Seagrass Habitat in the Port of Thursday Island: Annual seagrass monitoring report 2023

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KEY FINDINGS

Seagrass Condition 2023

GOOD

- Annual monitoring of seagrass meadows around Thursday Island was conducted between 17 - 18th March 2023.
- The overall condition of seagrass in the Port of Thursday Island was good in 2023 with all meadows in satisfactory or better condition.
- Some meadows had experienced a decline in one or more of the indicators measured (biomass, area or species compositon) since the previous year, but still remained in a good or satisfactory conditon compared with the expected baseline.
- Climate conditions were favourable overall for seagrass growth in 2023.
- These results indicate the seagrass community in the Port of Thursday Island was in a healthy and resilient state in 2023.

IN BRIEF

Seagrasses have been monitored in the Port of Thursday Island biennially since 2002 and annually since 2016. Nine seagrass meadows representing the range of different seagrass community types found in the Thursday Island region are monitored and assessed for changes in area, biomass, and species composition. These indicators are used to develop a seagrass condition index (see section 2.4 of this report for further details). In addition, every three years all seagrasses within the greater port limits are mapped and assessed.

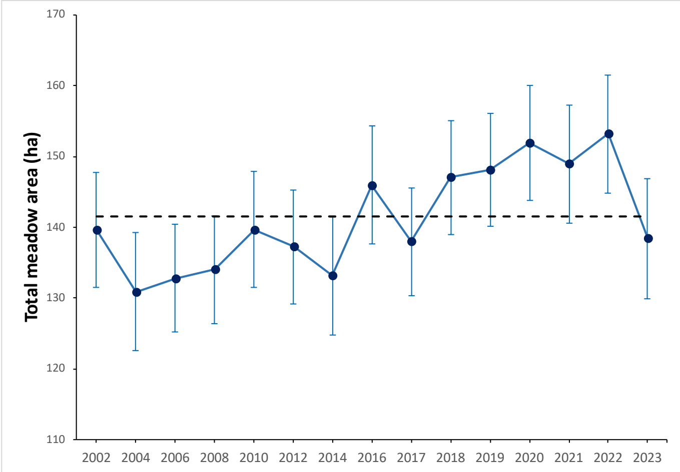

Figure 1 Total area of seagrass within the Thursday Island monitoring meadows from 2002 to 2023 (error bars = "R" reliability estimate). Dashed line indicates long-term average of meadow area.

In March 2023 the overall condition of seagrass in the Port of Thursday Island annual monitoring meadows was good. The total area of seagrass habitat mapped within the nine monitoring meadows in 2023 (138 ± 8.5 ha) was a decrease from previous years, but was only just below the long-term average of 141 ha (Figure 1). All meadows were in good or satisfactory condition in 2023 (Figure 2).

Climate conditions were favourable leading up to the March 2023 survey with no major storms or cyclones affecting the area. Air temperature, rainfall and exposure were above average in 2022/23 while solar radiation was slightly below average (Figure 3). There were some declines in seagrass condition throughout Thursday Island in 2023 compared to the previous year which may reflect the lower light conditions, but none of these resulted in declines of any indicator to be considered poor. All meadows and individual indicators remained in satisfactory or better condition. These results point to a healthy seagrass community in the Port of Thursday Island and a key indicator of a healthy marine environment in the port. Throughout the wider Torres Strait in 2022, seagrass was in a good condition in the Inner Cluster and in a satisfactory condition in the Western, Central and Eastern Clusters (Carter et al. 2022). Some habitats within this area were of concern, for example the subtidal seagrass within these Clusters which declined in 2019 showed no signs of recovery in 2022 (Carter et al. 2022). At Weipa, the next closest seagrass long-term monitoring location to Thursday Island (Figure 4), seagrasses were similarly in good condition. For full details of the Queensland ports seagrass monitoring program see: https://www.tropwater.com/project/management-of-ports-and-coastal-facilities/

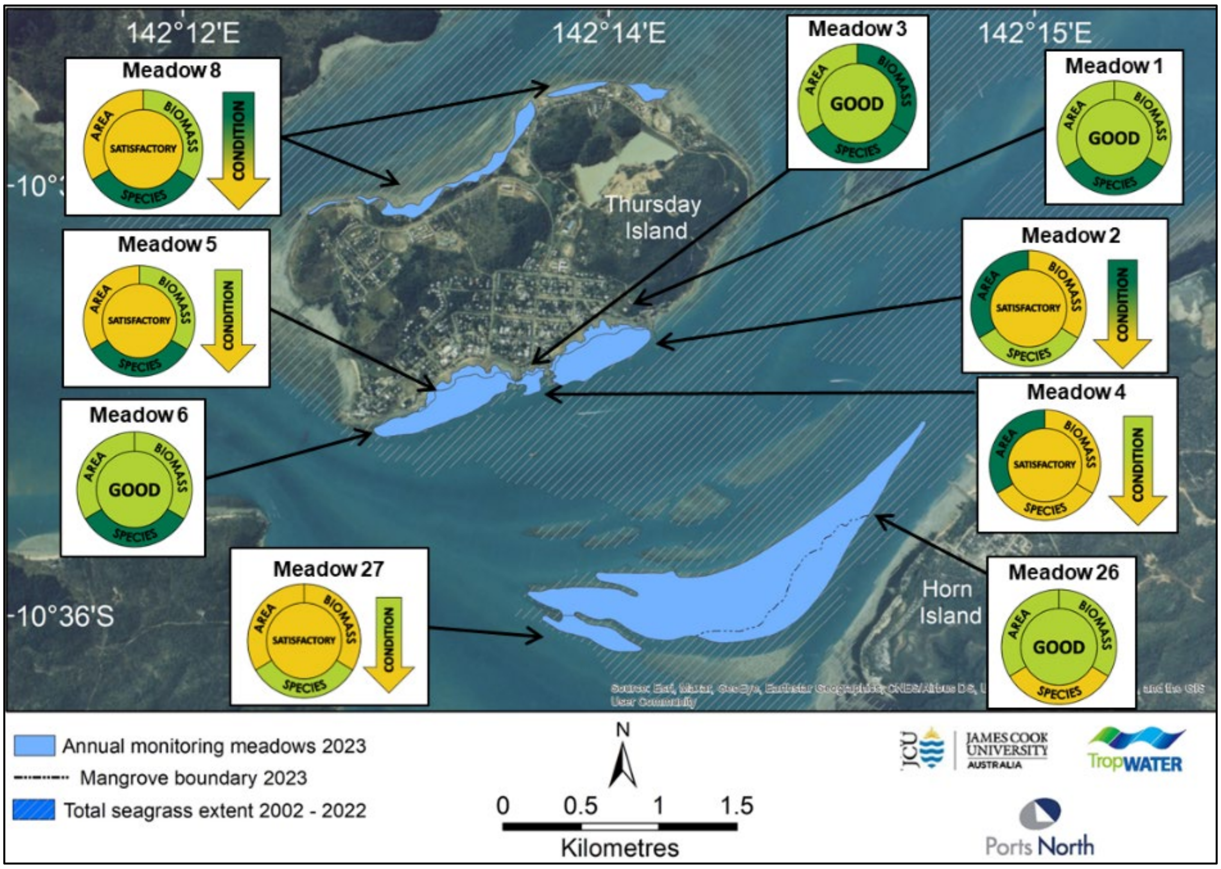

FIGURE 3 SEAGRASS CONDITION FOR PORT OF THURSDAY ISLAND ANNUAL MONITORING MEADOWS IN 2023.

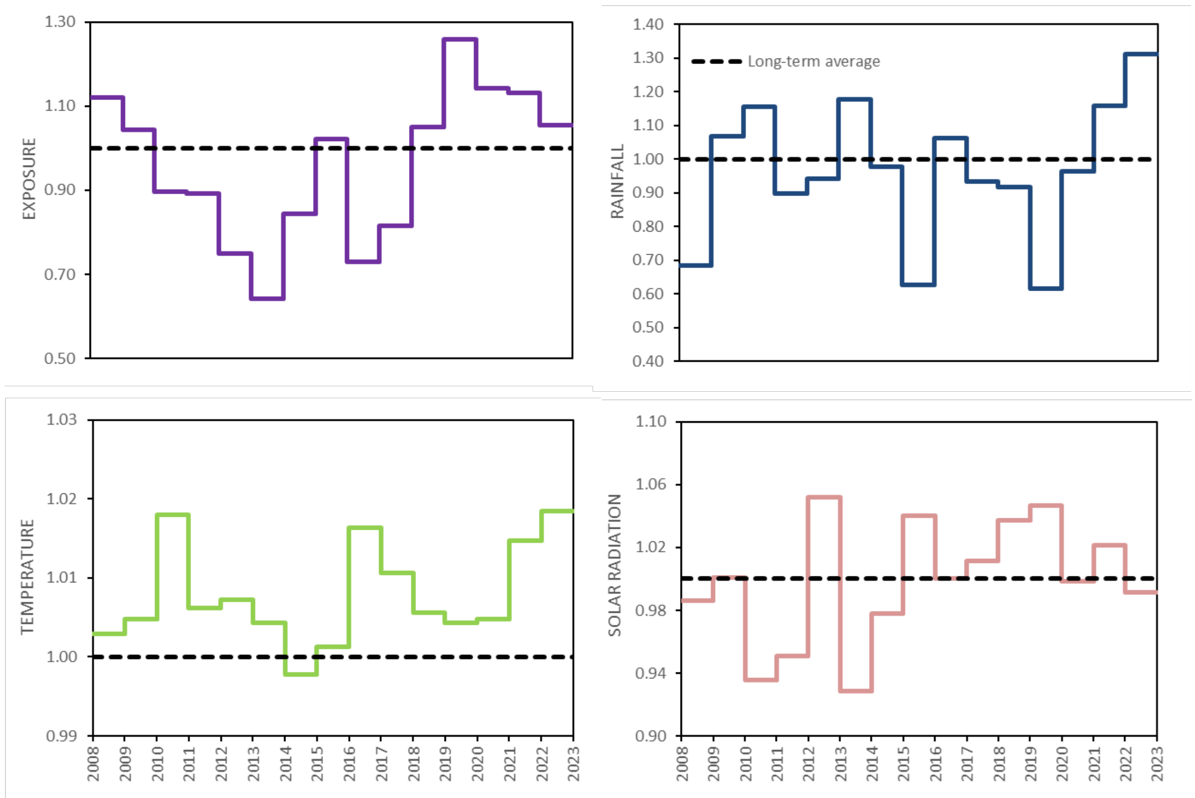

FIGURE 2 DIAGRAMMATIC SUMMARY OF CLIMATE TRENDS IN THURSDAY ISLAND: CHANGES IN CLIMATE VARIABLES AS A PROPORTION OF THE LONG-TERM AVERAGE. SEE SECTION 3.3 FOR DETAILED CLIMATE DATA.

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1 INTRODUCTION

Seagrasses provide a range of critically important and economically valuable ecosystem services including coastal protection, support of fisheries production, nutrient cycling, and particle trapping (Costanza et al. 2014; Hemminga & Duarte 2000; Costanza et al. 1997). Seagrass meadows show measurable responses to changes in water quality, making them ideal candidates for monitoring the long-term health of marine environments (Orth et al. 2006; Abal & Dennison 1996; Dennison et al. 1993).

1.1 QUEENSLAND PORTS SEAGRASS MONITORING PROGRAM

A long-term seagrass monitoring and assessment program has been established in the majority of Queensland's commercial ports. The program was developed by James Cook University's Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) in partnership with the various Queensland port authorities. While each location is funded separately, a common methodology and rationale is used, providing a network of seagrass monitoring locations throughout Queensland (Figure 4).

FIGURE 4 LOCATION OF QUEENSLAND PORT SEAGRASS ASSESSMENT SITES

A strategic long-term assessment and monitoring program for seagrasses provides port managers and regulators with key information to ensure that seagrasses and ports can co-exist. These results are useful for planning and implementing port development and maintenance programs to ensure minimal impact on seagrasses. The program also provides an ongoing assessment of many of the most threatened seagrass communities in Queensland.

The data collected as part of this program has resulted in significant advances in the science and knowledge of tropical seagrass ecology. This data has been instrumental in developing tools, indicators and thresholds for the protection and management of seagrasses. The program also provides an understanding of the drivers of tropical seagrass change. It provides local information for individual ports as well as feeding into regional assessments of the status of seagrasses.

For more information on the program and reports from the other monitoring locations see https://www.tropwater.com/project/management-of-ports-and-coastal-facilities/

1.2 SEAGRASS MONITORING PROGRAM

Torres Strait Island communities rely on coastal marine habitats for subsistence and have strong cultural and spiritual links to these environments. Due to the high reliance on fishing in the Thursday Island area, habitats that support commercial and traditional fisheries, such as seagrasses, are of critical importance to the region. The loss of seagrass habitat in Torres Strait would have detrimental effects on the species reliant on seagrass, and local island communities. For example, substantial seagrass diebacks (up to 60%) have been documented twice in central Torres Strait and linked to dramatic increases in local dugong mortality (Marsh et al. 2004; Long and Skewes 1996). Threats to seagrass in the region include shipping-related oil spills and structural habitat damage, climate change

(Carter et al. 2014) and seagrass diebacks. Torres Strait seagrass distribution, density and species composition also varies significantly seasonally and annually, with change largely driven by environmental conditions (Carter et al. 2014; Mellors et al. 2008).

Following a fine-scale baseline survey of seagrass habitat conducted at the port in March 2002, an annual seagrass monitoring program was established consisting of a subset of nine representative meadows in the port (annual monitoring meadows). The monitoring meadows represent the range of seagrass species, habitat types (intertidal and subtidal) and meadow community types identified within the port limits. The results from the program inform an evaluation of the health of the port marine environment and help identify possible detrimental effects of port operations on seagrass meadows. The program also provides an assessment of climate-related influences on seagrass meadows, and acts as a reference tool for other organisations involved in management of community use of the inshore area. Results of this program also form a critical component of the Torres Strait wide regional assessment and reporting on seagrass condition to aid in management of the Torres Strait seagrass resources and their reliant fish and animal communities (see Carter et al. 2020).

This report presents results of the March 2023 annual seagrass monitoring including:

- Maps of seagrass distribution, density and species composition within the long-term annual monitoring meadows.
- Assessments of seagrass condition in the monitoring meadows within the context of historical seagrass conditions and discussion of the observed changes in a regional and state-wide context.
- Discussion of the implications of monitoring results in relation to the overall health of the marine environment in the port.

2 METHODS

2.1 FIELD SURVEYS

Survey and monitoring methods followed the established techniques for JCU's Queensland-wide seagrass monitoring programs. The annual seagrass monitoring surveys of the nine long-term monitoring meadows (Figure 2) were conducted on 17 – 18th March 2023.

Intertidal meadows were sampled at low tide using a helicopter. GPS was used to map the position of meadow boundaries and sites for assessment were scattered haphazardly within each meadow. Sites were assessed as the helicopter hovered less than one metre above the substrate (Figure 5 A). Shallow subtidal meadows were sampled by boat using camera drops and van Veen grab (Figure 5 B, C). A Van Veen sediment grab (grab area 0.0625 m^{-2}) was used to confirm sediment type and seagrass species. Subtidal sites were positioned at approximately 50 to 100 m intervals on a transect running perpendicular from the shoreline, or where major changes in bottom topography occurred. Transects continued to at least the seaward edge of any seagrass meadows that were encountered.

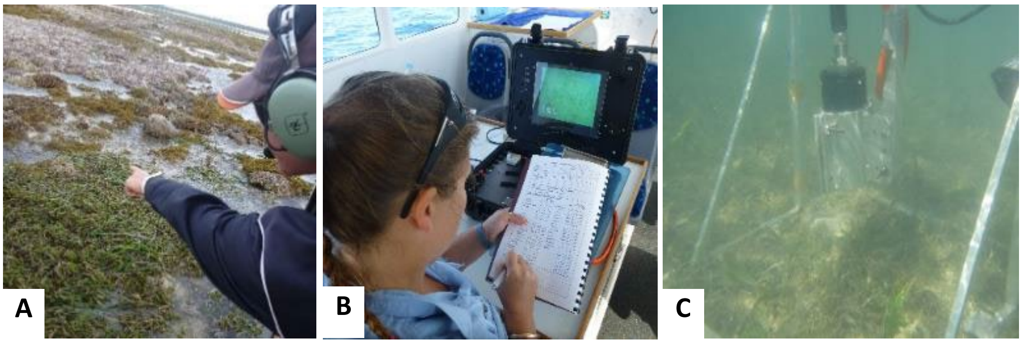

FIGURE 5 SEAGRASS MONITORING METHODS. (A) HELICOPTER AERIAL SURVEILLANCE, (B, C) BOAT-BASED CAMERA DROPS.

2.2 SEAGRASS BIOMASS ESTIMATES

Seagrass above-ground biomass was determined using a "visual estimates of biomass" technique (Mellors 1991; Kirkman 1978). At each site a 0.25 m^2 quadrat was placed randomly three times. An observer assigned a biomass rank to each quadrat while referencing a series of quadrat photographs of similar seagrass habitats where the above-ground biomass had previously been measured. Three separate ranges were used - low, high and *Enhalus* biomass. The percentage contribution of each species to each quadrat's biomass also was recorded.

At the survey's completion the observer ranked a series of calibration quadrat photographs representative of the range of seagrass biomass and species composition observed during the survey. These calibration quadrats had previously been harvested and the above-ground biomass weighed in the laboratory. A separate regression of ranks and biomass from the calibration quadrats was generated for each observer and applied to the biomass ranks recorded in the field. Field biomass ranks were converted into above-ground biomass estimates in grams dry weight per square metre (g DW m^{-2}) for each of the three replicate quadrats per site. Site biomass, and the biomass of each species, is the mean of the three replicates. Seagrass biomass could not be determined from sites sampled only by van Veen grab.

Results from previous surveys suggested the analysis of biomass for meadows where the large growing species *E. acoroides* was present but not dominant required a different method compared to meadows where *E. acoroides* was dominant (Roelofs et al. 2003). The dry weight biomass for *E. acoroides* is many orders of magnitude higher than other tropical seagrass species and dominates the average biomass of a meadow where it is present. Therefore, isolated *E. acoroides* plants occurring within the *H. uninervis* dominated meadows (Meadows 1, 3, 5 and 8) were excluded from biomass comparisons in order to track the dynamics of these morphologically distinct species.

2.3 HABITAT MAPPING AND GEOGRAPHIC INFORMATION SYSTEM

All survey data was entered into a Geographic Information System (GIS) using ArcGIS 10.8®. Satellite imagery of the Thursday Island area with information recorded during the monitoring surveys was combined to assist with mapping seagrass meadows. Three seagrass GIS layers were created:

2.3.1 SITE LAYER

The site (point) layer contains data collected at each site, including:

- Site number.
- Temporal details – Survey date and time.
- Spatial details – Latitude and longitude.
- Habitat information – Sediment type; seagrass information including presence/absence, above-ground biomass (total and for each species) and biomass standard error (SE); site benthic cover (percent cover of algae, seagrass, benthic macro-invertebrates, open substrate) dugong feeding trail (DFT) presence/absence.
- Sampling method and any relevant comments.

2.3.2 BIOMASS INTERPOLATION

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

2.3.3 MEADOW LAYER

The meadow (polygon) layer provides summary information for all sites within each meadow, including:

- Meadow ID number – A unique number assigned to each meadow to allow comparisons among surveys.
- Temporal details – Survey date.
- Habitat information – Mean meadow biomass ± standard error (SE), meadow area (hectares) ± reliability estimate (R), number of sites within the meadow, seagrass species present, meadow density and community type (Tables 1, 2), meadow landscape category (Figure 6).
- Sampling method and any relevant comments.

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

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

Continuous seagrass cover
The majority of meadow area consists of continuous seagrass cover with a few gaps of unvegetated sediment.

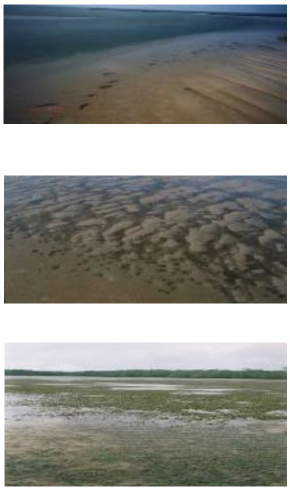

FIGURE 6 SEAGRASS MEADOW LANDSCAPE CATEGORIES: (A) ISOLATED SEAGRASS PATCHES, (B) AGGREGATED SEAGRASS PATCHES, (C) CONTINUOUS SEAGRASS COVER.

TABLE 1 NOMENCLATURE FOR SEAGRASS COMMUNITY TYPES.

Community type	**Species composition**
Species A	Species A is >90-100% of composition
Species A with Species B (2 species present) Species A with mixed species (>2 species)	Species A is >60-90% of composition
Species A/Species B	Species A is 40-60% of composition

TABLE 2 DENSITY CATEGORIES AND MEAN ABOVE-GROUND BIOMASS RANGES FOR EACH SPECIES USED IN DETERMINING SEAGRASS COMMUNITY TYPE IN THE PORT OF THURSDAY ISLAND.

Density	**Mean-above ground biomass (g DW m^{-2})**					
	***H. uninervis* (narrow)**	***H. ovalis* *H. decipiens***	***H. uninervis* (wide) *C. serrulata/rotundata* *S. isoetifolium***	***T. hemprichii* *H. spinulosa***	***Z. muelleri***	***E. acoroides* *T. ciliatum***
Light	< 1	< 1	< 5	< 15	< 20	< 40
Moderate	1 - 4	1 - 5	5 - 25	15 - 35	20 - 60	40 - 100
Dense	> 4	> 5	> 25	> 35	> 60	> 100

Meadow boundaries were constructed using GPS marked meadow boundaries where possible, seagrass presence/absence site data, field notes, colour satellite imagery of the survey region (Source: ESRI), and aerial photographs taken during helicopter surveys. Meadow area was determined using the calculate geometry function in ArcGIS®. Meadows were assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow (Table 3). Mapping precision ranged from

1 m for intertidal seagrass meadows with boundaries mapped by helicopter to 50 m for subtidal meadows with boundaries mapped by distance between sites with and without seagrass. The mapping precision estimate was used to calculate a buffer around each meadow representing error; the area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Meadows were described using a standard nomenclature system developed for Queensland's seagrass meadows. Seagrass community type was determined using the dominant and other species' percent contribution to mean meadow biomass (for all sites within a meadow) (Table 1). Community density was based on mean biomass of the dominant species within the meadow (Table 2).

TABLE 3 MAPPING PRECISION AND METHODS FOR SEAGRASS MEADOWS IN THE PORT OF THURSDAY ISLAND 2023

Mapping precision	Mapping method
1-10 m	Meadow boundaries mapped in detail by GPS from helicopter. Some meadow boundaries mapped by walking. Intertidal meadows completely exposed or visible at low tide. Relatively high density of mapping and survey sites. Recent aerial photography aided in mapping.
10-50 m	Meadow boundaries determined from helicopter and camera/grab surveys. Inshore boundaries mapped from helicopter. Offshore boundaries interpreted from survey sites and aerial photography. Relatively high density of mapping and survey sites.

2.4 SEAGRASS MEADOW CONDITION INDEX

A condition index was developed for seagrass monitoring meadows based on changes in mean above-ground biomass, total meadow area and species composition relative to a baseline (see Carter et al. 2023 for full details). Seagrass condition for each indicator at Abbot Point was scored from 0 to 1 and assigned one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor). Overall meadow condition is the lowest indicator score where this is driven by biomass or area. Where species composition is the lowest score, it contributes 50% of the overall meadow score, and the next lowest indicator (area or biomass) contributes the remaining 50% (Carter et al. 2023).

2.5 ENVIRONMENTAL DATA

Environmental data were collated for the 12 months preceding each survey:

- Tidal data was provided by Maritime Safety Queensland (MSQ) (© The State of Queensland Department of Transport and Main Roads 2022, Tidal Data) for Thursday Island (www.msq.qld.gov.au).
- Data for rainfall (mm), air temperature (°C), and global solar exposure (MegaJoules, MJ m^{-2}) were obtained for the nearest weather station from the Australian Bureau of Meteorology (BOM) (Horn Island, Station #027058; http://www.bom.gov.au/climate/data/).

3 RESULTS

3.1 SEAGRASSES IN THURSDAY ISLAND

A total of 305 sites were surveyed in the 2023 annual monitoring survey (Figure 7). Nine seagrass species were recorded with seven seagrass community types identified in the monitoring meadows (Figure 8; Table 4). The total area of seagrass habitat mapped within the nine annual monitoring meadows was 138 ± 8.5 ha (Figure 1).

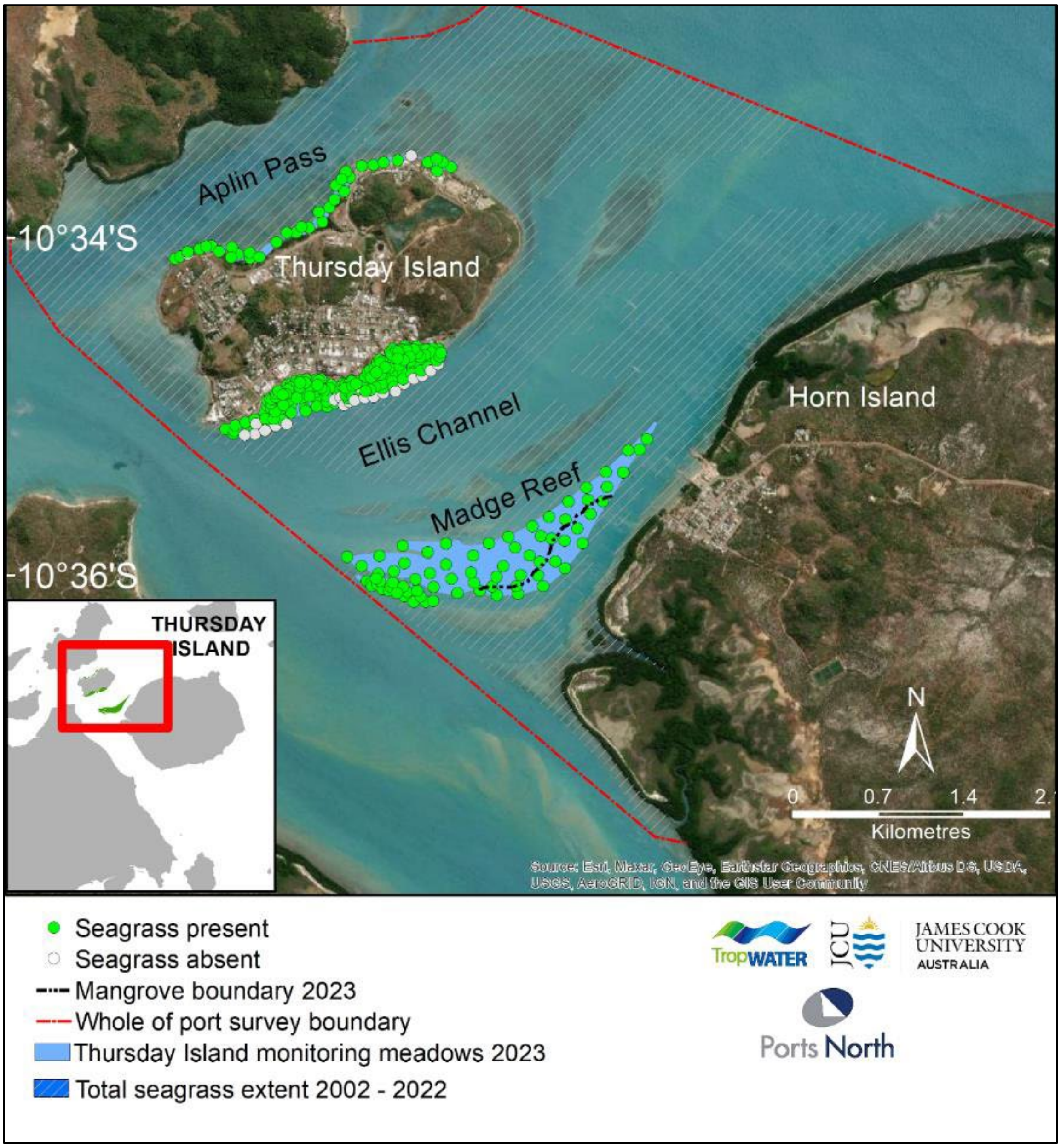

FIGURE 7 PORT OF THURSDAY ISLAND SEAGRASS MEADOWS AND SEAGRASS PRESENCE/ABSENCE AT SITES SURVEYED IN 2023.

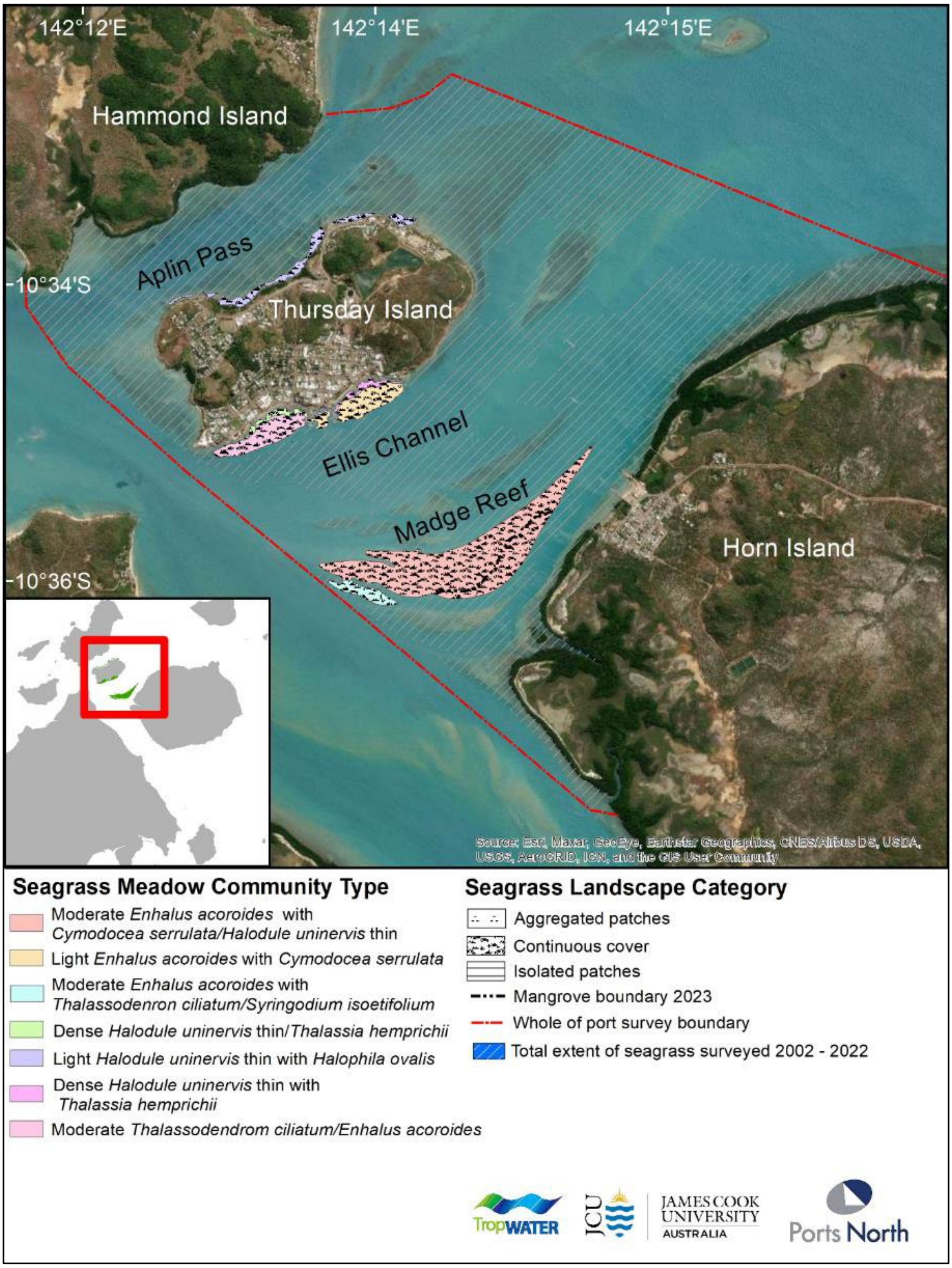

FIGURE 8 PORT OF THURSDAY ISLAND SEAGRASS DISTRIBUTION AND COMMUNITY TYPE FOR 2023 SEAGRASS MONITORING MEADOWS

TABLE 4 SEAGRASS SPECIES PRESENT AT THE PORT OF THURSDAY ISLAND IN 2023.

FAMILY	SPECIES			
CYMODOCEACEA E Taylor		*Cymodocea serrulata* (R.Br.) Aschers and Magnus		*Halodule uninervis* (thin and wide leaf morphology) (Forssk.) Boiss.
		*Cymodocea rotundata* Asch. & Schweinf.		*Syringodium isoetifolium* (Ashcers.) Dandy
ZOSTERACEAE Drummortier		*Zostera muelleri* subsp. *capricorni* (Aschers.)		*Thalassodendron ciliatum* (Forssk.) Hartog
HYDROCHARITACEAE Jussieu		*Thalassia hemprichii* (Ehrenb. ex Solms) Asch.		*Halophila ovalis* (R. Br.) Hook. F.
		*Enhalus acoroides* (L.F.) Royle		

3.2 SEAGRASS CONDITION FOR ANNUAL MONITORING MEADOWS

The overall condition of seagrasses in the Port of Thursday Island annual monitoring meadows was good in March 2023 (Table 5). All monitoring meadows were in good or satisfactory condition, however there were decreases in condition of at least one indictor in all but one seagrass meadow compared to 2022, with overall condition declines in some meadows. Despite these changes, seagrass condition in the port as a whole had a good score in 2023 and no individual meadows were rated as being poor.

The combined area of all annual monitoring meadows had been at or above the long-term average since 2016, in 2023 total area declined to 138 ± 8 ha, which is only slightly below the long-term average of 141.5 ha (Figure 2). Meadow area is the most stable of the three indicators (biomass, area and species composition) throughout the monitoring meadows, however some of the meadows around Thursday Island are adjacent to subtidal meadows where the boundary of the subtidal meadows and their communities has shifted into the intertidal.

TABLE 5 GRADES AND SCORES FOR SEAGRASS INDICATORS (BIOMASS, AREA AND SPECIES COMPOSITION) FOR THE PORT OF THURSDAY ISLAND 2023.

Meadow	Biomass	Area	Species Composition	Overall Meadow Score
1	0.79	0.77	0.92	0.77
2	0.64	0.96	0.77	0.64
3	0.94	0.72	0.9	0.72
4	0.6	0.88	0.62	0.6
5	0.76	0.62	0.99	0.62
6	0.85	0.82	0.86	0.82
8	0.75	0.64	0.96	0.64
26	0.75	0.77	0.63	0.69
27	0.54	0.61	0.76	0.54
Overall Score for the Port of Thursday Island				**0.67**

3.2.1 Inshore *Halodule uninervis* dominated meadows (Meadows 1, 3, 5, 8)

The intertidal *Halodule uninervis* meadows around Thursday Island have remained relatively stable in terms of overall condition over the last few years, but there were declines in some metrics and in overall condition in 2023. Meadow 1 and 3 remained in good condition and meadow 5 and 8 had reductions in meadow area and biomass which caused declines in overall meadow condition to satisfactory (Figures 2, 11, 13, 15 and 17; Table 5).

Seagrass biomass in these inshore *H. uninervis* meadows remained in good or very good condition and was close to or above the long-term average in 2023 (Figures 11, 13, 15 and 17). Meadow area remained stable in meadow 1 and 3, while area declines and meadow fragmentation caused a downgrading in condition to satisfactory in meadow 5 and 8 (Figures 11, 13, 15 and 17). Species composition remained in very good condition in these meadows (Figures 11, 13, 15 and 17).

The monitoring meadow at the south-east end of Thursday Island (meadow 1) remained in a good condition with decreases in biomass and a small increase in area (Figure 11). In 2023, meadow biomass declined by more than half from 16.2 ± 2.9 g DW m^{-2}, the highest biomass recorded since monitoring began, to 7.14 ± 1.11 g DW m^{-2} (Figure 11, Appendix 2a). Despite this decrease, biomass was above baseline levels and higher than both the 2019 and 2021 surveys. There was a small increase in meadow area from 2.67 ± 0.45 ha in 2022, to 2.83 ± 0.46 ha, this was just above baseline levels and resulted in area maintaining a good score (Table 5, Figure 11). This meadow was once again dominated by *H. uninervis* making up 73% of the meadow composition, with a decrease in the proportion of *T. hemprichii* present, and an increase in the less stable species *H. ovalis* which made up 15% of species composition (Figure 11; Appendix 1).

The only meadow in Thursday Island that did not have any declines in condition in 2023 was meadow 3, located between the Main and Engineer's wharves, which maintained a good overall condition. Biomass and area remained in very good and good condition respectively. Species composition also remained in very good condition, despite an increase in dominance of the less stable species *H. ovalis* which increased from 3.9% of the overall biomass in 2022 to 13% in 2023 (Figure 13, Appendix 1). *Halodule uninervis* remained the dominant species in this meadow and made up 83.6% of meadow biomass.

The *H. uninervis* meadow at the western end of Thursday Island (meadow 5) declined from good to satisfactory condition in 2023. This drop in condition was due to a small reduction in area from 3.4 ± 0.4 ha in 2022 to 2.9 ± 0.4 ha in 2023 (Figure 15, Appendix 2b). Biomass and species composition remained in good and very good condition respectively (Figure 15, Appendix 1; 2a).

The only annual monitoring meadow on the northern side of Thursday Island (meadow 8) declined from very good to satisfactory condition in 2023 (Table 5, Figure 17). Meadow biomass decreased to close to the baseline level from 15.1 ± 1.8 g DW m^{-2} in 2022 to 8.3 ± 1.4 g DW m^{-2} in 2023 but remained in good condition (Figure 17, Appendix 2a). Meadow area decreased from 16.1 ± 1.1 ha in 2022 to 11.4 ± 1.1 ha in 2023, resulting in a change in condition from very good to satisfactory (Figure 17, Appendix 2b). Species composition remained in a very good condition, with an increase in the percentage of *H. uninervis* (Figure 17, Appendix 1).

3.2.2 *Enhalus acoroides* dominated meadows (Meadows 2, 4, 6, 26, 27)

The *E. acoroides* dominated monitoring meadows had a continuous cover of light or moderate *E. acoroides* with mixed species present with the exception of meadow 6 which was dominated by *T. ciliatum* (Figures 12, 14, 16, 18 and 19). All of these meadows declined in biomass in 2023 and meadow 2, 4 and 27 also had overall declines in condition (Table 5). Meadow area remained relatively stable with increases in some meadows, and declines in area scores only seen in meadow 26 and 27 (Figures

18 and 19). Species composition scores declined in meadow 2, 4 and 26 as the percentage of *E. acoroides* declined (Figures 12, 14 and 18).

Thursday Island meadows

The intertidal/subtidal meadow at the south-eastern end of Thursday Island (meadow 2) declined from an overall very good condition in 2022 to satisfactory in 2023 (Figure 12). This decline in condition was driven by a drop in biomass from 59.2 ± 6.5 g DW m^{-2} in 2022 to 34.7 ± 2.5 g DW m^{-2} in 2023 (Figure 12, Appendix 2a). The area of high biomass seagrass present in the centre of this meadow in 2022 was absent in 2023 and seagrass coverage was more patchy overall (Figure 9, 12). Meadow area increased by 0.5 ha compared to 2022 and maintained a very good condition (Figure 12, Appendix 2b). There was a small drop in the percentage of *E. acoroides* in this meadow which led to a decline in the species composition condition from very good to good (Figure 12, Appendix 1).

Overall condition in the smallest *E. acoroides* meadow between the main Thursday Island wharves (meadow 4) decreased again in 2023 to satisfactory (Table 5). This decrease was driven by a decline in biomass from 48.8 ± 10.5 g DW m^{-2} in 2022 to 23.3 ± 4.4 g DW m^{-2} in 2023 and a change in species composition, with a reduction in the biomass made up of *E. acoroides* from 69.9% to 60.2% (Figure 14; Appendix 1). Similar to meadow 2, biomass at meadow 4 was patchier in 2023, and had declined by over half since 2022, resulting in a change in score from very good to satisfactory (Table 5, Figure 9, 14, Appendix 2a). Area remained in very good condition in this meadow (Figure 14, Appendix 2b).

Overall meadow condition of meadow 6 remained in good condition in 2023 (Table 5). Biomass declined from 105.4 ± 32.0 g DW m^{-2} in 2022 to 49.6 ± 8.2 g DW m^{-2} in this meadow in 2023 but remained above baseline levels and was rated as being in good condition (Figure 16, Appendix 2a). The area of this meadow; increased slightly from 12.3 ± 1.1 ha in 2022 to 13.9 ± 1.1 ha in 2023, remaining good and above baseline levels (Figure 16, Appendix 2b). High biomass hotspots were again present in this meadow, dominated by *T. ciliatum* (Figure 9, 16, Appendix 2a). Species composition remained in very good condition with 79.8% of biomass made up of *E. acoroides* and *T. ciliatum* (Figure 16; Appendix 1).

Madge Reef meadows

The intertidal *E. acoroides* meadows at Madge Reef to the south of Thursday Island; meadow 26 and 27 were in good and satisfactory condition respectively in 2023 (Table 5). Biomass declined in both of these meadows, with meadow 26 having a biomass of 44.0 ± 3.9 g DW m^{-2} (good condition), and meadow 27 declining from 75.1 ± 18.32 g DW m^{-2} to the lowest biomass recorded in the history of the monitoring program of 13.9 ± 4.9 g DW m^{-2} (satisfactory) (Figure 18, 19, Appendix 2a).

Area declined slightly in both meadows. In meadow 26 area declined by almost 10 ha and was at the baseline level of 87.8 ± 3.5 ha and in good condition, and meadow 27 declined from 7.6 ± 0.7 ha in 2022 to 5.9 ± 0.7 ha in 2023 (satisfactory condition) (Figure 18, 19). The hotspots of high biomass seen in 2022 were much reduced in 2023 (Figure 10).

Species composition in meadow 26 declined from good to satisfactory condition in 2023 as the percentage of the dominant species *E. acoroides* reduced from 81.6% in 2022 to 55.3% in 2023, whereas *C. serrulata* increased from 0.2% to 19.1% (Figure 18, Appendix 1). In meadow 27, the percentage of *T. ciliatum* declined from 33.2% in 2022 to 16.9% in 2023 but E. *acoroides* increased from 57.7% to 63.6% (Figure 19, Appendix 1).

An area of expanding mangroves has been monitored in this meadow over the course of the program. In 2023 the biomass of seagrass in this mangrove recruitment area was once again lower than the rest of the meadow, possibly due to mangrove establishment (Figure 10).

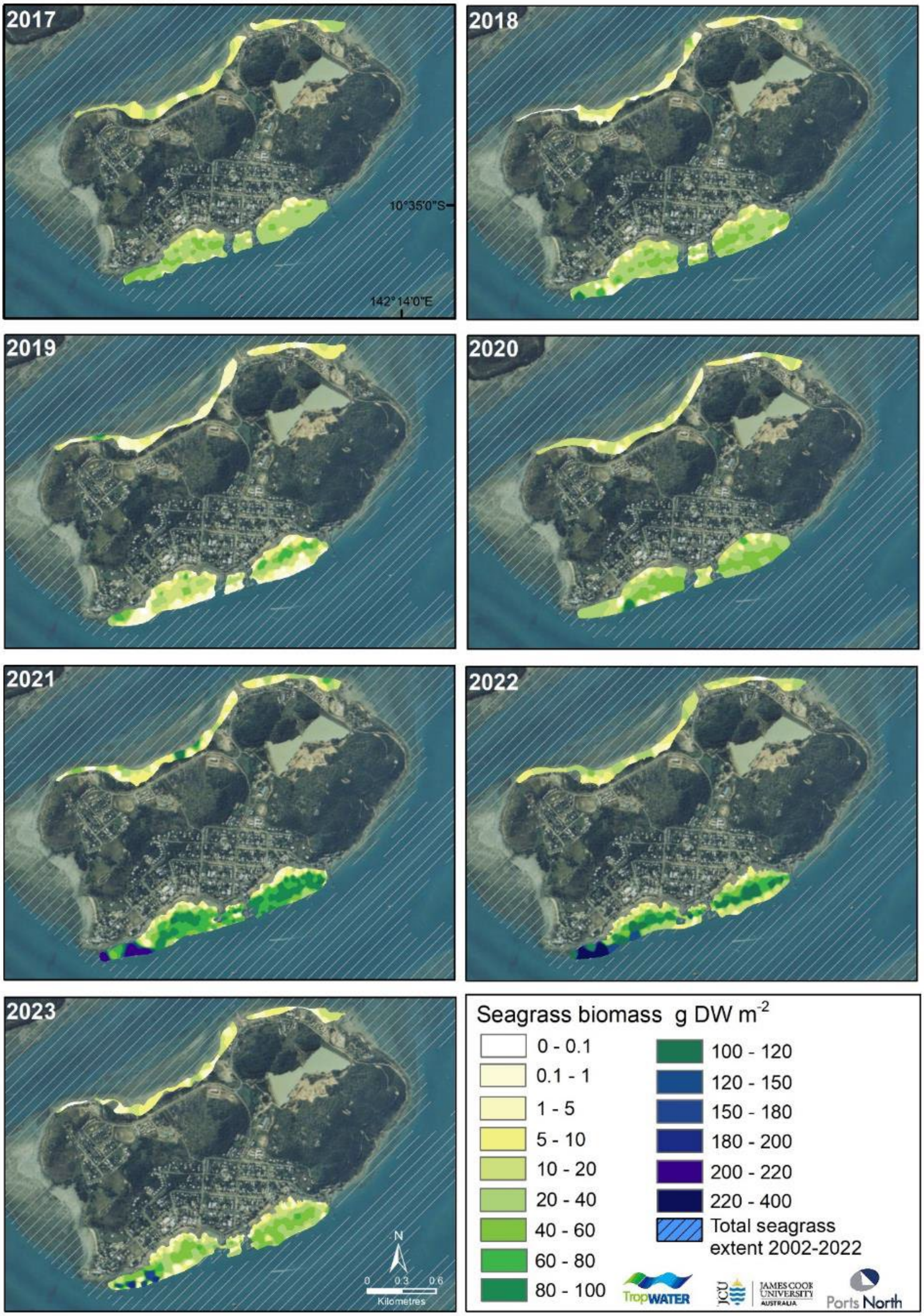

Figure 9 Changes in biomass and area (Meadows 1-6 and 8) in the Port of Thursday Island (2017-2023)

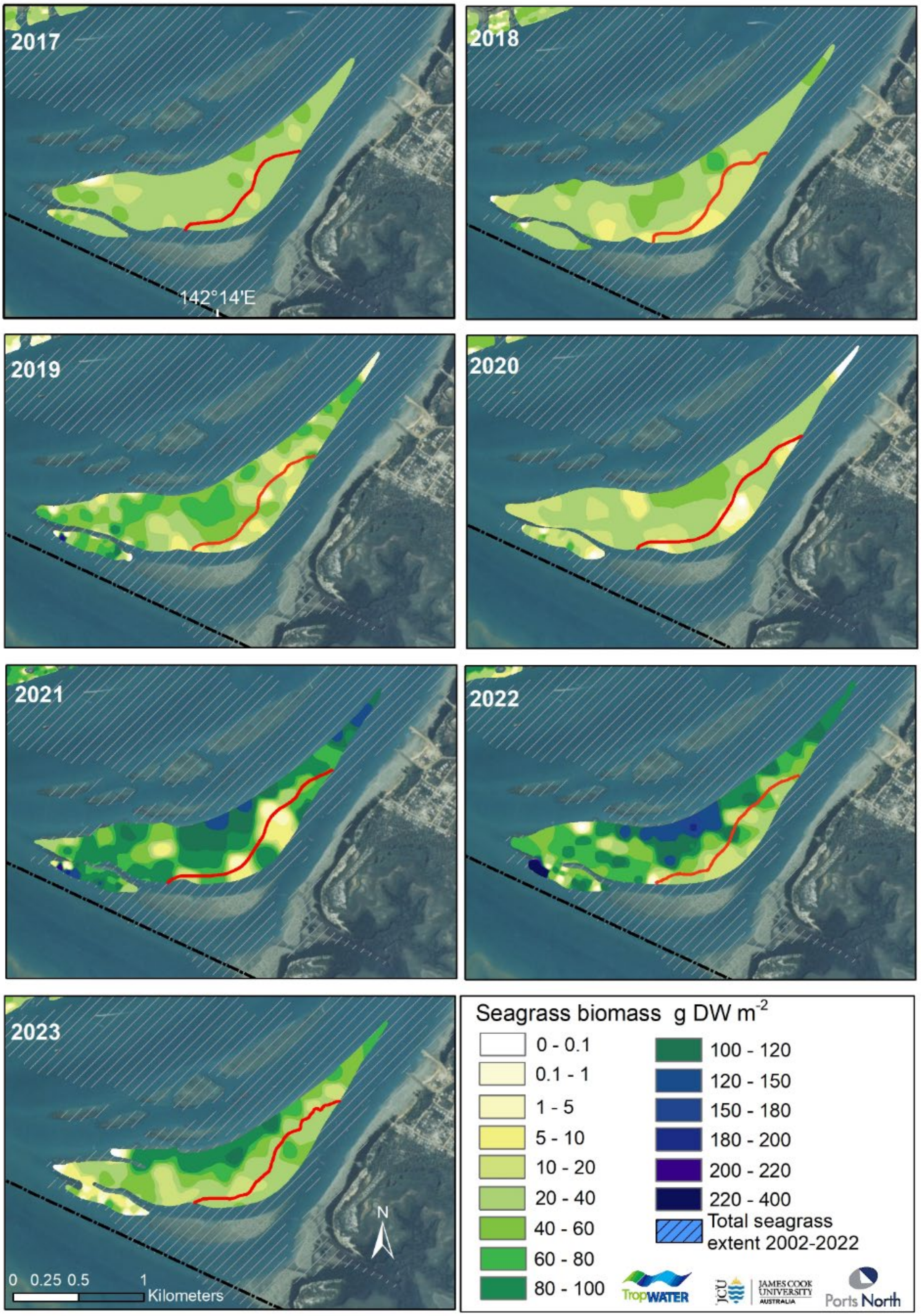

FIGURE 10 CHANGES IN BIOMASS AND AREA (MEADOWS 26 AND 27) IN THE PORT OF THURSDAY ISLAND (2017-2023).

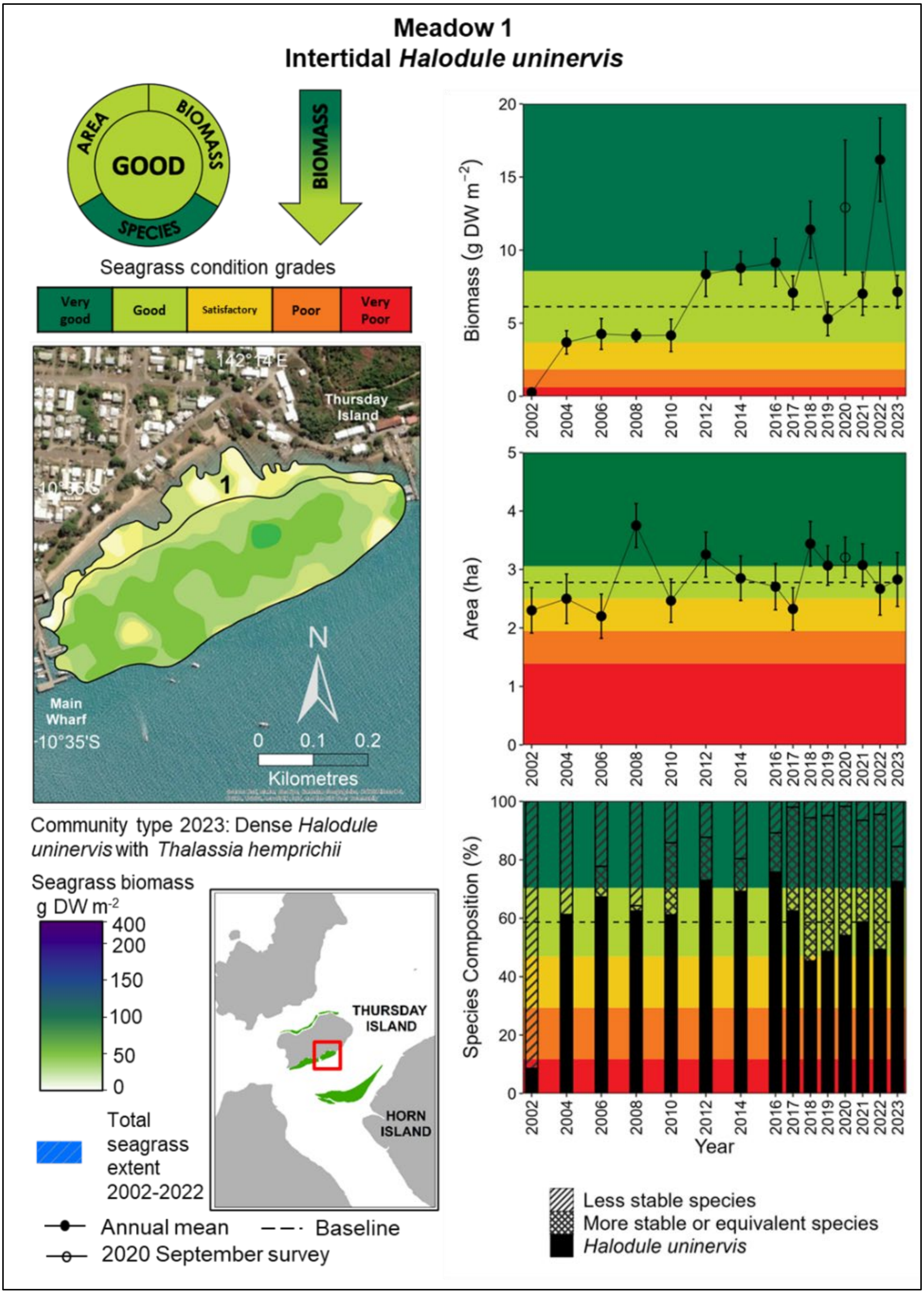

Figure 11 Changes in biomass, area and species composition for the Halodule uninervis dominated monitoring Meadow 1 at Thursday Island from 2002 to 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

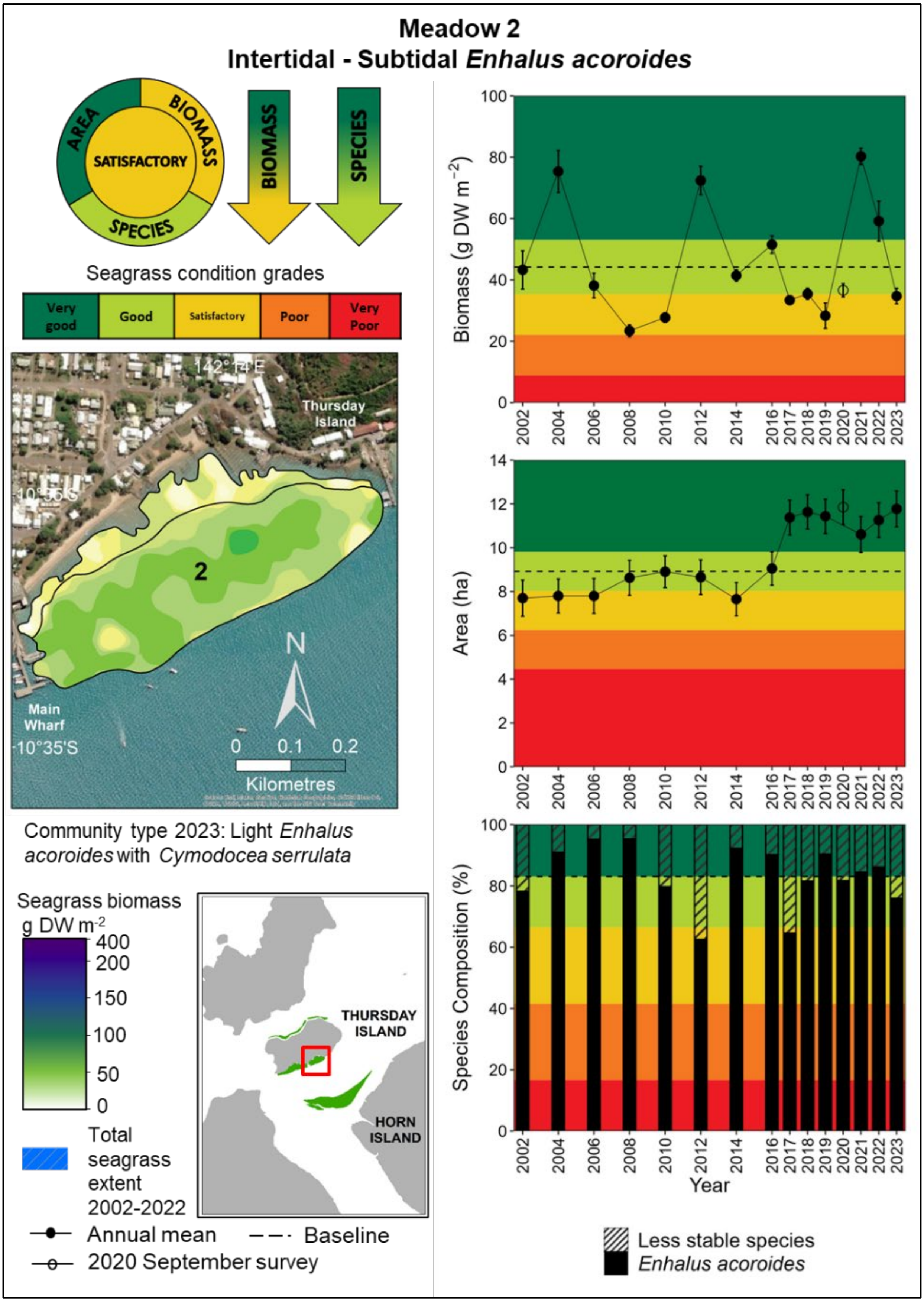

FIGURE 12 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE ENHALUS ACOROIDES DOMINATED MONITORING MEADOW 2 AT THURSDAY ISLAND FROM 2002 TO 2023 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

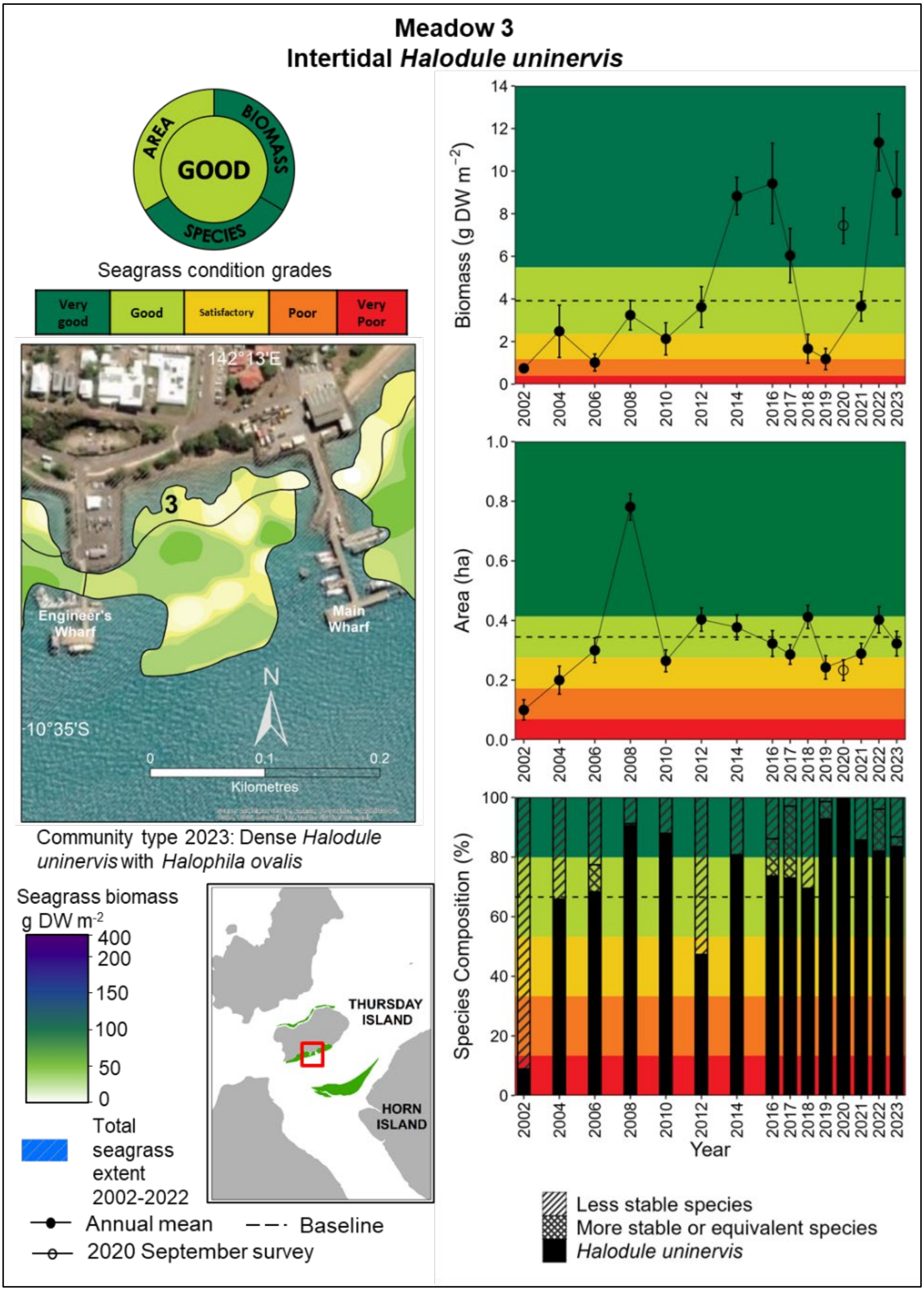

Figure 13 Changes in biomass, area and species composition for the Halodule uninervis dominated monitoring Meadow 3 at Thursday Island from 2002 to 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

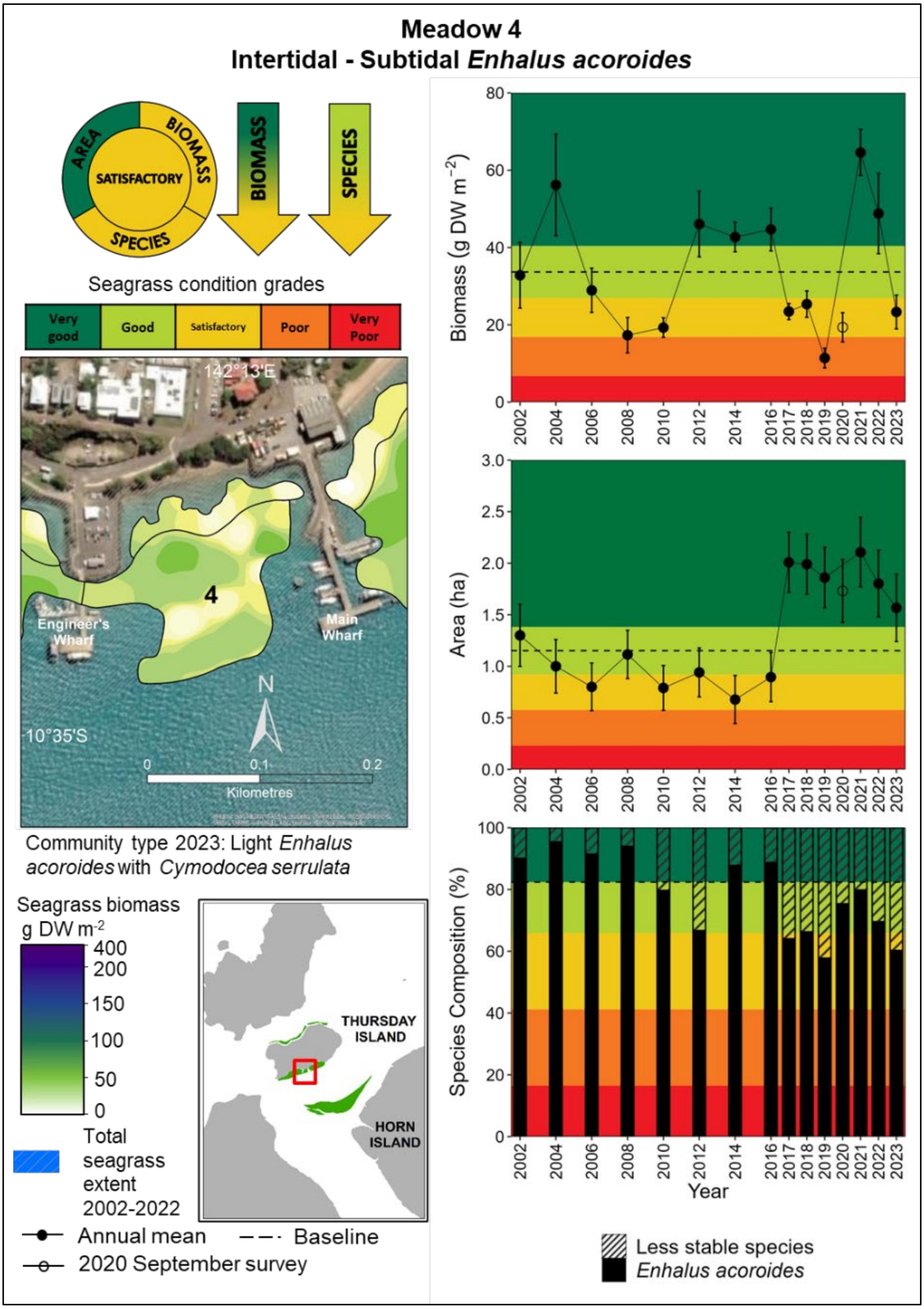

Figure 14 Changes in biomass, area and species composition for the *Enhalus acoroides* dominated monitoring Meadow 4 at Thursday Island from 2002 to 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

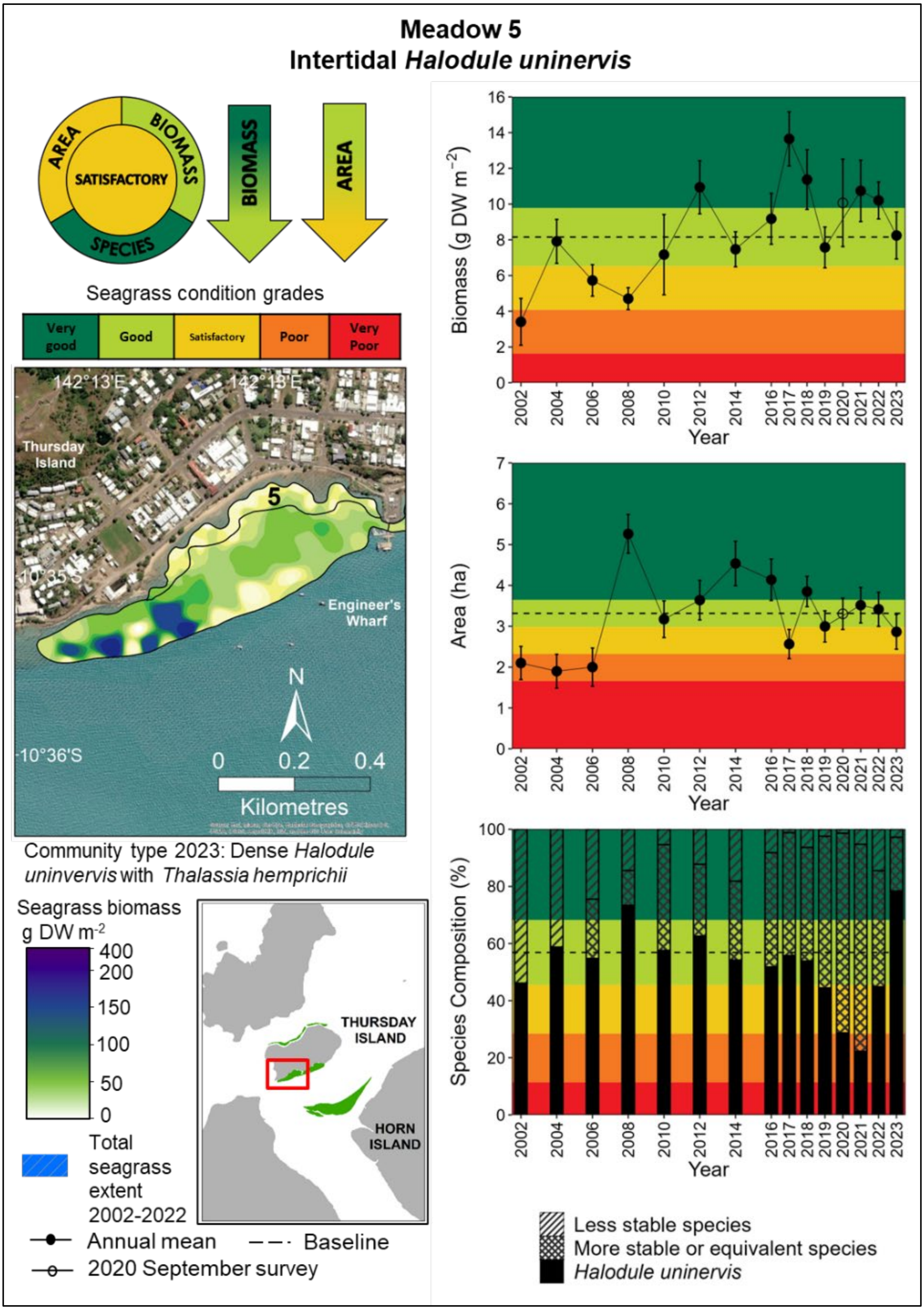

Figure 15 Changes in biomass, area and species composition for the *Halodule uninervis* dominated monitoring Meadow 5 at Thursday Island from 2002 to 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

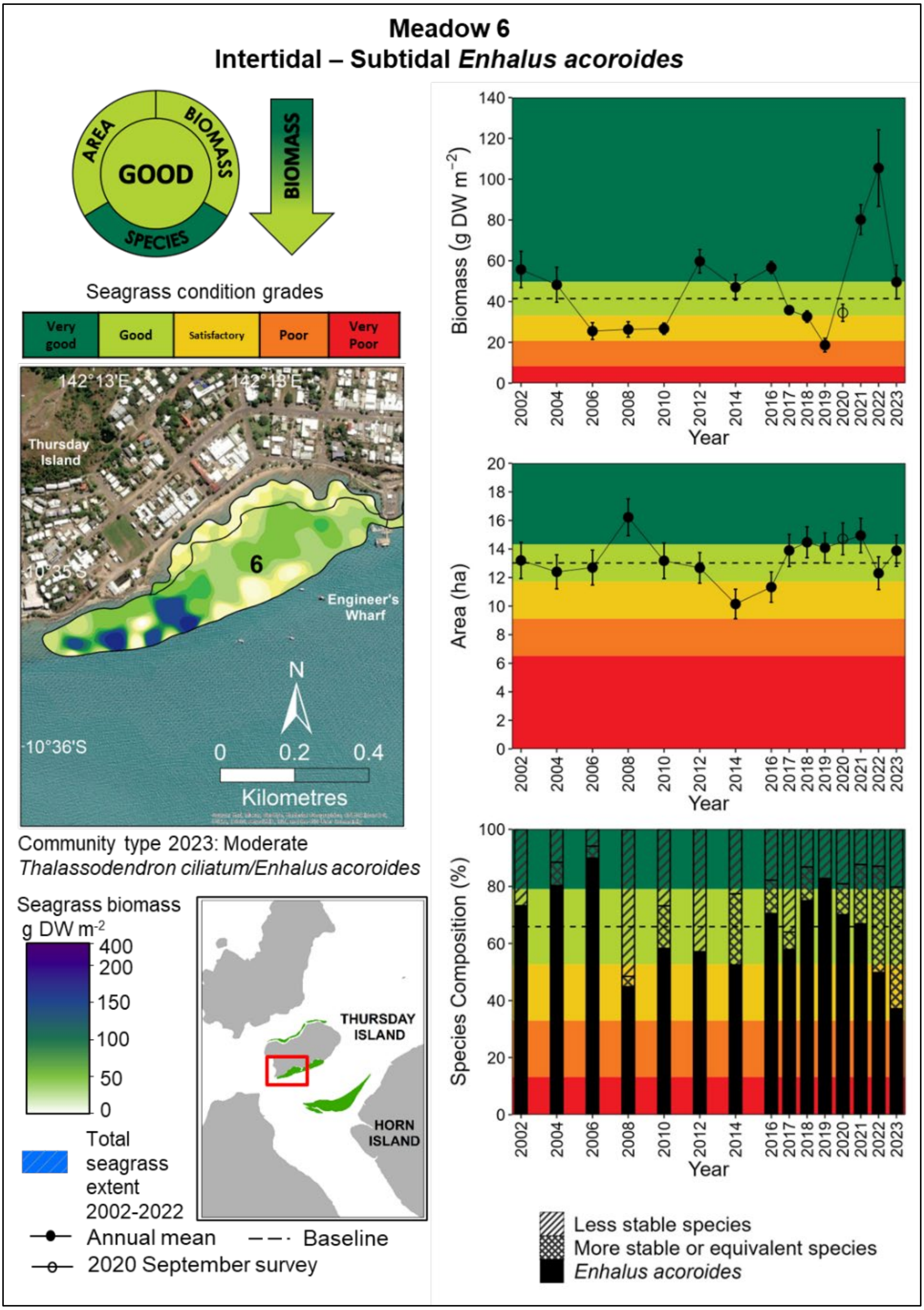

Figure 16 Changes in biomass, area and species composition for the Enhalus acoroides dominated monitoring Meadow 6 at Thursday Island from 2002 to 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

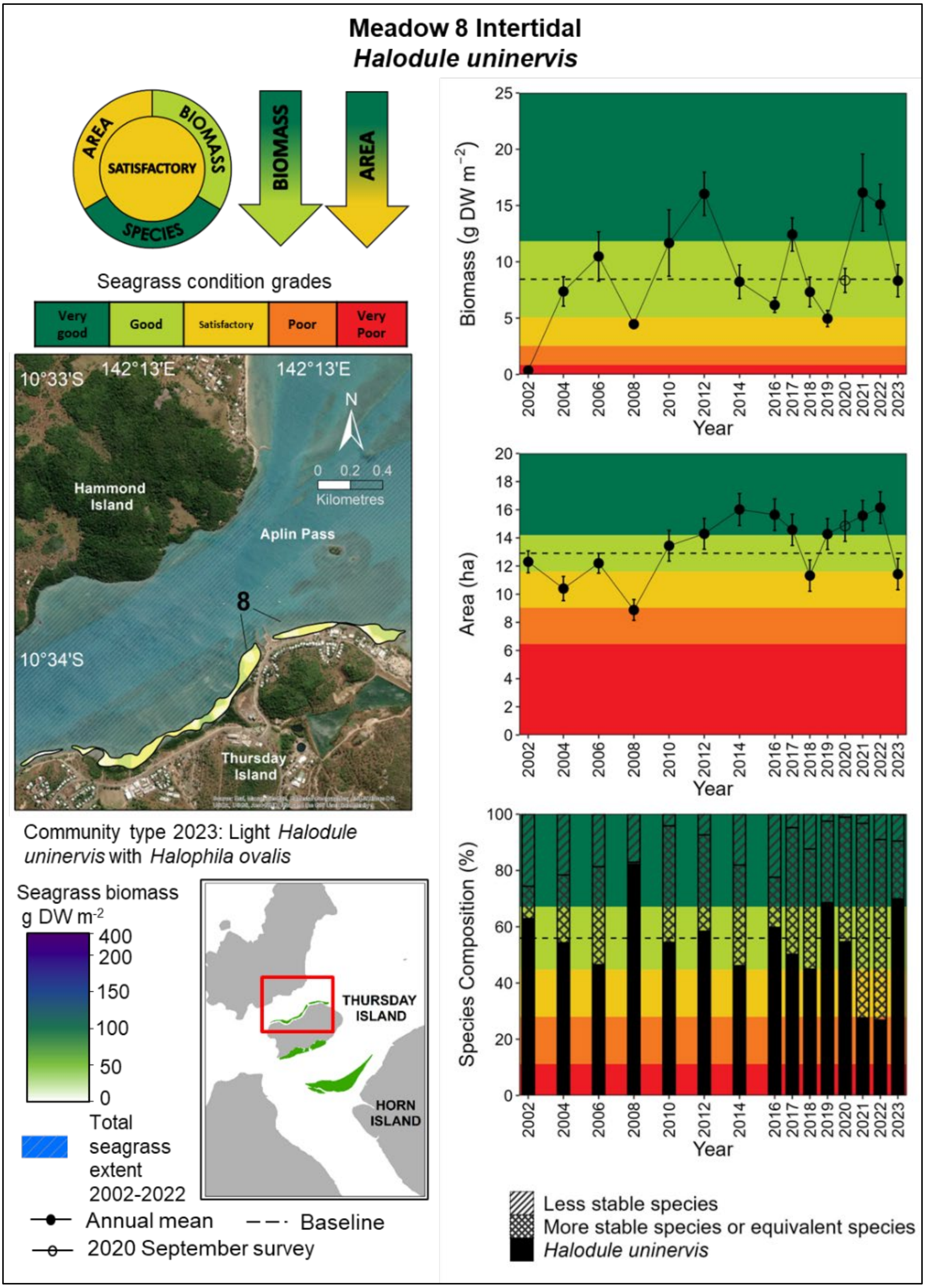

Figure 17 Changes in biomass, area and species composition for the Halodule uninervis dominated monitoring Meadow 8 at Thursday Island from 2002 to 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

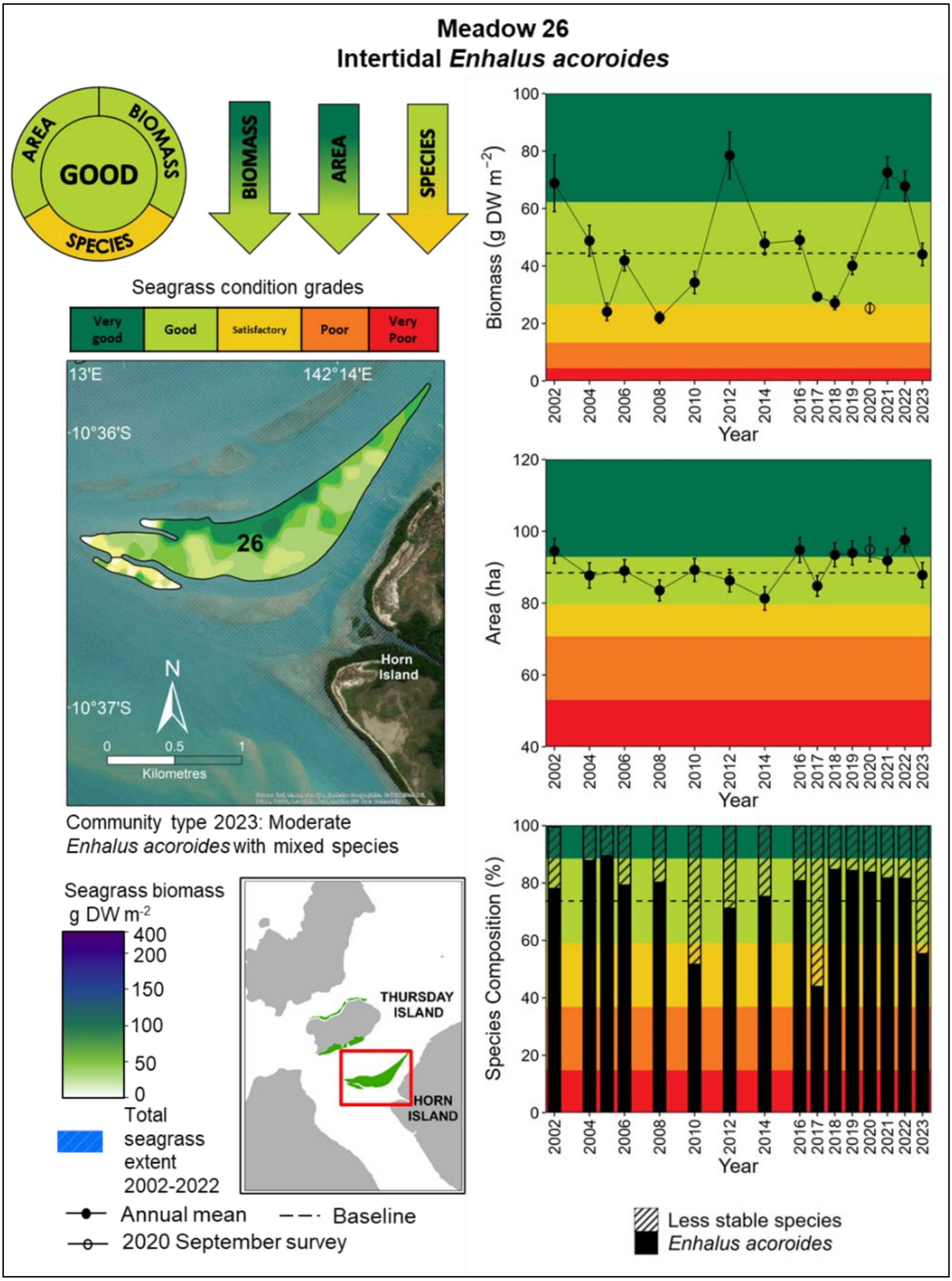

FIGURE 18 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE ENHALUS ACOROIDES DOMINATED MONITORING MEADOW 26 AT MADGE REEFS FROM 2002 TO 2023 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

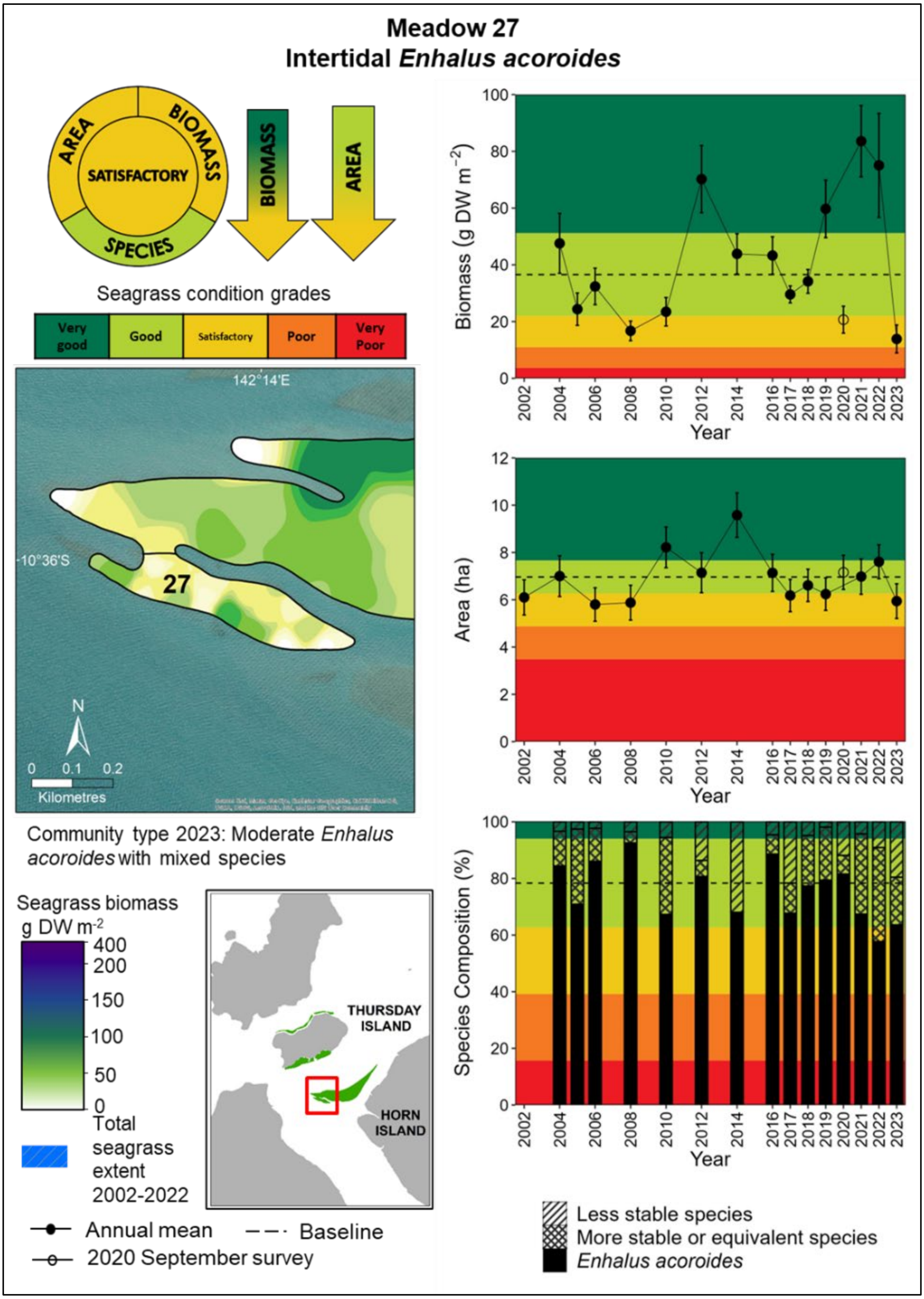

Figure 19 Changes in biomass, area and species composition for the Enhalus acoroides dominated monitoring Meadow 27 at Madge Reefs from 2002 to 2023 (biomass error bars = SE; area error bars = "R" reliability estimate).

3.3 THURSDAY ISLAND ENVIRONMENTAL CONDITIONS

3.3.1 RAINFALL

Total annual rainfall in the Thursday Island area in the 12 months leading up to the 2023 survey was well above the long-term average (Figure 20). This was driven by above-average rainfall in December 2022 and January 2023, however the survey month (March 2023) had below-average rainfall (Figure 21).

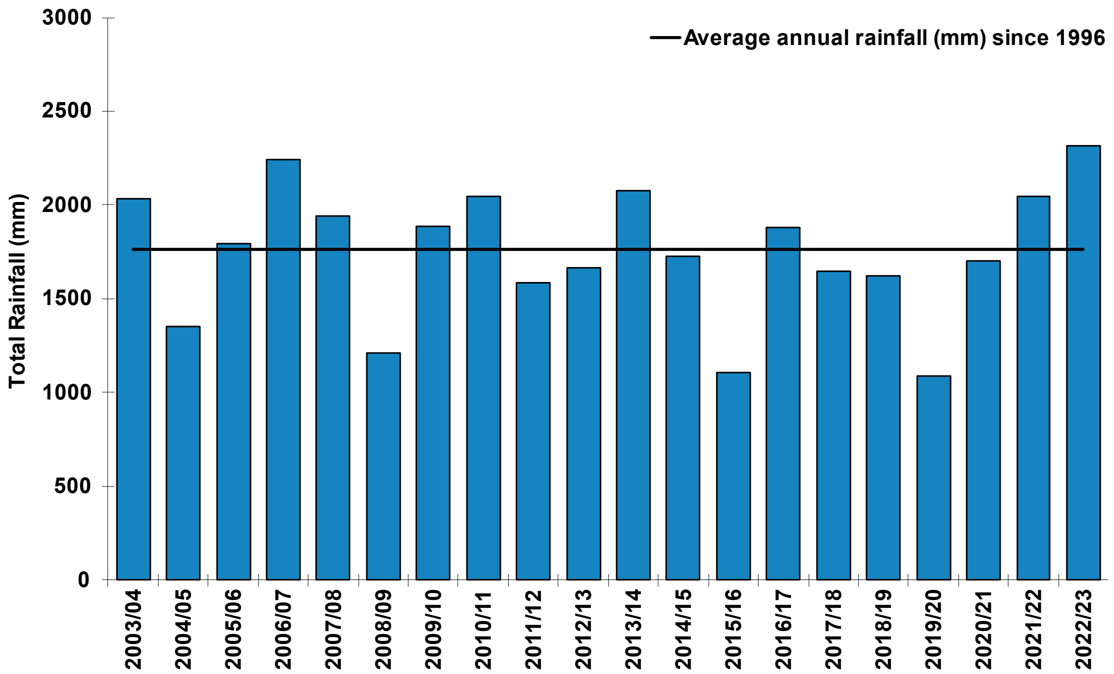

FIGURE 20 TOTAL ANNUAL RAINFALL (MM) RECORDED AT HORN ISLAND, 2003/04 – 2022/23, IN EACH 12 MONTHS PRIOR TO SEAGRASS SURVEY.

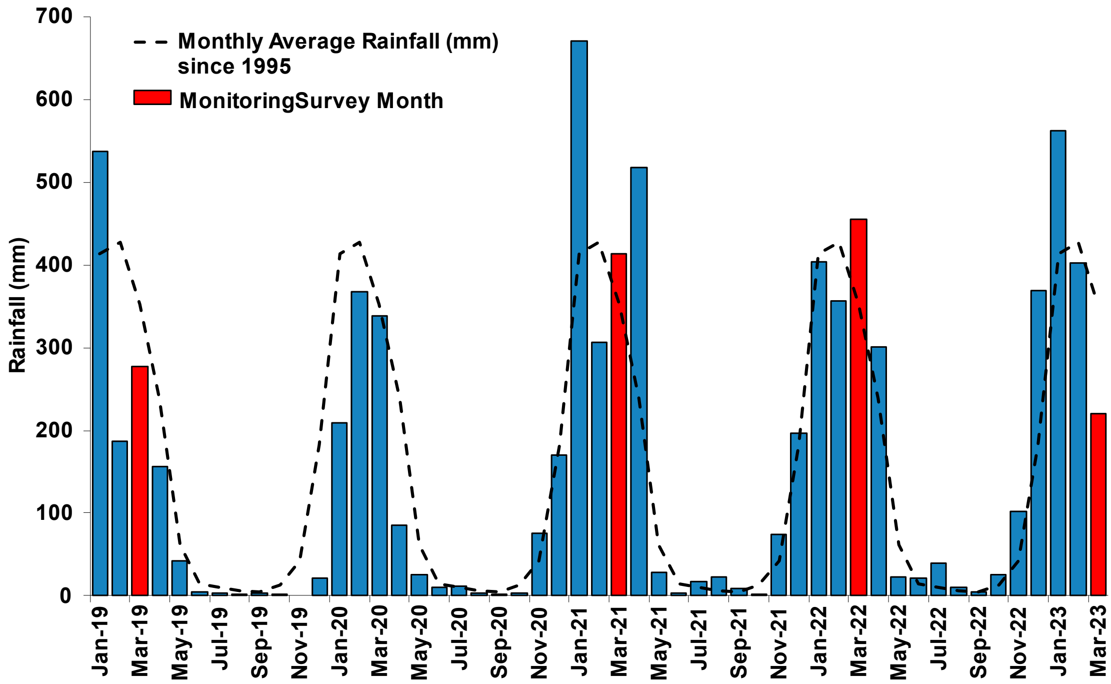

FIGURE 21 TOTAL MONTHLY RAINFALL (MM) RECORDED AT HORN ISLAND, JANUARY 2019 - MARCH 2023.

3.3.2 Air Temperature

The annual average maximum daily air temperature has remained above the long-term average of 30.48°C since 2015/16 (Figure 22). Temperatures were well above-average from September to November 2022 and were also above-average in the survey month March 2023 (Figure 23).

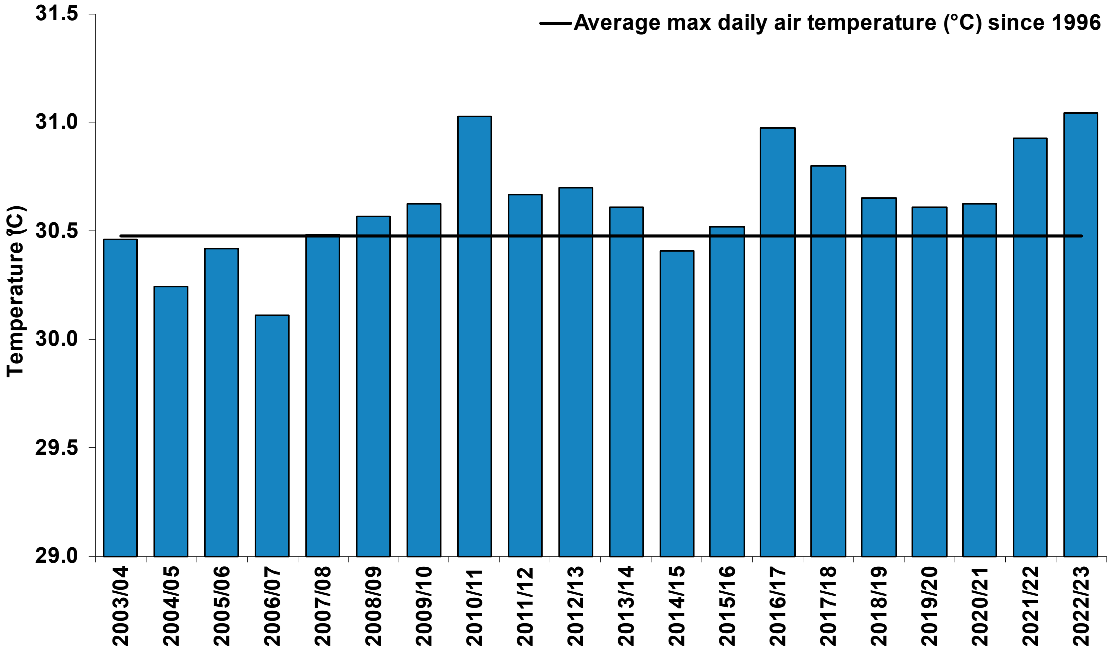

Figure 22 Mean maximum daily air temperature (°C) recorded at Horn Island, 2003/04 - 2022/23. Twelve month year is twelve months prior to survey.

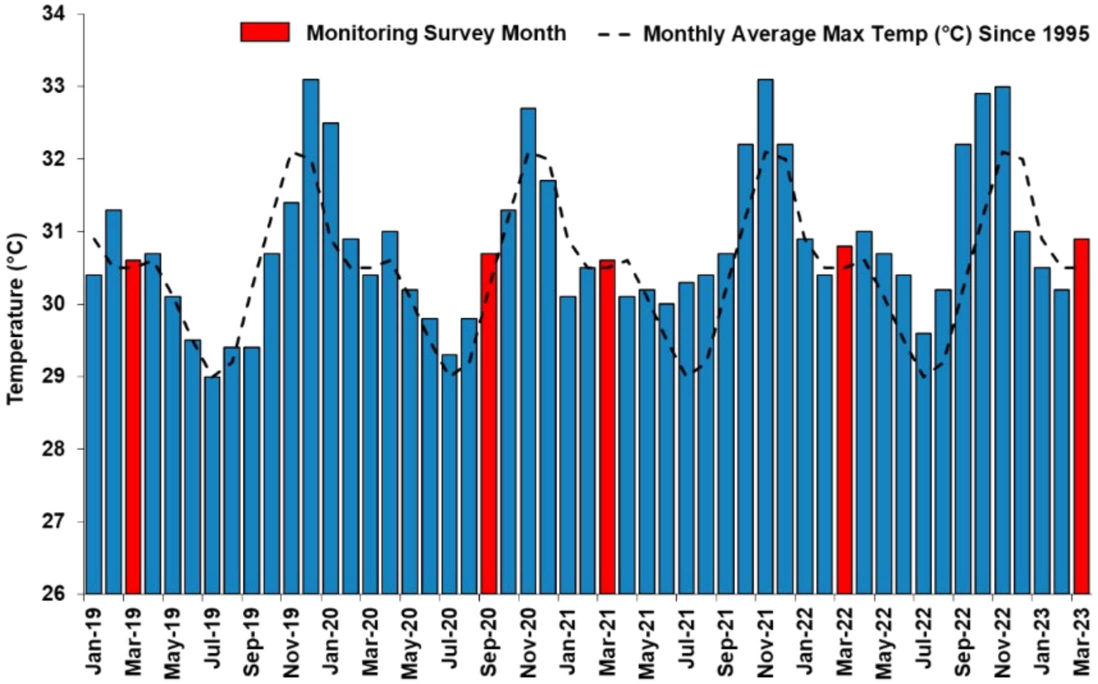

Figure 23 Monthly mean maximum daily air temperature (°C) recorded at Horn Island, January 2019 – March 2023.

3.3.3 Daily Global Solar Exposure

Daily global solar exposure is a measure of the total amount of solar energy falling on a horizontal surface in one day. Values are generally highest in clear sun conditions during spring/summer and lowest during winter. Global solar exposure in the area was below-average in 2022/23 at 20.76 MJ m^{-2} (MegaJoules m^{-2}) (Figure 24), monthly values were close to or below the average in the 12 months prior to the survey but was above-average in March 2023 (Figure 25).

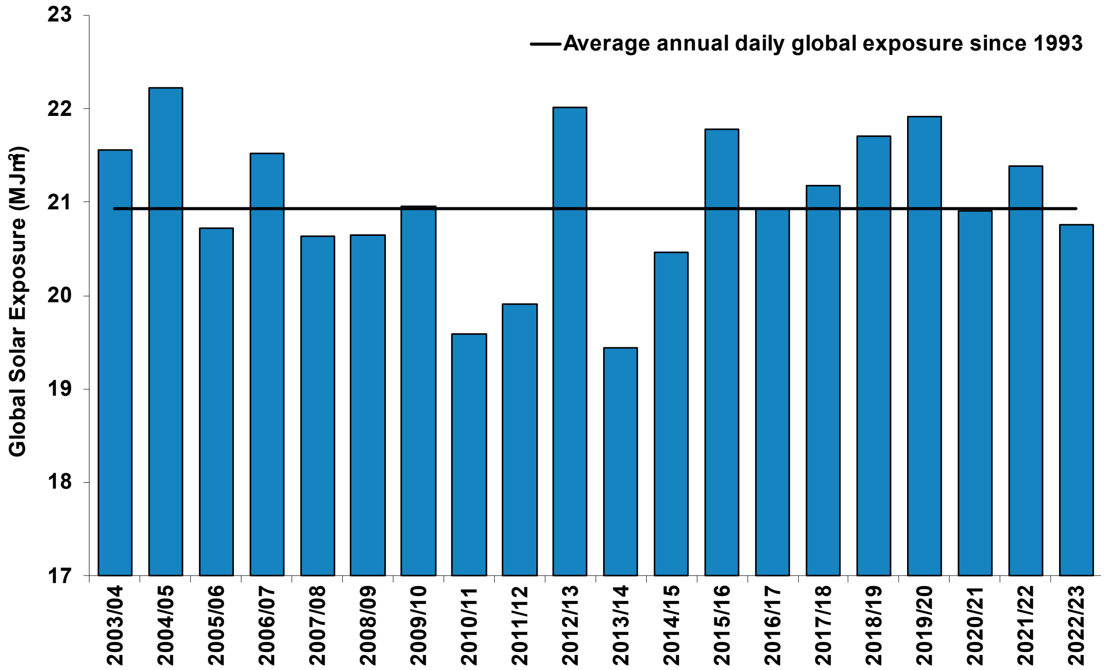

Figure 24 Mean daily global exposure (MegaJoules m^{-2}) recorded at Horn Island, 2003/04 – 2022/23. Twelve month year is twelve months prior to survey.

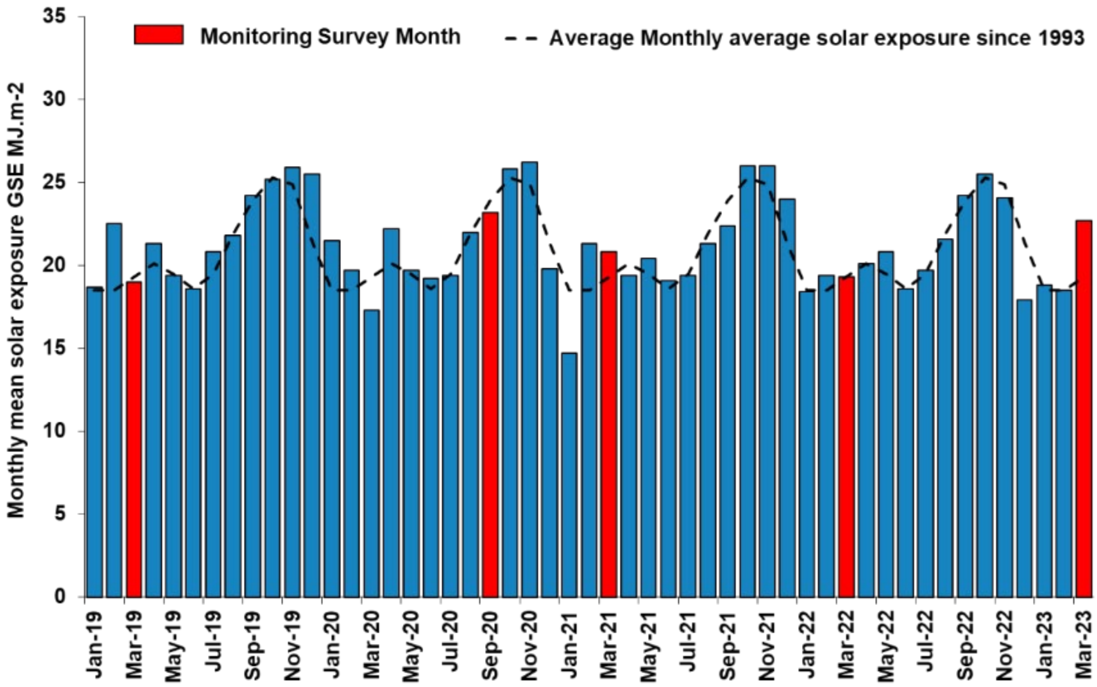

Figure 25 Mean daily global solar exposure (MegaJoules m^{-2}) recorded at Horn Island, January 2019 - March 2023.

3.3.4 Tidal Exposure of Seagrass Meadows

Annual daytime exposure to air for intertidal seagrass was above-average in 2023 (Figure 26). Intertidal banks were exposed for a total of 194 daytime hours in the 12 months prior to the survey (Figure 26). Monthly daytime exposure to air was also below-average in the year prior to the survey, with the exception of February 2022 (Figure 27).

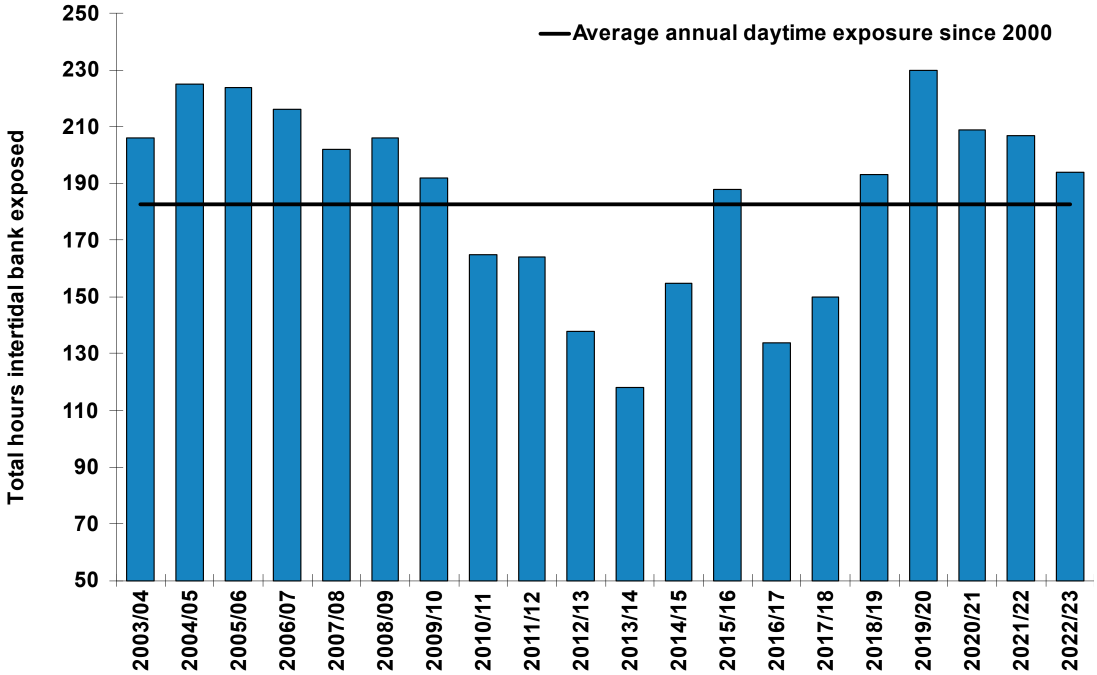

Figure 26 Total hours daytime exposure (annual) of intertidal seagrass in The Port of Thursday Island; 2003/04 – 2022/23. Twelve month year is twelve months prior to survey. *Assumes intertidal banks become exposed at a tide height <0.8m above Lowest Astronomical Tide.

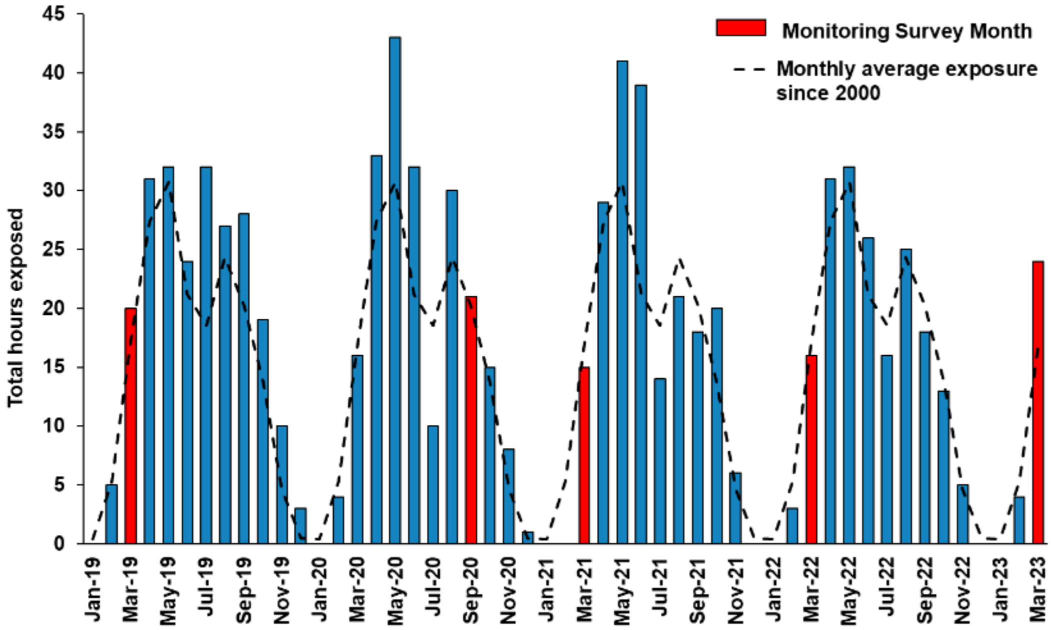

Figure 27 Total hours of daytime exposure (monthly), January 2019 to March 2023. *Assumes intertidal banks become exposed at a tide height <0.8m above Lowest Astronomical Tide. Predicted data used for Jan-Mar 2023 as gauge was not operational.

4 DISCUSSION

Seagrasses in the Port of Thursday Island maintained an overall good condition in 2023, for the third consecutive year. Although there were some declines in meadow condition, all meadows were in satisfactory or good condition. Total meadow area declined but remained just below the long-term average, and much of this decline was driven by expansion of the subtidal non-monitoring meadows into areas previously occupied by the intertidal monitoring meadows, and as such does not represent a true loss in overall seagrass. Overall species composition remained stable, with some decreases in dominance of *E. acoroides*.

Biomass declines in all but one monitoring meadow resulted in downgrading of biomass scores in 2023 for most meadows at Thursday Island. This was driven by declines across the meadow as a whole but was also due to fewer high biomass hotspots being present in the monitoring meadows. These biomass values were within the natural fluctuations seen in previous years, and only three meadows had dropped below their baseline averages. The smaller meadow off Madge Reef (Meadow 27), had the largest biomass decline. This meadow is located on the reef top and seagrass is found amongst the coral. In 2023 the survey team noted that the seagrass here looked much shorter, and there may have been some targeted grazing by dugongs or green turtles leading to these declines. Both *E. acoroides* and *T. ciliatum* had reduced in their abundance which would also impact meadow biomass. Despite these reductions, all of the meadows at Thursday Island maintained a continuous coverage of seagrass and were well within previous ranges of biomass recorded in the program.

In 2022 seagrass species in the port as a whole had shifted towards the more stable species *E. acoroides* and *T. ciliatum*, but in 2023 there was a shift back towards less stable species in the monitoring meadows. This is likely to be due to natural fluctuations within these meadows, however any future shifts in species should be monitored closely, as similar shifts have been a precursor to larger scale declines in other parts of Torres Strait (Carter et al. 2020, 2021).

There were no major weather events that were likely to have impacted on seagrass condition in 2022. Environmental factors were favourable for seagrass growth through much of 2022 and 2023, however both rainfall and air temperatures were above average and may have been somewhat less favourable for seagrass growth than previous years. Annual air temperature was above average, due to peaks in summer months (particularly from September to November), however tidal exposure was around average in these months, meaning the seagrass blades were likely less susceptible to exposure related stress such as desiccation and leaf burning at low tide. The period of tidal exposure found to be most influential on *E. acoroides* growth is the month prior to observation (Unsworth et al. 2012), although the tide gauge was not operational during this period, predicted values show that the exposure was high during this period, which may have impacted *E. acoroides*, particularly in the shallower reef top communities.

The seagrasses around Thursday Island were reproducing sexually, the survey team observed both *S. isoetifolium* and *E. acoroides* flowers during the survey. Although asexual reproduction is the most important mechanism for recolonisation after disturbance in many tropical seagrass meadows, the presence of a seed bank and production of seeds is also important in terms of recovery from large scale impacts (Rasheed 2004, Rasheed et al 2014).

The seagrass around Thursday Island is likely to be an important feeding ground for dugongs and green turtles, especially given the declines in seagrass observed nearby in the Western Cluster (Carter et al. 2020, 2021). Although no large herbivores were observed in the 2023 survey, there was evidence of grazing in some areas with cropped seagrass leaves and dugong feeding trails. These types of seagrass meadows are an important food source for a range of herbivore groups (Scott et al. 2018), and experiments have shown there is high herbivory pressure at sites in the region where seagrass meadows have declined (Scott et al. 2022). As both dugongs and green turtles can move large distances to feed in Torres Strait (Cleguer et al., 2016, Gredzens et al., 2014) the healthy seagrass around Thursday Island may become even more important as a foraging ground, should the declines in other neighbouring regions continue.

The 2023 Thursday Island seagrass survey shows the monitoring meadows have remained in a good condition. Some declines in meadows have been observed and will be monitored going forward, but these meadows remain healthy and resilient to disturbance. Seagrass condition in the Port of Thursday Island is a key indicator of overall marine environmental health, with the 2023 results indicating a healthy marine environment in the port, and most meadows likely to be resilient to pressures that may affect seagrass growth during 2023. The results of this program also form a critical component to the Torres Strait regional seagrass report that incorporates community and JCU monitoring in the broader Torres Strait region (Carter et al 2021).

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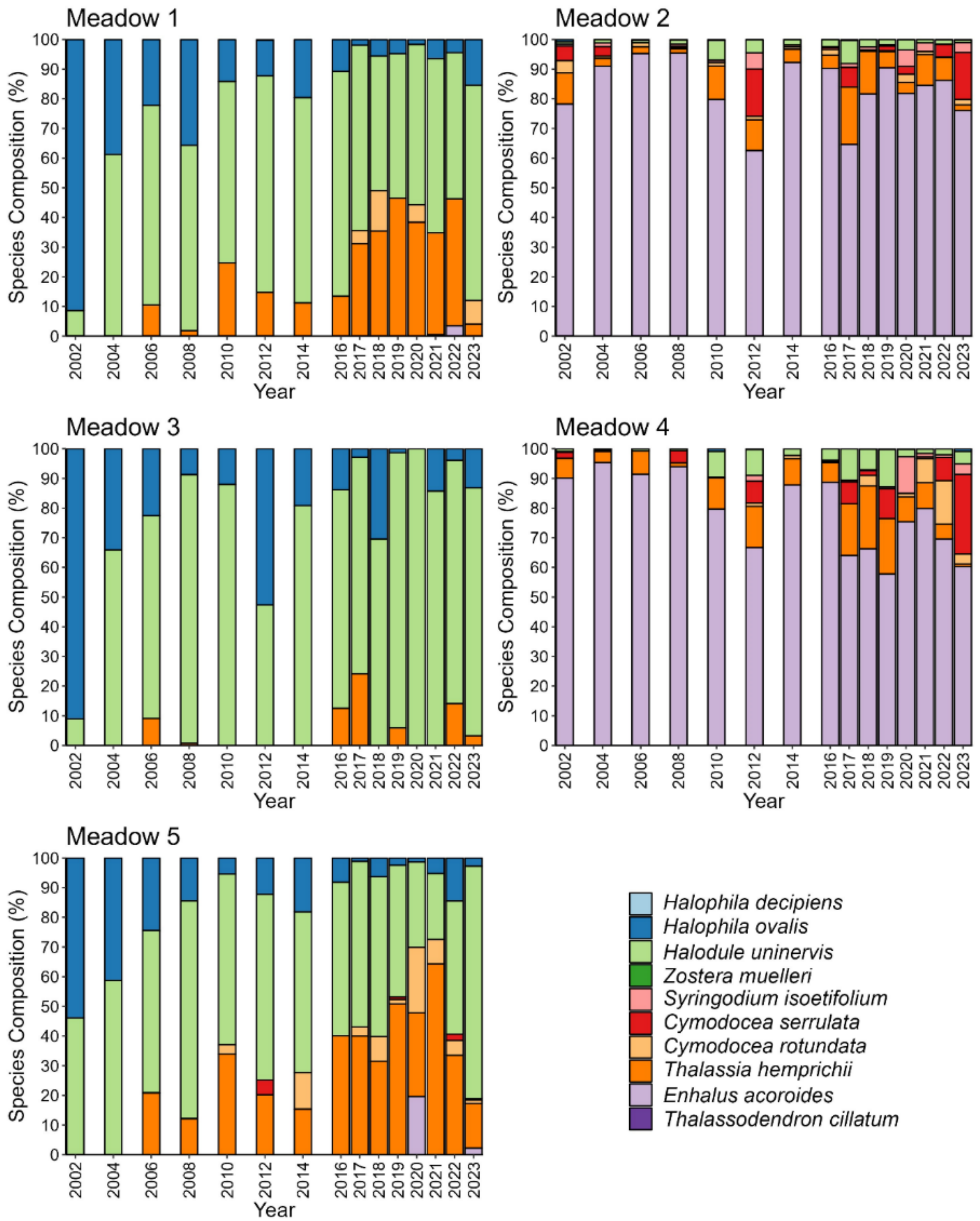
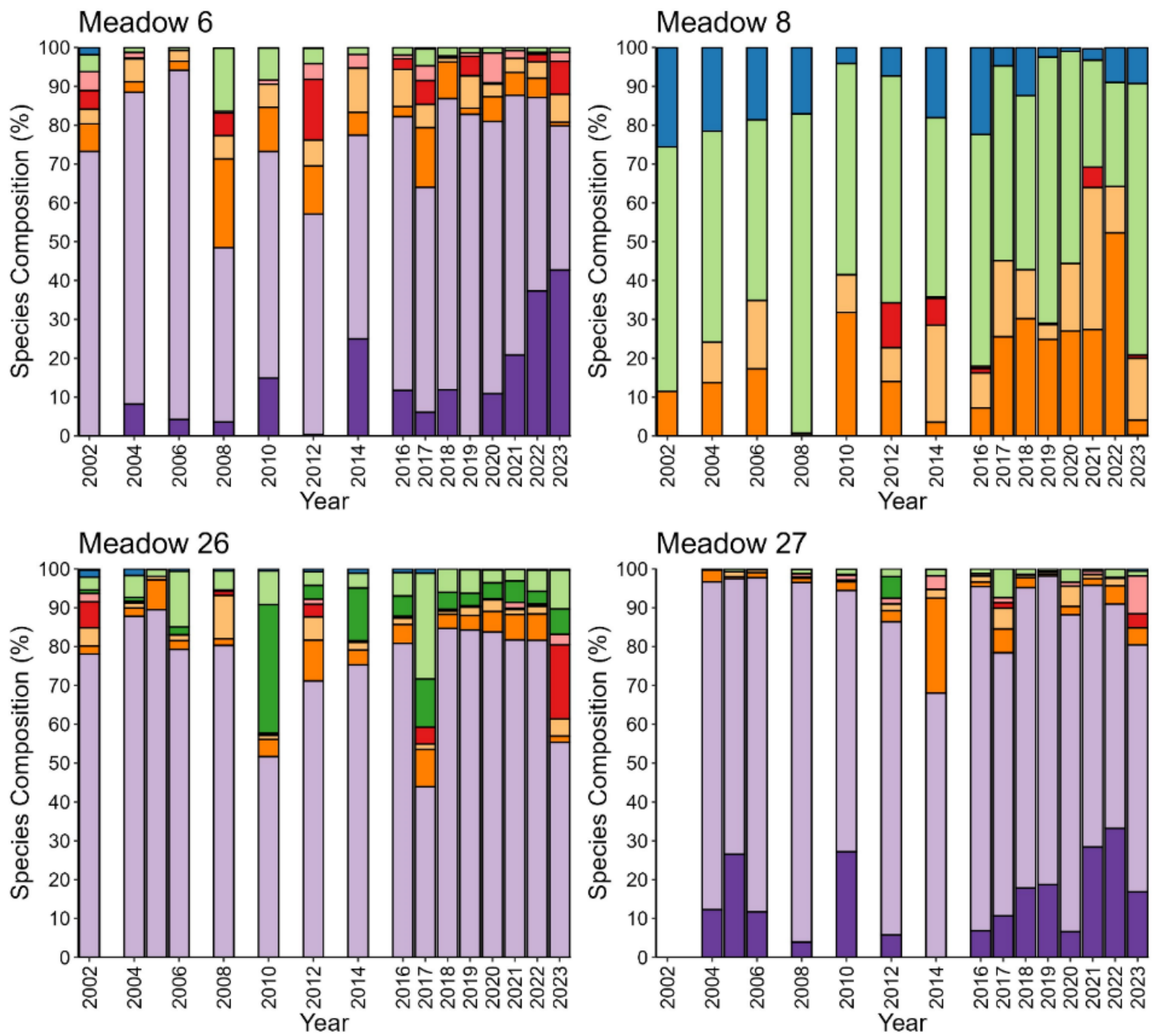
6 APPENDICIES

APPENDIX 1. SEAGRASS SCORE CALCULATION

Species composition of monitoring meadows in the Port of Thursday Island; 2002–2023.




Meadow 6
Meadow 8
Meadow 26
Meadow 27
Species Composition (%)
Year
0
10
20
30
40
50
60
70
80
90
100
2002
2004
2006
2008
2010
2012
2014
2016
2017
2018
2019
2020
2021
2022
2023

APPENDIX 4A

Mean above-ground seagrass biomass (g DW m^{-2}) ± standard error and number of biomass sampling sites (in brackets) for each monitoring meadow within the Port of Thursday Island, 2002–2023.

Monitoring Meadow	Mean Biomass ± SE (g DW m^{-2}) (no. of sites)															
	March 2002	March 2004	March 2005	March 2006	March 2008	February 2010	February 2012	February 2014	March 2016	March 2017	April 2018	March 2019	September 2020	March 2021	March 2022	March 2023
1 Intertidal *Halodule* dominated	0.27 ± 0.13 (10)	3.69 ± 0.80 (28)		4.26 ± 1.05 (23)	4.15 ± 0.43 (22)	4.17 ± 1.11 (27)	8.35 ± 1.53 (17)	8.77 ± 1.13 (25)	9.15 ± 1.64 (25)	7.08 ± 1.15 (26)	10.98 ± 0.81 (25)	5.3 ± 1.16 (19)	12.91 ± 4.61 (14)	7.01 ± 1.48 (23)	16.18 ± 2.86 (21)	7.14 ± 1.12 (26)
2 Subtidal *Enhalus* dominated	43.26 ± 6.25 (12)	75.38 ± 6.85 (14)		38.16 ± 4.04 (20)	23.40 ± 1.95 (19)	27.73 ± 1.56 (35)	72.41 ± 4.63 (25)	41.46 ± 1.90 (34)	51.53 ± 2.85 (34)	33.40 ± 1.22 (37)	35.45 ± 1.82 (43)	28.32 ± 4.13 (39)	36.62 ± 2.17 (29)	80.29 ± 2.69 (41)	59.18 ± 6.51 (35)	34.73 ± 2.51 (41)
3 Intertidal *Halodule* dominated	0.75 ± 0.07 (3)	2.48 ± 1.23 (7)		1.02 ± 0.40 (8)	3.24 ± 0.69 (9)	2.13 ± 0.75 (12)	3.62 ± 0.95 (5)	8.83 ± 0.88 (5)	9.42 ± 1.89 (9)	6.04 ± 1.27 (8)	1.66 ± 0.68 (8)	1.18 ± 0.5 (11)	7.44 ± 0.84 (2)	3.65 ± 0.70 (9)	11.35 ± 1.33 (13)	8.97 ± 1.95 (10)
4 Subtidal *Enhalus* dominated	32.80 ± 8.49 (14)	56.19 ± 13.10 (6)		28.92 ± 5.71 (5)	17.30 ± 4.56 (5)	19.27 ± 2.52 (17)	46.07 ± 8.46 (17)	42.70 ± 3.81 (14)	44.66 ± 5.54 (12)	23.44 ± 2.09 (18)	25.34 ± 3.41 (21)	11.4 ± 2.54 (19)	19.36 ± 3.77 (9)	64.57 ± 5.96 (21)	48.79 ± 10.39 (15)	23.32 ± 4.37 (15)
5 Intertidal *Halodule* dominated	3.41 ± 1.31 (8)	7.91 ± 1.23 (26)		5.73 ± 0.88 (25)	4.71 ± 0.62 (26)	7.17 ± 2.25 (18)	10.94 ± 1.49 (21)	7.47 ± 0.98 (24)	9.18 ± 1.42 (20)	13.65 ± 1.52 (20)	11.37 ± 1.69 (35)	7.57 ± 1.14 (30)	10.07 ± 2.45 (13)	10.74 ± 1.72 (34)	10.20 ± 1.04 (40)	8.24 ± 1.32 (35)
6 Subtidal *Enhalus* dominated	55.71 ± 8.91 (15)	48.22 ± 8.54 (18)		25.52 ± 4.14 (22)	26.34 ± 3.76 (24)	26.70 ± 2.77 (50)	59.74 ± 5.72 (27)	47.03 ± 6.29 (34)	56.74 ± 2.94 (43)	35.81 ± 1.35 (48)	32.64 ± 2.81 (49)	18.65 ± 3.36 (35)	34.49 ± 4.21 (28)	80.17 ± 7.33 (41)	105.44 ± 18.78 (32)	49.56 ± 8.29 (40)
8 Intertidal *Halodule* dominated	0.36 ± 0.25 (5)	7.37 ± 1.31 (31)		10.48 ± 2.18 (31)	4.46 ± 0.39 (32)	11.67 ± 2.95 (23)	16.04 ± 1.92 (31)	8.23 ± 1.49 (48)	6.17 ± 0.67 (55)	12.43 ± 1.48 (33)	7.32 ± 1.32 (43)	4.96 ± 0.72 (36)	8.34 ± 1.07 (39)	16.15 ± 3.41 (45)	15.09 ± 1.78 (39)	8.32 ± 1.43 (33)
26 Intertidal *Enhalus* dominated	68.81 ± 9.83 (18)	48.78 ± 5.37 (31)	24.08 ± 3.03 (25)	41.89 ± 3.54 (32)	22.01 ± 1.97 (33)	34.24 ± 3.86 (33)	78.47 ± 8.11 (26)	47.84 ± 3.96 (33)	49.01 ± 3.19 (40)	29.33 +/- 1.53 (38)	27.14 ± 2.30 (41)	40.1 ± 3.08 (61)	25.28 ± 1.84 (49)	72.56 ± 5.39 (50)	67.77 ± 5.25 (60)	44.03 ± 3.92 (54)
27 Intertidal *Enhalus* dominated	N/A (1)	47.57 ± 10.55 (13)	24.36 ± 5.71 (8)	32.38 ± 6.44 (10)	16.72 ± 3.45 (10)	23.45 ± 5.02 (25)	70.20 ± 11.85 (20)	43.85 ± 7.08 (21)	43.28 ± 6.60 (16)	29.57 +/- 2.98 (15)	34.16 ± 4.18 (15)	59.72 ± 10.15 (20)	20.66 ± 4.74 (16)	83.57 ± 12.55 (21)	75.05 ± 18.32 (22)	13.86 ± 4.92 (19)

APPENDIX 4B

Total meadow area + R (ha) for each monitoring meadow within the Port of Thursday Island, 2002 – 2023.

Monitoring Meadow	Total meadow area + R (ha)														
	March 2002	March 2004	March 2006	March 2008	February 2010	February 2012	February 2014	March 2016	March 2017	April 2018	March 2019	September 2020	March 2021	March 2022	March 2023
1 Intertidal *Halodule* dominated	2.30 ± 0.80	2.50 ± 0.90	2.20 ± 0.80	3.75 ± 0.19	2.47 ± 0.74	3.25 ± 0.77	2.85 ± 0.77	2.71 ± 0.79	2.32 ± 0.73	3.44 ± 0.77	3.07 ± 0.34	3.20± 0.35	3.07± 0.37	2.70± 0.45	2.82± 0.46
2 Subtidal *Enhalus* dominated	7.70 ± 2.30	7.80 ± 1.60	7.80 ± 1.60	8.63 ± 0.86	8.91 ± 1.47	8.65 ± 1.59	7.65 ± 1.53	9.05 ± 1.55	11.38 ± 1.61	11.63 ± 1.58	11.44± 0.78	11.85± 0.79	10.61± 0.82	11.26± 0.80	11.77± 0.82
3 Intertidal *Halodule* dominated	0.10 ± 0.05	0.20 ± 0.10	0.30 ± 0.20	0.78 ± 0.04	0.26 ± 0.19	0.40 ± 0.20	0.38 ± 0.21	0.32 ± 0.22	0.29 ± 0.17	0.41 ± 0.20	0.24 ± 0.04	0.23 ± 0.03	0.29 ± 0.03	0.40 ± 0.04	0.32 ± 0.04
4 Subtidal *Enhalus* dominated	1.30 ± 0.60	1.00 ± 0.50	0.80 ± 0.50	1.11 ± 0.11	0.79 ± 0.45	0.94 ± 0.49	0.68 ± 0.48	0.89 ± 0.49	2.01 ± 0.60	1.99 ± 0.60	1.86 ± 0.29	1.73 ± 0.30	2.11 ± 0.34	1.80 ± 0.32	1.57 ± 0.33
5 Intertidal *Halodule* dominated	2.10 ± 0.80	1.90 ± 0.80	2.00 ± 0.90	5.26 ± 0.26	3.17 ± 0.90	3.64 ± 0.97	4.54 ± 1.09	4.14 ± 1.02	2.56 ± 0.72	3.85 ± 0.74	3.00 ± 0.38	3.31 ± 0.39	3.52 ± 0.43	3.42 ± 0.42	2.86 ± 0.43
6 Subtidal *Enhalus* dominated	13.20 ± 2.60	12.40 ± 2.40	12.70 ± 2.50	16.22 ± 1.62	13.18 ± 2.51	12.68 ± 2.16	10.15 ± 2.08	11.33 ± 2.14	13.90 ± 2.26	14.47 ± 2.18	14.08 ± 1.05	14.71 ± 1.11	14.94 ± 1.21	12.30 ± 1.14	13.88 ± 1.09
8 Intertidal *Halodule* dominated	12.30 ± 2.00	10.40 ± 2.20	12.20 ± 1.80	8.88 ± 0.44	13.44 ± 2.74	14.29 ± 2.74	16.02 ± 2.85	15.64 ± 2.82	14.57 ± 2.79	11.32 ± 2.78	14.27 ± 1.09	14.84 ± 1.08	15.58 ± 1.08	16.15 ± 1.12	11.43 ± 1.11
26 Intertidal *Enhalus* dominated	94.50 ± 1.50	87.70 ± 3.50	89.00 ± 3.10	83.52 ± 4.18	89.24 ± 3.19	86.26 ± 3.11	81.30 ± 3.23	94.75 ± 3.42	84.77 ± 2.88	93.43 ± 3.31	93.95 ± 3.29	94.92 ± 3.38	91.84 ± 3.32	97.58 ± 3.32	87.82 ± 3.49
27 Intertidal *Enhalus* dominated	6.10 ± 0.70	7.00 ± 0.90	5.80 ± 0.70	5.88 ± 0.29	8.22 ± 0.86	7.15 ± 0.85	9.58 ± 0.94	7.14 ± 0.79	6.18 ± 0.68	6.61 ± 0.68	6.24 ± 0.69	7.16 ± 0.72	6.98 ± 0.75	7.61 ± 0.72	5.94 ± 0.73