Torres Strait Seagrass Report Card 2022

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Please be advised this report may contain images of persons who have died. We offer our apologies for any distress caused if this occurs.

Acknowledgments

The authors acknowledge the traditional owners and custodians on whose land and sea areas seagrass monitoring activities take place. This report card, and the monitoring programs on which it is based, would not be possible without the collaboration between TropWATER and the following Ranger groups - Mura Badhulgau, Mua Lagalgau, Mabuygiw, Porumalgal, Iamalgal, Warraberalgal, Masigalgal and Meriam Gesep A Gur Keparem Le. Thank you for your hard work and dedication to monitoring seagrass habitat in Torres Strait.

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List of Figures

List of Tables

Contents

Summary

- Seagrass is a critical habitat in Torres Strait. Extensive seagrass meadows support populations of dugong, green turtle, and fishery species. Strong cultural and spiritual links exist between Torres Strait Island communities and these species and environments.

- The Torres Strait Seagrass Monitoring Program (TSSMP) incorporates an extensive network of seagrass monitoring programs that regularly assess the condition of this key habitat. The TSSMP incorporates the Torres Strait Seagrass Observers Program, Ranger Subtidal Monitoring Program, Queensland Ports Seagrass Monitoring Program, and Reef-top Monitoring Program. Data from these programs are integrated and used to produce this report on seagrass condition.

- Twenty-seven sites/meadows were classified for the 2022 report card across the Western, Central, Eastern and Inner Island Clusters.

- Overall, seagrasses in the Inner Cluster were in a good condition, and in a satisfactory condition in the Western, Central and Eastern Clusters.

- Within these Clusters there were individual sites and types of meadows where seagrass condition is of concern, including:
    a. Subtidal seagrass biomass at the Dugong Sanctuary, Orman Reefs and Dungeness Reef remain very low and show no signs of recovery following large scale declines that were first noted in 2019 surveys (2020 report card).
    b. Condition of seagrass percent cover at some intertidal sites at Mabuyag Island, Poruma Island and Mer Island continued to be well-below average.

- Investigations into the role of herbivory in seagrass declines in the Western Cluster were undertaken at Mabuyag Island and Kai Reef in 2021-2022 and demonstrate the significant impact large herbivores such as turtle and dugong can have on seagrass condition.

- Intertidal reef-top seagrass at Kai and Gariar Reefs (Orman Reefs) has recovered to good condition following declines in recent years.

- Badu Island's Upai site (BD2) reached 10-years of monitoring data, meaning that the baselines for this location are now set.

- This report card highlights areas where information is lacking and suggests a pathway for better understanding seagrass dynamics, and improving representativeness and reliability of condition scores for seagrass in Torres Strait Island Clusters. We recommend: (1) establishing monitoring in the Top-Western Cluster, (2) expanding subtidal monitoring, (3) expanding meadow-scale monitoring in the Eastern Cluster, (4) establishing a comprehensive testing program for seagrass disease, and (5) adding local weather/wind and benthic light stations in areas of concern. These additions would vastly improve our annual assessment of seagrass condition and drivers of observed changes in the region.

Introduction

Torres Strait Seagrass

Torres Strait seagrass meadows are abundant, widespread, and contain some of the greatest species diversity in the Indo-Pacific (Carter et al. 2014; Coles et al. 2003; Poiner and Peterkin 1996). These seagrass habitats are of national significance due to their large size, their role in sustaining fisheries, and as a food source for the iconic and culturally important species dugong and turtle, which play a vital role in the ecology and cultural economy of the region (TSRA 2016).

Torres Strait Islanders depend heavily on their surrounding marine resources, and their consumption of marine species are among the highest in the world (Kleisner et al. 2015; Johannes and MacFarlane 1991). Most of these important species, including fish, prawns, beche de mer, and tropical rock lobster, are reliant on seagrass during some stage of their life-cycle (Marsh et al. 2015; Unsworth and Cullen 2010; Heck et al. 2008; Green 2006). The loss of seagrass would have detrimental flow on effects to Torres Strait Islanders' spiritual, cultural and economic well-being (TSRA 2016; Kleisner et al. 2015; Faury 2009).

Several substantial seagrass diebacks have been documented in Torres Strait. These include a widely reported dieback in the early 1970s (Johannes and MacFarlane 1991), and less widespread diebacks in north-western Torres Strait in the early 1990s (Poiner and Peterkin 1996) and in the Orman Reefs area in 1999-2000 (Marsh et al. 2004). The direct cause of these diebacks is still debated, but they are known to have significant impacts on local herbivore populations and were linked to dramatic increases in local dugong mortality and declines in dugong health (Marsh et al. 2004; Long and Skewes 1996). The 2020 and 2021 seagrass report cards showed significant declines in seagrass condition in the Orman Reefs-Mabuyag Island region. These declines were concerning because of their widespread nature across seagrass habitats, including intertidal reef-top and subtidal reef-associated meadows and coastal intertidal meadows at two Mabuyag Island locations. Potential reasons for these declines were investigated, with disease ruled out (Carter et al 2021). The role of herbivory from green turtles and dugong was recently assessed at Mabuyag Island and Orman Reefs (see discussion). The role of altered environmental conditions could not be determined due to a lack of local environmental data and established baselines (Carter et al. 2021d).

Torres Strait Seagrass Monitoring Program (TSSMP)

Seagrass habitats are ideal indicators for monitoring marine environmental health as they show measurable responses to changes in environmental condition (Orth et al. 2006; Abal and Dennison 1996; Dennison et al. 1993). A robust assessment of seagrass condition first requires baseline information on seagrass abundance, species composition, and meadow area, plus ongoing monitoring to understand natural variation and detect seagrass change.

The Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) at James Cook University (JCU) have been collecting baseline Torres Strait seagrass data and monitoring seagrass condition in the Port of Thursday Island since 2002. Seagrass monitoring was prioritised by the Torres Strait Scientific Advisory Committee, and expanded by the Torres Strait Regional Authority (TSRA) Land and Sea Management Unit (LSMU) when the Torres Strait Ranger Program began in 2009. The Torres Strait Seagrass Monitoring Program (TSSMP) incorporates three types of seagrass monitoring data: small-scale intertidal transects, medium-scale subtidal blocks, and large meadow-scale monitoring that incorporates spatial change in seagrass assessments. Several long-term monitoring programs undertaken by TropWATER with the TSRA LSMU or Ports North assess seagrass condition and change in the region (Table 1). These programs are:

(1) **Torres Strait Seagrass Observers Program (small-scale transect-based monitoring)** – This program is led by Torres Strait Rangers who monitor intertidal seagrass at permanently marked transect sites

representative of their home patch intertidal meadows. Rangers selected sites based on traditional use of the meadow or disturbance concerns (e.g. proximity to a storm water drain). Six islands (Mabuyag, Badu, Mua, Poruma, Iama, and Mer) are monitored as part of the program, with two sites on each island. Data collected is analysed by TropWATER.

(2) **Ranger Subtidal Monitoring Program (medium-scale block-based monitoring)** – This program is led by Torres Strait Rangers who monitor seagrass in subtidal monitoring blocks in the Dugong Sanctuary, Dungeness Reef and Orman Reefs. Data collected is analysed by TropWATER.

(3) **Reef-top Monitoring Program (large-scale meadow-based monitoring)** – The reef-top program began in 2017 at Dungeness Reef and now includes Orman Reefs and Masig Island. Aerial surveys are conducted by TropWATER staff annually and provide an assessment of intertidal reef-top seagrass condition at important turtle and dugong foraging areas.

(4) **Queensland Ports Seagrass Monitoring Program (large-scale meadow-based monitoring)** – The ports program is a TropWATER-led long-term seagrass monitoring and assessment program that occurs across Queensland. Monitoring of Thursday Island's port is funded by Ports North.

The individual programs that make up TSSMP differ in monitoring frequency and the seagrass condition indicators assessed. The program collectively monitors seagrass condition at 12 intertidal transect sites, 13 intertidal and subtidal whole-meadows, and three subtidal meadow blocks (Figure 1, Table 1). Monitoring incorporates eleven seagrass species from three families (Figure 2), and occurs within four of the five traditional island clusters (http://www.tsra.gov.au/the-torres-strait/community-profiles) - Western, Central, Eastern and Inner. No monitoring currently occurs in the Top-Western Cluster.

Table 1. The Torres Strait Seagrass Monitoring Program (TSSMP) incorporates several long-term monitoring programs.

	Torres Strait Seagrass Monitoring Program			
	Torres Strait Seagrass Observers Program	**Reef-top Intertidal Program**	**Ranger Subtidal Monitoring Program**	**Thursday Island Ports Program**
Island cluster	Western, Central, Eastern	Western, Central	Western, Central	Inner
No. sites/meadows	12 sites	4 meadows	3 meadows	9 meadows
Condition indicators	Percent cover, species composition	Biomass, area, species composition	Biomass, species composition	Biomass, area, species composition
Habitat	Intertidal island	Intertidal reef-top	Subtidal	Intertidal island and reef-top, subtidal
Spatial scale	3 permanent transects per site	Whole-meadow	3 monitoring blocks per meadow	Whole-meadow
Temporal scale	Biannual	Annual	Annual	Annual
Funding provider	TSRA	TSRA	TSRA	Ports North

Report Card Objectives

The objectives of the 2022 Torres Strait report card were to provide:

(1) An assessment of Torres Strait seagrass condition in 2022 including grades and scores.
(2) A report describing data collection and methods used to determine grades and scores.

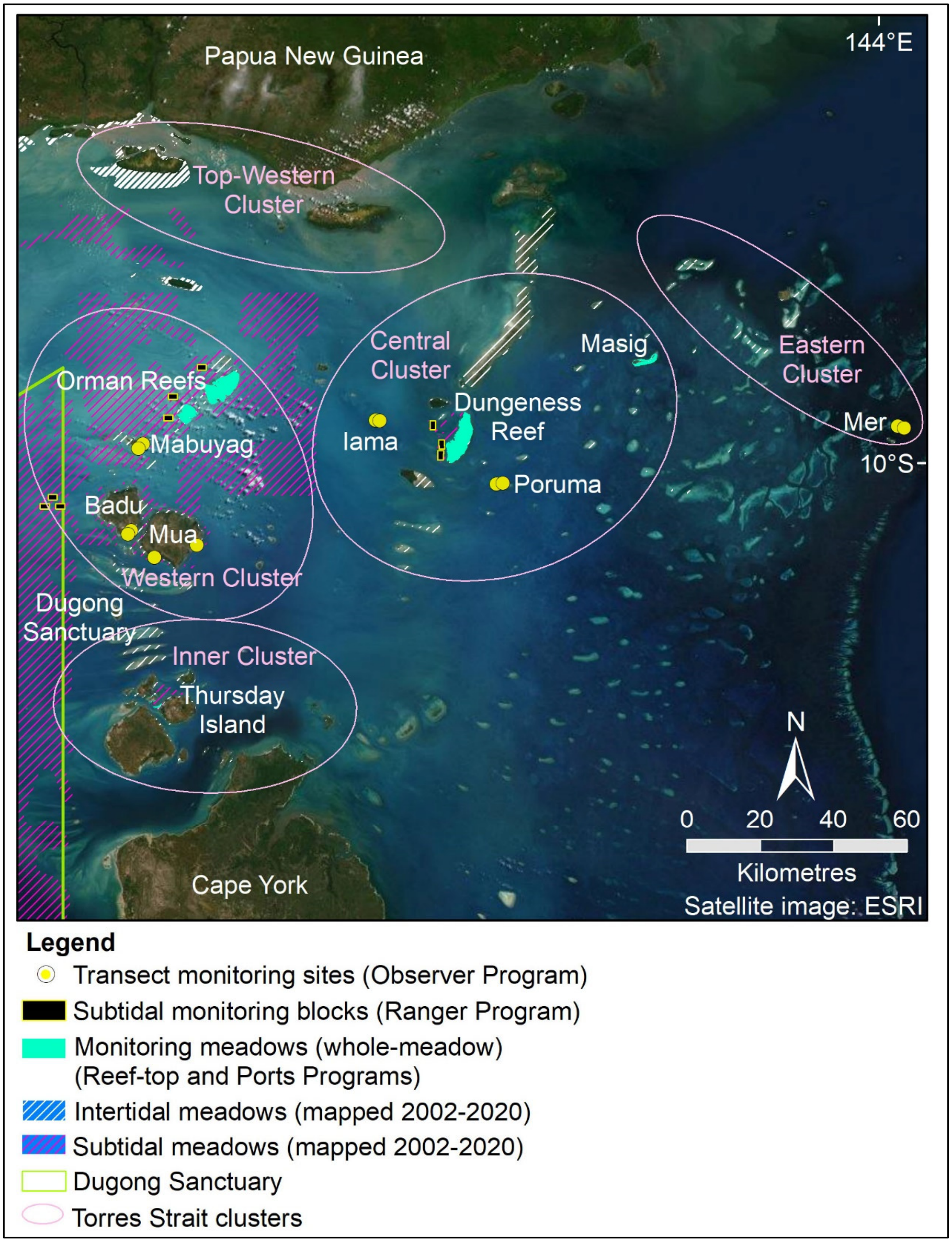

Figure 1. The Torres Strait Seagrass Monitoring Program incorporates four long-term monitoring programs spanning four island clusters.

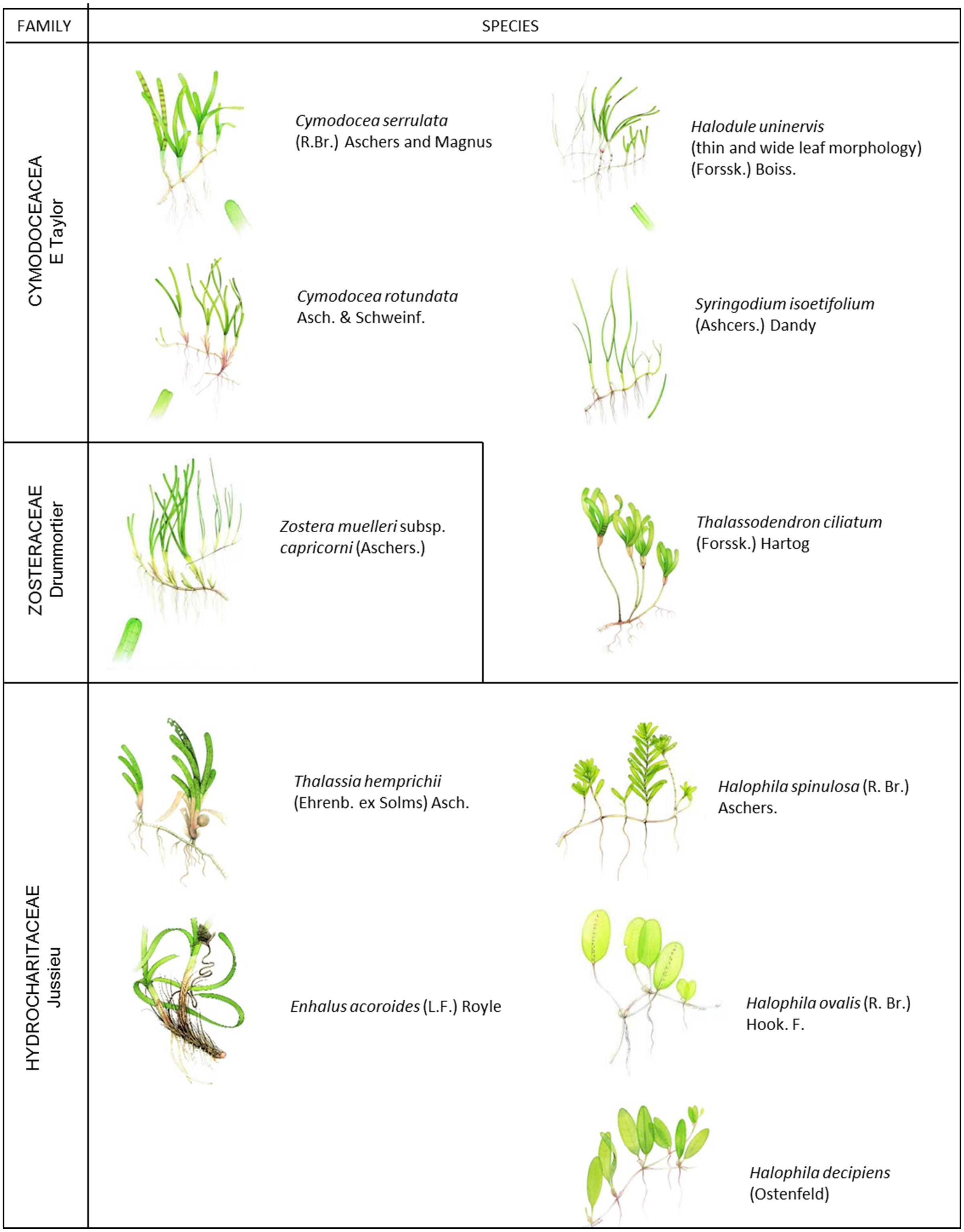

Figure 2. Seagrass species recorded across Torres Strait Seagrass Monitoring Program monitoring sites/ meadows.

Methods

Sampling Approach and Data Collection Methods for Seagrass Indicators

The TSSMP survey times and frequencies vary, ranging from quarterly to biannual (observer and subtidal programs) to annual (reef-top and ports programs). This report card only uses data collected from September – April for intertidal surveys, and September – March for subtidal block surveys. The exclusion of data from late autumn and winter was based on expert discussion and examination of historical monitoring data, where a season of low seagrass abundance occurred from May to August during Sager, the south-east wind period. High seagrass abundance occurs from September to April during Naiger (north-east wind period) and Kuki (north-west monsoon) (McNamara et al. 2010; also see https://www.qcaa.qld.edu.au/about/k-12-policies/aboriginal-torres-strait-islander-perspectives/resources/seasons-stars). Excluding data collected when seagrass senesces controls for seasonal variation at each site, and means results for programs that survey only during the peak seagrass growing season are comparable with programs that survey throughout the year. This is a common practice for other Queensland report cards (Carter et al. 2016).

Survey methods vary among the TSSMP programs. These are:

(1) Torres Strait Seagrass Observers Program (small-scale transect-based monitoring) – Each site is a 50m x 50m relatively homogeneous area (low variability, even topography) in each seagrass meadow. Within each site, three replicate 50 m long transects are laid parallel to each other, 25 m apart and perpendicular to the beach. Along each transect, the rangers record seagrass percent cover and species composition within a 0.25 m^2 quadrat, with quadrats placed at 5 m intervals along a transect (Figure 3a, b). For each quadrat percent cover is estimated with the assistance of standardized percent cover photographs, and the percent contribution of individual species to total cover (species composition).

(2) Ranger Subtidal Monitoring Program (medium-scale block-based monitoring) – Survey methods follow the established techniques for the TropWATER subtidal block seagrass monitoring program, where three transects are surveyed in each of three blocks per meadow (Carter et al. 2017). Quadrats are assessed using underwater video. At each site, a GoPro is lowered from the ranger vessel to the sea floor (Figure 3d) and 10 replicate "camera drops" are conducted approximately 5 m apart while the boat moves at drift speed. The camera frame serves as a 0.25 m^2 quadrat, and the footage is viewed on an iPad at the surface and recorded. A sample of seagrass is collected in the field using a van Veen grab (grab area 0.0625 m^2) to identify species present at each transect (Figure 3e, f). Video footage is sent back to TropWATER scientists where biomass and species composition estimates are made.

(3) Reef-top Monitoring Program Queensland Ports Seagrass Monitoring Program (large-scale meadow-based monitoring) – Survey methods follow the established techniques for the TropWATER Queensland-wide ports seagrass monitoring program (see Unsworth et al. 2012; Rasheed and Unsworth 2011; Taylor and Rasheed 2011). Intertidal meadows are sampled at low tide using a helicopter (Figure 3c). GPS is used to record the position of meadow boundaries. Seagrass presence/absence, biomass, species composition is determined from three replicate 0.25 m^2 quadrats placed randomly within a 10 m^2 circular area while the helicopter maintains a low hover. Sites are randomly scattered within each meadow.

(4) Queensland Ports Seagrass Monitoring Program (large-scale meadow-based monitoring) – Survey methods for intertidal meadows are the same as for the reef-top program. Shallow subtidal meadows are sampled by boat using underwater video camera and van Veen grab. The camera frame serves as a 0.25 m^2 quadrat with three replicate quadrats per site, and the video footage is analysed in real time using CCTV on the boat. Sites are located along transects perpendicular to the shoreline at ~50 - 100 m intervals, or where major changes in bottom topography occur, and extend to the offshore edge of each seagrass meadow.

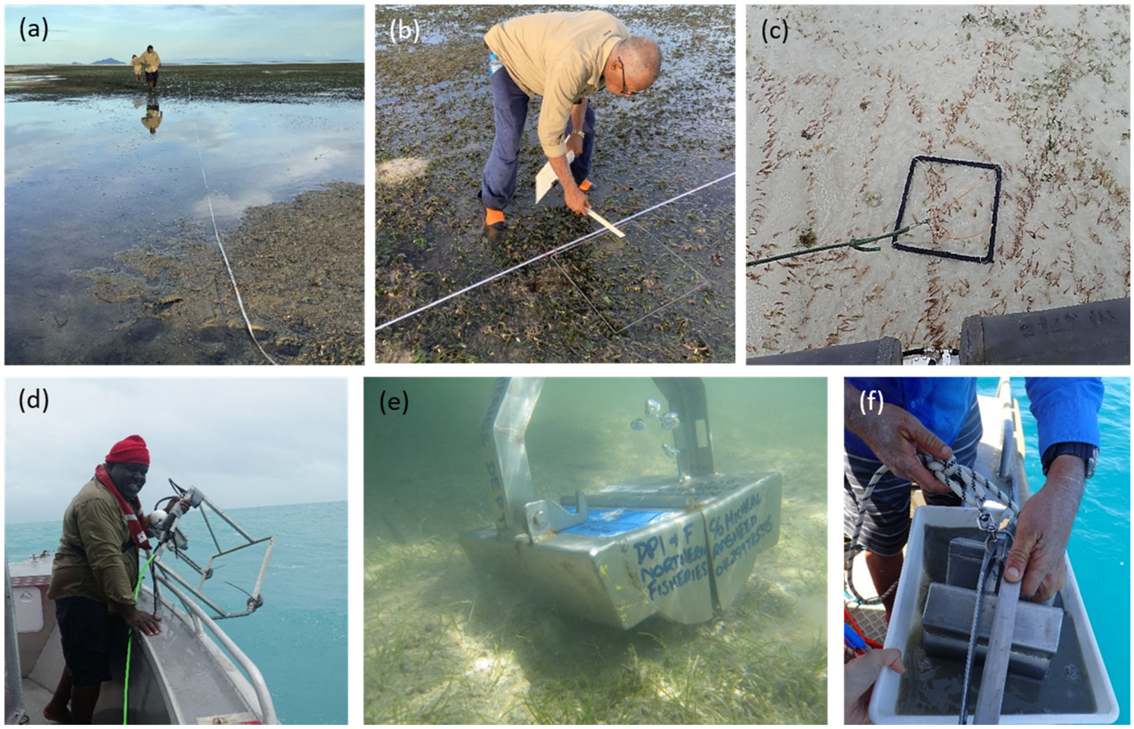

Figure 3. Seagrass survey methods include (a, b) walking along permanent transects, (c) quadrat lowered from a hovering helicopter, (d) underwater video drops and (e, f) van Veen grab. Photos courtesy Mua Lagalgau Rangers and TropWATER.

Biomass and Species Composition

Seagrass above-ground biomass was determined for the ranger, ports, and reef-top programs using a "visual estimates of biomass" technique (Mellors 1991; Kirkman 1978). For each quadrat a TropWATER trained observer assigns a biomass rank made in reference to a series of 12 quadrat photographs of similar seagrass habitats for which the ranks were previously measured (reference quadrats). The percent contribution of each seagrass species to above-ground biomass within each quadrat is also recorded. Three separate ranges are used - low biomass, high biomass, and *Enhalus acoroides* biomass. At the completion of ranking, the observer ranks a series of five calibration quadrat photographs that had previously been harvested and biomass measured in the laboratory for each range. A separate regression equation of biomass ranks versus actual biomass is calculated for each observer and each range, and applied to the biomass ranks given in the field. Field biomass ranks are converted into above-ground biomass estimates in grams dry weight per square metre (g DW m^{-2}).

Species composition is calculated as the percent contribution of individual species to either above-ground biomass (ranger subtidal, ports, and reef-top programs) or total percent cover (observer program).

Meadow Area

Meadow area is assessed only in the large-scale meadow-based monitoring programs (ports and reef-top programs). Seagrass presence/absence site data, mapping sites, field notes, and satellite imagery are used to construct meadow boundaries in ArcGIS®. Seagrass meadows are assigned a meadow identification number; this allows individual meadows to be compared among years. Monitoring meadows are referred to by identification numbers throughout this report. Meadow area is determined in hectares using the calculate geometry function in ArcGIS. Meadows are assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow (Table 2). The mapping precision estimates are used to create a buffer representing the error around each meadow, the area of which is expressed as a meadow reliability estimate (R) in hectares.

Table 2. Mapping precision and methodology for seagrass meadows in Torres Strait.

Mapping precision	**Mapping methodology**
5 m	Meadow boundary mapped in detail by GPS from helicopter, Intertidal meadows completely exposed or visible at low tide.
10 m	Meadow boundary determined from helicopter and/or boat surveys, Inshore boundaries interpreted from helicopter sites, Offshore boundaries interpreted from survey sites and aerial photography, Moderately high density of mapping and survey sites.
20 m	Meadow boundaries determined from helicopter and/or boat surveys, Inshore boundaries interpreted from helicopter sites, Offshore boundaries interpreted from boat survey sites, Lower density of survey sites for some sections of boundary.
50 m	Meadow boundaries determined from helicopter and/or boat surveys, Meadow boundaries determined from seagrass presence/absence data, Low density of survey sites for some sections of boundary.

Seagrass Condition

Seagrass condition is determined using a condition index to assess changes in abundance (biomass/percent cover), species composition, and meadow area (reef-top and ports programs only) relative to each site/meadow's baseline. Seagrass condition for each indicator in each site/meadow is scored from 0 – 1 and assigned one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor). The flow chart in Figure 4 summarises the methods used to calculate seagrass condition. Detailed description of how the report card method was developed can be found in Bryant et al. (2014), Carter et al. (2015), and Carter et al. (2016). Appendix 1 provides detailed methods used to determine baseline calculations, classify meadows, define thresholds, provide grades and scores, and aggregate those scores.

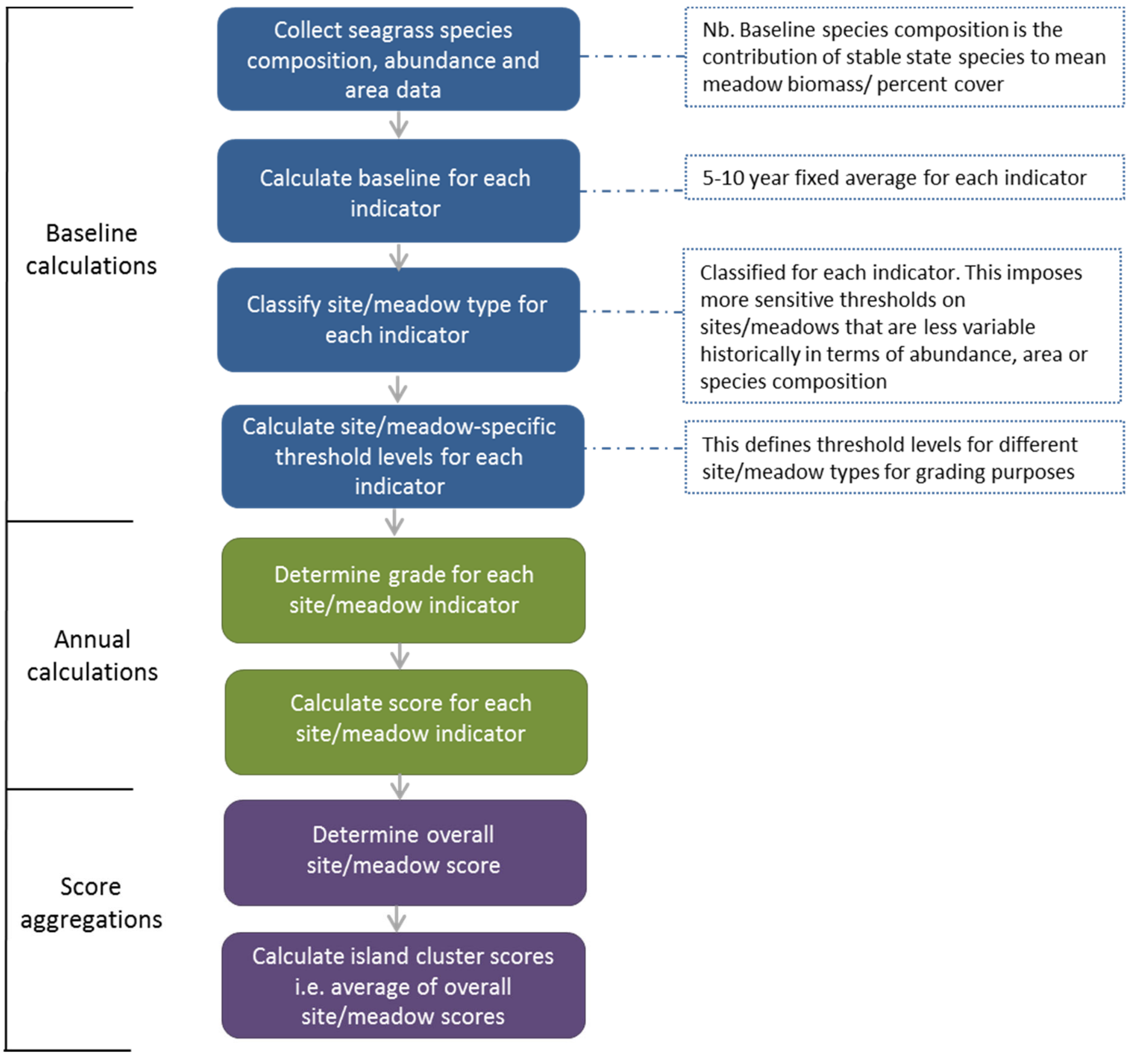

Figure 4. Flow chart of steps used to determine Torres Strait grades and scores.

Results

Meadow Classifications

Twenty-seven sites/meadows were classified for this report card. Of those, ~78% were characterised as having stable species composition. Site MR1 at Mer Island, and meadows M2 and M4 at Thursday Island are the only locations to be classed as single species due to the dominance of *T. hemprichii* and *E. acoroides*, respectively. All other sites/meadows are classed as mixed species (Table 3). Biomass/ percent cover was stable in 44% of sites/meadows. Meadow-scale monitoring occurred at 13 locations, nine of which are at Thursday Island/Madge Reef in the Inner Cluster; meadow area was classed as stable or highly stable in 11 of these meadows (Table 3).

Overall Site/Meadow Condition and Data Availability

Overall grades and scores were produced for 25 of the sites/meadows. Of the sites/meadows with overall condition scores, over half of the sites (17) were in overall good condition or very good condition, three were in satisfactory condition, three were in poor condition, and two were in very poor condition (Table 4). Overall site/meadow scores were largely driven by abundance scores in the Western, Central and Eastern Clusters, and meadow area in the Inner Cluster (Table 4). The poor condition at Mabuyag Island site MG1, Poruma Island site PM2, and Mer Island site MR2 were due to reductions in percent cover. Very poor seagrass condition at Orman Reefs subtidal (OR7) and Dugong Sanctuary (DS1) were due to biomass declines. Where meadow scale monitoring occurs, meadow area was in good or very good condition (Table 4).

An important milestone was reached in the monitoring program in 2022 with Badu Island's Upai site (BD2) reaching 10-years of monitoring data, meaning that the baselines for this location are now set. Overall grades and scores for Dungeness Reef subtidal and Masig Island intertidal will be incorporated into the report card when 5 years of baseline data has been collected.

Overall Cluster Condition

The Western, Eastern and Central Clusters were in satisfactory condition, and the Inner Cluster was in good condition (Table 4).

Table 3. Classifications representing the historical stability or variability of seagrass site/meadow for biomass/ percent cover, area, and species composition within Torres Strait Island Clusters. Classifications were based on the coefficient of variation of the baseline for each indicator. int = intertidal; sub = subtidal.

ISLAND CLUSTER	LOCATION	SITE/ MEADOW ID	ABUNDANCE (BIOMASS or PERCENT COVER)	AREA	SPECIES COMPOSITION
Western	Mabuyag Island (int)	MG1#	Stable	^	Variable – mixed species
		MG2#	Variable	^	Stable – mixed species
	Badu Island (int)	BD1	Stable	^	Stable – mixed species
		BD2	Stable	^	Stable – mixed species
	Mua Island (int)	MU1	Variable	^	Stable – mixed species
		MU3	Stable	^	Variable – mixed species
	Orman Reefs (int)	OR2#	Variable	Highly stable	Stable – mixed species
		OR5#	Variable	Highly stable	Variable – mixed species
	Orman Reefs (sub)	OR7#	Variable	^	Variable – mixed species
	Dugong Sanctuary (sub)	DS1#	Variable	^	Variable – mixed species
Central	Iama Island (int)	IM1	Stable	^	Stable – mixed species
		IM2	Stable	^	Stable – mixed species
	Poruma Island (int)	PM1#	Stable	^	Stable – mixed species
		PM2#	Variable	^	Variable – mixed species
	Dungeness Reef (int)	DR6#	Variable	Stable	Stable – mixed species
	Dungeness Reef (sub)	DR1#	Variable	^	Variable – mixed species
	Masig Island (int)	MS1#	Variable	Highly stable	Stable – mixed species
Eastern	Mer Island (int)	MR1	Stable	^	Stable – single species
		MR2	Variable	^	Stable – mixed species
Inner	Thursday Island (int)	M1	Variable	Stable	Stable – mixed species
		M3	Variable	Variable	Stable – mixed species
		M5	Stable	Stable	Stable – mixed species
		M8	Variable	Stable	Stable – mixed species
	Thursday Island (int-sub)	M2	Stable	Stable	Stable – single species
		M4	Stable	Variable	Stable – single species
		M6	Stable	Stable	Stable – mixed species
	Madge Reef (int)	M26	Variable	Highly stable	Stable – mixed species
		M27	Variable	Stable	Stable – mixed species

<10 years of data available to classify meadows. Classifications for these sites/meadows should be interpreted with caution until 10-year baselines are available.

^ Area data not collected in current monitoring program.

Table 4. Grades and scores (0-1 scale) for seagrass condition indicators (abundance, area, species composition) for sites/meadows and Torres Strait Island Clusters in 2022. Cells are coloured according to grade. See Appendix 1, Table A1.2 for grading scale.

Very good	Good	Satisfactory	Poor	Very Poor

ISLAND CLUSTER	LOCATION	SITE/ MEADOW ID	ABUNDANCE (BIOMASS or PERCENT COVER)	AREA	SPECIES COMP.	OVERALL SITE/ MEADOW SCORE	OVERALL CLUSTER SCORE
Western	Mabuyag Island (int)	MG1#	0.49	^	0.93	0.49	0.54
		MG2#	NS	^	NS	NS	
	Badu Island (int)	BD1	0.79	^	0.69	0.74	
		BD2	0.70	^	0.81	0.70	
	Mua Island (int)	MU1	0.78	^	0.88	0.78	
		MU3	0.61	^	0.76	0.61	
	Orman Reefs (int)	OR2#	0.66	0.76	0.76	0.66	
		OR5#	0.73	0.75	0.93	0.73	
	Orman Reefs (sub)	OR7#	0.17	^	0.94	0.17	
	Dugong Sanctuary (sub)	DS1#	0.001	^	1.00	0.001	
Central	Iama Island (int)	IM1	0.69	^	0.76	0.69	0.64
		IM2	0.61	^	0.68	0.61	
	Poruma Island (int)	PM1#	0.75	^	0.90	0.75	
		PM2#	0.32	^	1.00	0.32	
	Dungeness Reef (int)	DR6#	0.81	0.82	0.99	0.81	
	Dungeness Reef (sub)	DR1*	0.35	^	0.95	*	
	Masig Island (int)	MS1*	0.91	0.85	0.71	*	
Eastern	Mer Island (int)	MR1	0.69	^	0.60	0.65	0.50
		MR2	0.34	^	1.00	0.34	
Inner	Thursday Island (int)	M1	1	0.71	0.98	0.71	0.81
		M3	1	0.83	0.97	0.83	
		M5	0.86	0.78	0.93	0.78	
		M8	0.93	0.95	0.96	0.93	
	Thursday Island (int-sub)	M2	0.88	0.93	0.88	0.88	
		M4	0.89	0.92	0.69	0.79	
		M6	1	0.69	0.91	0.69	
	Madge Reef (int)	M26	0.88	0.98	0.80	0.84	
		M27	0.97	0.84	0.83	0.84	

Baseline conditions based on 5-10 years of data. Grades/scores for these sites/meadows should be interpreted with caution until 10-year baseline has been established.

* Baseline conditions based on <5 years of data. No overall grades or scores provided until 5 years of monitoring data is available.

^ Area data not collected in current monitoring program.

NS, no survey in 2022 growing season.

Seagrass Condition for Each Monitoring Site/Meadow

Western Island Cluster

Seagrass condition in the Western Island Cluster remained satisfactory in 2022. Very poor seagrass condition in the Dugong Sanctuary and Orman Reefs subtidal meadows, and poor seagrass condition at Mabuyag Island site MG1, was balanced by generally good seagrass condition at Badu and Mua Islands and Orman Reef intertidal reef-tops (Figure 5). Seagrass monitoring in this cluster includes six intertidal transect sites across Mabuyag, Badu and Mua Islands, whole-meadow monitoring of two intertidal reef-top meadows at Orman Reefs, and block monitoring of the Dugong Sanctuary and Orman Reefs subtidal meadows (Figure 5).

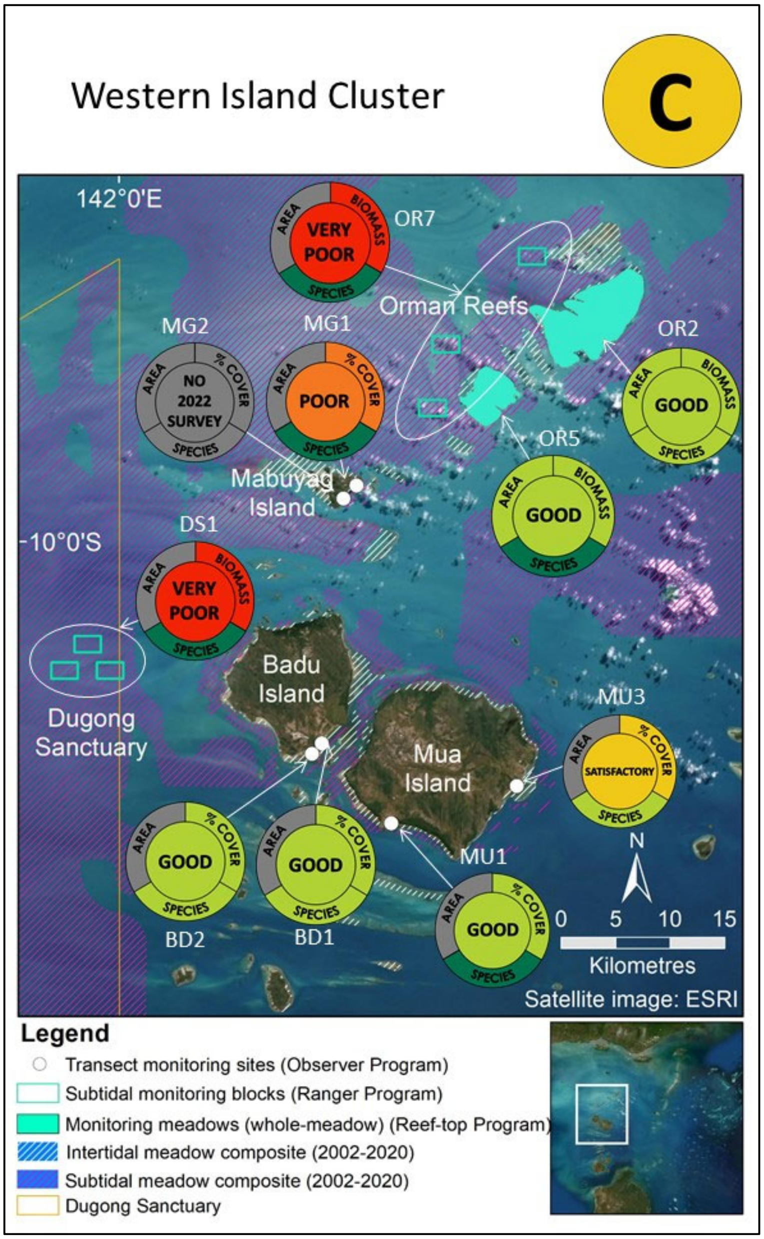

Figure 5. Seagrass condition across the Western Island Cluster of Torres Strait.

Mabuyag Island Site (MG1)

Monitoring at Panay, Mabuyag Island (site MG1) by Mabuygiw Rangers commenced in 2009 (Figure 6). Seagrass condition at Panay was poor in 2022 due to ongoing low percent cover at the site. Percent cover was relatively stable between 2009 and 2018, followed by a rapid decline from very good condition in 2018. Percent cover has remained ~21% between 2020 and 2022. The site continues to have high species diversity, with seven species recorded. Species composition has been variable over the years. The more stable species *T. hemprichii* replaced much of the *C. serrulata* in 2018 and 2020; in 2021 and 2022 *C. serrulata* had returned to being the dominant species (Figure 6).

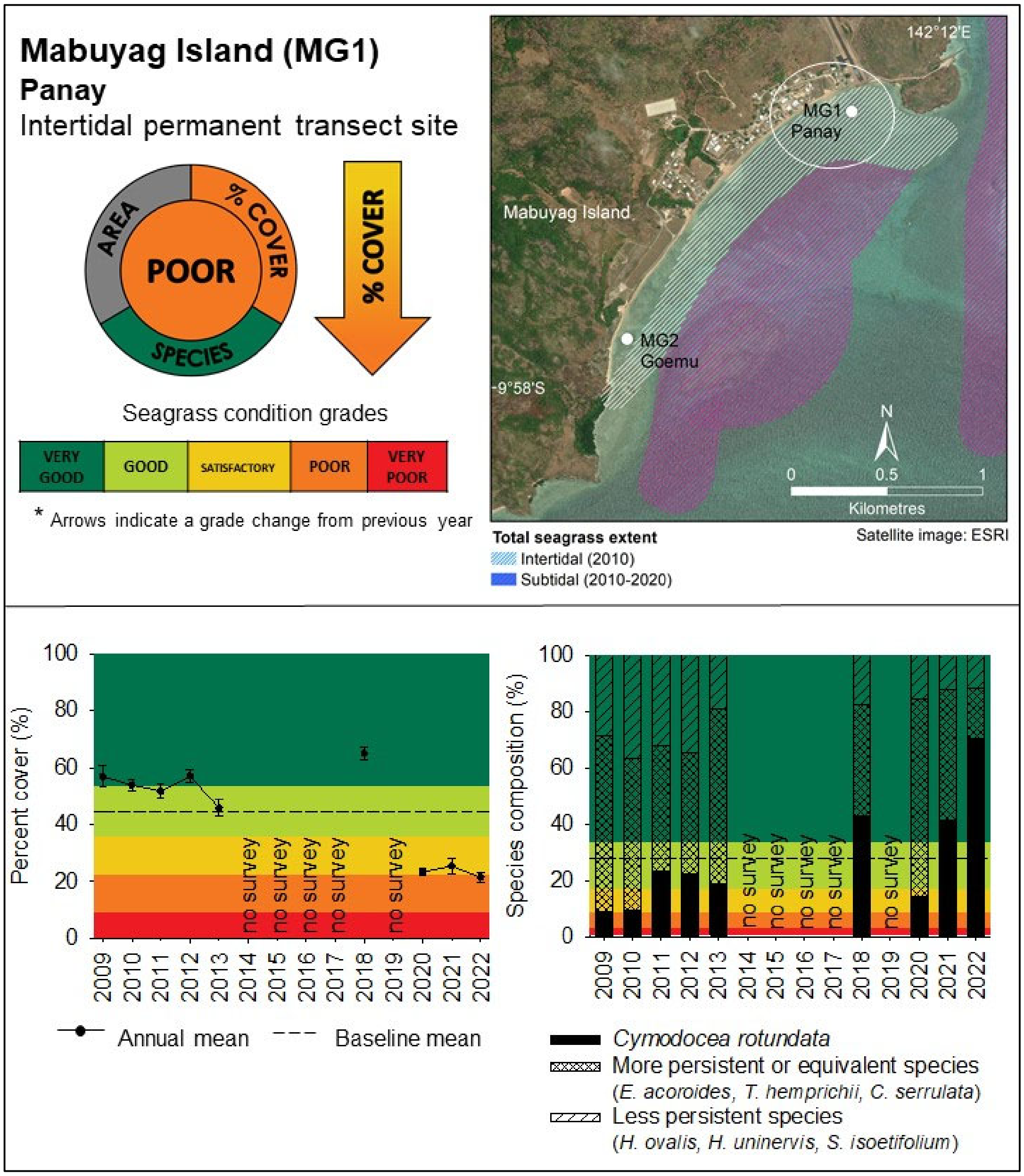

Figure 6. Seagrass mean percent cover and species composition at Mabuyag Island permanent transect site MG1, western Torres Strait, 2009 - 2022 (percent cover error bars = SE). Note: Baseline conditions based on 9 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Mabuyag Island Site (MG2)

The monitoring site MG2 (Goemu) at Mabuyag Island was established in 2010 and is monitored by the Mabuygiw Rangers (Figure 7). As with MG1 (Panay), the site has high species diversity, with seven species recorded historically. However, *E. acoroides* and *C. serrulata* were only recorded in 2012, and *S. isoetifolium* was not present in 2020 or 2021. The site is characterised by variable percent cover (Table 3). Seagrass condition at this site is unknown in 2022 because of technical issues with monitoring software (Figure 7).

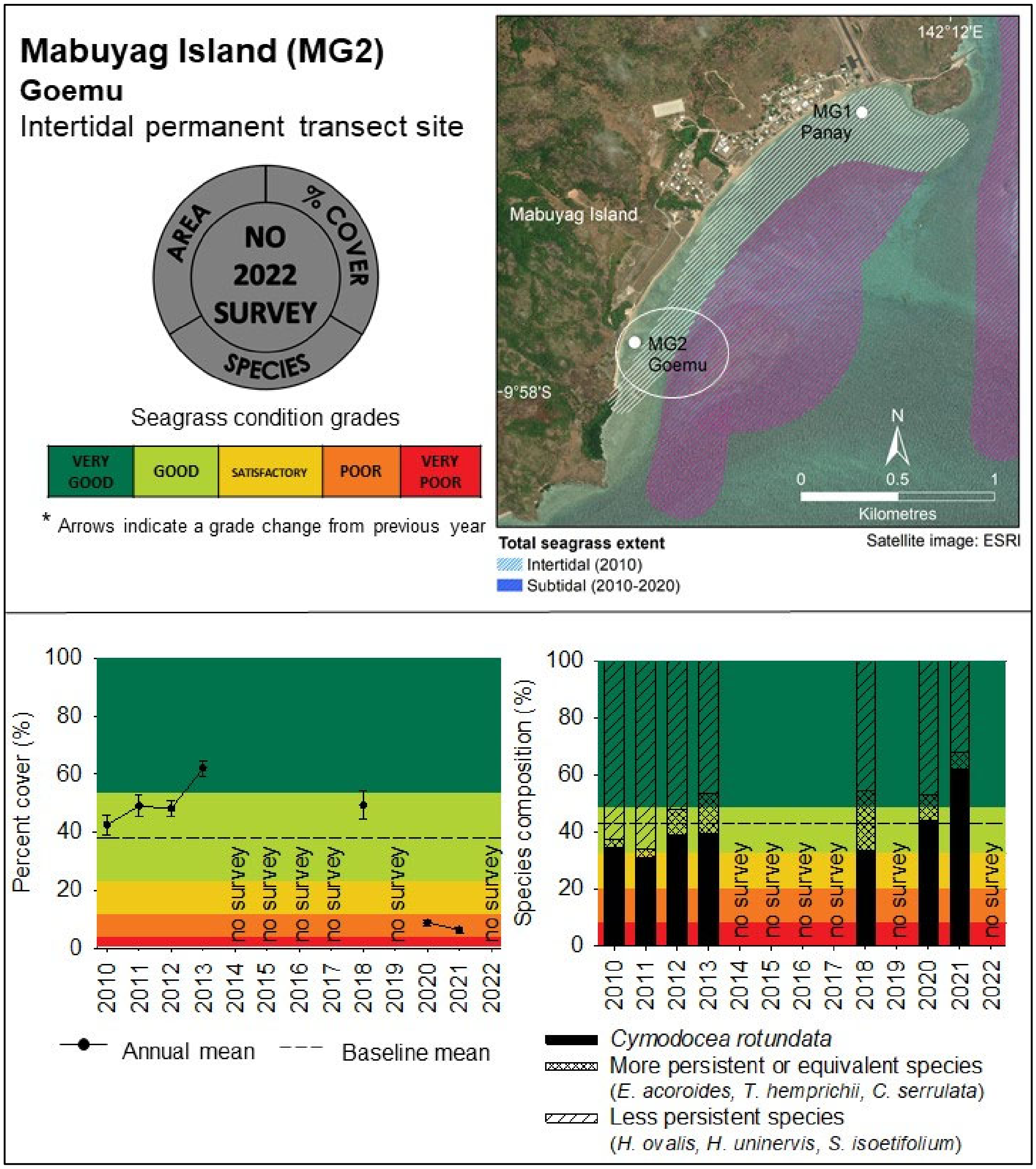

Figure 7. Seagrass mean percent cover and species composition at Mabuyag Island permanent transect site MG2, western Torres Strait, 2010 - 2022 (percent cover error bars = SE). Note: Baseline conditions based on 8 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Badu Island Site (BD1)

The transect monitoring site BD1 (Dogai Wak) at Badu Island was established in 2010 and is monitored by the Mura Badhulgau Rangers (Figure 8). The site is characterised by stable, mixed species and stable abundance (Table 3). Species composition condition improved due to an increase in the dominant species *H. uninervis* and a small amount (2%) of *C. rotundata* at the site, and a reduction in the less persistent species *H. ovalis*, relative to 2021. Seagrass percent cover declined from 49% (very good condition) to 35% (good condition) between 2021 and 2022, resulting in an overall grade of good at Dogai Wak in 2022 (Figure 8).

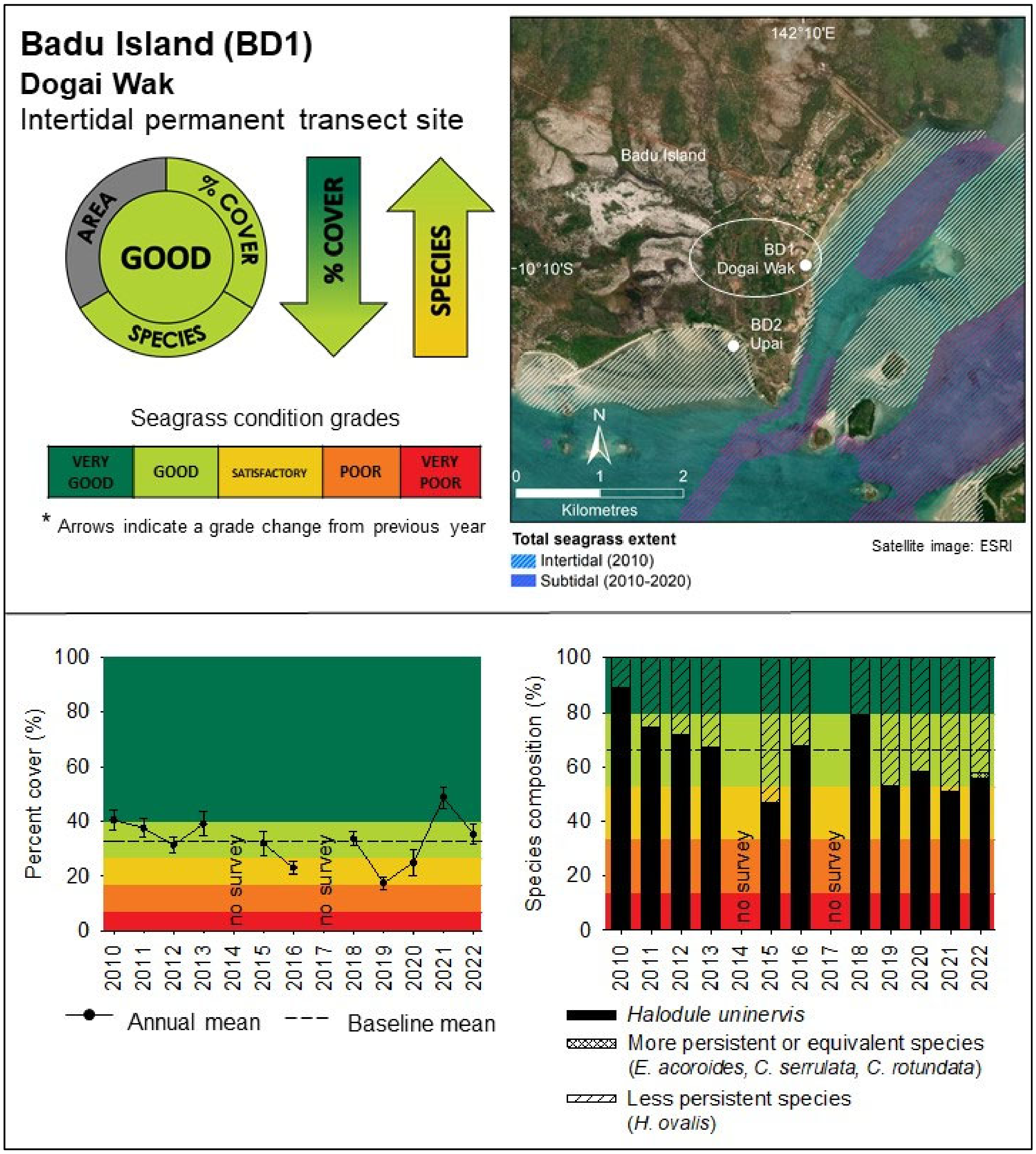

Figure 8. Seagrass mean percent cover and species composition at Badu Island permanent transect site BD1, western Torres Strait, 2010 - 2022 (percent cover error bars = SE).

Badu Island Site (BD2)

The transect monitoring site BD2 (Upai) at Badu Island is monitored by the Mura Badhulgau Rangers (Figure 9). This site reached ten years of monitoring data in 2022. Upai is characterised by stable percent cover and stable, mixed species composition (Table 3). Seven species have been recorded at this site, with five species regularly observed. In 2022, seagrass remained in good condition despite an increase in the dominant species *H. uninervis*. Seagrass abundance remained in good condition with a slight increase in percent cover from 40% cover in 2021 to 44% in 2022 (Figure 9). Overall site condition remained good (Figure 9).

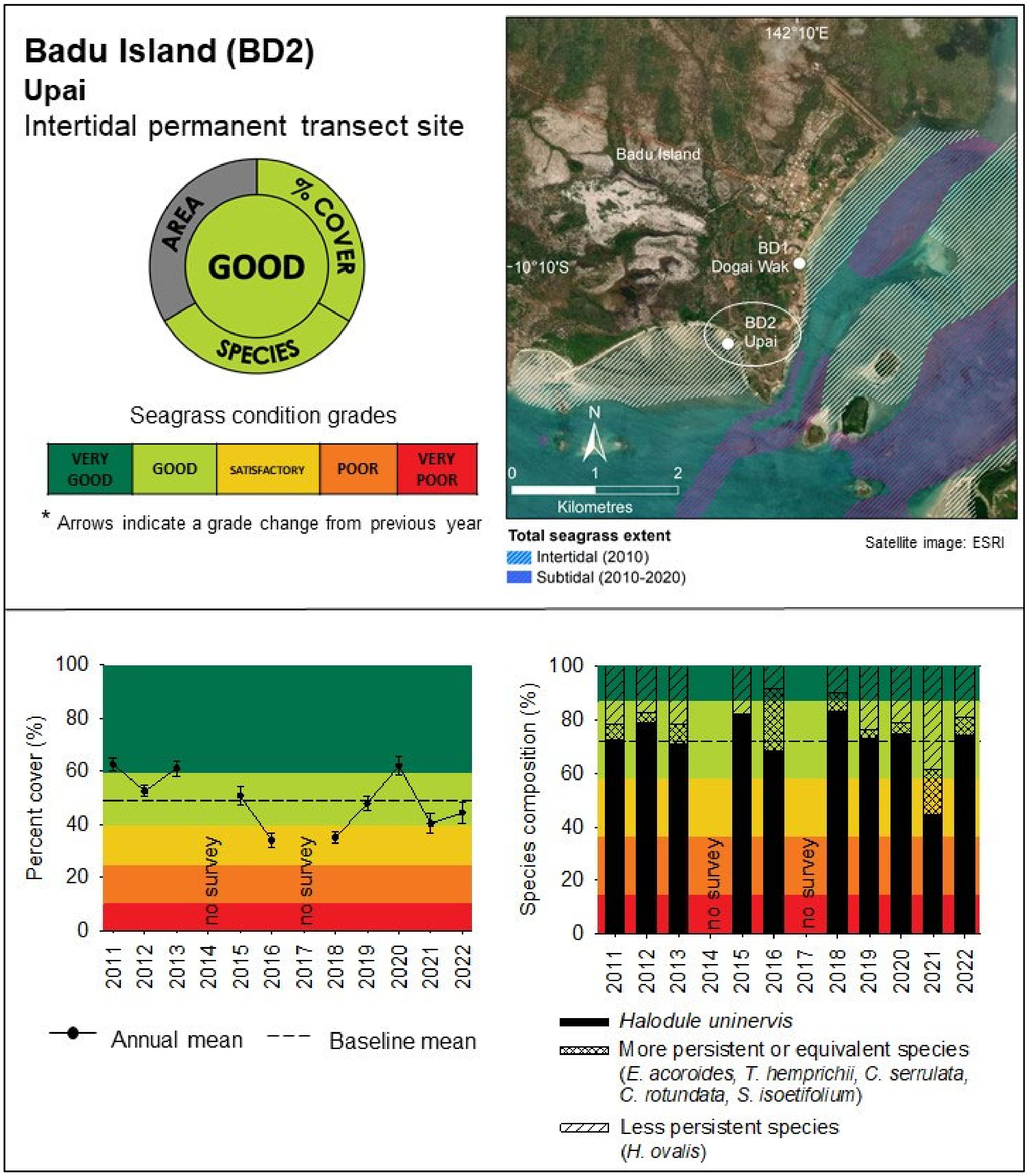

Figure 9. Seagrass mean percent cover and species composition at Badu Island permanent transect site BD2, western Torres Strait, 2011 - 2022 (percent cover error bars = SE).

Mua Island Site (MU1)

Monitoring at Kubin Beach Hotel, Mua Island (MU1), was established in 2011 and is conducted by the Mua Lagalgau Rangers. The site is characterised by variable percent cover and stable, mixed species composition (Table 3). Overall condition of the site was good in 2022 (Figure 10). Seagrass percent cover decreased from 42% (very good condition) in 2021 to 30% (good condition) in 2022. The contribution of the dominant species *T. hemprichii* also increased relative to less persistent species *H. uninervis* and *H. ovalis*, resulting in species condition improving from good condition in 2021 to very good condition in 2022 (Figure 10).

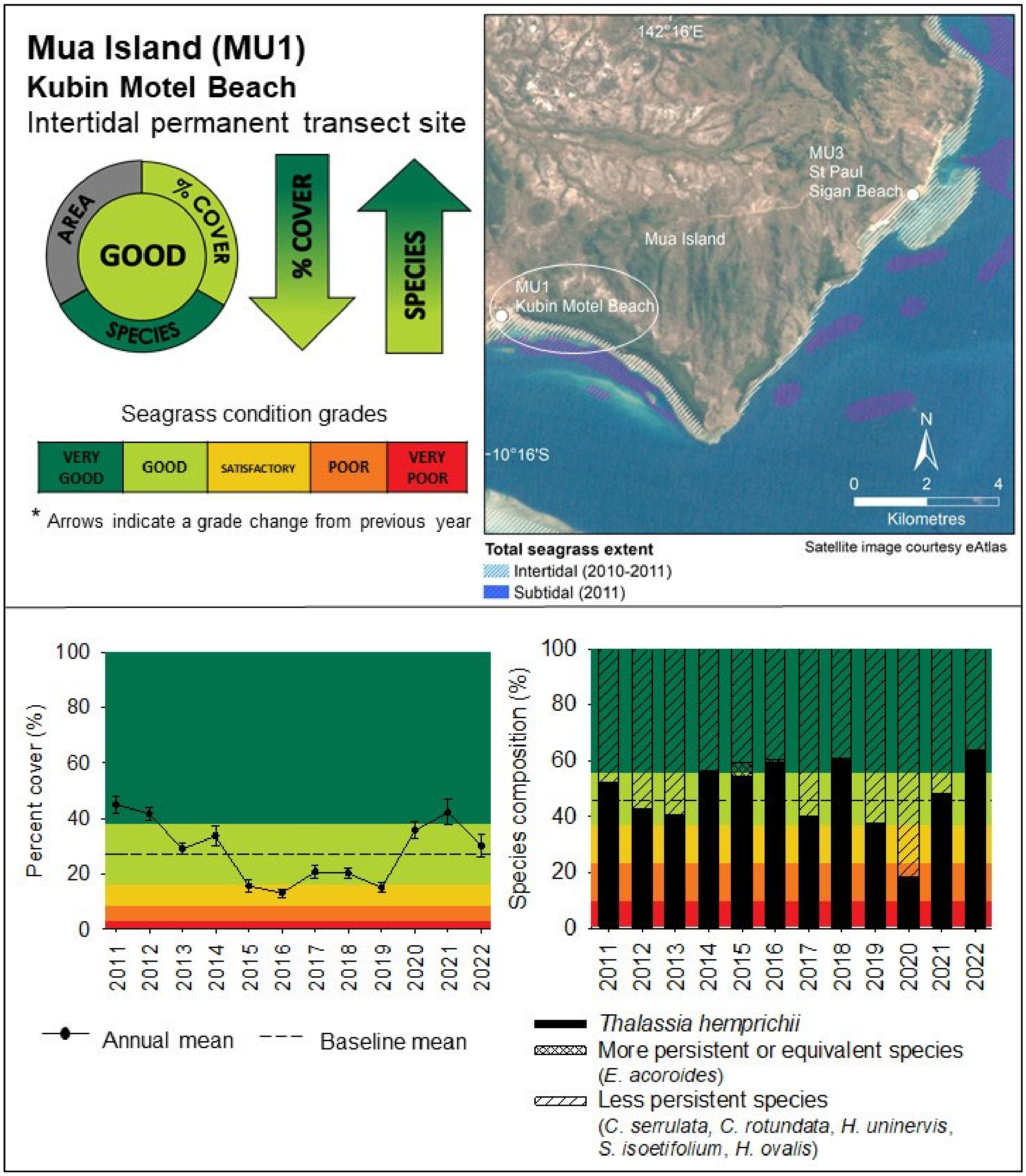

Figure 10. Seagrass mean percent cover and species composition at Mua Island permanent transect site MU1, western Torres Strait, 2011 - 2022 (percent cover error bars = SE).

Mua Island Site (MU3)

Monitoring at St Pauls Sigan Beach, Mua Island (MU3) is conducted by Mua Lagalgau Rangers. Ths site was established in late 2011 (2012 reporting year). Site MU3 is characterised by stable percent cover and variable, mixed species composition (Table 3). Overall site condition was satisfactory, a decline from very good in 2021 (Figure 11). This decline was due to a large reduction in percent cover, from 66% in 2021 to 31% in 2022. The dominant species *T. hemprichii* declined relative to less persistent species *C. rotundata* resulting in s species condition decline from very good in 2021 to good in 2022 (Figure 11).

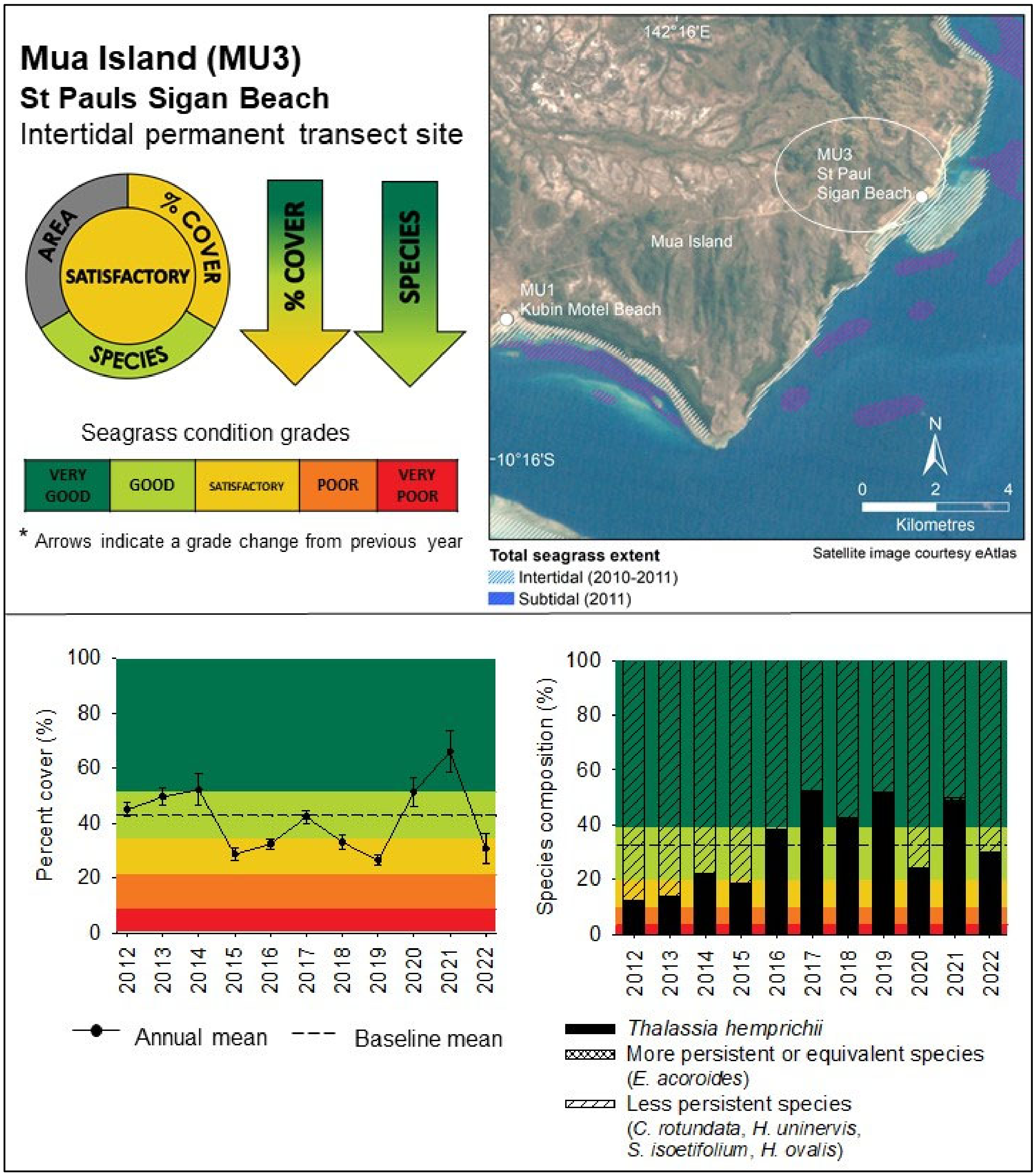

Figure 11. Seagrass mean percent cover and species composition at Mua Island permanent transect site MU3, western Torres Strait, 2012 - 2022 (percent cover error bars = SE).

Kai Reef - Orman Reefs Intertidal Meadow (OR2)

Kai Reef (OR2) is the largest reef in the Orman Reefs system. Monitoring was established in 2017 (2018 reporting year) because of the reef's value as a turtle foraging ground, and is conducted by TropWATER researchers. Preliminary assessments indicate variable biomass, highly stable area, and stable species composition (Figure 12; Table 3). Kai Reef's meadow biomass peaked in 2019, then declined dramatically over two years, resulting in a condition decline from very good in 2019 to satisfactory in 2021. Biomass hotspots remain in throughout the reef but are less dense than previous years. Despite biomass declines, area and species composition condition remain good, with the highly stable meadow continuing to cover the majority of Kai Reef's intertidal reef-top, and *T. hemprichii* remains the dominant species in the meadow (Figure 12).

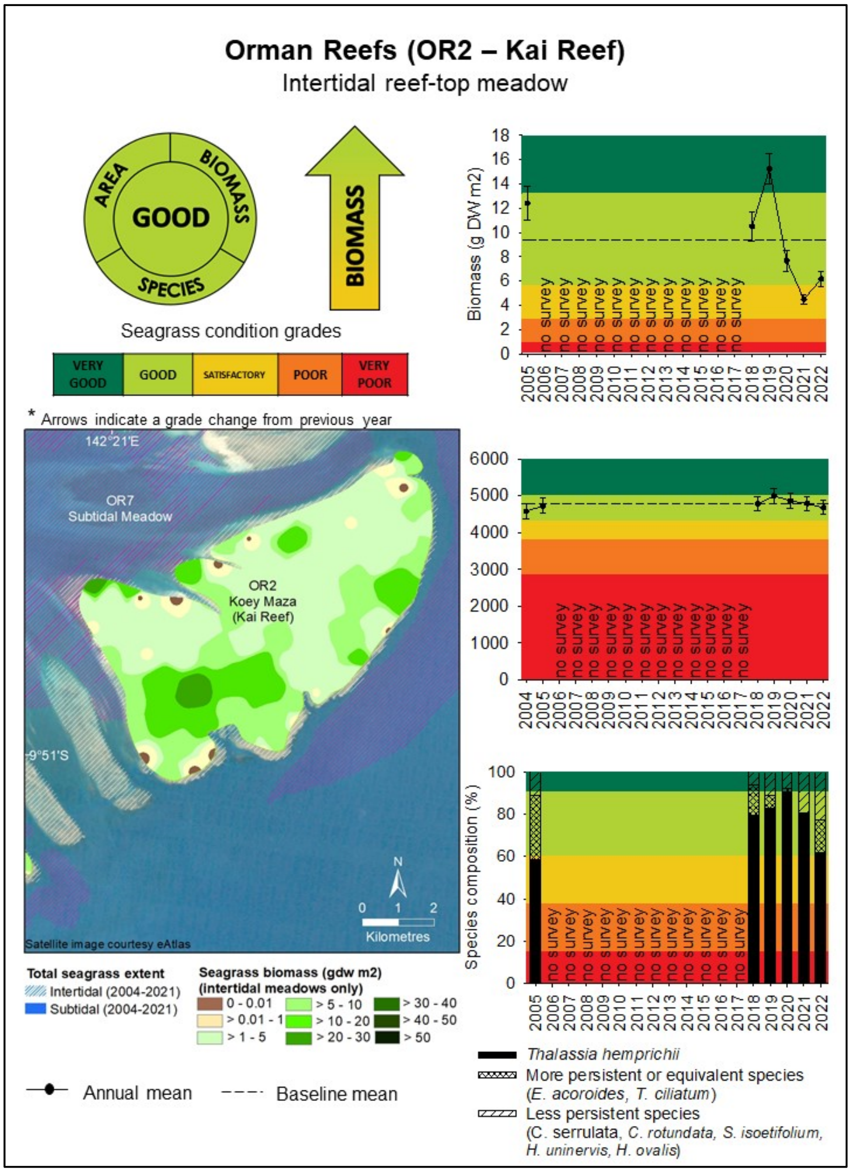

Figure 12. Seagrass mean biomass, area, and species composition at Orman Reefs (Kai Reef) intertidal meadow OR2, western Torres Strait, 2004/05 - 2022 (biomass error bars = SE; area error bars = reliability estimate). Note: Baseline conditions based on 6-7 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Gariar Reef - Orman Reefs Intertidal Meadow (OR5)

Gariar Reef (OR5) is in the southern section of the Orman Reefs system. Monitoring was established in 2017 (2018 reporting year) because of the reef's value as a turtle foraging ground, and is conducted by TropWATER researchers. Preliminary assessments indicate variable biomass, highly stable area, and variable species composition (Figure 13; Table 3). Biomass declined dramatically in 2020, from 27 g DW m^{-2} (very good condition) to 3 g DW m^{-2} (poor condition). Biomass increased slightly in 2021 to 5 g DW m^{-2} and again in 2022 to 11 g DW m^{-2} (good condition). Species composition remains very good because of the presence of the dominant species *T. hemprichii*. The meadow covers the majority of Gariar Reef's intertidal reef-top and area is highly stable; in 2022 area remained in good condition for the fifth year in a row (Figure 13).

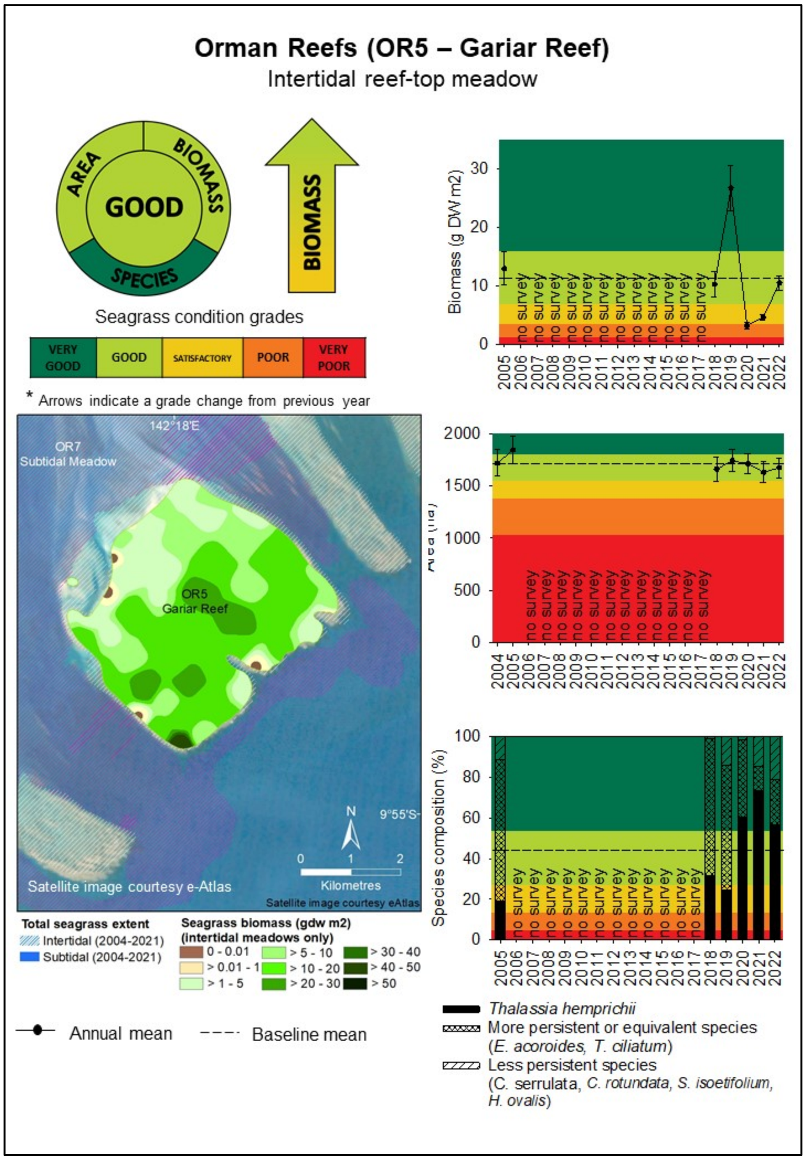

Figure 13. Seagrass mean biomass, area, and species composition at Orman Reefs (Gariar Reef) intertidal meadow OR5, western Torres Strait, 2004/05 - 2022 (biomass error bars = SE; area error bars = reliability estimate). Note: Baseline conditions based on 6-7 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Orman Reefs Subtidal Blocks (OR7)

Subtidal seagrass meadows surround Orman Reefs. Subtidal monitoring blocks are positioned along the western side of the reef system and are collectively referred to as OR7 (Figure 14). Subtidal blocks are monitored by the Mabuygiw and Mura Badhulgau Rangers. Overall meadow condition in 2022 was very poor for the third year following large reductions in seagrass biomass, from ~13 g DW m^{-2} in 2019 to <0.5 g DW m^{-2} in 2020 - 2022. The reduced biomass in 2020-2022 was largely due to the disappearance of the dominant subtidal species *H. spinulosa*. Species composition condition has been classed as very good despite the disappearance of *H. spinulosa* because more stable species (*C. serrulata*, *C. rotundata*, *H. uninervis*, *T. hemprichii*) continue to persist within the meadow, although at very low biomass (Figure 14). In 2022, *C. serrulata* became the baseline species due to the loss of *H. spinulosa*.

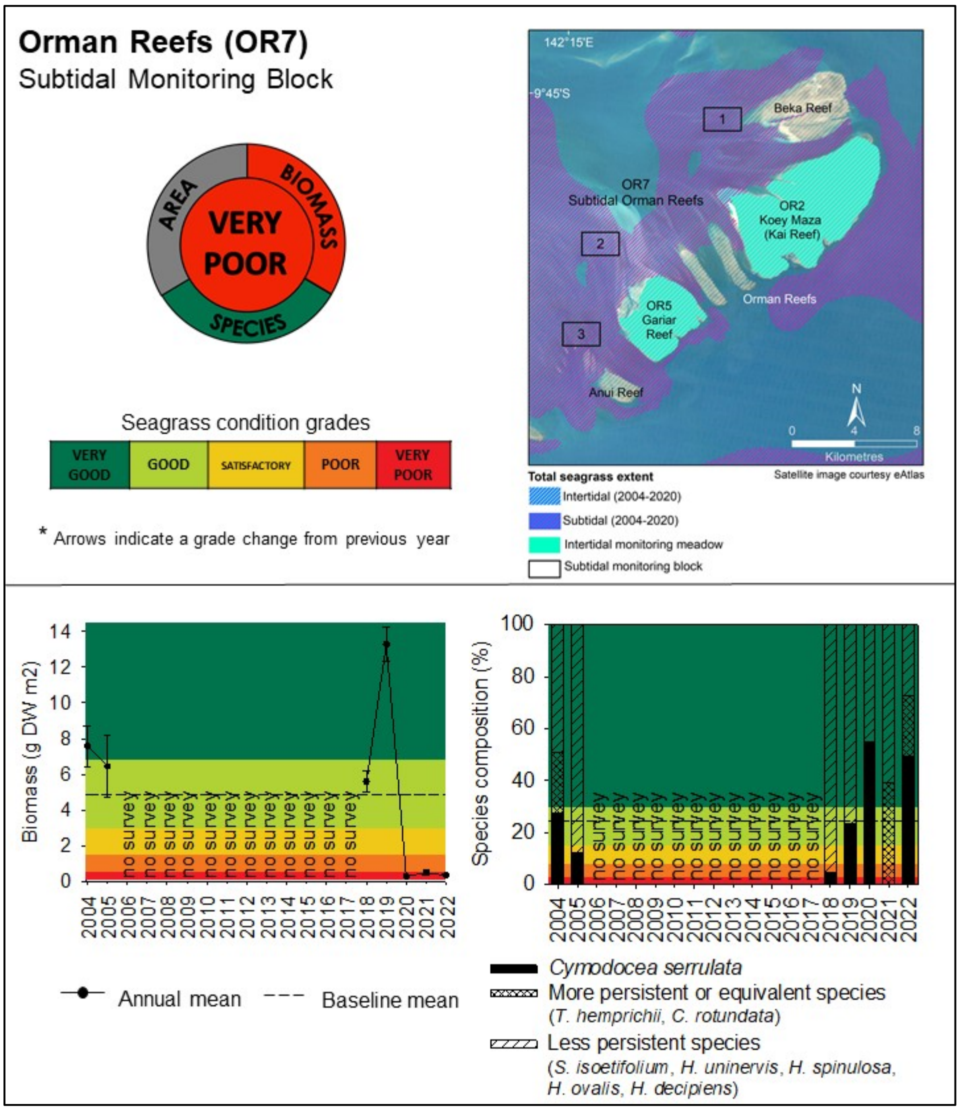

Figure 14. Seagrass mean biomass and species composition at Orman Reefs subtidal monitoring blocks, Western Cluster, 2004 - 2022 (biomass error bars = SE). Note: Baseline conditions based on 7 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Dugong Sanctuary Subtidal Blocks (DS1)

The Dugong Sanctuary contains a large subtidal meadow that historically spanned most of the sanctuary, but in recent years has become patchier. Subtidal monitoring blocks are positioned in the north-eastern part of the meadow and are collectively referred to as DS1 (Figure 15). Subtidal blocks are monitored by the Mabuygiw and Mura Badhulgau Rangers. Overall meadow condition in 2022 remained very poor. Biomass declined from 3 g DW m^{-2} in 2019 (very good condition) to <0.1 g DW m^{-2} in 2021 and 2022 (very poor condition). The reduced biomass in 2021 and 2022 is due to large areas with no seagrass and, where seagrass is present, low seagrass biomass biomass. In 2022 seagrass was present at only two sites, but the dominant subtidal species *H. spinulosa* had returned, resulting in a very good species composition grade. Species composition was very poor in 2021 due to the absence of *H. spinulosa* and presence of less persistent colonising species *H. ovalis* and *H. decipiens* (Figure 15).

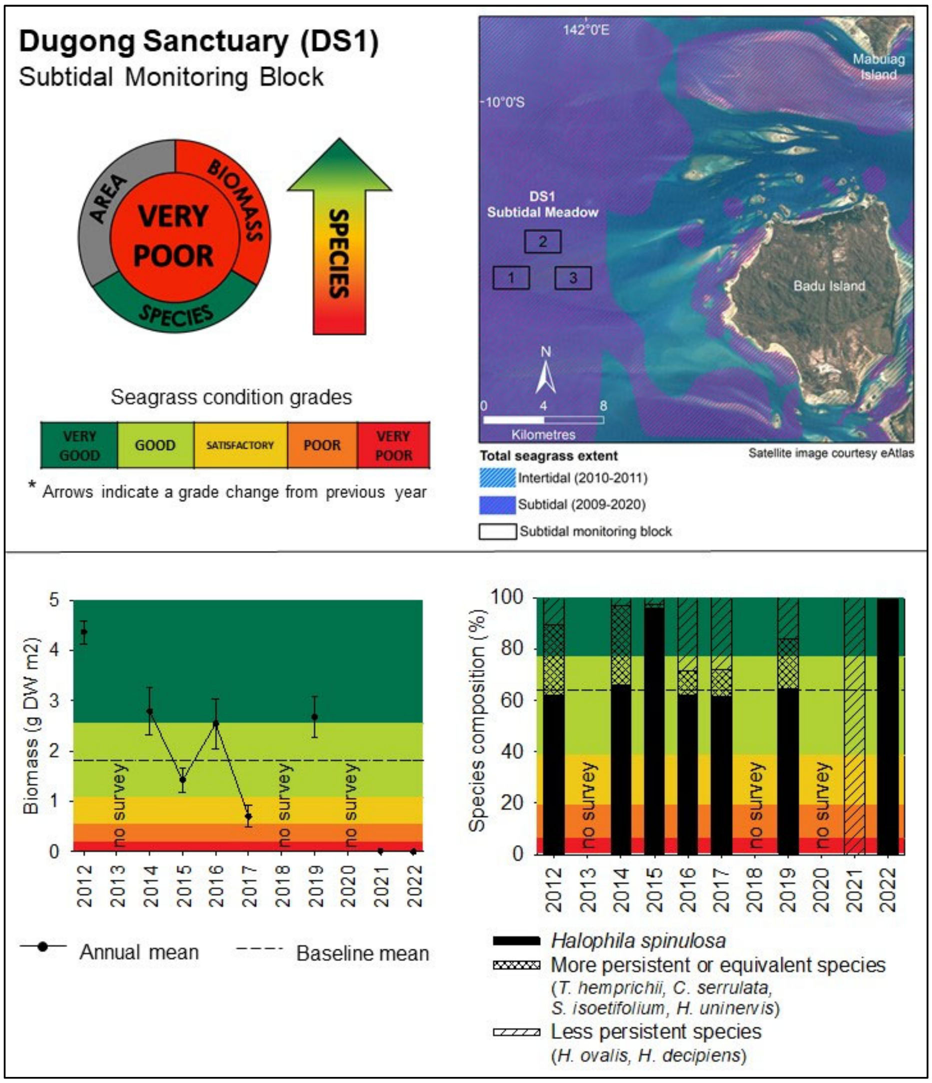

Figure 15. Seagrass mean biomass and species composition at Dugong Sanctuary subtidal monitoring blocks, western Torres Strait, 2012 - 2022 (biomass error bars = SE). Note: Baseline conditions based on 8 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Central Island Cluster

Seagrass condition in the Central Island Cluster declined from good to satisfactory in 2021, and remained in satisfactory condition in 2022 largely due to the decreases in seagrass abundance (percent cover) at Iama Island site IM2, and continued low cover at Poruma Island site PM2 for the second year (Figure 16). Seagrass monitoring in this cluster includes four intertidal transect sites at Iama and Poruma Islands, whole-meadow monitoring of Dungeness Reef and Masig Island intertidal reef-tops, and block monitoring of the Dungeness Reef subtidal meadow (Figure 16).

Figure 16. Seagrass condition across the Central Island Cluster of Torres Strait.

Iama Island Site (IM1)

The monitoring site IM1 at Mabuyag Point, north-west Iama Island, was established in August 2010 (2011 reporting year) (Figure 17). Seagrass abundance and species composition are both stable at this site (Table 3). This is a mixed species meadow with six species of seagrass recorded within the site. Species composition, percent cover, and therefore overall seagrass condition, all remained good in 2022 (Figure 17).

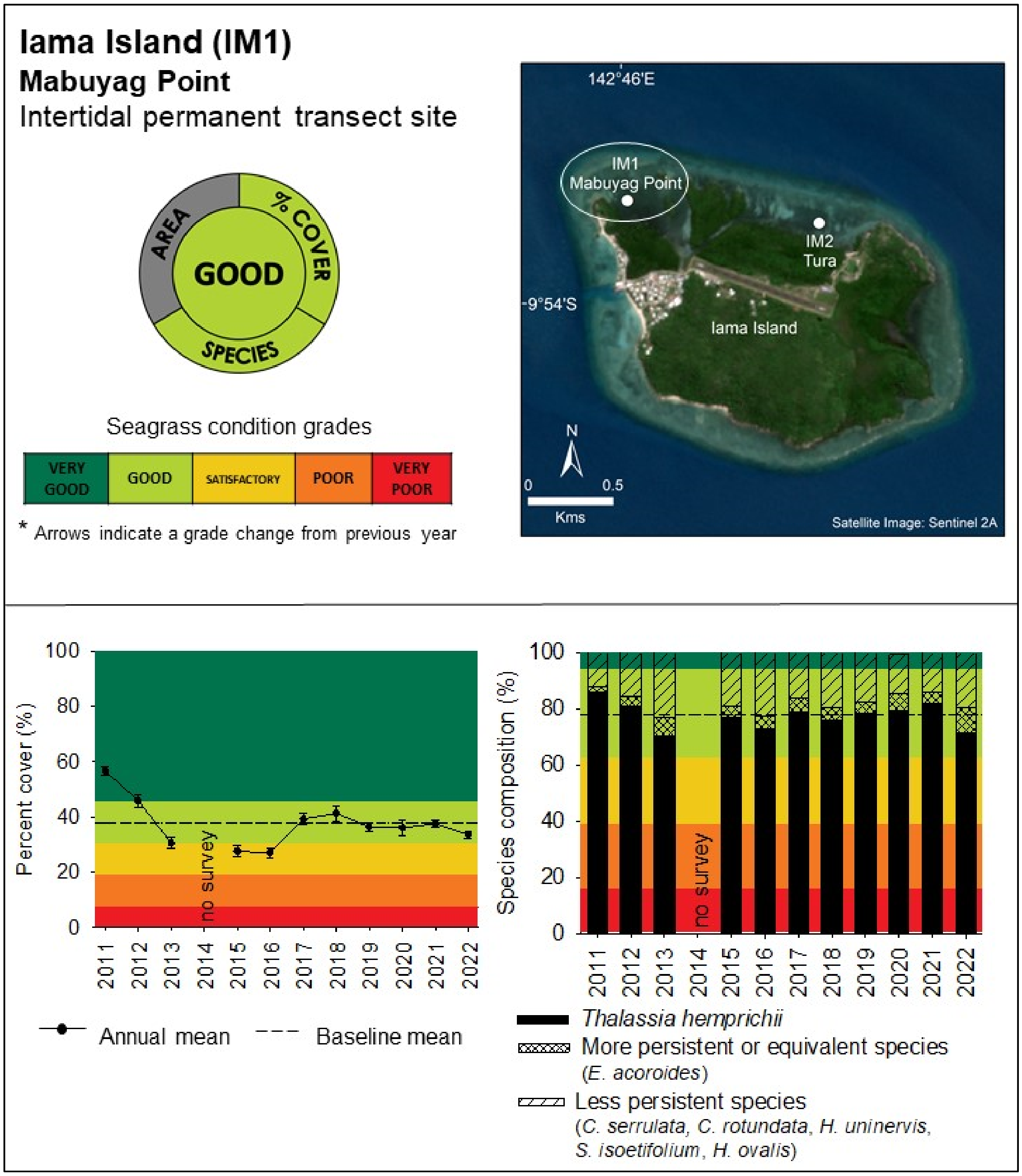

Figure 17. Seagrass mean percent cover and species composition at Iama Island permanent transect site IM1, central Torres Strait, 2011 - 2022 (percent cover error bars = SE).

Iama Island Site (IM2)

The monitoring site IM2 at Tura, Iama Island has been monitored by the Iamalgal Rangers since November 2010 (2011 reporting year) (Figure 18). Seagrass abundance and species composition at Tura are both stable (Table 3). Percent cover declines slightly, from 34% in 2021 (good condition) to 28% in 2022 (satisfactory condition). Species composition remained in good condition in 2022 (Figure 18).

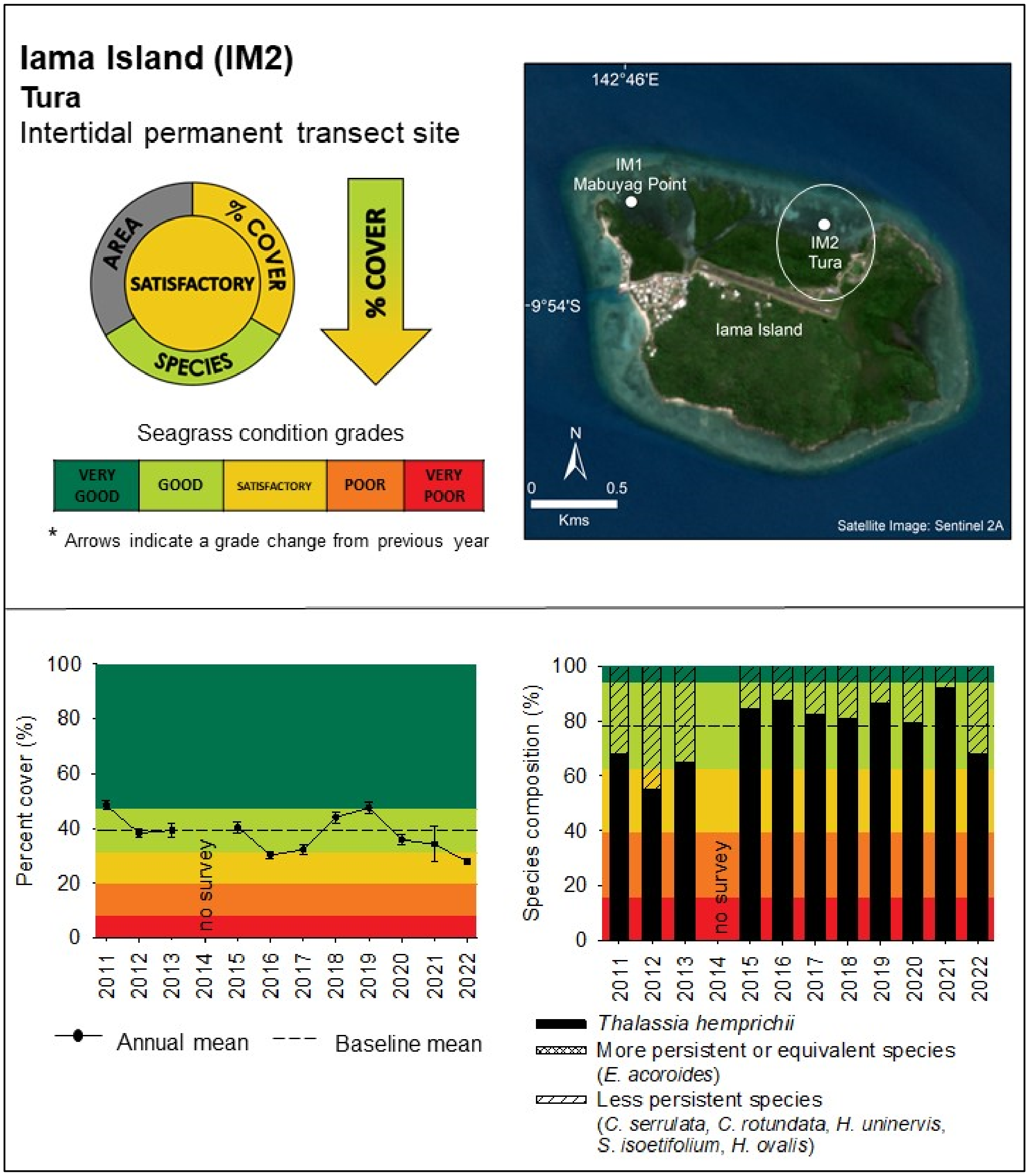

Figure 18. Seagrass mean percent cover and species composition at Iama Island permanent transect site IM2, central Torres Strait, 2011 - 2022 (percent cover error bars = SE).

Poruma Island Site (PM1)

Monitoring of PM1 at the south-west point of Poruma Island was established in August 2016 (2017 reporting year) by the Porumalgal Rangers. Preliminary assessments indicate stable percent cover and stable, mixed species composition (Table 3). Seagrass condition at PM1 in 2022 was good. Percent cover was 29% in 2022, similar to 31% in 2021 (good condition for both years). Species composition improved from good condition in 2021 to very good condition in 2022 due to an increase in the more persistent species *T. hemprichii* species relative to less stable species *H. uninervis* (Figure 19).

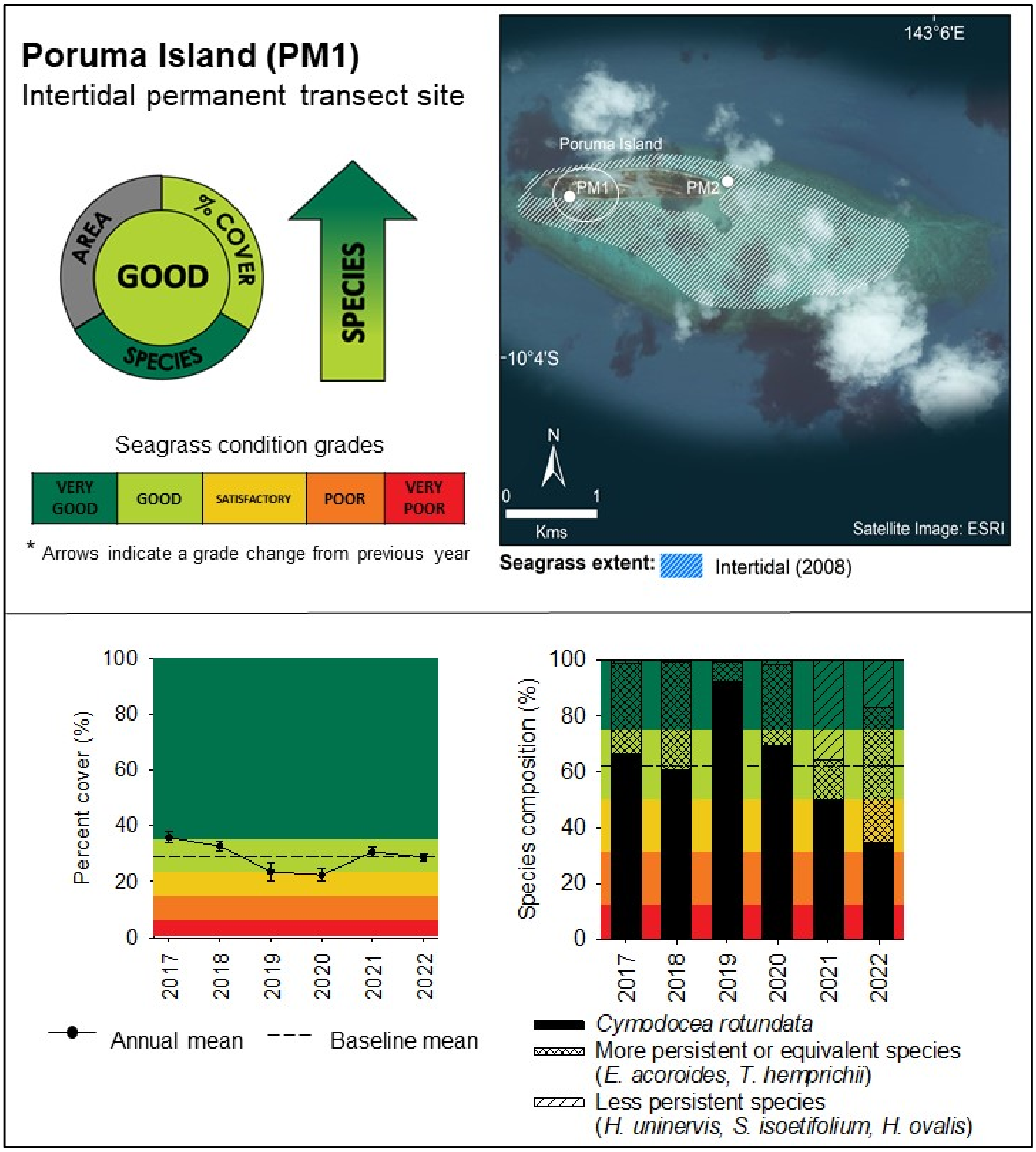

Figure 19. Seagrass mean percent cover and species composition at Poruma Island permanent transect site PM1, central Torres Strait, 2017 - 2022 (percent cover error bars = SE). Note: Baseline conditions based on 6 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Poruma Island Site (PM2)

Monitoring of PM2 at north-east Poruma Island started in August 2016 (2017 reporting year). The site is monitored by the Porumalgal Rangers. Preliminary assessments indicate variable percent cover and variable, mixed species composition dominated by *C. rotundata* (Table 3). Seagrass condition at PM2 in 2022 was poor due to large sand movement which covered the site two years ago. Percent cover declined from 15% in 2020 (good condition) to 3% in 2021 and 2% in 2022 (Figure 20). Species composition improved from very poor in 2021 to very good in 2022 due to the return of the dominant species *C. rotundata* relative to the less persistent species *H. uninervis* that dominated in 2021.

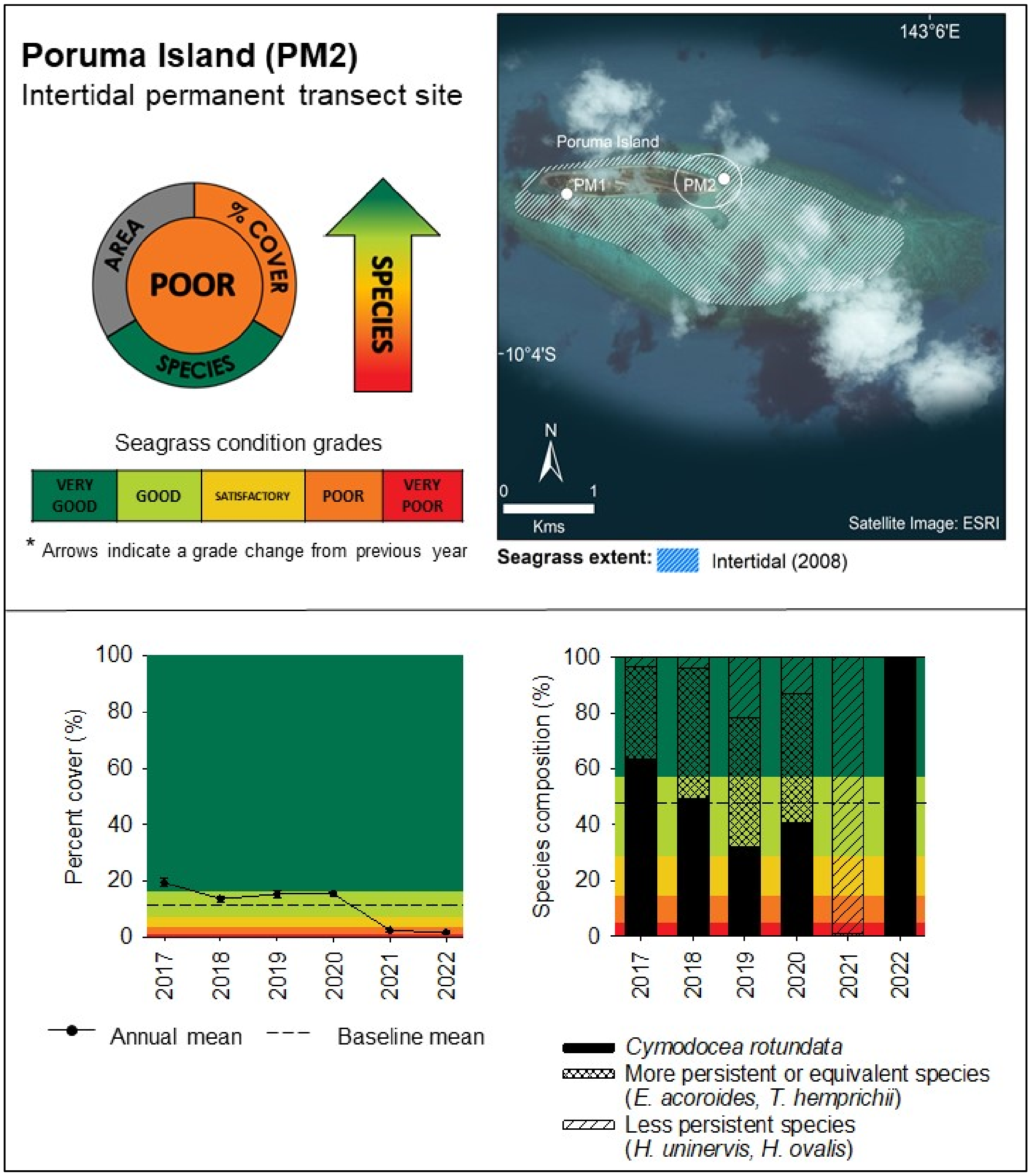

Figure 20. Seagrass mean percent cover and species composition at Poruma Island permanent transect site PM2, central Torres Strait, 2017 - 2022 (percent cover error bars = SE). Note: Baseline conditions based on 6 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Dungeness Reef Intertidal Meadow (DR6)

The Dungeness Reef meadow DR6 covers the majority of the reef-top intertidal area (Figure 21). Monitoring was established in late 2016 (2017 reporting year) because of the reef's value as a turtle foraging ground, and is conducted by TropWATER researchers. Preliminary assessments indicate the meadow has variable biomass, stable area and stable, mixed species (Table 3). Overall meadow condition in 2022 was good, with area and biomass above the long-term average. Species composition was very good. Five species are found in the meadow, but the dominant species *T. hemprichii* and the more stable and persistent species *E. acoroides* continued to contribute over 90% of meadow biomass (Figure 21). High biomass areas were mostly along the north-east edge of the reef and associated with the species *E. acoroides* and *T. ciliatum*.

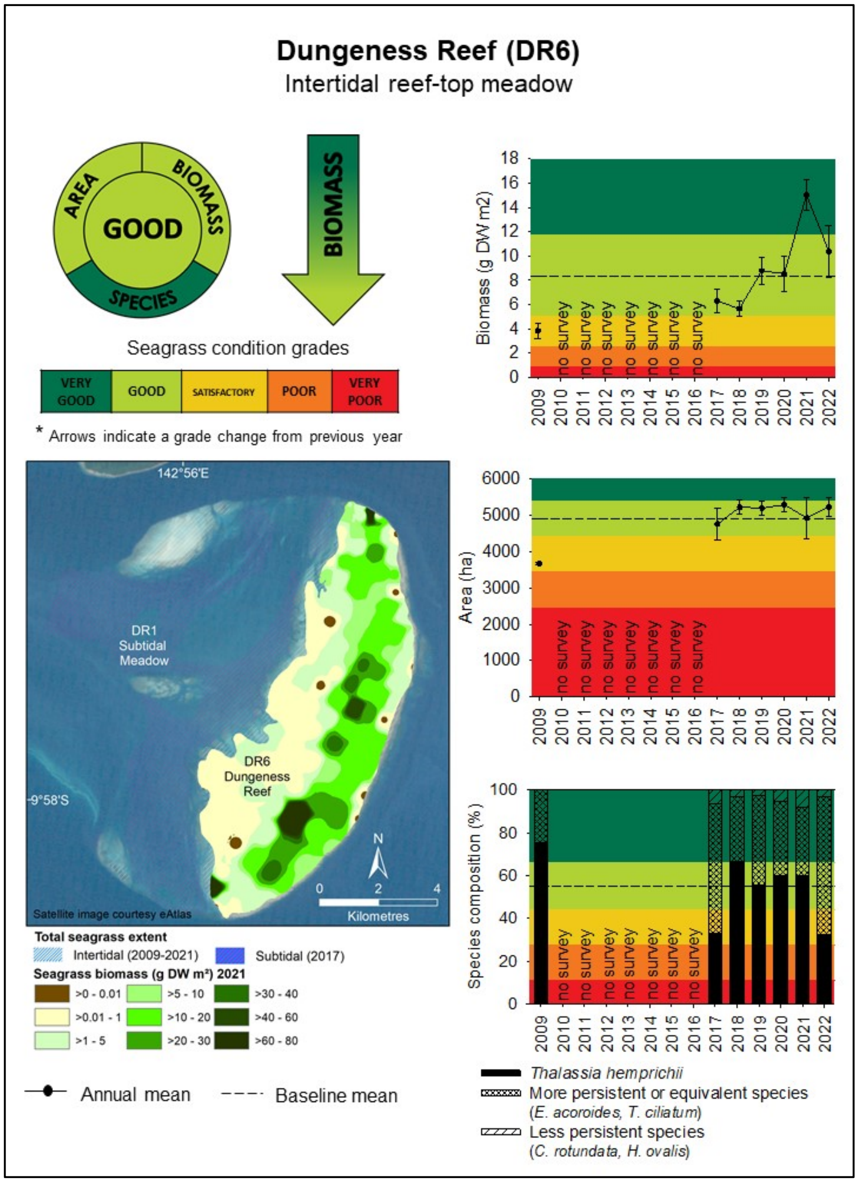

Figure 21. Seagrass mean biomass and species composition at Dungeness Reef intertidal meadow 6, central Torres Strait, 2009 - 2022 (biomass error bars = SE; area error bars = reliability estimate). Note: Baseline conditions based on 7 years of data; resulting grades should be interpreted with caution until the full 10-year baseline is available.

Dungeness Reef Subtidal Blocks (DR1)

An extensive subtidal seagrass meadow extends west of Dungeness Reef. Subtidal monitoring blocks within the meadow are collectively referred to as DR1 (Figure 22). These are monitored by Porumalgal, Iamalgal and Warraberalgal Rangers. No overall meadow score is provided for this meadow due to limited sampling events. Biomass improved slightly from <0.2 g DW m^{-2} in 2021 (very poor condition) to 0.71 g DW m^{-2} in 2022 (poor condition), but was still well below the baseline of 3.9 g DW m^{-2}. Biomass declines were again due to significant reductions in the dominant species *H. spinulosa* that is typical of subtidal communities, from 76% in 2020 to 18% in 2021 and 24% in 2022. Species composition condition remained very good because remnants the more persistent species *C. serrulata* contributed more to species composition than in previous years (Figure 22).

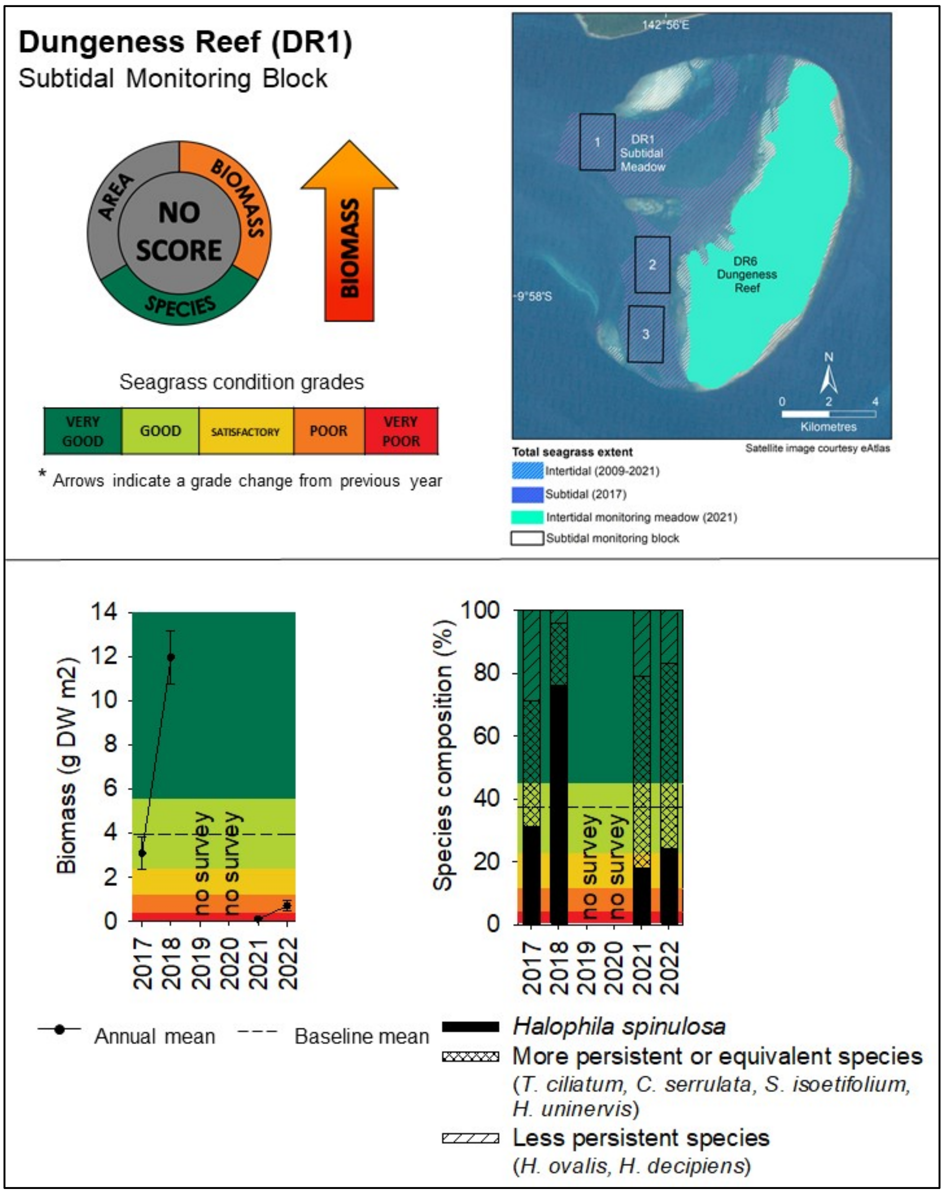

Figure 22. Seagrass mean biomass and species composition at Dungeness Reef subtidal monitoring blocks, central Torres Strait, 2017 - 2022 (biomass error bars = SE). Note: Baseline conditions based on 4 years of data; no overall grades or scores available until 5 years of data is available.

Masig Island Intertidal Meadow (MS1)

The extensive intertidal reef-top seagrass meadow that surrounds Masig Island was incorporated into the monitoring program and report card in 2021. Species composition and area were in good condition in 2022. No overall meadow score is provided for Masig Island due to limited sampling events (Table 4). Preliminary assessments indicate a highly stable meadow area of ~810 ha and variable mean meadow biomass of ~8.5 g DW m^{-2}. Biomass is similar to Dungeness Reef's intertidal reef-top meadow (DR6). The mixed species community is dominated by *T. hemprichii*, which is typical of intertidal reef-top communities, including those at Dungeness Reef (DR6), Kai Reef (OR2) and Gariar Reef (OR5) (Figure 23).

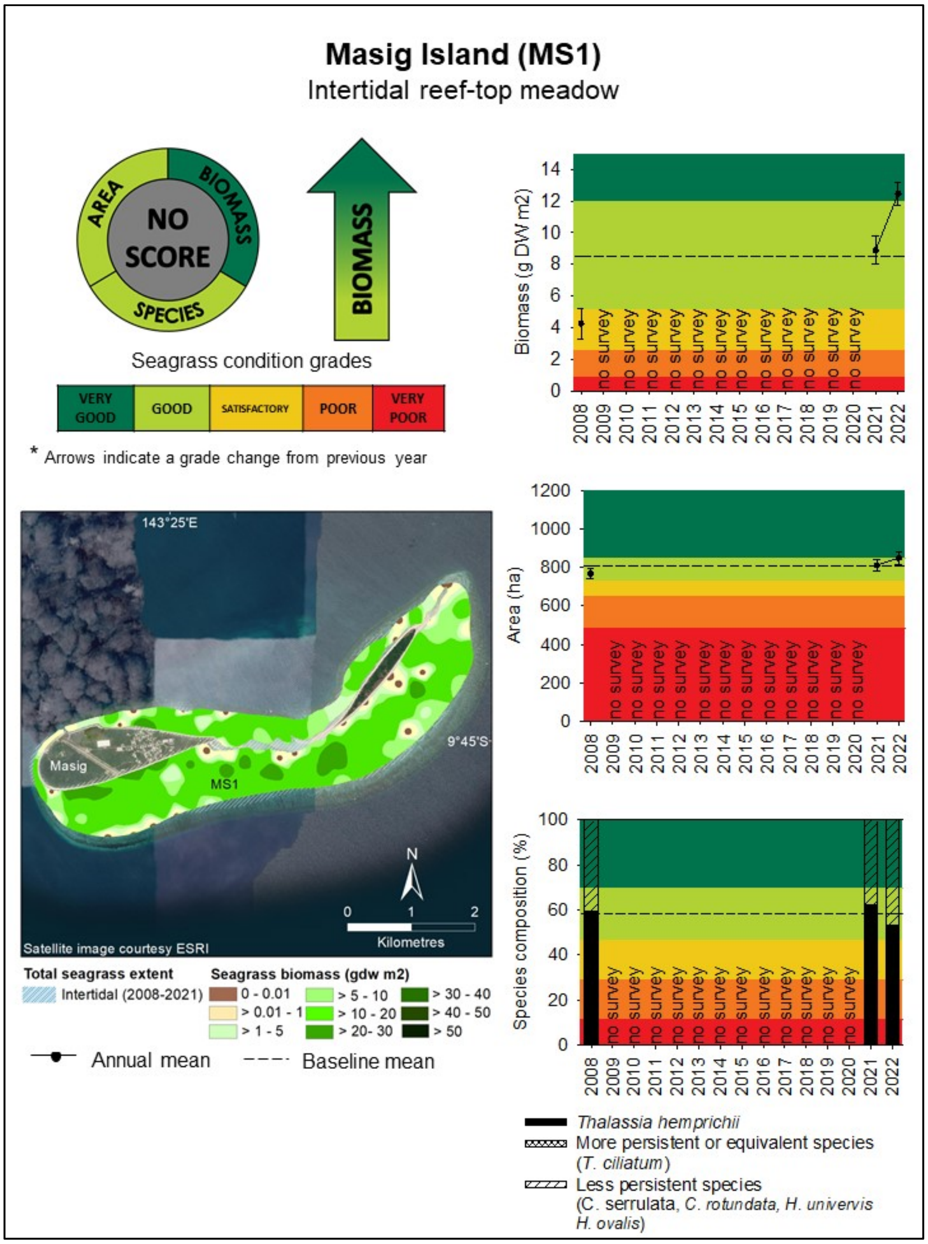

Figure 23. Seagrass mean biomass and species composition at Masig Island intertidal meadow, central Torres Strait, 2008 - 2022 (biomass error bars = SE). Note: Baseline conditions based on 3 years of data; no overall grades or scores available until 5 years of data is available.

Eastern Island Cluster

Seagrass condition in the Eastern Island Cluster was satisfactory in 2022, the same grade as in 2019 when this cluster was last surveyed (Figure 24). Seagrass monitoring in this cluster is limited to two intertidal transect sites at Mer Island.

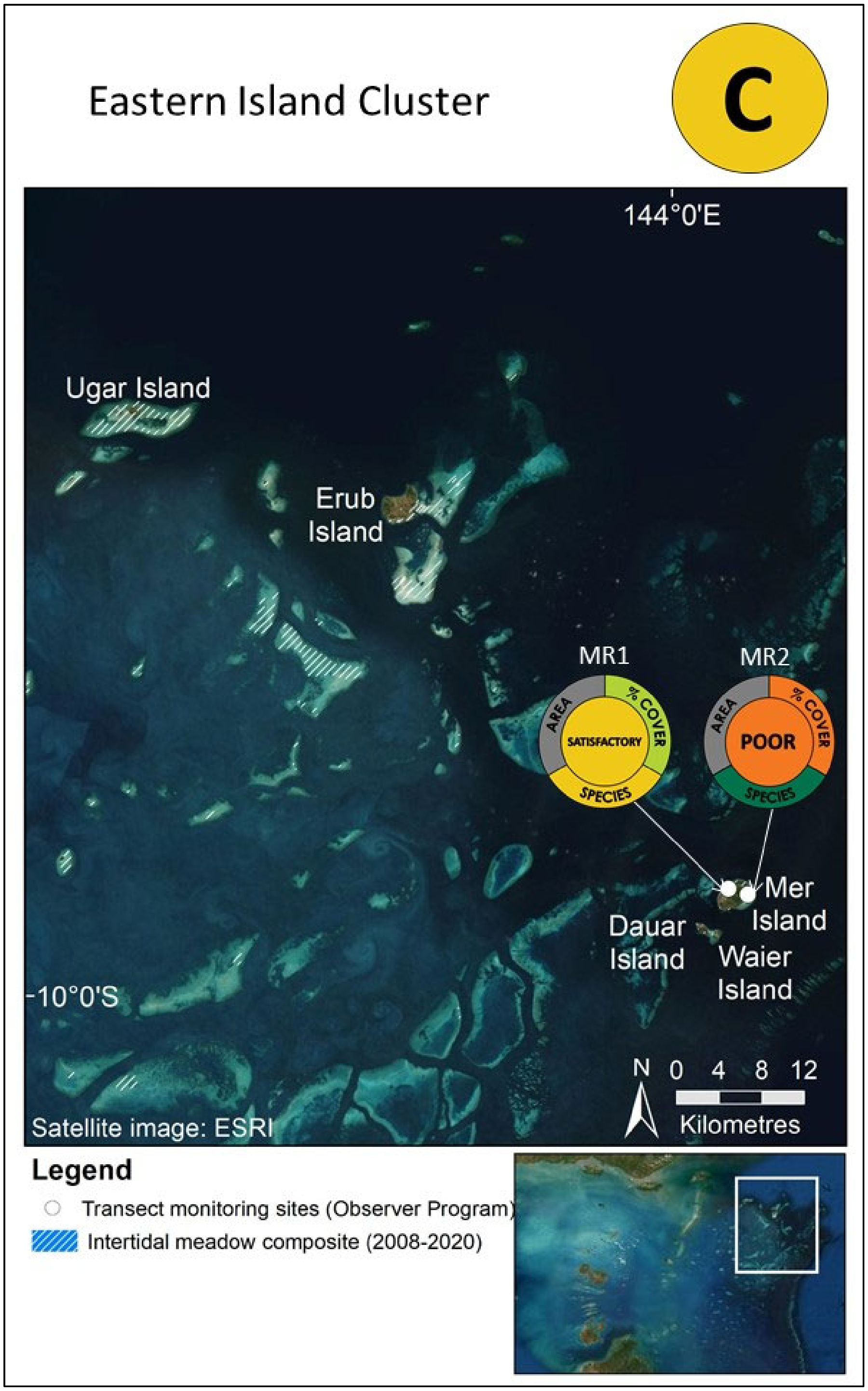

Figure 24. Seagrass condition across the Eastern Island Cluster of Torres Strait.

Mer Island Site (MR1)

The monitoring site MR1 (Maad) on the northern side of Mer Island is monitored by the Meriam Gesep A Gur Keparem Le Rangers (Figure 25). The site is characterised by stable percent cover and stable species composition dominated by a single species (> 80% *T. hemprichii*) (Table 3). Species composition remained in satisfactory condition due to ongoing loss in the dominant species *T. hemprichii* relative to the less persistent species *C. rotundata* that occurred between 2019 and 2020. Percent cover, and overall site condition, was good in 2022 (Figure 25).

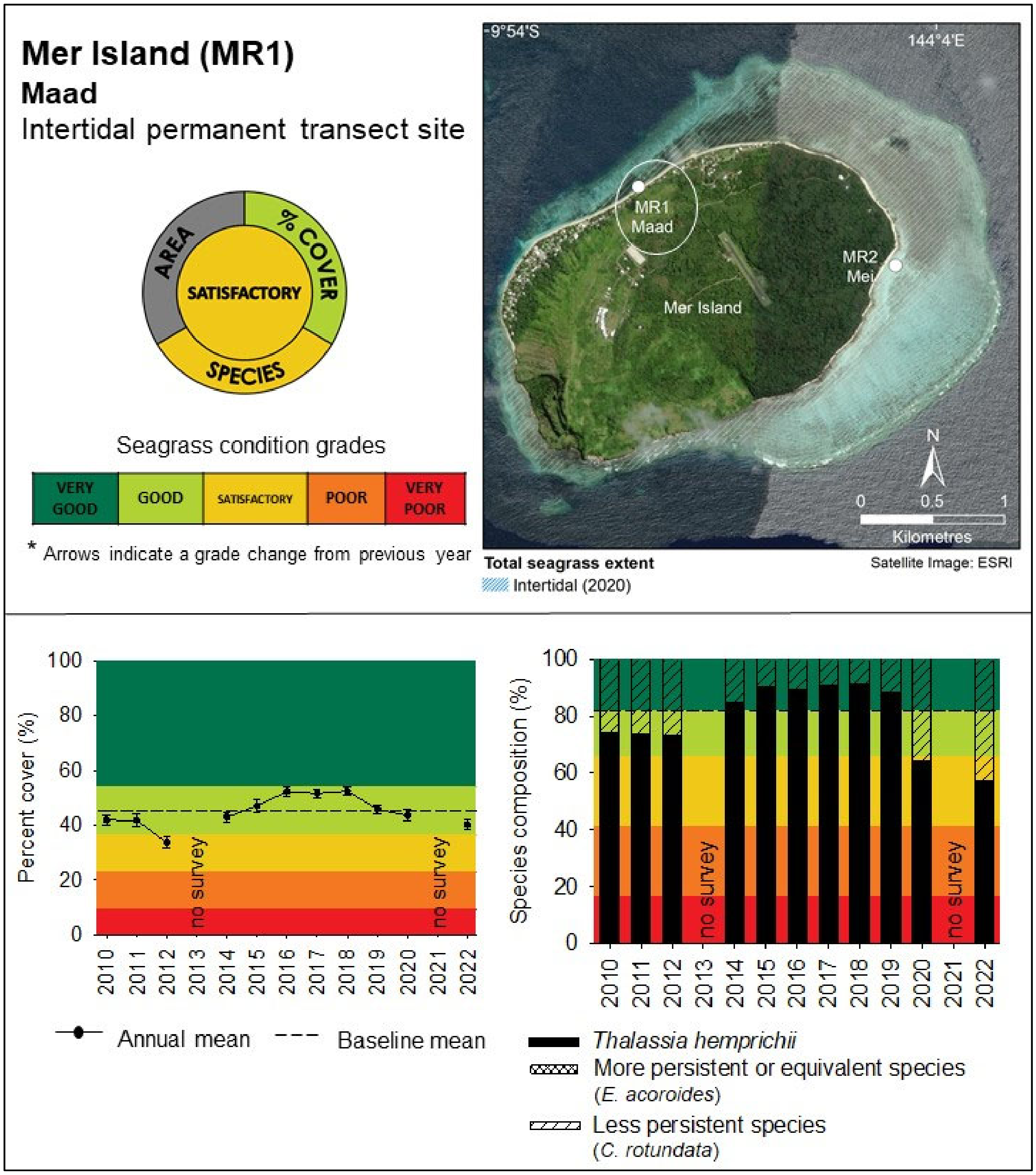

Figure 25. Seagrass mean percent cover and species composition at Mer Island permanent transect site MR1, eastern Torres Strait, 2010 - 2022 (percent cover error bars = SE).

Mer Island Site (MR2)

The monitoring site MR2 (Mei) on the eastern side of Mer Island has been monitored by the Meriam Gesep A Gur Keparem Le Rangers since 2010 (Figure 26). The site is characterised by variable percent cover and stable, mixed species composition (Table 3). This site is more diverse than MR1 with four species recorded. This site was in poor condition in 2022, with the ongoing trajectory of percent cover decline continuing. In 2022, seagrass cover was 5%, the lowest coverage recorded at this site since monitoring began. Species composition remained in very good condition in 2022, with above average contribution of the tracking species *C. rotundata* and the more stable species *T. hemprichii* (Figure 26).

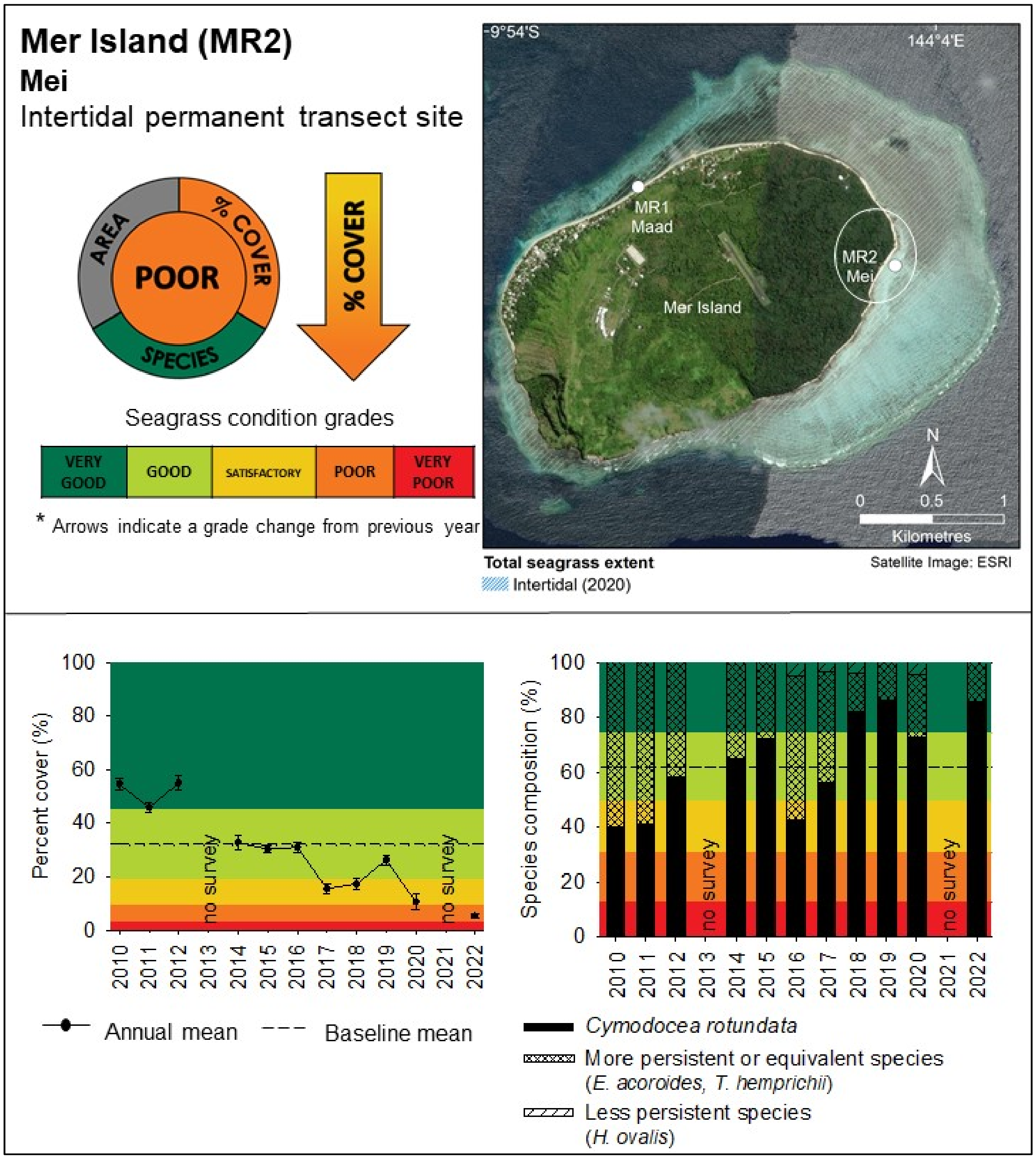

Figure 26. Seagrass mean percent cover and species composition at Mer Island permanent transect site MR2, eastern Torres Strait, 2010 - 2022 (percent cover error bars = SE).

Inner Island Cluster

The overall condition of seagrasses at Thursday Island and Madge Reefs was good in 2022 (Figure 27). All monitoring meadows were in good or very good overall condition, with all seagrass metrics also good or very good (Table 4). Biomass condition was very good in all monitoring meadows in 2022. Seagrass in this cluster is monitored across six intertidal and three intertidal-subtidal meadows by TropWATER as part of the ports program. Results from an "out-of-season" survey in September 2020 (Inner Cluster annual surveys always occur in March-April) are presented on figures but are not included in score and grade calculations for this cluster.

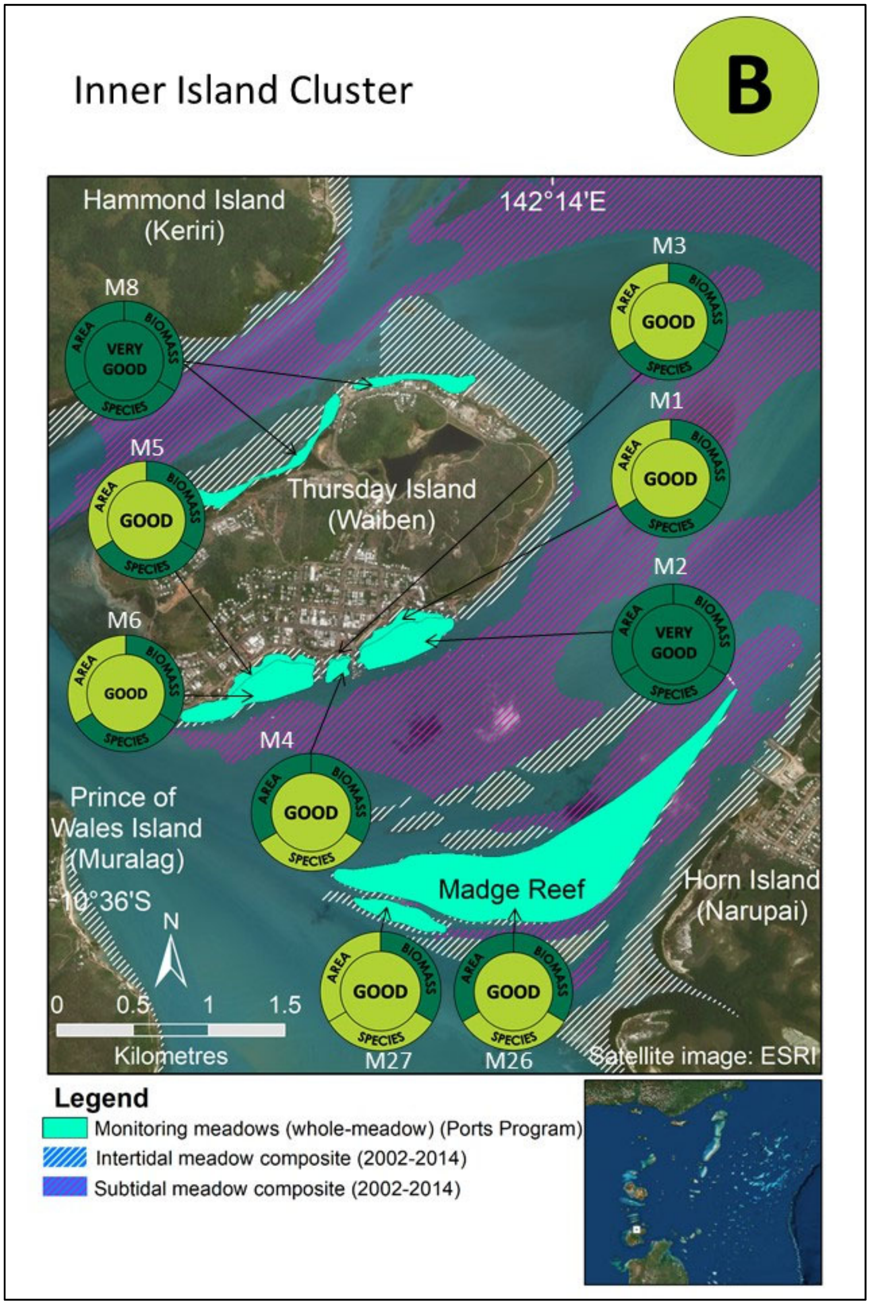

Figure 27. Seagrass condition across the Inner Island Cluster of Torres Strait.

Thursday Island (Waiben) Intertidal Meadow (M1)

The Thursday Island meadow M1 is a small intertidal meadow characterised by stable area and species composition, but variable biomass (Table 3). The overall meadow condition was good in 2022, driven by a small decrease in meadow area (Figure 28). Meadow biomass more than doubled between 2021 and 2022 to the greatest biomass recorded since monitoring began (16 g DW m^{-2}). Species composition condition remained very good, with over 90% of meadow biomass coming from the dominant species *H. uninervis* and the more stable and persistent species *T. hemprichii* (Figure 28). Baseline meadow biomass of ~6 g DW m^{-2} is typical of other *H. uninervis* dominated meadows at Thursday Island.

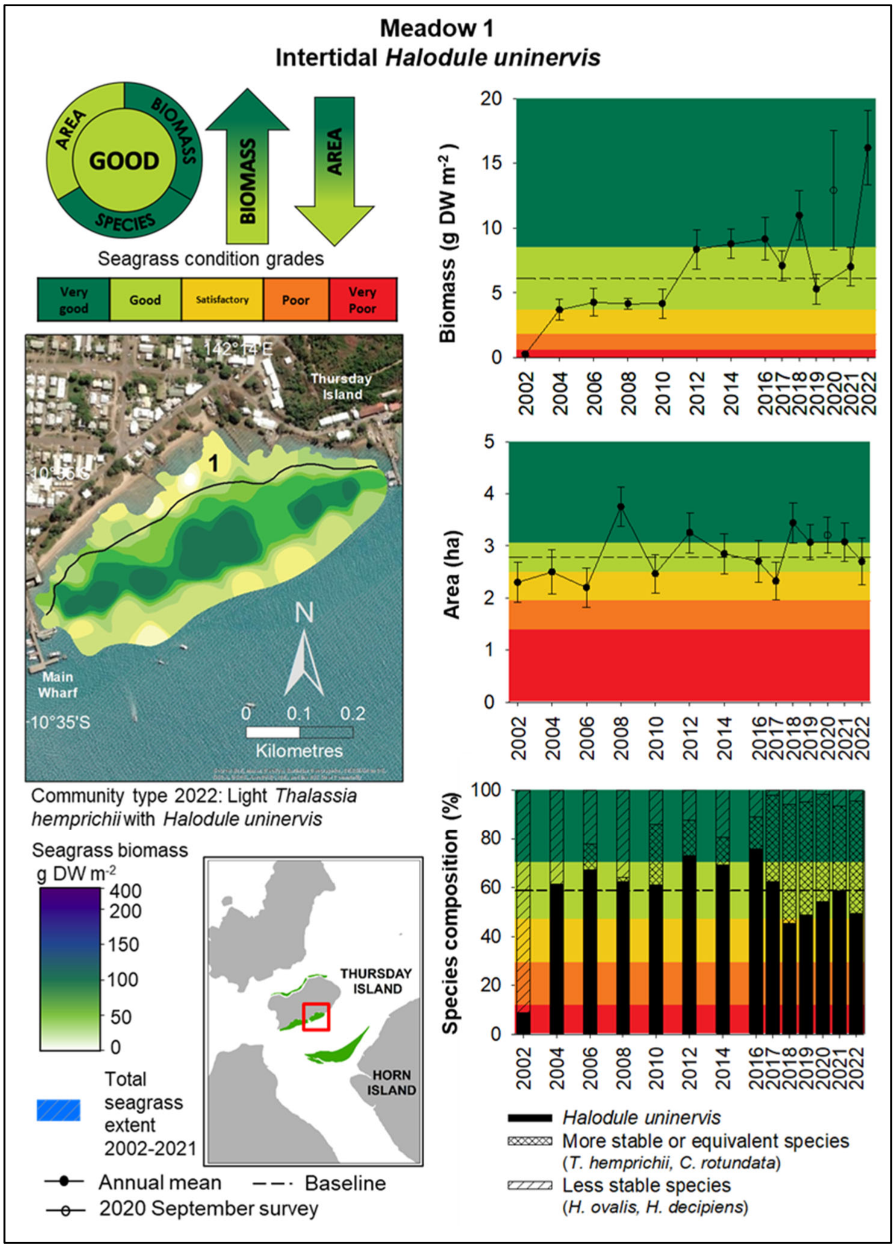

Figure 28. Seagrass mean biomass, area and species composition at Thursday Island intertidal meadow 1, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Thursday Island (Waiben) Intertidal-Subtidal Meadow (M2)

The Thursday Island meadow M2 is adjacent to M1, with the boundary between meadows defined by the transition from a *H. uninervis* dominated to *E. acoroides* dominated meadow (Figure 29). Meadow M2 is characterised by stable area, biomass and species composition (Table 3). The meadow extends from the intertidal zone into shallow subtidal waters. Overall meadow condition, and the condition of all three indicators, remained very good in 2022. *E. acoroides* remained the dominant species relative to less persistent species such as *T. hemprichii* and *H. uninervis* (Figure 29).

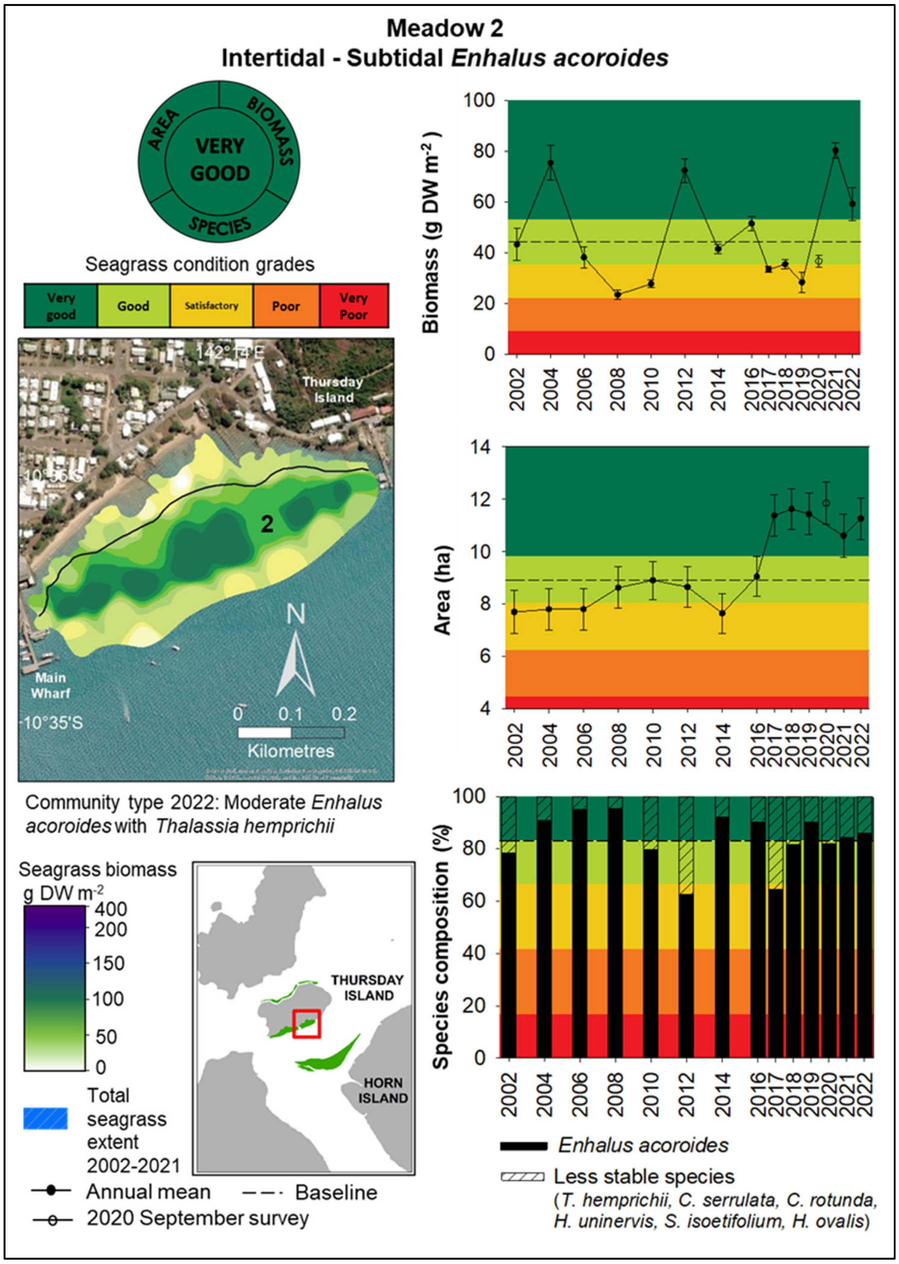

Figure 29. Seagrass mean biomass, area and species composition at Thursday Island intertidal-subtidal meadow 2, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Thursday Island (Waiben) Intertidal Meadow (M3)

The Thursday Island meadow M3 is a small intertidal meadow between the Engineer's Wharf and Main Wharf (Figure 30). The meadow is characterised by stable species composition, but variable biomass and area (Table 3). Overall meadow condition remained good in 2022. Meadow biomass increased three-fold between 2021 and 2022 to the greatest biomass recorded since monitoring began (11 g DW m^{-2}). Species composition condition remained very good due to the dominant species *H. uninervis* comprising 82% of seagrass biomass, and the more persistent species *T. hemprichii* comprising 14%, relative to less stable species (Figure 30).

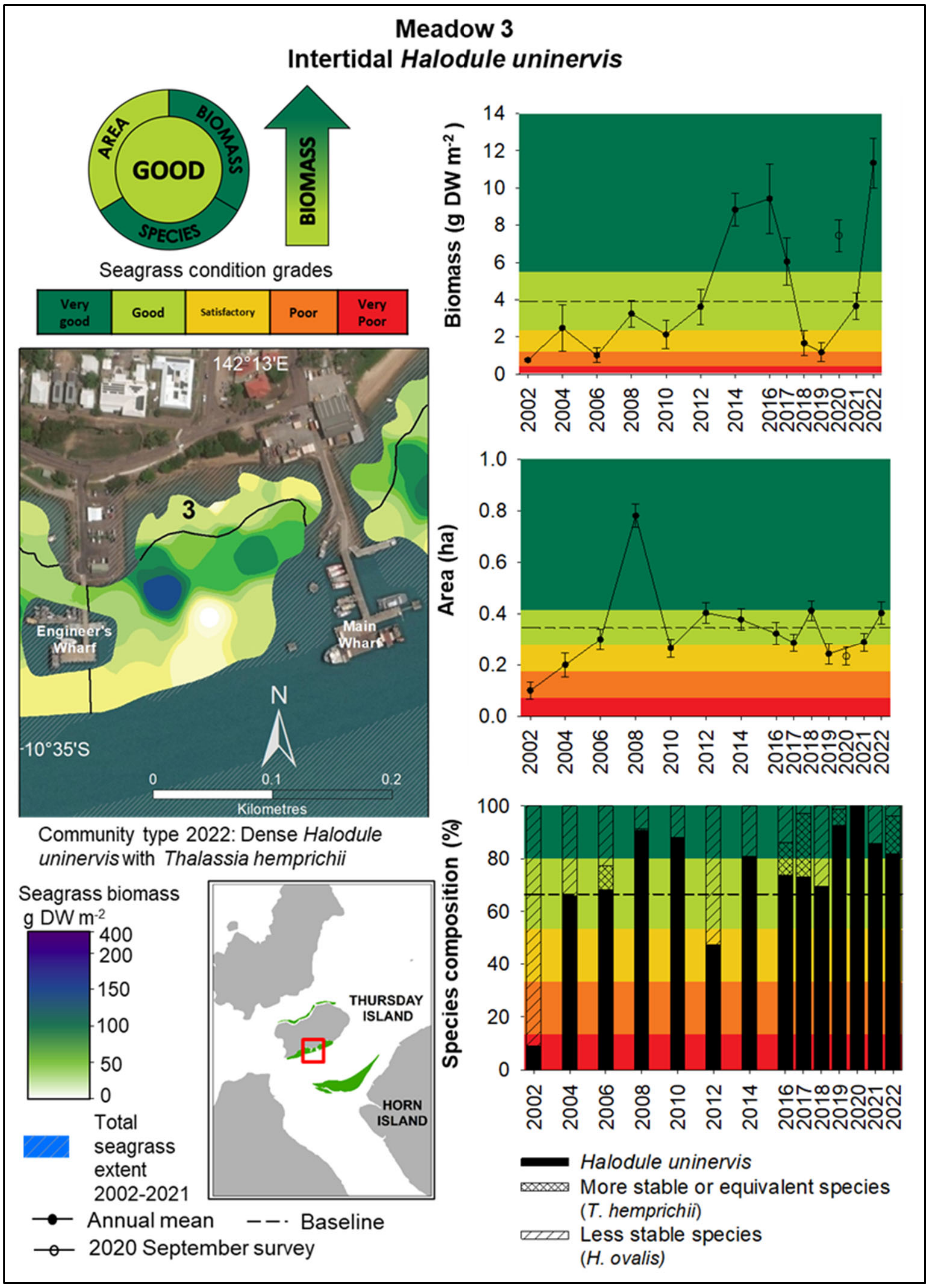

Figure 30. Seagrass mean biomass, area and species composition at Thursday Island intertidal meadow 3, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Thursday Island (Waiben) Intertidal/Subtidal Meadow (M4)

The Thursday Island meadow M4 is adjacent to M3, with the meadow boundary defined by the transition from a *H. uninervis* dominated to *E. acoroides* dominated meadow (Figure 31). Meadow M4 extends from the intertidal zone into shallow subtidal waters and is characterised by stable biomass and species composition, and variable area (Table 3). Meadow condition was good in 2022. Biomass was in very good condition. Species composition condition remained good. Area was in very good condition and remains largely unchanged since 2017 (Figure 31).

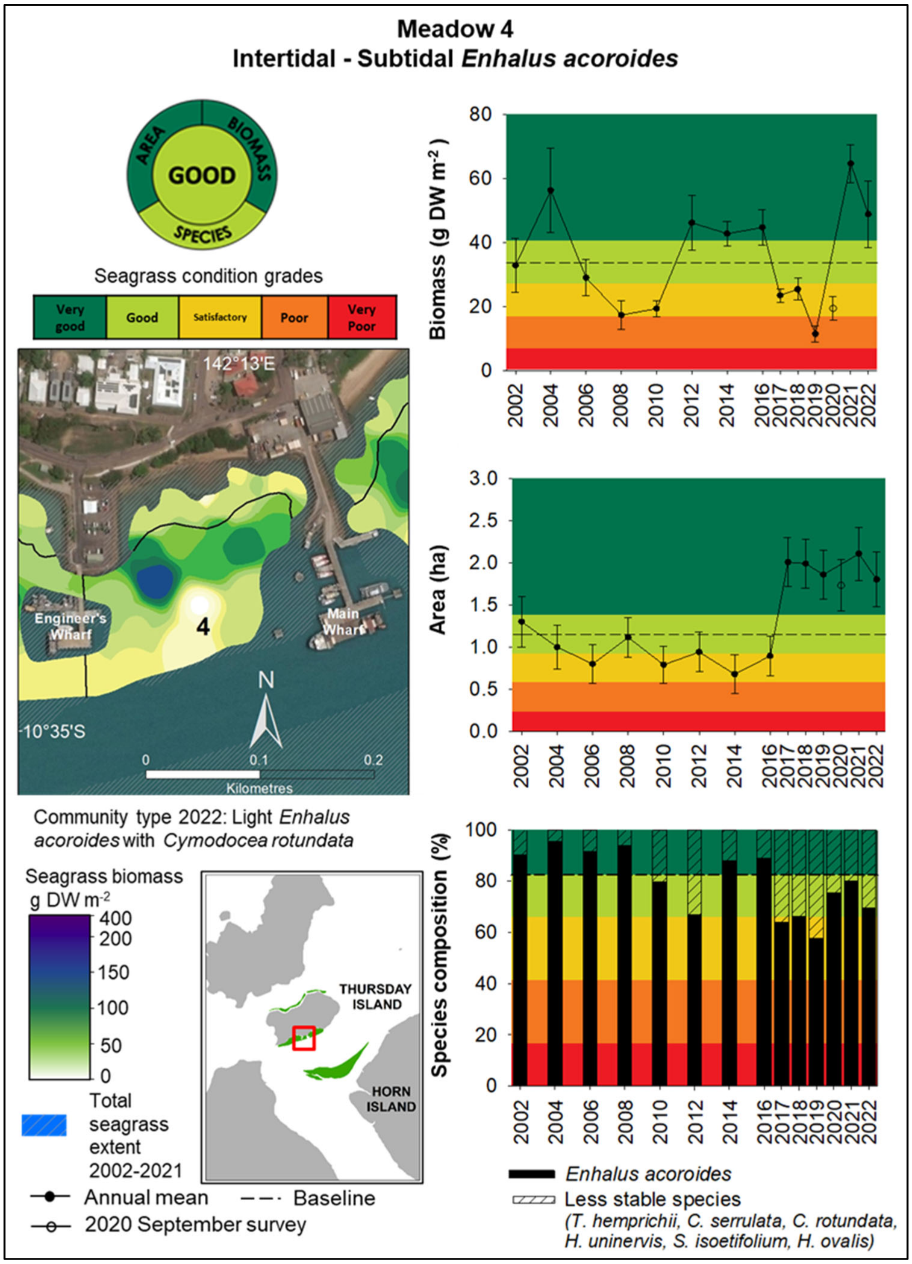

Figure 31. Seagrass mean biomass, area and species composition at Thursday Island intertidal-subtidal meadow 4, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Thursday Island (Waiben) Intertidal Meadow (M5)

The Thursday Island meadow M5 is a small intertidal meadow characterised by stable biomass, area and species composition (Table 3). In 2022, overall meadow condition was good (Figure 32). Meadow biomass has remained above the baseline value of 8 g DW m^{-2} since 2019 (very good condition). Species composition was very good; the meadow was comprised almost entirely of the dominant species *H. uninervis* and more stable and persistent species *T. hemprichii* (Figure 32).

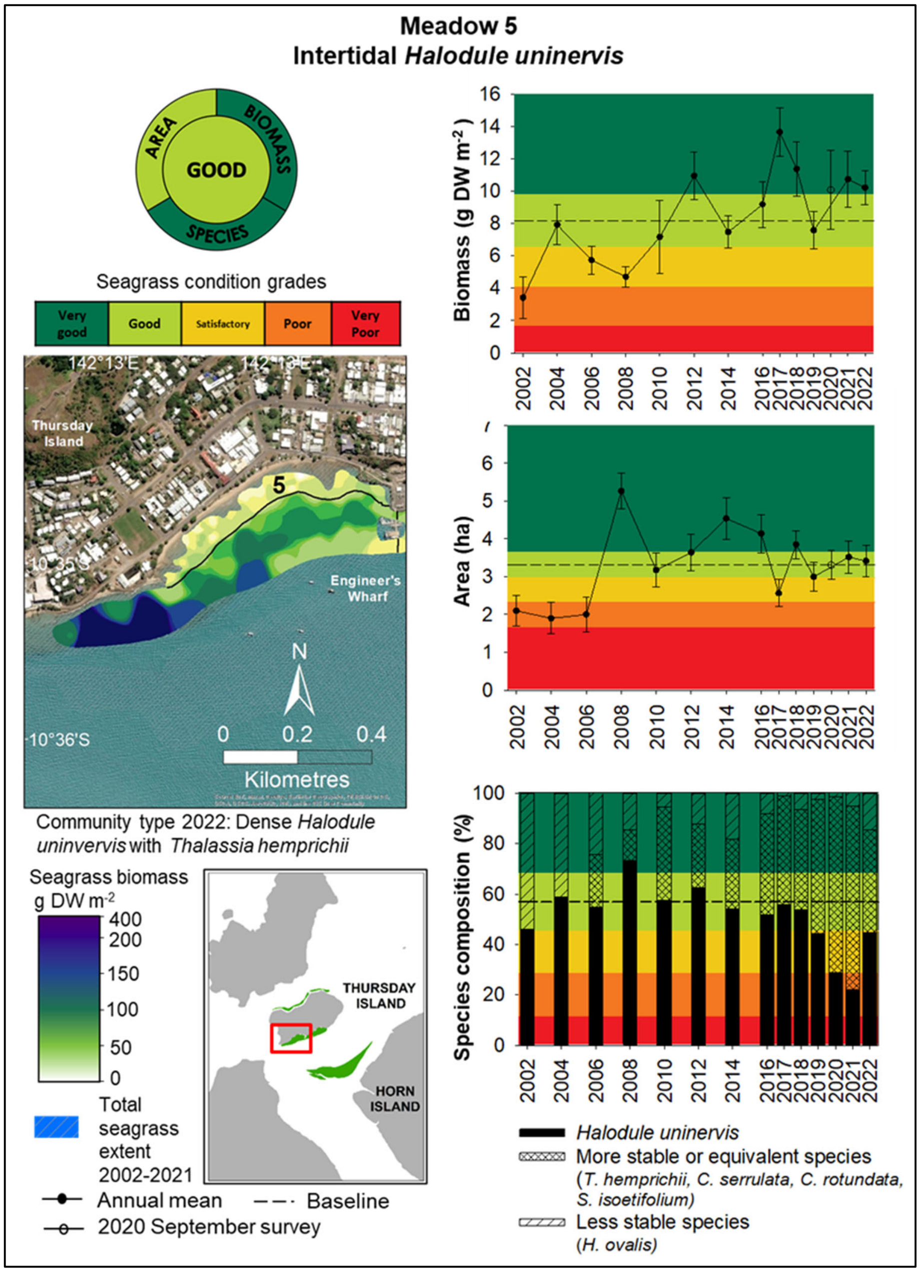

Figure 32. Seagrass mean biomass, area and species composition at Thursday Island intertidal meadow 5, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Thursday Island (Waiben) Intertidal/Subtidal Meadow (M6)

The Thursday Island meadow M6 is adjacent to M5, with the meadow boundary defined by the transition from a *H. uninervis* dominated to *E. acoroides* dominated meadow (Figure 33). The meadow extends from the intertidal zone into shallow subtidal waters. Meadow M6 is characterised by stable area, biomass, and species composition (Table 3). Biomass continued to increase for the second year, from 19 g DW m^{-2} in 2019 (poor condition), to 80 g DW m^{-2} in 2021 (very good condition), to 105 g DW m^{-2} in 2022. This improvement followed successive biomass declines between 2016 and 2019. Area condition declined from very good in 2021 (15 ha) to good in 2022 (12 ha). Species composition condition remained very good due to the ongoing dominance of *E. acoroides* and *T. ciliatum* relative to less persistent species (Figure 33).

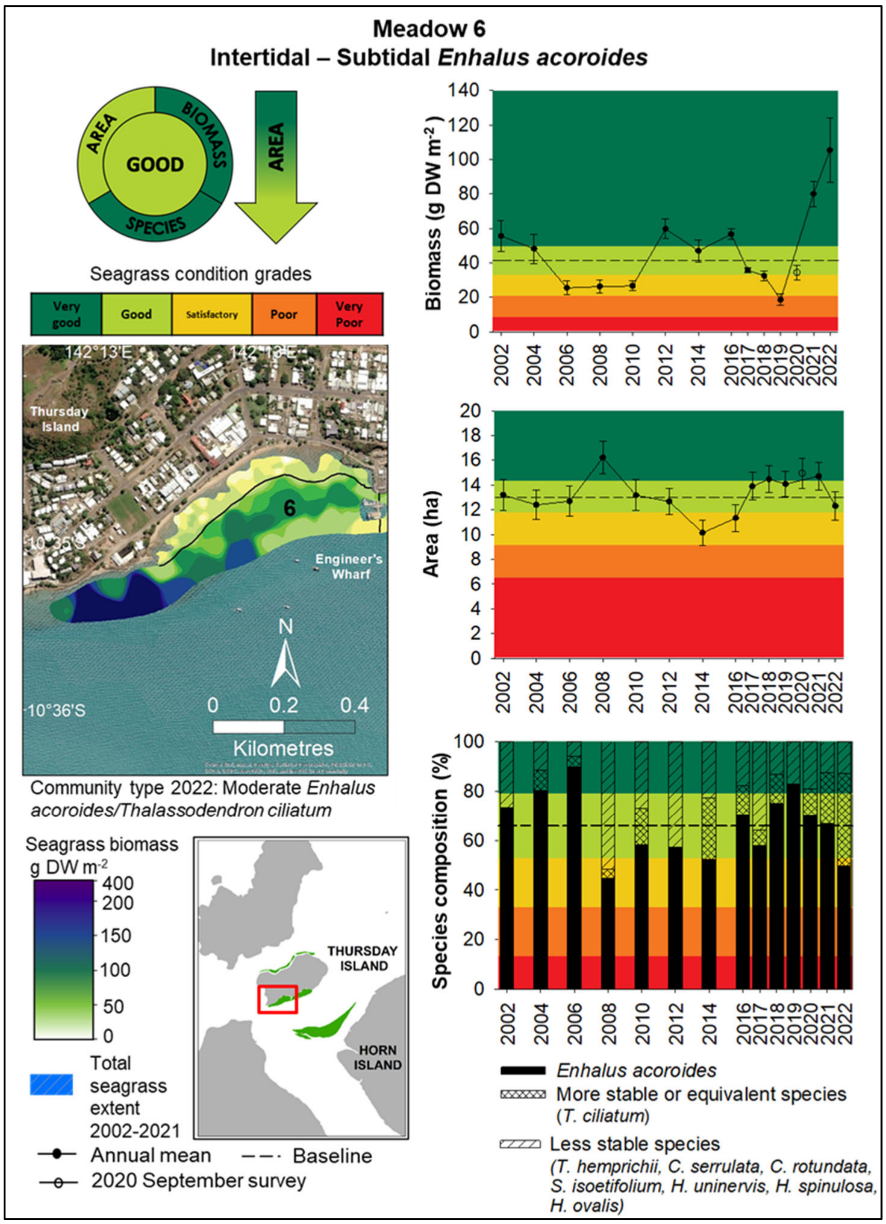

Figure 33. Seagrass mean biomass, area and species composition at Thursday Island intertidal-subtidal meadow 6, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Thursday Island (Waiben) Intertidal Meadow (M8)

Meadow 8 is a long thin intertidal meadow that extends along the northern shore of Thursday Island (Figure 34). It is characterised by stable area and species composition, but variable biomass (Table 3). Meadow condition in 2022 remains very good. Biomass and meadow area remain at record highs. Species composition condition remains dominated by *H. uninervis* and more stable and persistent species *T. hemprichii* and *C. rotundata* (Figure 34).

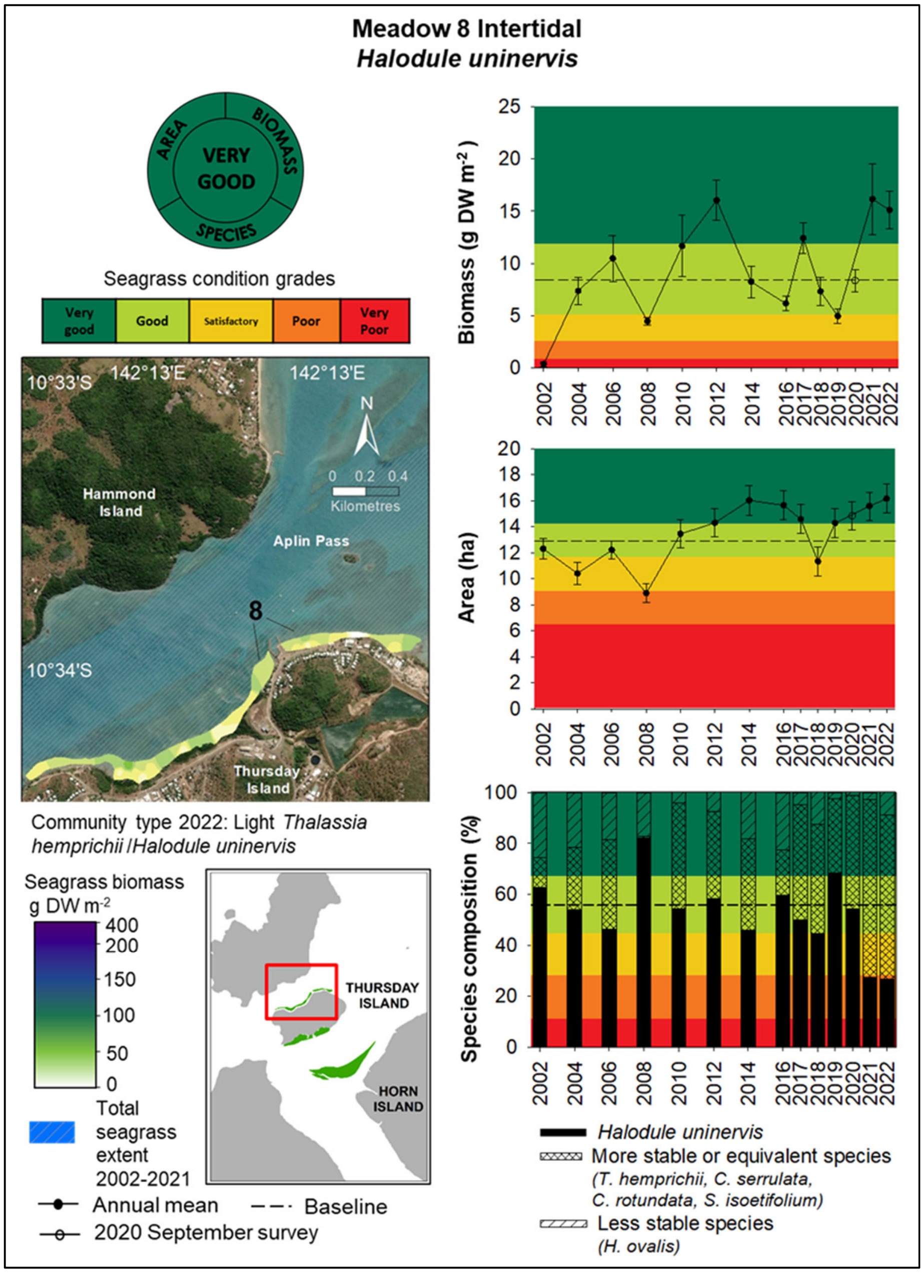

Figure 34. Seagrass mean biomass, area and species composition at Thursday Island intertidal meadow 8, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Madge Reef Intertidal Meadow (M26)

Meadow M26 at Madge Reefs covers the majority of the intertidal reef-top (Figure 35). Meadow area is highly stable, species composition is stable, and biomass is variable (Table 3). The meadow was in good condition in 2022, with no grade changes in species composition or biomass. Meadow area increased from 92 ha in 2021 (good condition) to 98 ha in 2022 (very good condition; Figure 35).

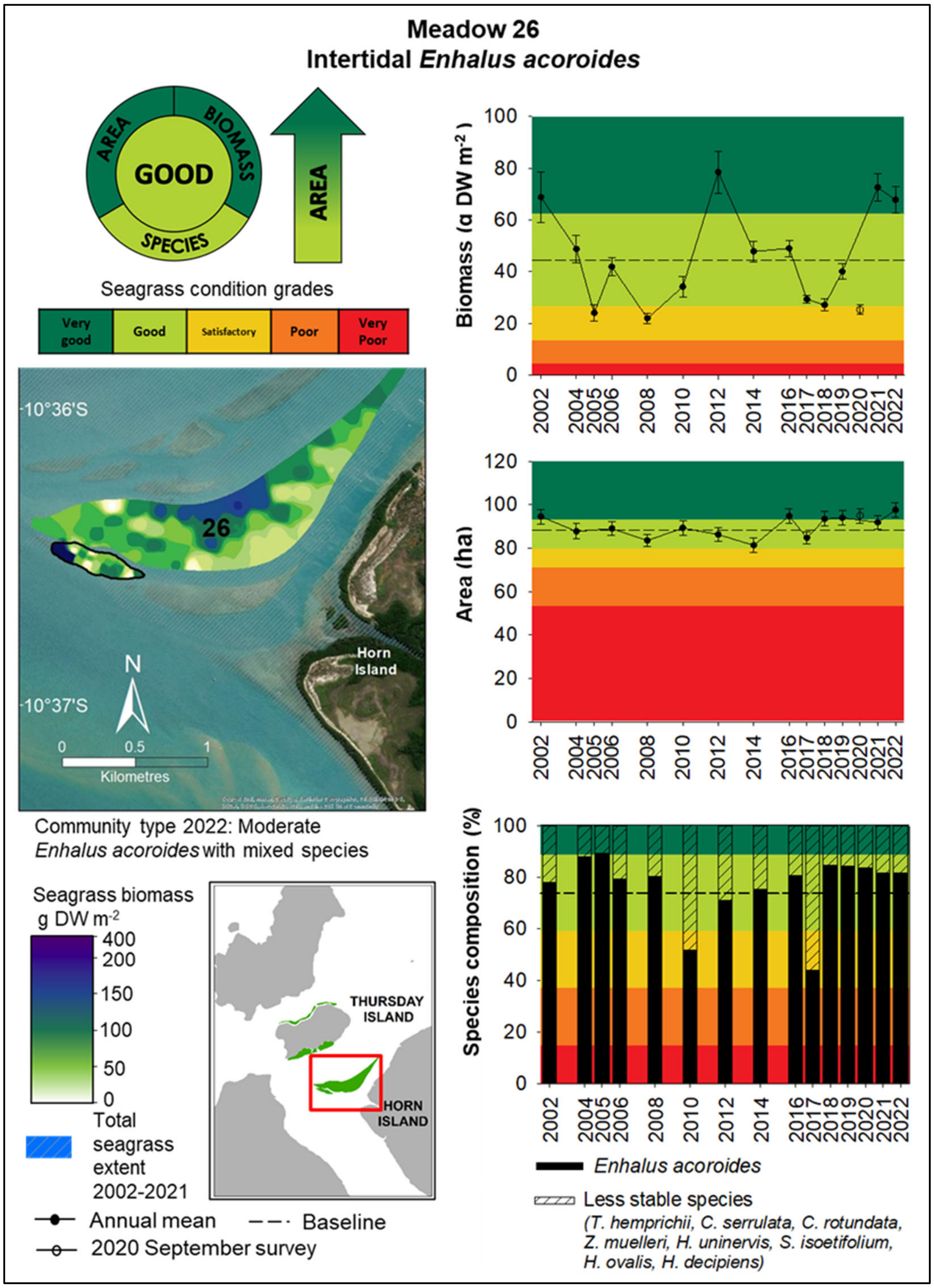

Figure 35. Seagrass mean biomass, area and species composition at Madge Reefs intertidal meadow 26, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Madge Reef Intertidal Meadow (M27)

Meadow M27 is a small intertidal reef-top meadow that forms part of Madge Reefs (Figure 36). Meadow area and species composition are stable, while biomass is variable (Table 3). Meadow area remained in good condition in 2022. Biomass maintained record highs with 75 g DW m^{-2}. The dominant species *E. acoroides* and *T. ciliatum* continued to account for almost all of the meadow's biomass (Figure 36).

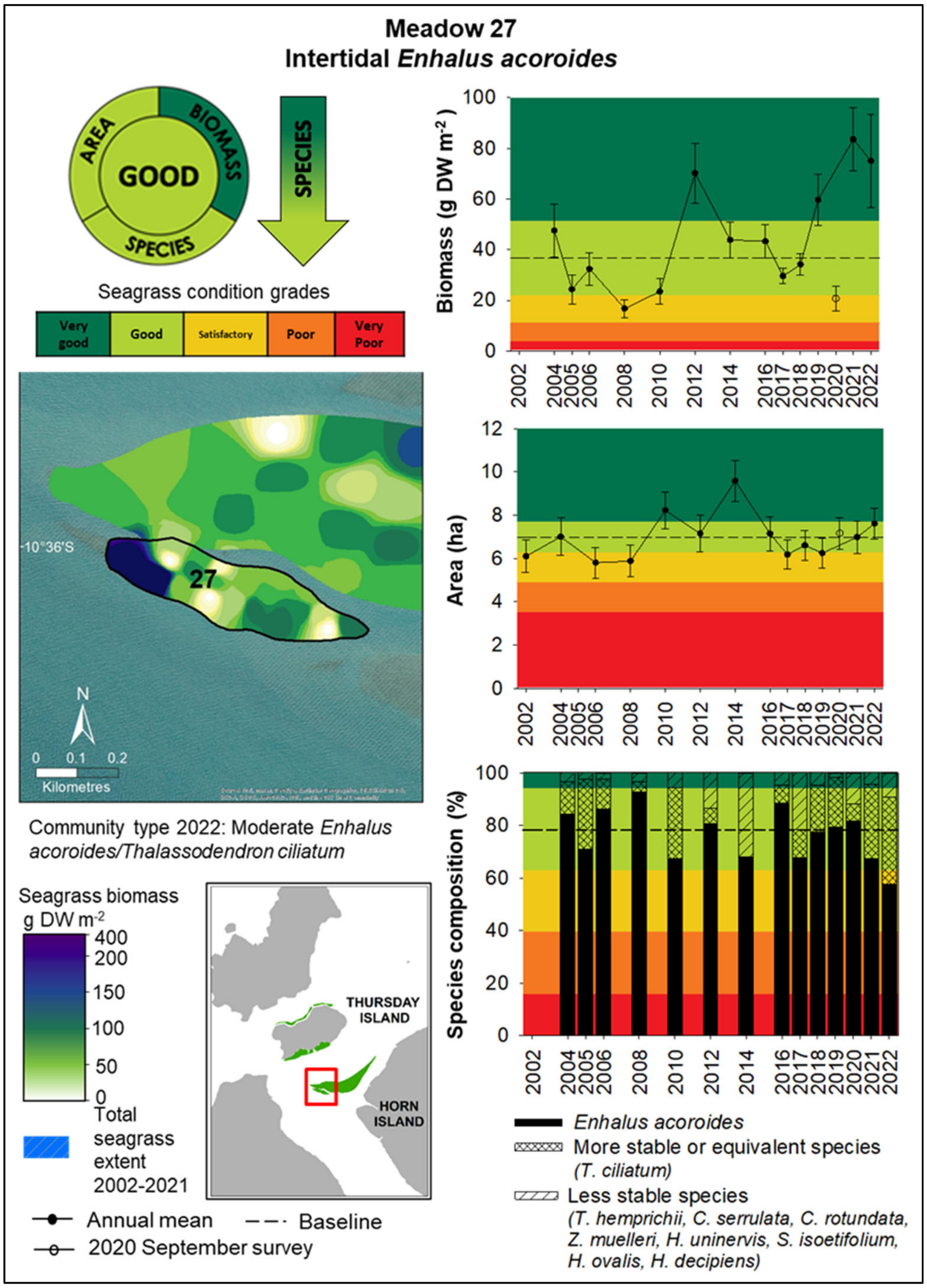

Figure 36. Seagrass mean biomass, area and species composition at Madge Reefs intertidal meadow 27, Torres Strait Inner Island Cluster, 2002 - 2022 (biomass error bars = SE; area error bars = reliability estimate).

Discussion

Seagrass Condition in Torres Strait

The Torres Strait seagrass annual report card enables comparisons of seagrass habitat condition using key characteristics of seagrass health - abundance (biomass/percent cover), area, and species composition. In 2022, the strength of this integrated approach is again clear. Areas of concerning seagrass decline were identified in two monitoring programs – the Ranger-led Torres Strait Seagrass Observers Program and the Ranger-led Subtidal Monitoring Program. The Reef-top Monitoring Program recorded the recovery of intertidal meadows at Orman Reefs, and the Queensland Ports Seagrass Monitoring Program recorded intertidal and shallow subtidal meadows in good or very good condition around Thursday Island and Madge Reefs.

The decline of seagrass in the Western Cluster first documented in the 2020 report card, and the emergence of localised declines in the Central Cluster in 2021 and Eastern Cluster in 2022, remains concerning. Biomass remains significantly reduced in the Dugong Sanctuary, Orman Reefs and Dungeness Reef, with all meadows in poor or very poor condition (Figure 37). The typically dominant subtidal species *H. spinulosa* had returned to the Dugong Sanctuary this year, but remained diminished at Orman Reefs and Dungeness Reef. An extensive subtidal seagrass survey conducted in December 2020 of the northern Dugong Sanctuary and Orman Reef subtidal waters confirmed these declines in biomass and *H. spinulosa* were widespread (Carter et al. 2021a). Similar reductions were also observed during surveys of the southern Dugong Sanctuary in late 2021 (Carter et al. in prep). Deeper water areas between Thursday and Horn Islands were examined in March 2022 for the first time in three years, and similarly recorded a decline in area of meadows and a reduction in the presence of *H. spinulosa* compared to previous surveys in 2019 and 2004 (Scott et al 2022). As these areas are only examined every 3 years it is unclear when these declines occurred, and it is possible that it was during a similar time period as noted in other areas of the Torres Strait.

Declines in high diversity, high biomass subtidal seagrass habitat in the Western, Central and Inner Clusters is alarming because this region is where Torres Strait's most extensive subtidal seagrass habitat occurs. Seagrass growing conditions in this region are ideal, with subtidal meadows historically extending throughout shallow waters (<20 m) west of the Warrior Reefs and into the Dugong Sanctuary where the light environment for growth is ideal (Carter et al. 2022a). Subtidal seagrass is limited in other regions. For example, seagrass does not grow beyond the western edge of the Dugong Sanctuary where waters are deeper than 30 m, is sparse in the Top-Western Cluster where low light conditions from turbid water along the Papua New Guinea coastline limit the light available for seagrass growth even in very shallow water, and is also limited in the Eastern Cluster because inter-reef depths often exceed 40 m (Carter et al. 2022a).

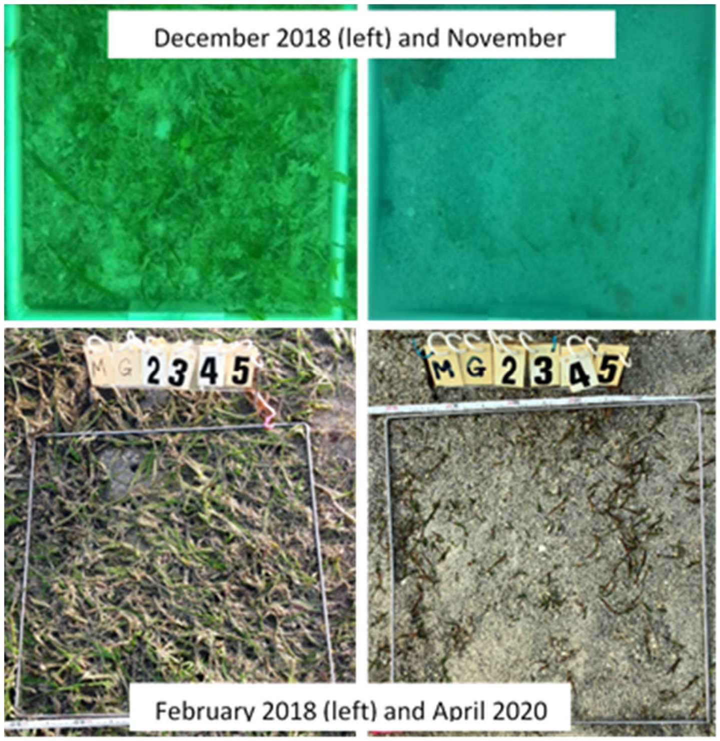

Figure 37. Seagrass abundance (biomass/ percent cover) remains at historic lows at: (a) subtidal Orman Reefs, and (b) Mabuyag Island.

Intertidal seagrass condition in 2022 was much better than for subtidal meadows, particularly with the increase in biomass on Kai and Gariar Reefs (Figure 38), relatively stable seagrass condition at the majority of transect sites, and record high biomass for many of the intertidal and shallow subtidal meadows around Thursday Island and Madge Reefs. Seagrass percent cover remained diminished at Mabuyag Island for the third year, there has been no recovery at Poruma Island's north-east site (PM2), and percent cover at Mer Island site MR2 has also declined to poor condition.

The reduced cover at Poruma Island and Mer Island sites is quite localised (Freddie David and Aaron Bon, pers.com). An extensive, high biomass meadow was mapped that covered the majority of the intertidal reef-top that fringes Mer Island, indicating a large and healthy meadow (Carter et al. 2021b). Large and diverse seagrass meadows were also mapped around the continental islands of Erub, Dauar and Waier Islands in 2020 (Carter et al. 2021b), and around Ugar Island in 2022 (Reason et al. 2022). Limited subtidal seagrass in the Eastern Cluster means these intertidal seagrass meadows have high ecological importance because they account for the majority of seagrass habitat in this region (Carter et al. 2021b). The expansion of intertidal annual monitoring to a network of locations in the Eastern Cluster would ensure a more comprehensive assessment of seagrass condition and reduce the likelihood of small-scale change at a single transect site having such a large impact on Cluster-scale reporting.

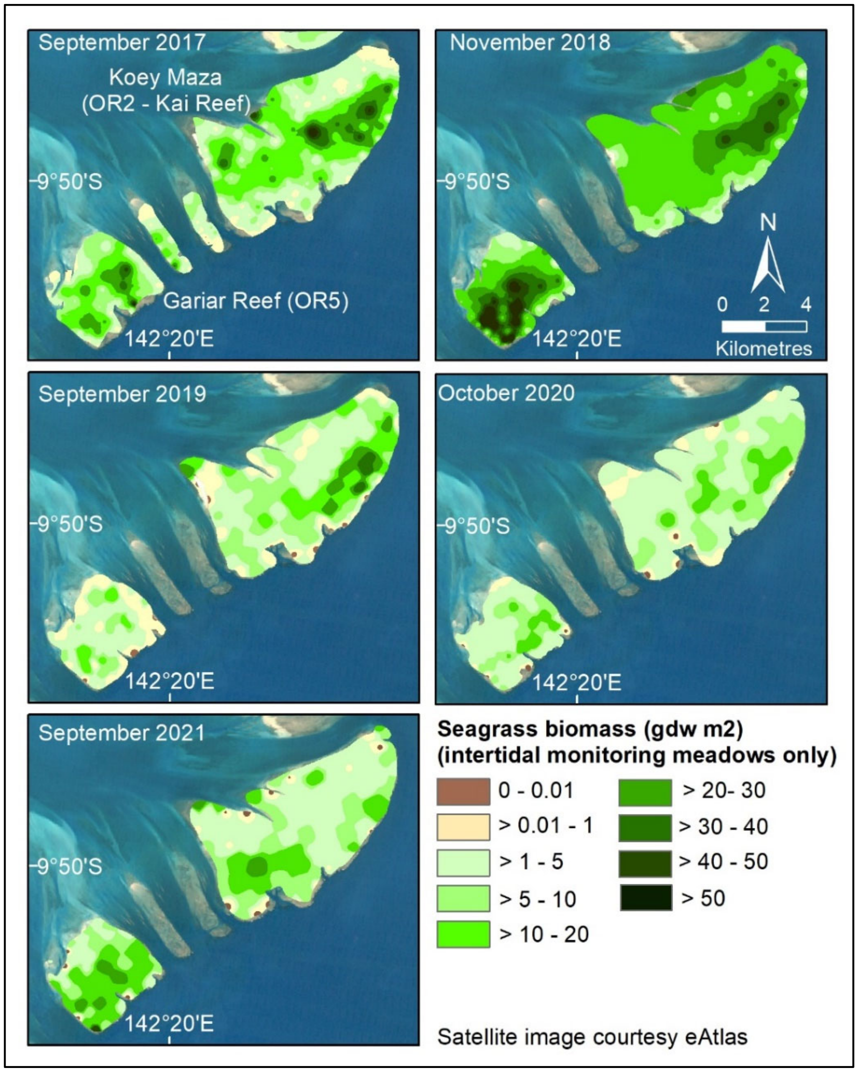

Figure 38. Change in seagrass biomass across intertidal reef-top meadows at Kai and Gariar Reefs (Orman Reefs), 2017-2022 (2018-2022 reporting years).

Potential Causes of Seagrass Declines

Large-scale episodic seagrass loss in Torres Strait has been reported before, including in the early 1970s across Torres Strait (Johannes and MacFarlane 1991), in north-western Torres Strait in the early 1990s (Poiner and Peterkin 1996), and around Orman Reefs in 1999-2000 (Marsh et al. 2004). Threats and pressures on Torres Strait seagrass vary in spatial scale. Small-scale localised pressures include trampling, boat traffic, propeller scars and infrastructure work; medium-scale pressures include shipping and port activities/accidents and turtle and dugong overgrazing; and large-scale pressures include run-off during the wet season, migrating sand waves, disease and climate change (Scott et al. 2021a; Waterhouse et al. 2013; Green et al. 2010; Halpern et al. 2008; Green 2006). No definitive cause of previous Torres Strait seagrass declines were established, but the scale of loss implicates medium to large-scale pressures. Discussions between Rangers, TSRA, Traditional Owners and TropWATER identified three potential causes for seagrass declines in the Orman Reefs-Mabuyag Island region that warranted further investigation: seagrass disease, increased dugong and turtle density and feeding intensity, and altered environmental conditions.

Disease

Disease has been attributed to large-scale seagrass diebacks in temperate waters (Trevathan-Tackett et al. 2018; Sullivan et al. 2013). Three known groups of pathogens can cause seagrass disease, all of which are understudied: labyrinthulids, oomycetes and Phytomyxea (Sullivan et al. 2013). The potential role of disease was not investigated in previous Torres Strait seagrass diebacks, but *Labyrinthula*-caused lesions have been recorded on seagrass leaves in temperate Australia (Trevathan-Tackett et al. 2018), and pathogenic forms of *Labyrinthula* spp. have been attributed to seagrass "wasting disease" reported since the 1930s (Martin et al. 2016; Fischer-Piette et al. 1932). The triggers for *Labyrinthula* to become pathogenic are believed to be host-stress situations (Martin et al. 2016). It is likely that where pathogenic *Labyrinthula* is detected, other environmental stressors are also contributing to seagrass stress that make it susceptible to *Labyrinthula* (Sullivan et al. 2018; Martin et al. 2016; Bishop 2013). A collaboration between TSRA, Rangers, TropWATER and the Department of Agriculture, Water and Environment (DAWE) examined seagrass samples collected from Mabuyag Island and Orman Reefs in 2020 for pathogenic forms of *Labyrinthula*. Despite the presence of *Labyrinthula* in seagrass samples, as is normal elsewhere, there is no evidence for the existence of a pathogenic relationship (Richard Davis, DAWE, pers. comm.).

Increased Herbivory by Turtles and Dugong

Large numbers of herbivores can lead to overgrazing and significant declines in seagrass biomass (Fourqurean et al. 2010; Lal et al. 2010; Masini et al. 2001). Recent work on the Great Barrier Reef demonstrated significant increases in seagrass biomass when turtles and dugong were prevented from grazing small plots (**Error! Reference source not found.**) (Scott et al. 2021a; b). Torres Strait has globally significant populations of green turtles and dugong that consume large quantities of seagrass per day - up to 5 kgs for green turtles and 40 kgs for dugong (Preen 1992). Overgrazing by unusually large numbers of turtles and dugong were attributed by one source as a cause of the large-scale dieback in the 1970s in Johannes and MacFarlane (1991). The observations of TropWATER scientists, Rangers and Traditional Owners also indicated high levels of herbivory by green turtle and dugong was a likely contributor to declines in intertidal seagrass abundance at Orman Reefs-Mabuyag Island that commenced in 2019. Mabuygiw Ranger Terrence Whap received numerous reports of high dugong and turtle densities in the area when declines occurred, and that dugong and turtle were coming in close to the Mabuyag Island foreshore more frequently than usual. Mura Badhulgau Ranger Troy Laza observed the same behaviour of dugong at Badu Island. TropWATER researchers observed evidence of dugong feeding up to the shoreline at Mabuyag Island in 2019, and greater densities of green turtles and dugong at Orman Reefs during the 2019 and 2020 surveys compared with previous years.

The effect of turtle and dugong grazing on seagrass was investigated at Mabuyag Island and Kai Reef (Orman Reefs) by Traditional Owners, Mabuygiw Rangers and TropWATER researchers in 2021 in response to seagrass declines. The removal of grazing pressure resulted in seagrass significantly higher canopy height and greater biomass compared with areas open to grazing by the end of the seven-month experiment (Figure 39). Very high grazing pressure, particularly by green turtles, means herbivory was a likely key driver of seagrass declines and a cause of continued pressure on seagrass abundance at both sites (Scott et al. 2022).

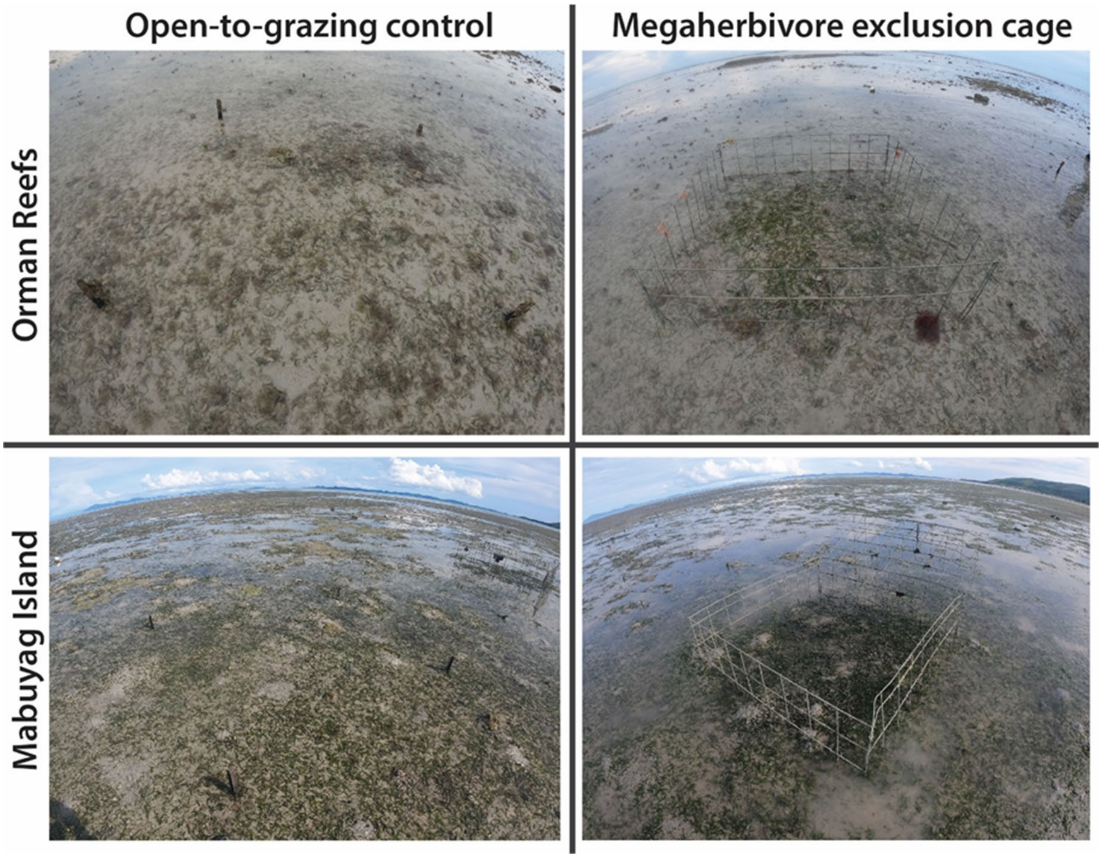

Figure 39: Field observations from final sampling in April 2022 at Orman Reefs and Mabuyag Island.

Environmental Conditions

Seagrass distribution, abundance and species composition reflects the environmental conditions meadows grow in, including exposure to run-off, physical disturbance, light, tidal fluctuations, and water temperature (Carter et al. 2021c). Environmental fluctuations during extreme weather - strong winds, turbulent water flow, storm surge, increased rainfall, and increased sediment movement - can cause significant seagrass declines due to reductions in the light required for seagrass growth, and sediment movement that can either bury or dislodge plants, meadows, and seed banks (Waycott et al. 2007). This occurs periodically along Queensland's east coast, where flooding, storms and tropical cyclones associated with La Nina periods have caused significant seagrass loss (Carter et al. 2022b; Coles et al. 2015; Rasheed et al. 2014).

One proposed cause of previous seagrass diebacks in Torres Strait is reduced light from sediment resuspension from two maximum deposition areas on either side of Torres Strait, with resuspension exacerbated during periods of prolonged monsoon winds and/or extreme weather (Saint-Cast 2008). Interpretation of wind patterns that may drive erosion and sediment deposition and influence seagrass condition is limited by a lack of local long-term environmental data outside of Thursday Island. However, there was evidence that environmental conditions may have contributed to recent seagrass declines in Torres Strait. Senior Mabuygiw Ranger Terrence Whap observed large areas of intertidal seagrass around Mabuyag Island removed through erosion in 2019-2022. Affected species were small, shallow-rooted *H. ovalis* and *H. uninervis*, while large and deep-rooted *E. acoroides* remained in previously diverse meadows (Figure 40). Rangers and TropWATER scientists also observed a change from fine muddy sediment to sand along Mabuyag Island's coast and at transect monitoring sites. Ranger Whap attributed this influx of sandy sediment into Mabuyag Island's coastal meadows to personal observations of the island experiencing much windier conditions than usual in recent years. Porumalgal Ranger Freddie David observed the decline at site PM2 was caused by the build-up of sand on the eastern side of Poruma Island which smothered an area of seagrass, but that this was very localised and extensive seagrass habitat remained around Poruma Island (Freddie David, pers. comm). A similar situation exists at Mer Island site MR2. Ranger Aaron Bon observed that this transect site is located near a fish trap that was repaired in 2013-2014. The repairs triggered a localised change in sand movement, with sand moving from the beach onto the seagrass meadow. With the repaired wall continuing to retain sand at the site, seagrass percent cover has continued to decline at this relatively small section of meadow, while the broader meadow that surrounds Mer Island remains in healthy and stable (Aaron Bon, pers. comm).

Marine heatwaves can also cause significant seagrass loss. For example, in Shark Bay, Western Australia, the single largest global loss in dense seagrass extent occurred in the summer of 2010-2011 following two months of elevated water temperatures (Strydom et al. 2020; Arias-Ortiz et al. 2018). Water temperature is unlikely to have contributed to recent seagrass declines in the Orman Reefs-Mabuyag Island region, with no evidence of dramatic or prolonged spikes in water temperature recorded at Thursday Island or Mabuyag Island in 2019-2020 when seagrass declines first occurred (Carter et al. 2021d). In addition, Torres Strait seagrass species have a relatively high temperature tolerance compared to the temperate/ sub-tropical species lost in Shark Bay.

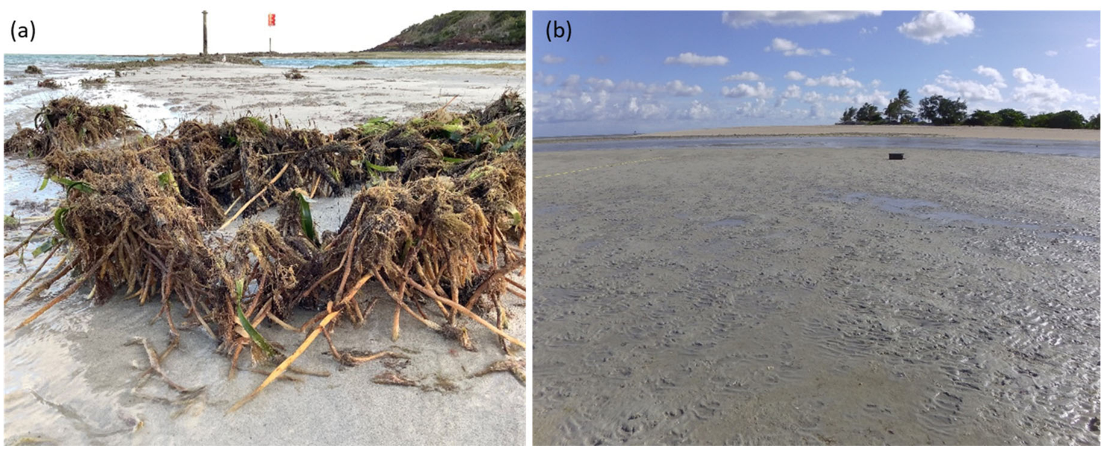

Figure 40. (a) Erosion left the roots of the seagrass E. acoroides *exposed and washed away smaller seagrass species at Mabuyag Island in 2019. (b) Seagrass at site PM2 on the north-eastern side of Poruma Island was covered in sand in 2021 and remained in poor condition in 2022. Photos courtesy: T. Whap and Porumalgal Rangers.*

Timeline for Recovery

Seagrass recovery time following loss can vary. Experimental work at Mabuyag Island demonstrated recovery can take anything from several months (assuming asexual reproduction is possible), to several years for intertidal meadows of large growing species if total meadow loss occurred and recovery depends only on sexual reproduction (Taylor et al. 2013). Following widespread loss in Torres Strait in the early-1970s, Johannes and Macfarlane reported intertidal and deep-water seagrass took a decade to recover (Johannes and MacFarlane 1991). Decadal-scales of decline and recovery have also occurred along Queensland's east coast (Carter et al. 2022b). This cycle has been most pronounced in the last decade following large-scale loss in 2009-2011 during a La Nina associated period of above average rainfall, river flow and tropical cyclones (McKenna et al. 2015).

High connectivity, the presence of a viable seedbank, and a return to environmental conditions that support seagrass recruitment are key to seagrass recovery (Grech et al. 2018; Rasheed et al. 2014). There is good potential for subtidal seagrass recovery assuming the reasons for the initial decline have passed. Connectivity in Torres Strait is high (Schlaefer et al. 2022; Johnson et al. 2018), there remains patchy seagrass coverage despite significant abundance declines, the persistence of *H. spinulosa* that has experienced the worst declines at a reduced number of sites, and the relatively short time elapsed since declines began, means recovery is likely via a range of mechanisms. These include dispersal of seagrass fragments and seeds, recovery of biomass in remaining plants, and germination of seeds within existing seed banks. Recovery in *Halophila* dominated meadows is generally quickest as *Halophila* species are fast growing and produce large amounts of seed so can rapidly take advantage when favourable conditions return (York et al. 2015; Rasheed et al. 2014). *Halophila* meadows generally produce substantial long-lived seed banks in the sediment that allow for seagrass recovery, with seeds remaining viable for at least two years (Hovey et al. 2015; Rasheed et al. 2014; McMillan 1991; McMillan and Soong 1989). Ongoing monitoring will provide a valuable opportunity to observe when and how different seagrass communities recover from these declines in the coming years.

Report Card Strengths, Limitations and General Recommendations

Report Card Strengths

The extensive seagrass monitoring and research effort in Torres Strait continues to enhance our understanding of this important habitat. The 2022 report card highlights the value of a monitoring network of complementary programs and the long-term data sets these generate. Integrating the results of these efforts into a single report card provides a powerful means of evaluating current seagrass condition and allowing comparisons among habitats and clusters, identifying areas of concern, and providing an indication of seagrass resilience.

Continuation of annual data collection for the long-term monitoring program is critical for timely assessments of seagrass condition and identifying change. The time scale for effective long-term monitoring of ecosystems depends on the time scale of the ecological process being studied, which for many systems is measured in decades (Lindenmayer and Likens 2009). This period allows studies to separate changes in population patterns from seasonal differences (within-year variability) and annual variability or “noise”.

Analysis of long-term datasets on seagrass change throughout Queensland, including sites with over 25 years of data, demonstrates that a 10 year period of monitoring is required to set reliable baselines for seagrass condition (Bryant et al. 2014). That 10-year milestone has now been achieved for the majority of long-term monitoring locations in Torres Strait, most recently at Badu Island (BD2) in 2022. This report card also provides interim scores for monitoring locations with 5-9 years of baseline data. Only Dungeness Reef subtidal (4 years) and the recently added Masig Island intertidal meadow (3 years) have less than 5 years data. As the program matures, and more locations achieve 10 years of information, the representativeness and robustness of the program will continue to improve.

Report Card Limitations

Significant gaps in our knowledge of seagrass condition in Torres Strait remain. These include the Top-Western Cluster where no monitoring occurs, and the Eastern Cluster where monitoring is limited to two transect sites at Mer Island and no meadow-scale monitoring occurs. Subtidal seagrass declines have highlighted the limited number of deep-water monitoring locations across all clusters.

The spatial scale at which monitoring occurs is an important consideration when extrapolating monitoring results to determine trends. The seagrass scores for many of the Eastern Cluster in particular is reliant on small-scale permanent transect monitoring. This scale of monitoring does not provide essential information on change in seagrass meadow extent - a key indicator of pressure-driven change on seagrass meadows - and an essential component of seagrass condition required for management of dugong, turtle and fisheries. Where small-scale variability occurs within a meadow, larger meadow-scale monitoring is likely to produce a more reliable measure of overall condition and change. Recent declines at Poruma Island's site PM2 and Mer Island's site MR2 provide good examples of this, with both sites in poor condition due to localised sand movement that have not impacted the broader meadow surrounding these islands (Freddie David and Aaron Bon, pers.com). The addition of meadow-scale monitoring to the network, such as at Masig Island in 2020, provides a more holistic approach for sampling and provides context when localised declines are detected.

Recommendations

The current monitoring effort in Torres Strait is substantial; however, to improve the program's ability to meet management requirements we recommend the following should resources and funding opportunities allow:

(1) Establish seagrass monitoring in the Top-Western Cluster. Seagrass data collected during a large-scale baseline survey in late 2015 provides a good basis for selecting meadows suitable for monitoring.

(2) Establish meadow-scale seagrass monitoring in clusters where this does not occur so that changes in meadow area, a fundamental indictor of seagrass meadow condition, can be included in future condition assessments. Potential meadows include Boigu Island in the Top-Western Cluster and Ugar, Erub, Mer, Dauar and Waier Islands in the Eastern Cluster. This could include investigating the potential for Ranger or Community-led drone surveys of intertidal seagrass meadows for inhabited islands.

(3) Establish additional subtidal block monitoring in clusters where this currently does not occur so that this important and extensive habitat is better represented in future condition assessments. Recommended locations include south of Boigu Island in the Top-Western Cluster, west of the Warrior Reefs in the Central Cluster, and the southern section of the Dugong Sanctuary.

(4) Conduct baseline surveys in areas where data is lacking or is more than 10 years old, and potentially important seagrass habitat is most likely. For intertidal seagrass this includes the Warrior Reefs (Central Cluster) and Saibai Island (Top-Western Cluster). For subtidal seagrass this includes the region between the Warrior Reefs and Gebar Island (Central Cluster).

The seagrass condition declines described in this report card highlight the importance of regular monitoring to detect change, but the limitations of monitoring only one component of the environment, e.g. seagrass, and not a range of ecosystem indicators makes it difficult to identify the causes of seagrass change. To overcome this we recommend:

(1) *Regular turtle and dugong monitoring*. Turtle and dugong aerial surveys occur sporadically in Torres Strait (Cleguer et al. 2016; Hagihara et al. 2016; Fuentes et al. 2015), but not at the frequency that variations in animal density can be linked to seagrass dynamics. Unmanned aerial vehicles (UAVs) or drones are increasingly being used as a cost-effective and efficient method to monitor large marine animals, including dolphins, manatees, turtles and whales (Dunstan et al. 2020; Ramos et al. 2018; Rees et al. 2018; Hodgson et al. 2017). We recommend a pilot study to explore the use of drones as a more cost-effective method for island/meadow scale turtle and dugong monitoring at a range of locations in Torres Strait.

(2) *Expanded herbivore exclusion experiments*. Regional patterns in turtle and dugong herbivory, and the pressure these animals place on seagrass meadows across Torres Strait, are unknown. An expanded herbivore exclusion experiment across Torres Strait would answer critical questions on how herbivores and their movements interact with changes in seagrass meadows. An integrated monitoring program that included seagrass, green turtle and dugong, and exclusion cages, would help determine: (1) herbivory pressure on seagrass at the regional scale including variations due to animal migration; (2) habitat-scale movement where loss of seagrass in one habitat forces movement into adjacent habitats.

(3) *Comprehensive disease/pathogen assessment of Torres Strait seagrass.* Preliminary testing at the Cairns DAWE lab found no evidence of pathogenic *Labyrinthula.* However, this was based on a small number of samples from Mabuyag Island and Orman Reefs only. We recommend development of a comprehensive testing program for disease that includes testing for seagrass samples across the network of monitoring locations to develop a baseline, and opportunistic testing of samples when lesions on leaf blades are evident during monitoring. Testing of *H. spinulosa* is a priority.

(4) *Establishing light monitoring.* As a critical driver of seagrass change, some in-situ benthic light (PAR) logging at key locations would provide valuable insight into the role of light in seagrass changes observed in the Torres Strait.

(5) *Local wind and weather stations*. Interpretation of environmental conditions that may drive erosion and sediment deposition and thereby influence seagrass condition is currently limited by the lack of local weather data.

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Appendices

Appendix 1.

Baseline Calculations

Baseline conditions for site/meadow biomass/percent cover, area and species composition were established from annual means calculated during the first 10 years of monitoring. This baseline was set based on results of the 2014 pilot report card (Bryant et al. 2014). Where <10 years of data were available the baseline was calculated over the longest available time period. Condition assessments with 5-10 years of data should be considered preliminary as the baseline will be updated annually. Sites/meadows with <5 years of data are included in this report but no overall grades/scores are presented due to the lack of data.

Baseline conditions for species composition were determined based on the annual percent contribution of each species to mean site/meadow biomass/percent cover of the baseline years. Meadows were classified as single species (one species comprising ≥80% of baseline species composition) or mixed species dominated (no species comprise ≥80% of baseline species composition). Where a meadow baseline contained an approximately equal split in two species (i.e. two species accounted for 40–60% of the baseline), the baseline was set according to the percent composition of the more persistent/stable species of the two (Figure A1).

Meadow Classification

A classification system was developed for the three condition indicators in recognition that for some seagrass sites/meadows these measures are historically stable, while in others they are relatively variable. The coefficient of variation (CV) for each baseline for each site/meadow was used to determine historical variability. Site/meadow biomass/percent cover and species composition were classified as stable or variable (Table A1). Meadow area also has additional highly stable and highly variable classes (Table A1). The CV was 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 site/meadow abundance (biomass/percent cover), area and species composition baselines.

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

Grade and Score Calculations

A score system (0 – 1) and score range was applied to each grade to allow numerical comparisons of seagrass condition among sites/meadows and Torres Strait Island Clusters (Table A2).

Score calculations for each site/meadow's condition required calculating the biomass/percent cover, area and species composition for that year (described in Section 2.1), allocating a grade for each indicator by comparing 2019 biomass/percent cover, area, and species values against site/meadow-specific thresholds for each grade, then scaling biomass/percent cover, 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 A2). Within each site/meadow, the upper limit for the very good grade (score = 1) for percent cover and species composition were set as 100%. For biomass and area, the upper limit was 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. For sites/meadows with <10 years of baseline data this upper limit will be recalculated each year until the 10-year baseline period is complete.

An example of calculating a meadow score for area in satisfactory condition is provided in Appendix 2.

Table A1.2 Score range and grading colours used in the Torres Strait 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 was determined to be anything less than in “perfect” condition (i.e. a score <1), a decision tree was used to determine whether equivalent and/or more persistent/stable species were driving this grade/score (Figure A1). If this was the case, the species composition score and grade for that year was recalculated including those species. Concern regarding any decline in the stable state species was reserved for those meadows where the directional change from the stable state species is of concern (Figure 5). This would occur when the stable state species is replaced by species considered earlier colonisers. Such a shift indicates a decline in meadow stability (e.g. a shift from *T. hemprichii* 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 was 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*, the most marginal species found in Torres Strait, 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).

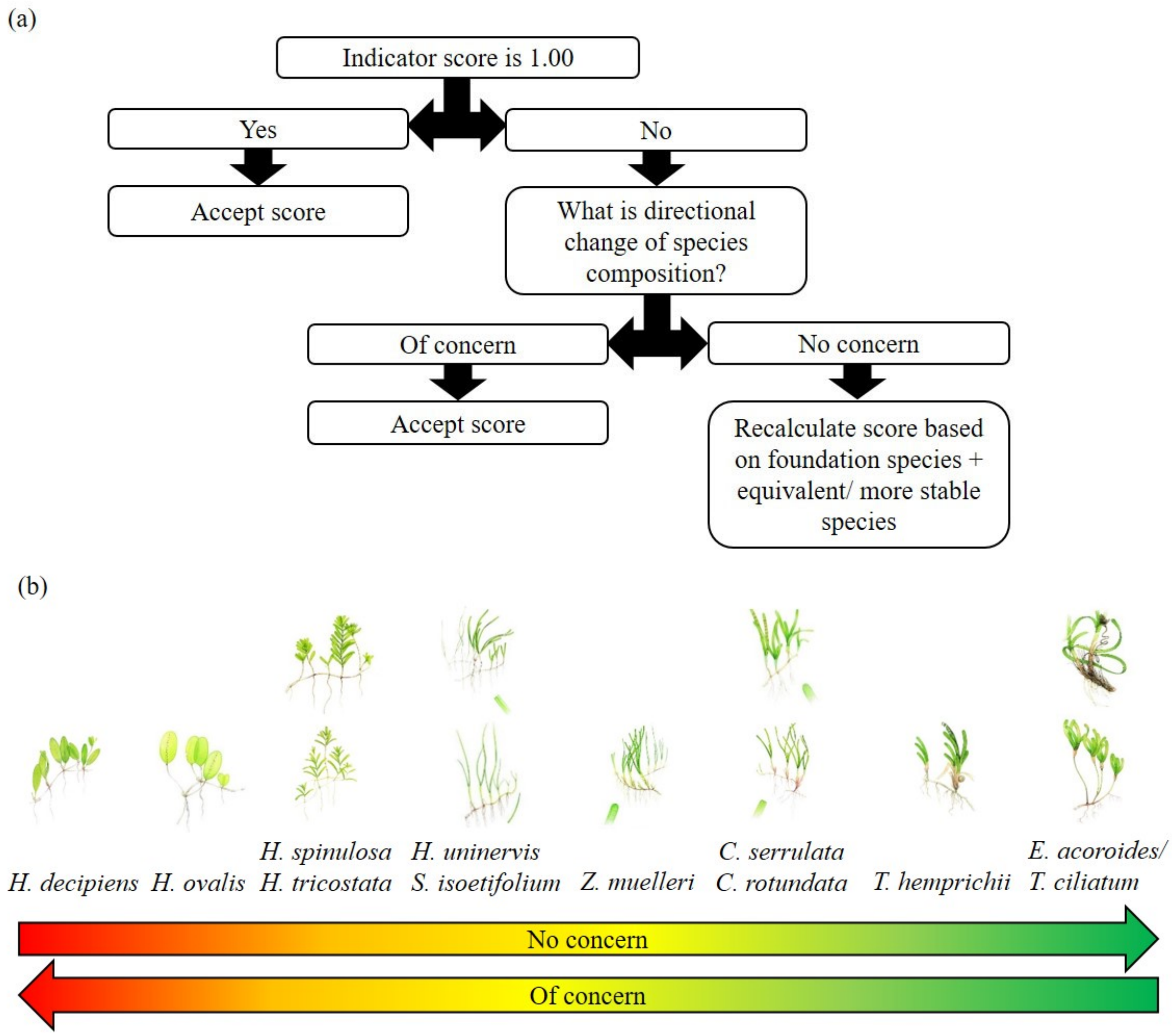

Figure A1.1 (a) Decision tree and (b) directional change assessment for grading and scoring species composition.

Threshold Definition

Each seagrass condition indicator was assigned one of five grades: very good (A), good (B), satisfactory (C), poor (D), very poor (E). Threshold levels for each grade were set relative to the baseline and based on site/meadow class. This approach accounted for historical variability within the monitoring sites/meadows and expert knowledge of the different site/meadow types and assemblages in the region (Table A3).

Score Aggregation

The overall site/meadow grade and score is defined as the lowest indicator score where this is driven by biomass/percent cover or area. Where species composition is the lowest score, it contributes 50% of the overall site/meadow score, and the next lowest indicator (area or biomass/percent cover) contributes the remaining 50%. The lowest of the biomass/percent cover or area scores, rather than the mean of the three indicator scores, was applied in recognition that a poor grade for either of these indicators described a seagrass meadow in poor condition. The 50% weighting of species composition acknowledges that this is an important characteristic of a seagrass meadow in terms of defining meadow stability, resilience, and ecosystem services, but is not as fundamental as having some seagrass present, regardless of species, when defining overall condition.

Torres Strait Island Cluster grades/scores were calculated by averaging the overall site/meadow scores for each monitoring site/meadow within a given cluster, and assigning the corresponding grade to that score. Where multiple sites/meadows were present within a cluster, no weighting system was applied at this stage of the analysis. The classification process applies smaller and more sensitive thresholds for stable sites/meadows, and less sensitive thresholds for variable sites/meadows. The classification process serves therefore as a proxy weighting system where any condition decline in the stable sites/meadows is more likely to trigger a grade reduction compared with more variable sites/meadows. Cluster grades therefore are more sensitive to changes in stable than variable sites/meadows.

Table A1.3 Threshold levels for grading seagrass indicators for various site/meadow classes relative to the baseline. Upwards/downwards arrows are included in figures where a change in condition grade has occurred in any of the three indicators (biomass/percent cover, area, species composition) from the previous year.

Seagrass condition indicators/ Site/meadow class		**Seagrass grade**				
		A Very good	**B Good**	**C Satisfactory**	**D Poor**	**E Very Poor**
Biomass/ Percent cover	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			Decrease below threshold		

	from previous year	from previous year

Appendix 2. An example of calculating a meadow score for area in satisfactory condition in 2022.

1. Determine the grade for the 2022 (current) area value (i.e. satisfactory).

2. Calculate the difference in area (A_{diff}) between the 2022 area value (A_{2022}) and the area value of the lower threshold boundary for the satisfactory grade ($A_{satisfactory}$):

$$A_{diff} = A_{2022} - A_{satisfactory}$$

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

3. Calculate the range for area values (A_{range}) in that grade:

$$A_{range} = A_{good} - A_{satisfactory}$$

Where $A_{satisfactory}$ is the upper threshold boundary for the satisfactory grade.

Note: For species composition and percent cover, 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 maximum value of the mean plus the standard error (i.e. the top of the error bar) for a given year during the baseline period for that indicator and meadow.

4. Calculate the proportion of the satisfactory grade (A_{prop}) that A_{2022} takes up:

$$A_{prop} = \frac{A_{diff}}{A_{range}}$$

5. Determine the area score for 2022 ($Score_{2022}$) by scaling A_{prop} against the score range (SR) for the satisfactory grade ($SR_{satisfactory}$), i.e. 0.15 units:

$$Score_{2022} = LB_{satisfactory} + \left(A_{prop} \times SR_{satisfactory}\right)$$

Where $LB_{satisfactory}$ is the defined lower bound (LB) score threshold for the satisfactory grade, i.e. 0.50 units.