dependant species if similar conditions remain.

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7 APPENDICES

8.1 Seagrass Condition Calculations

7.1.1 Baseline Calculations

Baseline conditions for seagrass biomass, meadow area and species composition will be established from annual means calculated over the first 10 years of monitoring, following the methods of Carter et al. (2015) and Bryant et al. (2014).

Baseline conditions for species composition are based on the annual percent contribution of each species to mean meadow biomass of the baseline years. Meadows are classified as either single species dominated (one species comprising ≥80% of baseline species), or mixed species (all species comprise <80% of baseline species composition). Where a meadow baseline contains an approximately equal split in two dominant species (i.e. both species accounted for 40–60% of the baseline), the baseline is set according to the percent composition of the more persistent/stable species of the two (see A1.4 Grade and Score Calculations and Figure A1.1).

7.1.2 Meadow Classification

A meadow classification system was developed for the three condition indicators (biomass, area, species composition) in recognition that for some seagrass meadows these measures are historically stable, while in other meadows they are relatively variable. The coefficient of variation (CV) for each baseline for each meadow is used to determine historical variability. Meadow biomass and species composition are classified as either stable or variable (Table A1.1). Meadow area is classified as either highly stable, stable, variable, or highly variable (Table A1.1). The CV is calculated by dividing the standard deviation of the baseline years by the baseline for each condition indicator.

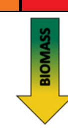
Table A1.1 Coefficient of variation (CV; %) thresholds used to classify stability or variability of meadow biomass, area and species composition.

Indicator	Class			
	Highly stable	Stable	Variable	Highly variable
Biomass	-	< 40%	≥ 40%	-
Area	< 10%	≥ 10, < 40%	≥ 40, <80%	≥ 80%
Species composition	-	< 40%	≥ 40%	-

7.1.3 Threshold Definition

Seagrass condition for each indicator is assigned one of five grades (very good (A), good (B), satisfactory (C), poor (D), and very poor (E)). Threshold levels for each grade are set relative to the baseline and based on meadow class. This approach accounts for historical variability within the monitoring meadows and expert knowledge of the different meadow types and assemblages in the region (Table A1.2).

Table A1.2. Threshold levels for grading seagrass indicators for various meadow classes relative to the baseline. Upwards/ downwards arrows are included where a change in condition has occurred in any of the three condition indicators (biomass, area, species composition) from the previous year.

Seagrass condition indicators/ Meadow class		Seagrass grade				
		A Very good	B Good	C Satisfactory	D Poor	E Very Poor
Biomass	Stable	>20% above	20% above - 20% below	20-50% below	50-80% below	>80% below
	Variable	>40% above	40% above - 40% below	40-70% below	70-90% below	>90% below
Area	Highly stable	>5% above	5% above - 10% below	10-20% below	20-40% below	>40% below
	Stable	>10% above	10% above - 10% below	10-30% below	30-50% below	>50% below
	Variable	>20% above	20% above - 20% below	20-50% below	50-80% below	>80% below
	Highly variable	> 40% above	40% above - 40% below	40-70% below	70-90% below	>90% below
Species composition	Stable and variable; Single species dominated	>0% above	0-20% below	20-50% below	50-80% below	>80% below
	Stable; Mixed species	>20% above	20% above - 20% below	20-50% below	50-80% below	>80% below
	Variable; Mixed species	>20% above	20% above- 40% below	40-70% below	70-90% below	>90% below
	Increase above threshold from previous year			Decrease below threshold from previous year		

7.1.4 Grade and Score Calculations

A score system (0–1) and score range is applied to each grade to allow numerical comparisons of seagrass condition (see Carter *et al.* 2015 for a detailed description, and Table A1.3). Score calculations for each meadow's condition require calculating the biomass, area and species composition for that year (see A1.1 Baseline Calculations, above), allocating a grade for each indicator by comparing the current year's values against meadow-specific thresholds for each grade, then scaling biomass, area and species composition values against the prescribed score range for that grade. Scaling was required because the score range in each grade was not equal (Table A1.3). Within each meadow, the upper limit for the very good grade (score = 1) for species composition is set as 100% (as a species could never account for >100% of species composition). For biomass and area, the upper limit is set as the maximum mean plus standard error (SE; i.e. the top of the error bar) value for a given year, compared among years during the baseline period.

An example of calculating a meadow score for biomass in good condition is provided in Appendix 2.

Table A1.3. Score range and grading colours used in the seagrass report card.

Grade	Description	Score Range	
		Lower bound	Upper bound
A	Very good	≥0.85	1.00
B	Good	≥0.65	<0.85
C	Satisfactory	≥0.50	<0.65
D	Poor	≥0.25	<0.50
E	Very poor	0.00	<0.25

Where species composition is determined to be anything less than in "perfect" condition (i.e. a score <1), a decision tree is used to determine whether equivalent and/or more persistent species are driving this grade/score (Figure A1.1). If this is the case then the species composition score and grade for that year is recalculated including those species. Concern regarding any decline in the stable state species should be reserved for those meadows where the directional change from the stable state species is of concern (Figure A1.1). This would occur when the stable state species is replaced by species considered to be earlier colonisers. Such a shift indicates a decline in meadow stability (e.g. a shift from *H. uninervis* to *H. ovalis*). An alternate scenario can occur where the stable state species is replaced by what is considered an equivalent species (e.g. shifts between *C. rotundata* and *C. serrulata*), or replaced by a species indicative of an improvement in meadow stability (e.g. a shift from *H. decipiens* to *H. uninervis* or any other species).

The directional change assessment is based largely on dominant traits of colonising, opportunistic and persistent seagrass genera described by Kilminster et al. (2015). Adjustments to the Kilminster model included: (1) positioning *S. isoetifolium* further towards the colonising species end of the list, as successional studies following disturbance demonstrate this is an early coloniser in Queensland seagrass meadows (Rasheed 2004); and (2) separating and ordering the *Halophila* genera by species. Shifts between *Halophila* species are ecologically relevant; for example, a shift from *H. ovalis* to *H. decipiens* may indicate declines in water quality and available light for seagrass growth as *H. decipiens* has a lower light requirement (Collier et al. 2016) (Figure A1.1).

Due to the taxonomic difficulty in separating the narrow leaf forms of *Z. muelleri* and *H. uninervis* during rapid field assessments as well as their very similar above ground morphology they were considered to be functionally equivalent for the Clairview species assessments.

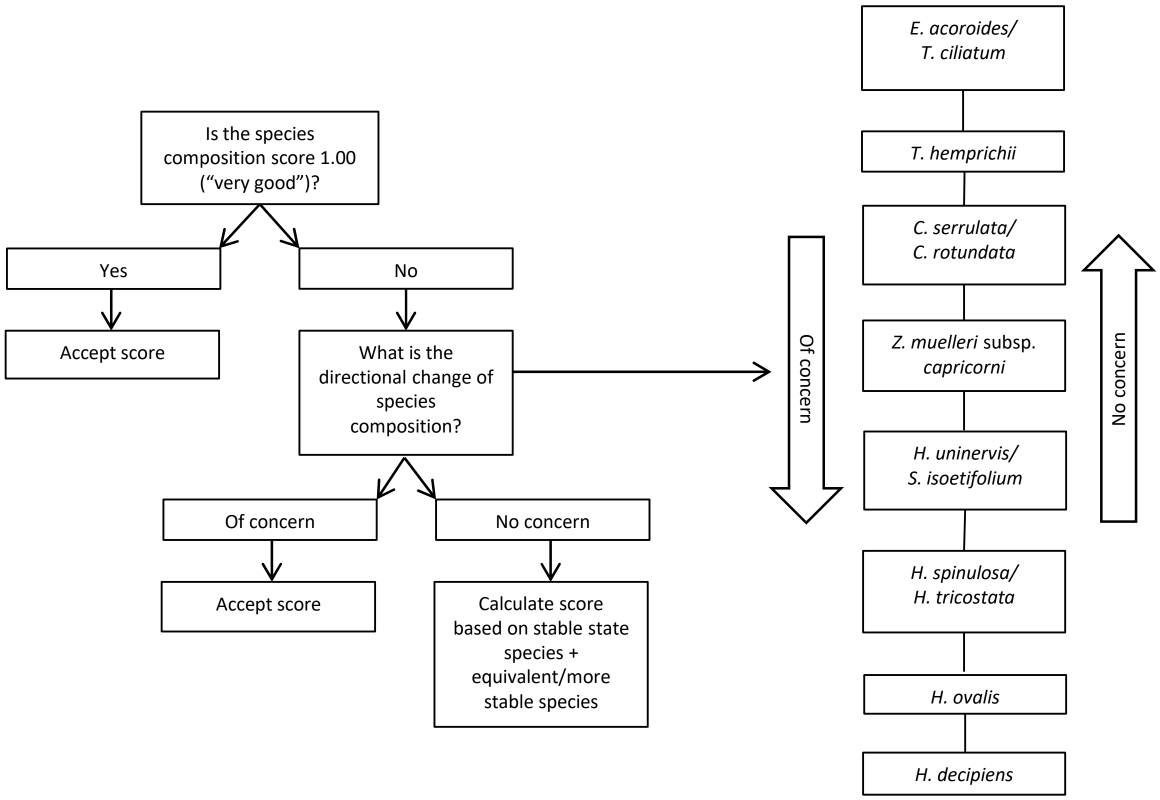


Figure A1.1. (a) Decision tree and (b) directional change assessment for grading and scoring seagrass species composition. Note that for the Clairview monitoring meadows the narrow leaf form of *Halodule uninervis* and *Zostera muelleri* are considered to be functionally equivalent.

7.1.5 Score Aggregation

Each overall meadow grade/score is defined as the lowest grade/score of the three condition indicators within that meadow. The lowest score, rather than the mean of the three indicator scores, is applied in recognition that a poor grade for any one of the three described a seagrass meadow in poor condition. Maintenance of each of these three fundamental characteristics of a seagrass meadow is required to describe a healthy meadow. This method allows the most conservative estimate of meadow condition to be made (Bryant et al. 2014). In cases where species composition is the lowest score, an average of both the species composition score and the next lowest score is used to determine the overall meadow score. This is to prevent a case where a meadow may have a spatial footprint and seagrass biomass but a score of zero due to changes in species composition.

7.2 Biomass score calculation example

1. Determine the grade for the 2019 (current) biomass value (i.e. good).

2. Calculate the difference in biomass (B_{diff}) between the 2019 biomass value (B_{2019}) and the biomass value of the lower threshold boundary for the "good" grade (B_{good}):

$$\mathrm{B_{diff}} = \mathrm{B_{2019}} - \mathrm{B_{good}}$$

Where B_{good} or any other threshold boundary will differ for each condition indicator depending on the baseline value, meadow class (stable, variable, highly variable [area only]), and whether the meadow is dominated by a single species or mixed species (species composition calculations only).

3. Calculate the range for biomass values (B_{range}) in that grade:

$$\mathrm{B_{range}} = \mathrm{B_{very\ good}} - \mathrm{B_{good}}$$

Where B_{good} is the upper threshold boundary for the good grade.

Note: For species composition, the upper limit for the very good grade is set as 100%. For area and biomass, the upper limit for the very good grade is set as the mean plus the standard error (i.e. the top of the error bar) for the maximum recorded mean annual value for that indicator and meadow.

4. Calculate the proportion of the good grade (B_{prop}) that B_{2019} takes up:

$$\mathrm{B_{prop}} = \frac{\mathrm{B_{diff}}}{\mathrm{B_{range}}}$$

5. Determine the biomass score for 2019 ($Score_{2019}$) by scaling B_{prop} against the score range (SR) for the good grade (SR_{good}), i.e. 0.20 units (see Table A1.3):

$$\mathrm{Score_{2019}} = \mathrm{LB_{good}} + \left(\mathrm{B_{prop}} \times \mathrm{SR_{good}}\right)$$

Where LB_{good} is the defined lower bound (LB) score threshold for the good grade, i.e. 0.65 units.