# Seagrass Habitat in the Port of Thursday Island: Annual seagrass monitoring report 2025

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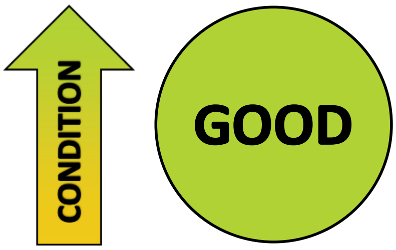
# KEY FINDINGS

**Seagrass Condition 2025**




- Annual monitoring of seagrass meadows around Thursday Island, including a whole of port survey was conducted between 7 - 10th March 2025.
- The overall condition of seagrass in the Port of Thursday Island improved to good in 2025 with seven out of nine meadows in a good or very good condition, while the remaining two improved from poor to satisfactory.
- Most seagrass indicators (biomass, area, and species composition) either improved or remained stable across the monitoring meadows.
- Environmental conditions were generally favourable for seagrass growth with most variables near long-term averages.
- The total area of seagrass across the Port increased, reaching the largest recorded extent to date. This included a notable recovery of deeper-water meadows, with increased area, biomass, and a shift toward more persistent species such as *H. uninervis*.
- These results indicate the seagrass communities in the Port of Thursday Island were in an overall resilient state in 2025 and were recovering well from the declines observed in 2024.

# 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.

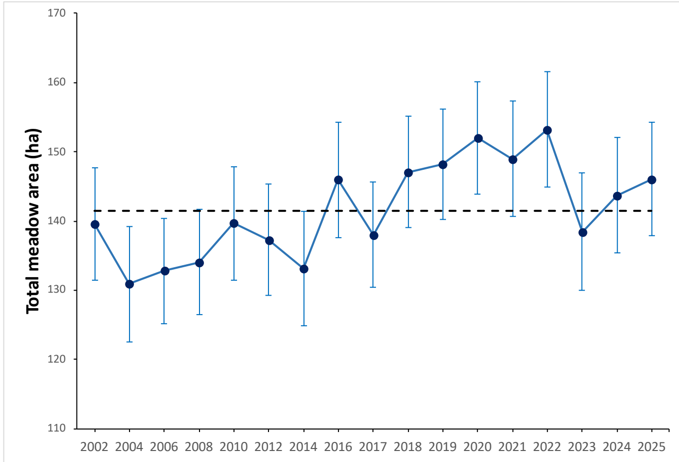



FIGURE 1 TOTAL AREA OF SEAGRASS WITHIN THE THURSDAY ISLAND MONITORING MEADOWS FROM 2002 TO 2025 (ERROR BARS = "R" RELIABILITY ESTIMATE). DASHED LINE INDICATES LONG-TERM AVERAGE OF MEADOW AREA.

In March 2025 the overall condition of seagrass in the nine annual monitoring meadows was good. The total seagrass area in these meadows in 2025 was 146 ± 8.2 ha, an increase from 2024 and above the long-term average of 141.4 ha (Figure 1). Most meadows were in good or very good condition in 2025, with only two in satisfactory condition (Figure 2).

The 2025 whole-of-port survey recorded the largest extent of seagrass mapped to date in the Port of Thursday Island (compared with 2022, 2019 and 2002). This was driven by an increase in area in the deep-water meadows, which had previously declined (Figure 2).

Climate conditions were generally favourable leading up to the March 2025 survey with no major storms or cyclones affecting the area. Air temperatures were well above average in 2024/25, solar radiation was slightly above average, rainfall was slightly below average and air exposure times for intertidal meadows were slightly elevated (Figure 3). Despite these warm conditions, seagrass condition improved across the Port, with no meadows dropping below satisfactory condition. The overall trend shows a recovery following previous declines, particularly those caused by high rainfall events in earlier years. These results point to a healthy seagrass community in the Port of Thursday Island, the majority of indicators were in good or very good condition, and none dropped below satisfactory. Throughout the wider Torres Strait in 2024, seagrass was in a satisfactory condition in all Clusters (Carter et al. 2024). At Weipa, the next closest seagrass long-term monitoring location to Thursday Island (Figure 4), seagrasses also improved from satisfactory to good condition in the most recent survey (Reason et al. 2025). For full details of the Queensland ports seagrass monitoring program see: [https://www.tropwater.com/project/management-of-ports-and-coastal-facilities/](https://www.tropwater.com/project/management-of-ports-and-coastal-facilities/)

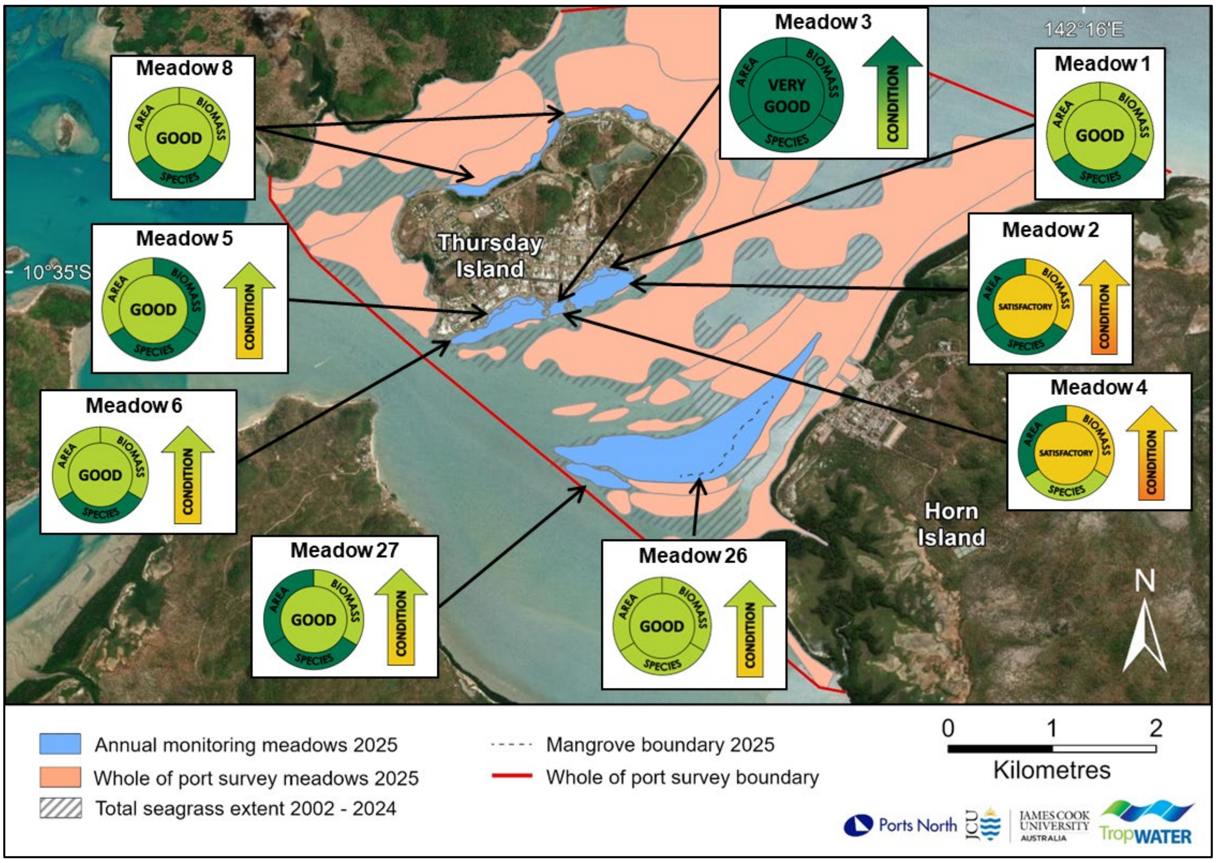



**FIGURE 2 SEAGRASS CONDITION FOR PORT OF THURSDAY ISLAND ANNUAL MONITORING MEADOWS IN 2025.**

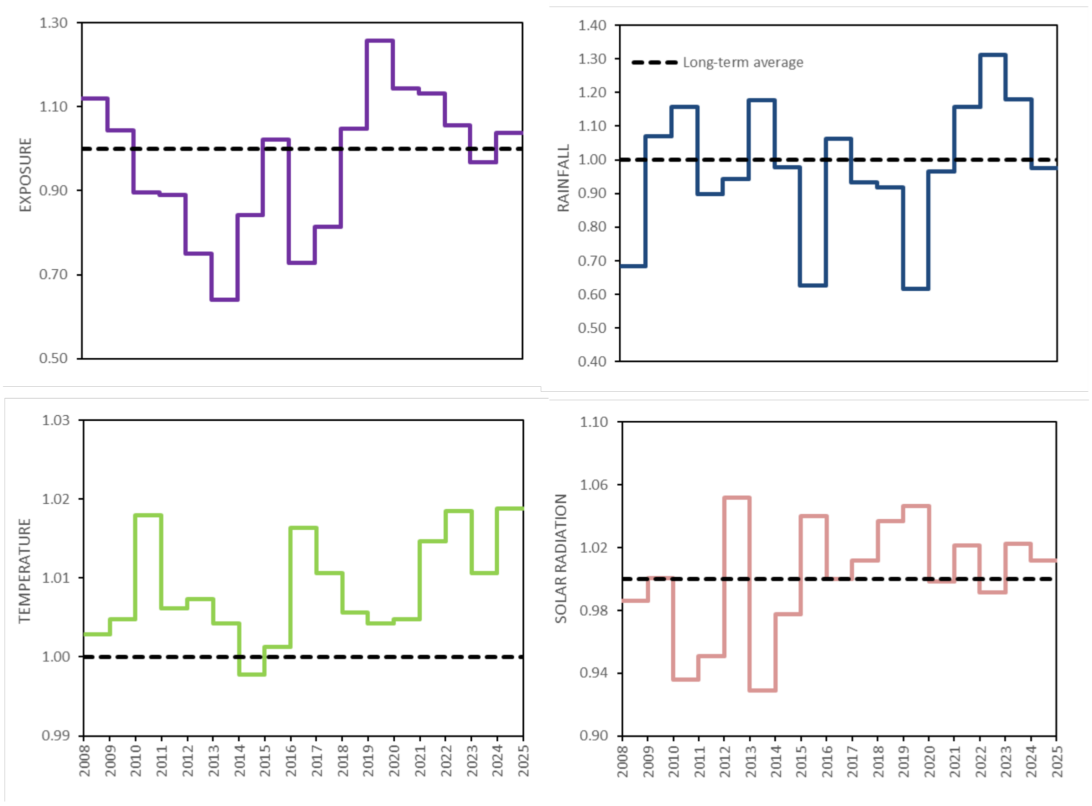



**FIGURE 3 DIAGRAMMATIC SUMMARY OF CLIMATE TRENDS IN THURSDAY ISLAND: CHANGES IN CLIMATE VARIABLES AS A PROPORTION OF THE LONG-TERM AVERAGE. SEE SECTION 3.3 FOR DETAILED CLIMATE DATA.**

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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).

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.


FIGURE 2 LOCATION OF QUEENSLAND PORT SEAGRASS ASSESSMENT SITES

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 2025 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.
- Comparison with the previous whole of port surveys of the extent and composition of seagrass meadows not included in annual monitoring meadows;
- 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 7 – 10$^{th}$ March 2025. In addition to the annual monitoring survey, mapping was extended to update the distribution of seagrasses within the whole of port limits area which was last conducted in 2022, this involved mapping and assessing all intertidal areas surrounding Thursday Island between Hammond to Horn Islands (Figure 8).

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 5A). Shallow subtidal meadows were sampled by boat using camera drops and van Veen grab (Figure 5B, 5C). 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.

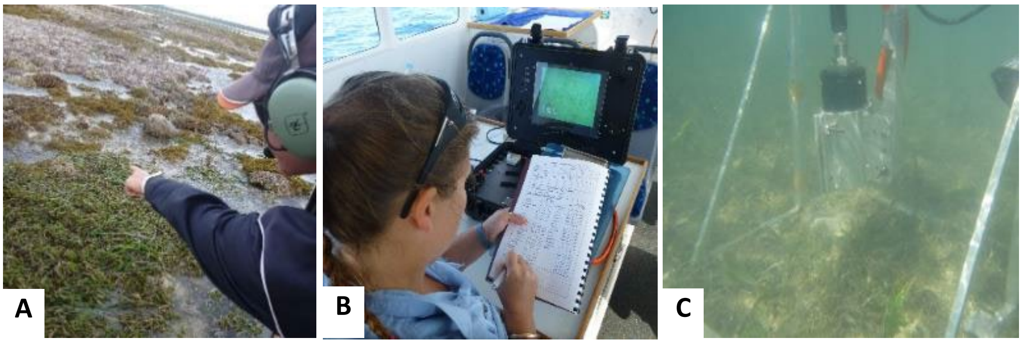



**FIGURE 3 SEAGRASS MONITORING METHODS. (A) HELICOPTER AERIAL SURVEILLANCE, (B, C) BOAT-BASED CAMERA DROPS.**

## 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.

<u>*Isolated seagrass patches*</u>
The majority of area within the meadow consists of unvegetated sediment interspersed with isolated patches of seagrass.

<u>*Aggregated seagrass patches*</u>
The meadow consists of numerous seagrass patches but still features substantial gaps of unvegetated sediment within the boundary.

<u>*Continuous seagrass cover*</u>
The majority of meadow area consists of continuous seagrass cover with a few gaps of unvegetated sediment.

FIGURE 4 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)<br>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 2024**

| Mapping precision | Mapping method |
|---|---|
| 1-10 m | Meadow boundaries mapped in detail by GPS from helicopter.<br>Some meadow boundaries mapped by walking.<br>Intertidal meadows completely exposed or visible at low tide.<br>Relatively high density of mapping and survey sites.<br>Recent aerial photography aided in mapping. |
| 10-50 m | Meadow boundaries determined from helicopter and camera/grab surveys.<br>Inshore boundaries mapped from helicopter.<br>Offshore boundaries interpreted from survey sites and aerial photography.<br>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 2024, 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 346 sites were surveyed in the 2025 annual monitoring survey, with an additional 379 sites in the whole of port area (Figure 7). Eleven seagrass species were recorded with five 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 145 ± 8.2 ha (Figure 1).

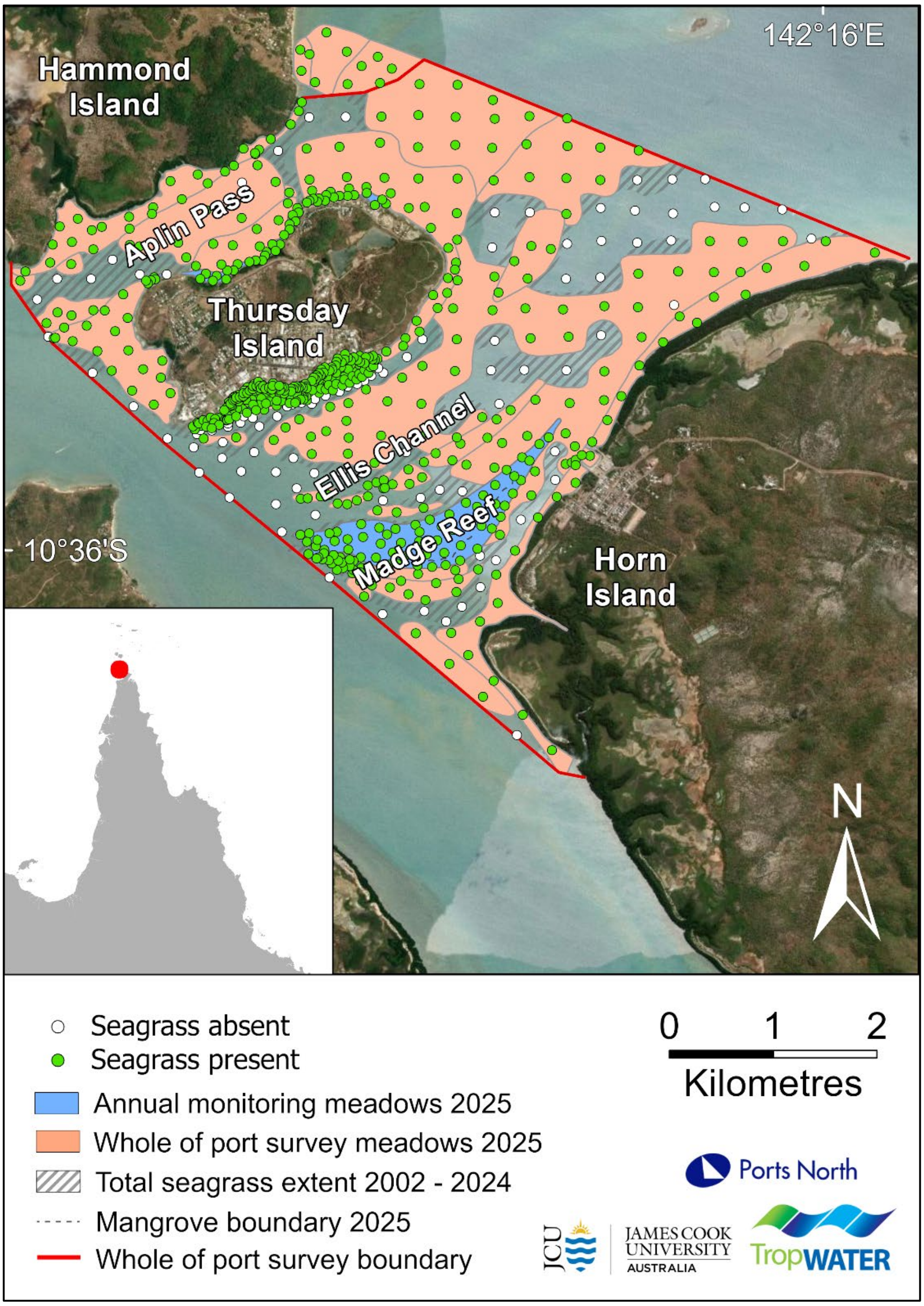



FIGURE 5 PORT OF THURSDAY ISLAND SEAGRASS MEADOWS AND SEAGRASS PRESENCE/ABSENCE AT SITES SURVEYED IN 2025.

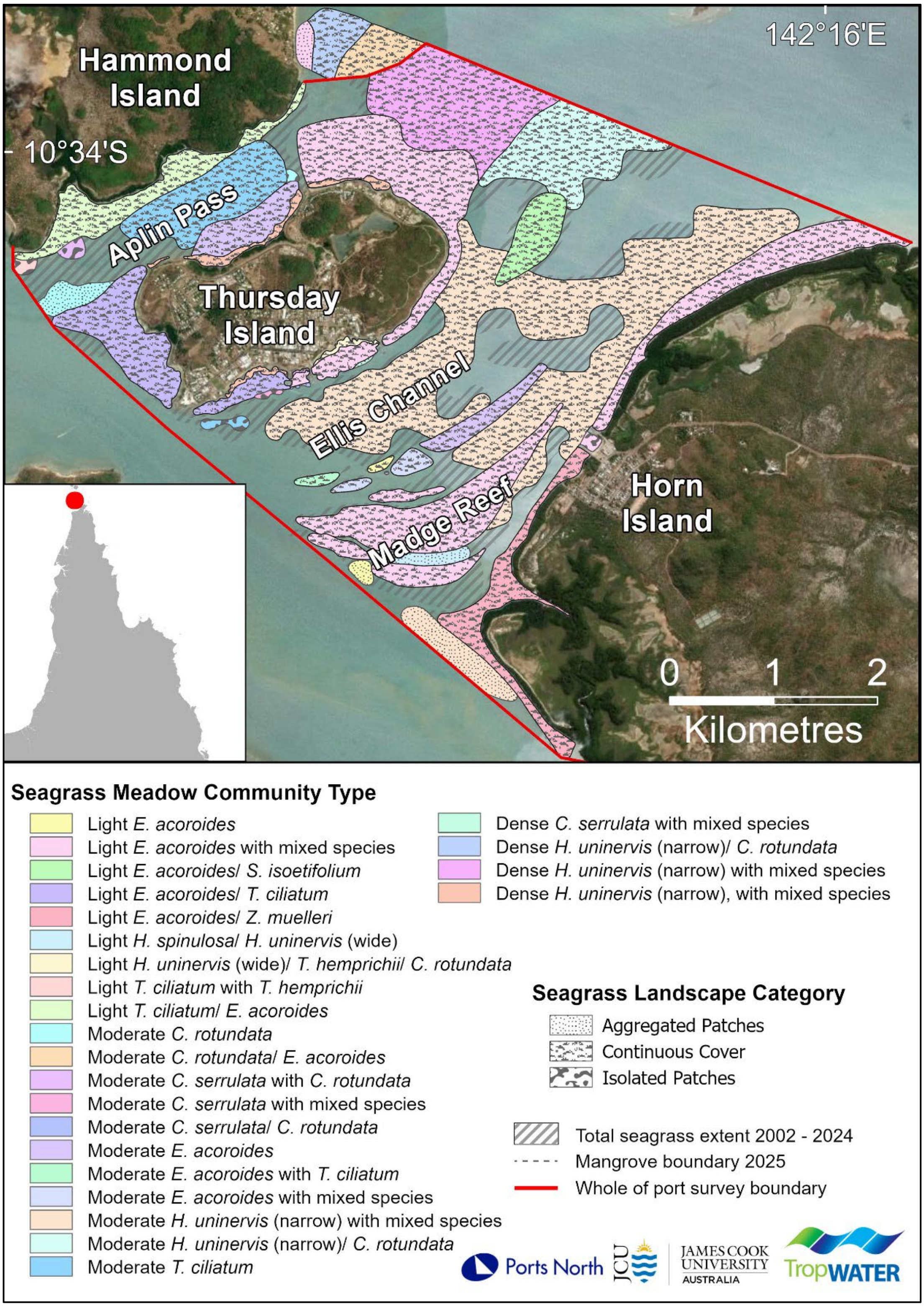



**Figure 6 Port of Thursday Island seagrass distribution and community type for 2025 seagrass monitoring meadows**

**TABLE 4 SEAGRASS SPECIES PRESENT AT THE PORT OF THURSDAY ISLAND IN 2025.**

| 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 |
| |  | *Halophila decipiens* Ostenf. |
| |  | *Halophila spinulosa* (R. Br.) Asch. |

## 3.2 SEAGRASS CONDITION FOR ANNUAL MONITORING MEADOWS

In March 2025, the overall condition of seagrasses in the Port of Thursday Island annual monitoring meadows was good (Table 5), an improvement from satisfactory in 2024. Of the nine monitoring meadows, seven were in good or very good condition, while the remaining two improved from poor to satisfactory (Figure 2). Most indicators either maintained or improved in condition compared to the previous year. The only declines observed were in biomass, which dropped from very good to good in two meadows.

The combined seagrass area of all monitoring meadows continued to increase for the third consecutive year. In 2025, the total area was 146 ± 8.2 ha, which is above the long-term average of 141.4 ha (Figure 1). Of the three condition indicators—biomass, area, and species composition—meadow area has been the most stable across years. In 2025, all meadows maintained or improved their area condition scores.

**TABLE 5 GRADES AND SCORES FOR SEAGRASS INDICATORS (BIOMASS, AREA AND SPECIES COMPOSITION) FOR THE PORT OF THURSDAY ISLAND 2025.**

| Meadow | Biomass | Area | Species Composition | Overall Meadow Score |
|---|---|---|---|---|
| **1** | 0.81 | 0.80 | 0.99 | 0.80 |
| **2** | 0.64 | 0.95 | 0.86 | 0.64 |
| **3** | 1 | 0.86 | 1 | 0.86 |
| **4** | 0.6 | 0.93 | 0.73 | 0.6 |
| **5** | 0.88 | 0.70 | 0.99 | 0.70 |
| **6** | 0.78 | 0.75 | 0.89 | 0.75 |
| **8** | 0.73 | 0.77 | 0.96 | 0.73 |
| **26** | 0.76 | 0.84 | 0.79 | 0.76 |
| **27** | 0.78 | 0.86 | 0.89 | 0.78 |
| **Overall Score for the Port of Thursday Island** | | | | **0.74** |

### 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. In 2025, all of these meadows maintained or improved their overall condition - meadows 1, 5, and 8 were in good condition and meadow 3 was in very good condition (Figures 2, 11, 13, 15 and 17; Table 5).

Seagrass biomass in all the inshore *H. uninervis* meadows was in either good or very good condition and was above the long-term average in 2025 except for meadow 8 which was slightly below the average (Figures 9, 11, 13, 15 and 17). Meadow area remained stable or improved to good condition in meadows 1, 5, and 8 and improved to very good condition in meadow 3 (Figures 11, 13 15 and 17). Species composition once again 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 in 2025, although biomass in this meadow did decline to good (Figure 11). Seagrass biomass declined from 12.6 ± 1.3 g DW $m^{-2}$ in 2024 to 7.7 ± 2.3 g DW $m^{-2}$ in 2025, reducing the score from very good to good, though it remains well above the long-term average (Figure 11, Appendix 2a). There was a small decrease in meadow area from to 3.0 ± 0.5 ha in 2024 to 2.9 ± 0.4 ha in 2025, but this maintained a good condition above the long-term average (Figure 11). Species composition remained in very good condition despite a decline in *H. uninervis* from 88% to 45%, due to an increase in more persistent species (*Thalassia hemprichii* and *Cymodocea rotundata*) and a reduction in less stable species *H. ovalis* (from 10% to 2%) (Figure 11; Appendix 1).

Meadow 3, located between the Main and Engineer's wharves, improved from good to very good overall condition (Figure 13, Appendix 2a). Meadow biomass increased slightly and remained in very good condition for the fourth consecutive year. Area increased from 0.35 ± 0.04 ha in 2024 to 0.44 ± 0.04 ha in 2025, improving the condition score from good to very good (Figure 13, Appendix 2a). Species composition remained very good condition, *Halodule uninervis* remained the dominant species with only 0.2% of the less stable species *H. ovalis* present (Figure 13, Appendix 1).

The *H. uninervis* meadow at the western end of Thursday Island (meadow 5) improved from satisfactory to good condition in 2025. Biomass decreased slightly from 13.8 ± 1.5 g DW $m^{-2}$ in 2024 to 11.0 ± 1.3 g DW $m^{-2}$ in 2025, but remained in very good condition. Area increased slightly once again, driving an improvement in condition from satisfactory to good for this metric (Figure 15, Appendix 2b). Species composition has remained in in very good condition since 2006 (Figure 15, Appendix 1).

The only annual monitoring meadow on the northern side of Thursday Island (meadow 8) maintained a good condition in 2025 (Table 5, Figure 17). Seagrass biomass declined from 16.3 ± 2.0 g DW $m^{-2}$ in 2024 to 7.9 ± 0.8 g DW $m^{-2}$ in 2025, reducing its score from very good to good (Figure 17, Appendix 2a). Meadow area increased by 0.2 ha in 2025, supporting continued good condition (Figure 17, Appendix 2b). Species composition remained in a very good condition, with the dominant species, *H. uninervis* making up over 90% of the biomass (Figure 17, Appendix 1).

### 3.2.2 *ENHALUS ACOROIDES* DOMINATED MEADOWS (MEADOWS 2, 4, 6, 26, 27)

In 2025, all *E. acoroides* dominated monitoring meadows showed improvement in condition to good or satisfactory, and all increased in biomass and improved their biomass score (Table 5). Most meadows were characterised by a continuous cover of light *E. acoroides* with mixed species present, except for meadow 6, which was dominated by both *E. acoroides* and *T. ciliatum* (Figures 12, 14, 16, 18 and 19). Meadow area remained stable with only minor changes in 2025, area condition was maintained in all meadows and improved in meadow 27 (Figure 19). Species composition scores improved in meadow 2 and 4, and remained stable in the other meadows (Figures 14, 18 and 19).

**Thursday Island meadows**

The intertidal/subtidal meadow at the south-eastern end of Thursday Island (meadow 2) improved from poor to satisfactory condition in 2025 (Figure 12). This improvement was driven by an increase in biomass from 19.5 ± 1.9 g DW $m^{-2}$ in 2024 to 34.6 ± 4.1 g DW $m^{-2}$ in 2025 (Figure 12, Appendix 2a). The area of high biomass seagrass which had declined in 2023 and 2024 was beginning to re-establish in 2025 (Figure 9, 12). Meadow area maintained a very good condition for the ninth year in a row (Figure 12, Appendix 2b). The percentage of the more stable species *E. acoroides* in this meadow increased from 67.4% in 2024 84.5% in 2025 to, resulting in an improvement from good to very good condition (Figure 12, Appendix 1).

Condition of the smallest *E. acoroides* meadow between the main Thursday Island wharves (meadow 4) improved from poor to satisfactory in 2025 (Table 5). This was due to an improvement in both biomass and species composition from poor to satisfactory. Seagrass biomass increased from 13.8 ± 1.5 g DW $m^{-2}$ in 2024 to 23.6 ± 4.7 g DW $m^{-2}$ in 2025 and the biomass made up of the more persistent species *E. acoroides* increased from 39.8% in 2024 to 72.8% in 2025, however the subtidal section of this meadow had very low *E. acoroides* biomass (Figure 9, 14; Appendix 1, Appendix 2a). Area remained in very good condition in this meadow (Figure 14, Appendix 2b).

Condition of meadow 6 also improved from satisfactory to good condition in 2025 (Table 5). This was due to an improvement in biomass from 32.8 ± 7.2 g DW $m^{-2}$ in 2024 to 43.9 ± 8.2 g DW $m^{-2}$ in 2025 (Figure 16, Appendix 2a). The area of this meadow was stable and remained in good condition, and slightly above baseline levels (Figure 16, Appendix 2b). High biomass hotspots remain present in this meadow, dominated by *T. ciliatum* on the reef top (Figure 9, 16, Appendix 2a). Species composition remained in very good condition with 85% of biomass made up of *E. acoroides* and *T. ciliatum*, a slight increase from 2024 (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 also improved in condition in 2025, from satisfactory to good (Table 5). Biomass increased substantially in both meadows to above baseline levels driving an improvement to good condition. Meadow 26 increased from 17.6 ± 1.2 g DW $m^{-2}$ in 2024 to 45.5 ± 3.3 g DW $m^{-2}$ in 2025 and meadow 27 increased from 14.1 ± 3.5 g DW $m^{-2}$ in 2024 to 41.3 ± 8.2 g DW $m^{-2}$ in 2025 (Figure 18, 19, Appendix 2a).

Area also increased for the second year in both Madge Reef meadows. In meadow 26 area increased by 1.81 ha to just above baseline level and remained in a good condition (Figure 18). Meadow 27 increased from 7.21 ± 0.75 in 2024 to 7.8 ± 0.7 ha in 2025 to, improving to a very good condition (Figure 19). Similar to meadows 2 and 4, the hotspots of high biomass that were not present in previous surveys had started to return in 2025 (Figure 10).

Species composition on Madge reef was maintained in good and very good condition in 2025. Meadow 26 was in good condition with further increases in the percentage of the dominant species *E. acoroides* from 70.7% in 2024 to 79% in 2025 (Figure 18, Appendix 1). In meadow 27 the species score was very good, the percentage of *T. ciliatum* increased from 29.2% in 2024 to 33.7% in 2025 and *E. acoroides* slightly decreased from 65.9% to 61.8% (Figure 19, Appendix 1).

An area of expanding mangroves has been monitored in this meadow over the course of the program. In 2025, the biomass of seagrass in this mangrove recruitment area was once again slightly lower than the rest of the meadow, possibly due to mangrove establishment (Figure 10).

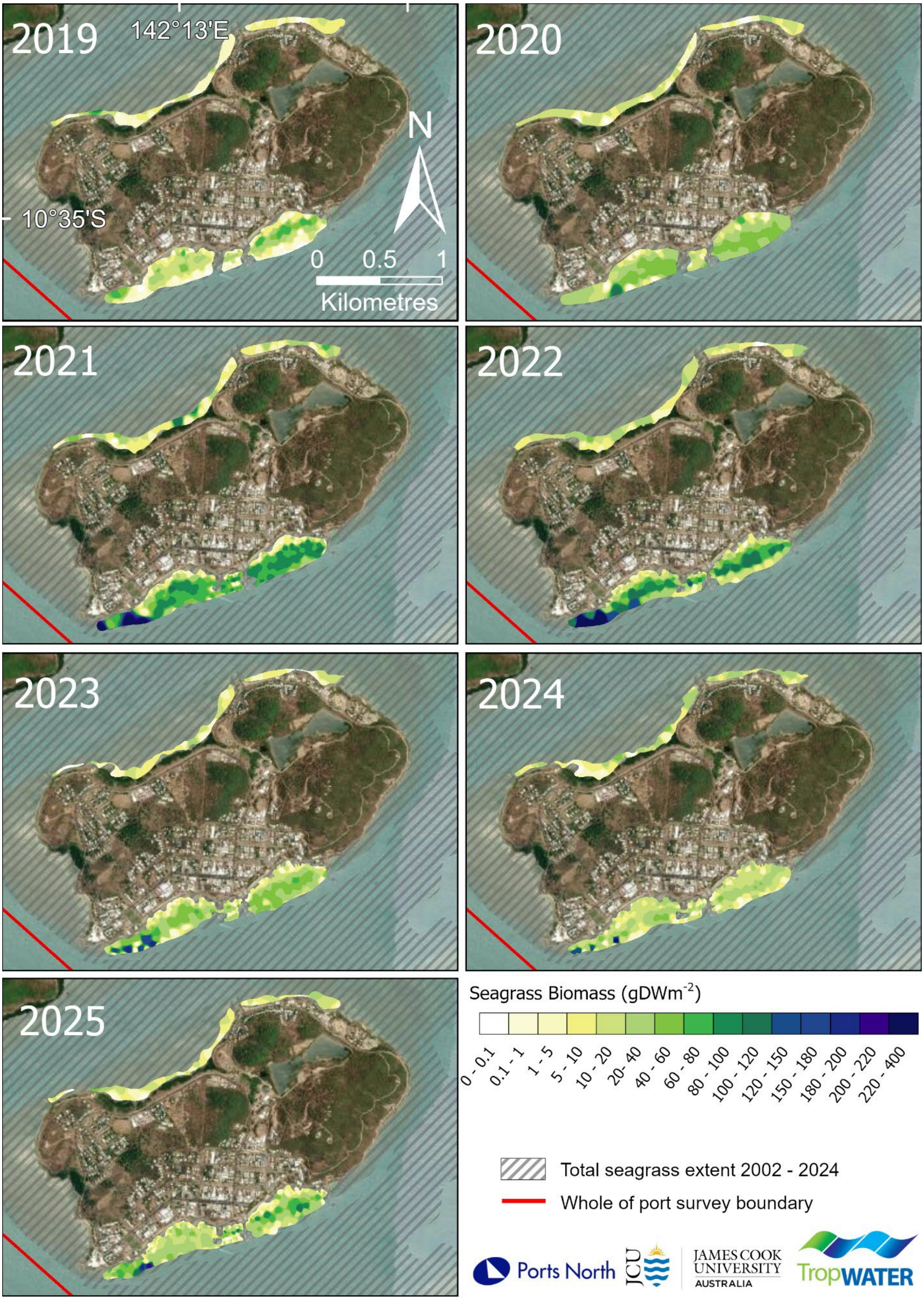



**FIGURE 7 CHANGES IN BIOMASS AND AREA (MEADOWS 1-6 AND 8) IN THE PORT OF THURSDAY ISLAND (2019-2025)**

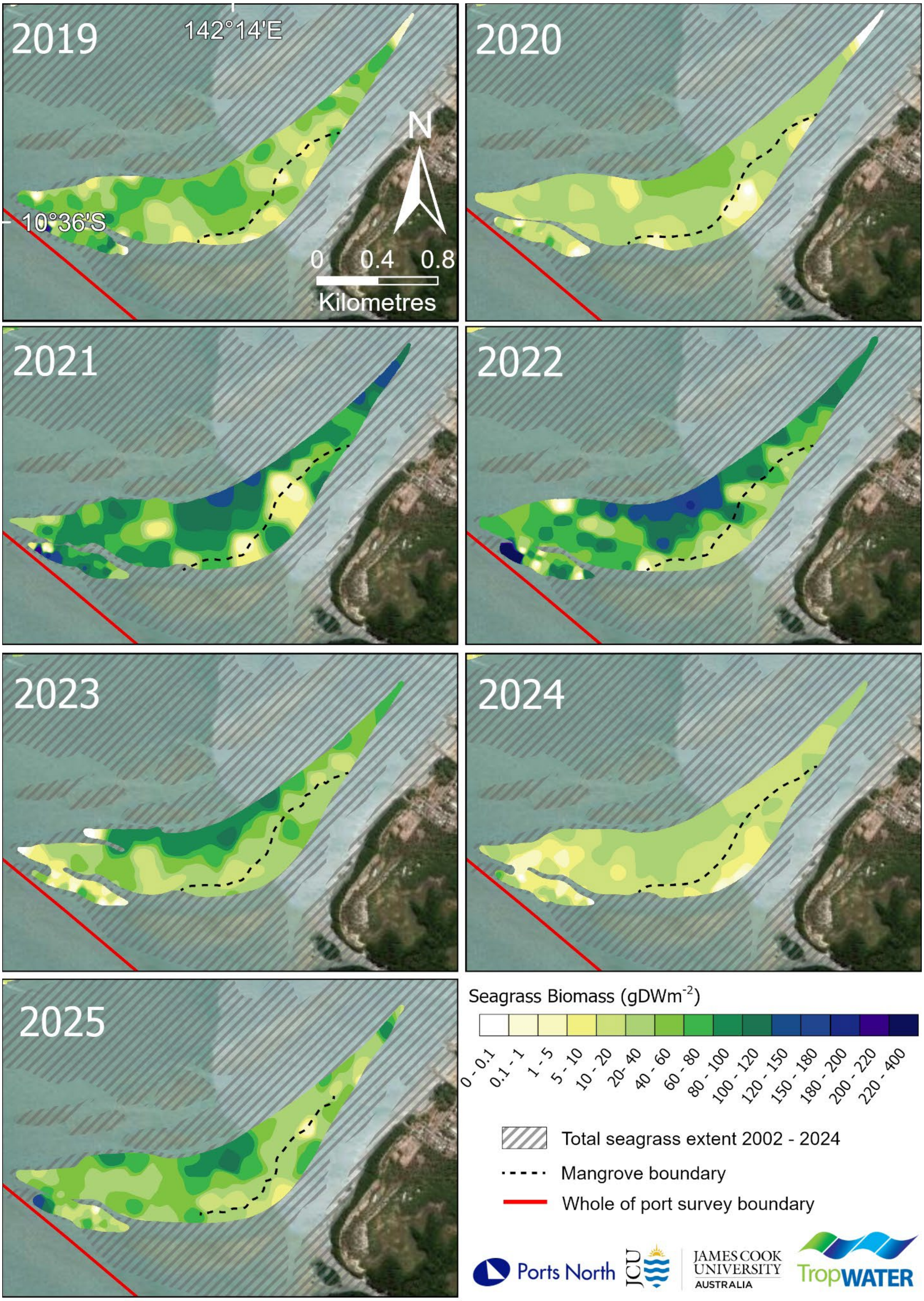



**FIGURE 8 CHANGES IN BIOMASS AND AREA (MEADOWS 26 AND 27) IN THE PORT OF THURSDAY ISLAND (2019-2025).**

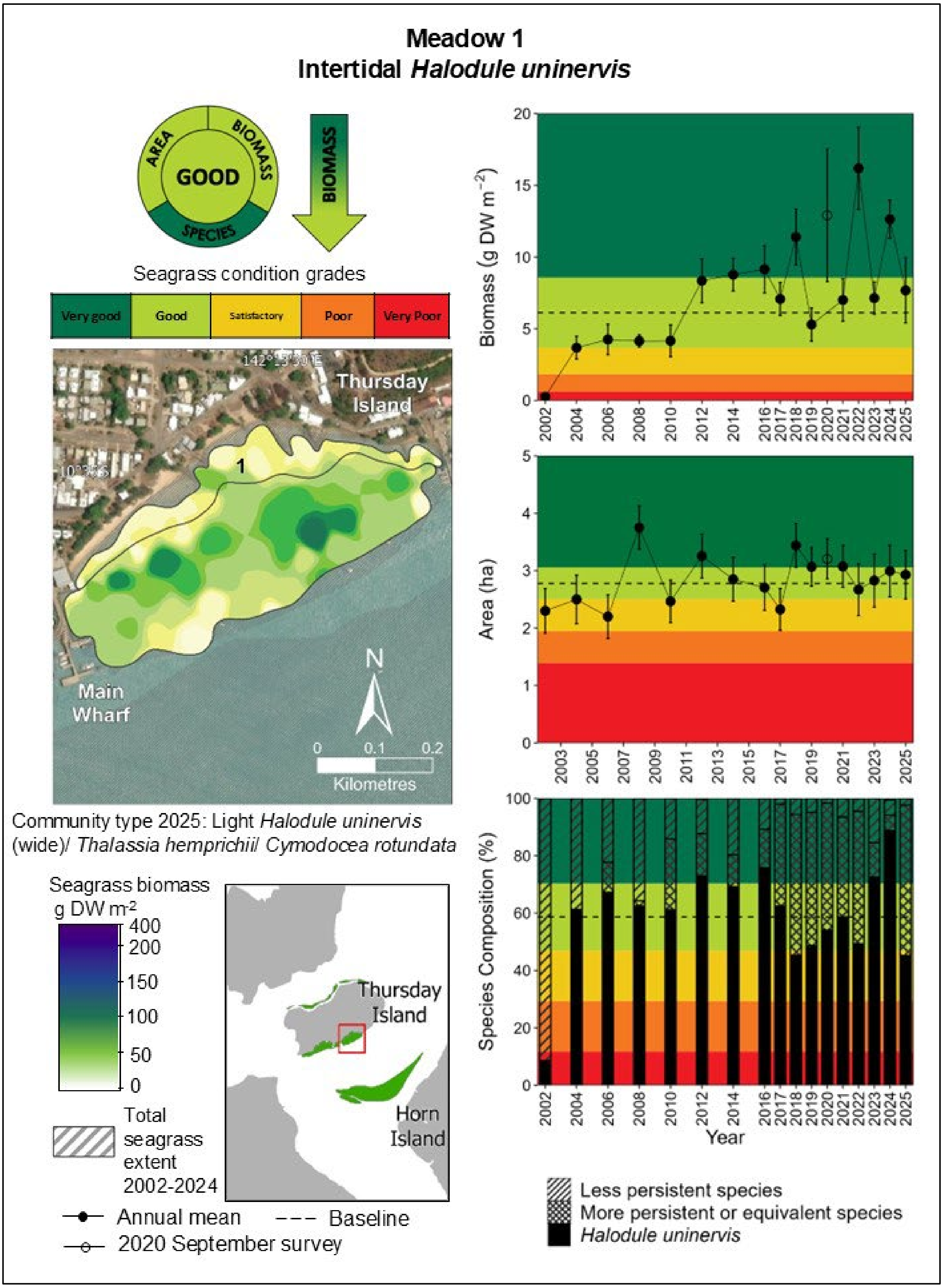



**FIGURE 9 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE *HALODULE UNINERVIS* DOMINATED MONITORING MEADOW 1 AT THURSDAY ISLAND FROM 2002 TO 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).**

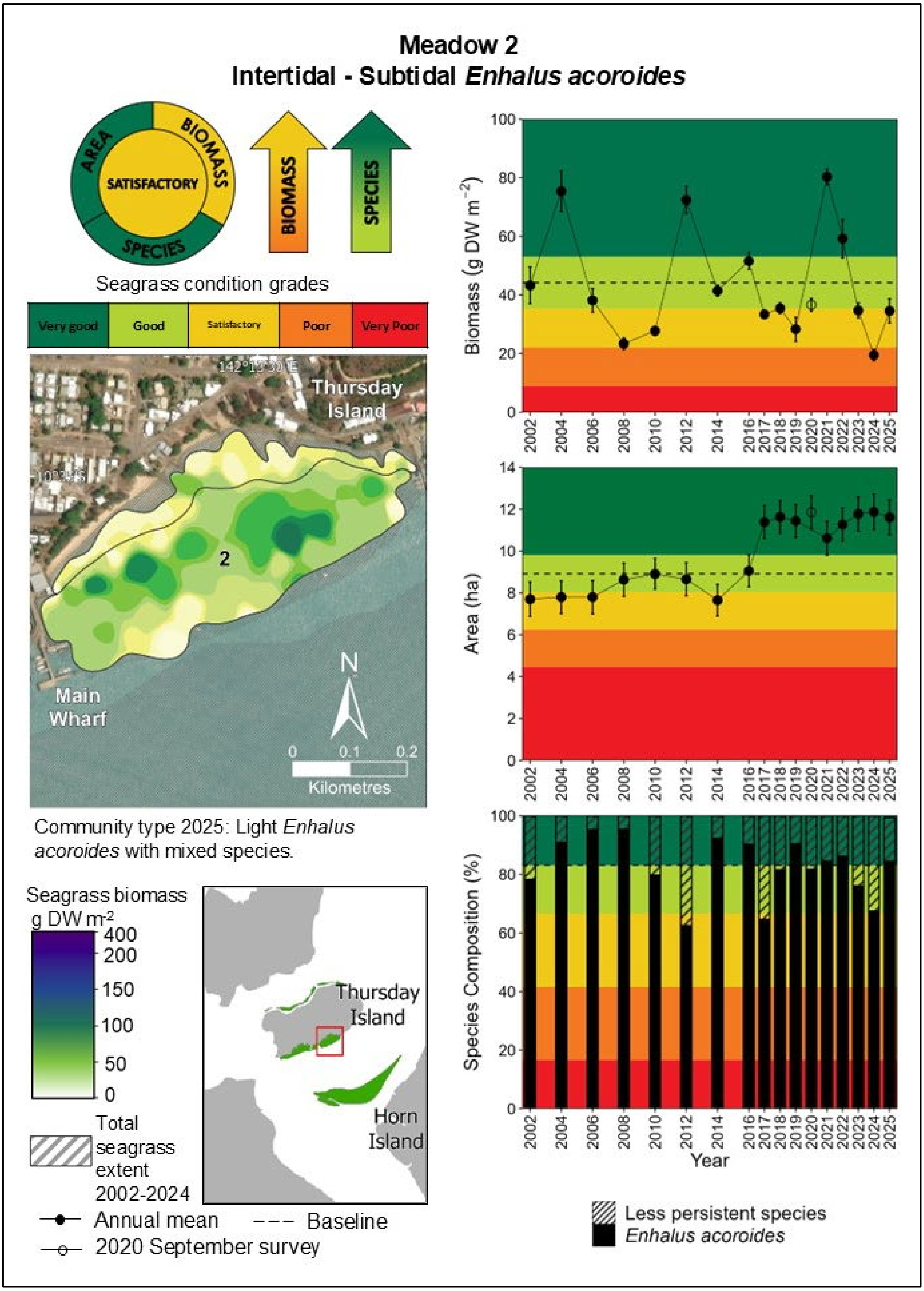



**Figure 10 Changes in biomass, area and species composition for the *Enhalus acoroides* dominated monitoring Meadow 2 at Thursday Island from 2002 to 2025 (biomass error bars = SE; area error bars = "R" reliability estimate).**

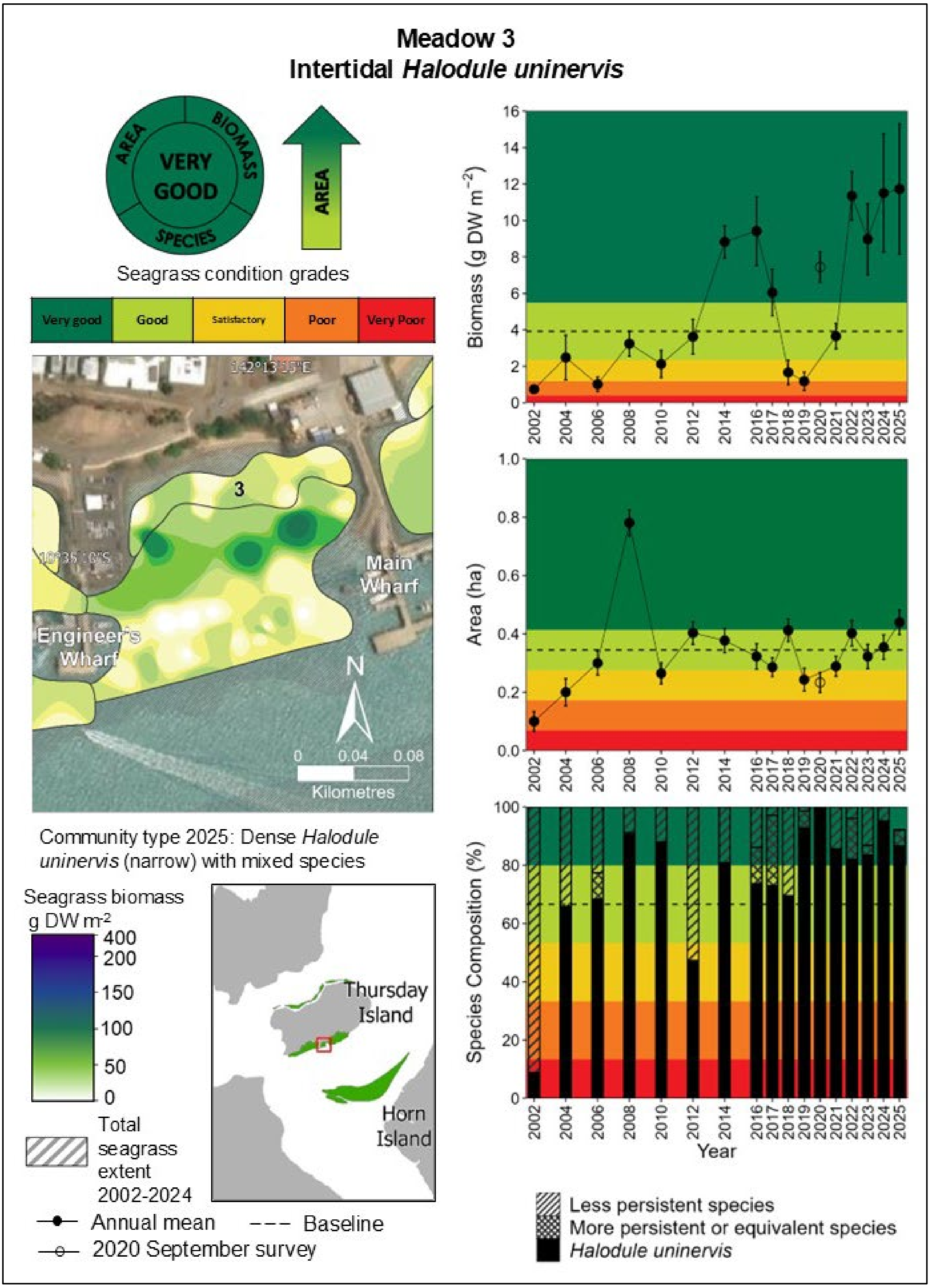



FIGURE 11 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE *HALODULE UNINERVIS* DOMINATED MONITORING MEADOW 3 AT THURSDAY ISLAND FROM 2002 TO 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

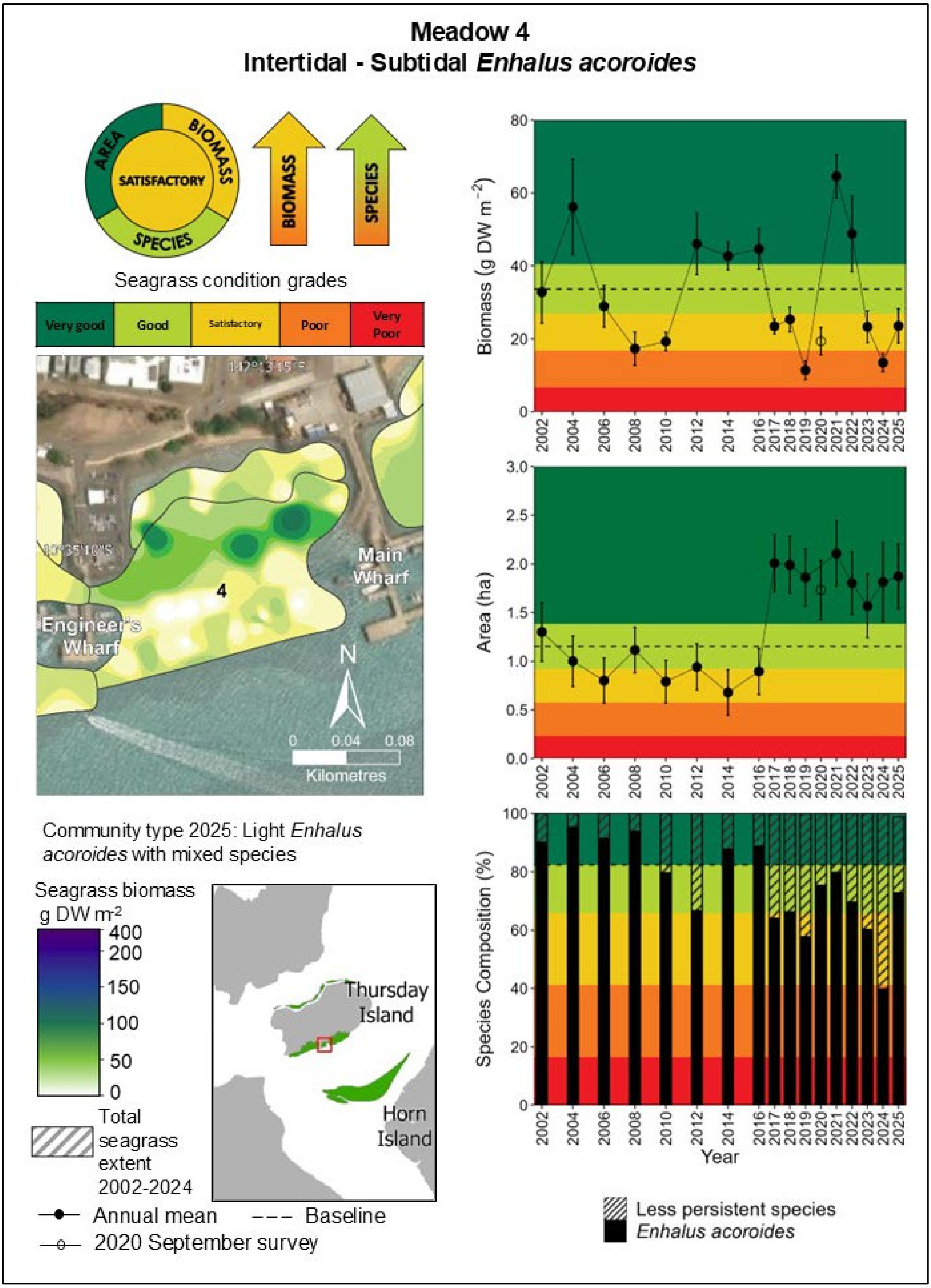



FIGURE 12 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE *ENHALUS ACOROIDES* DOMINATED MONITORING MEADOW 4 AT THURSDAY ISLAND FROM 2002 TO 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

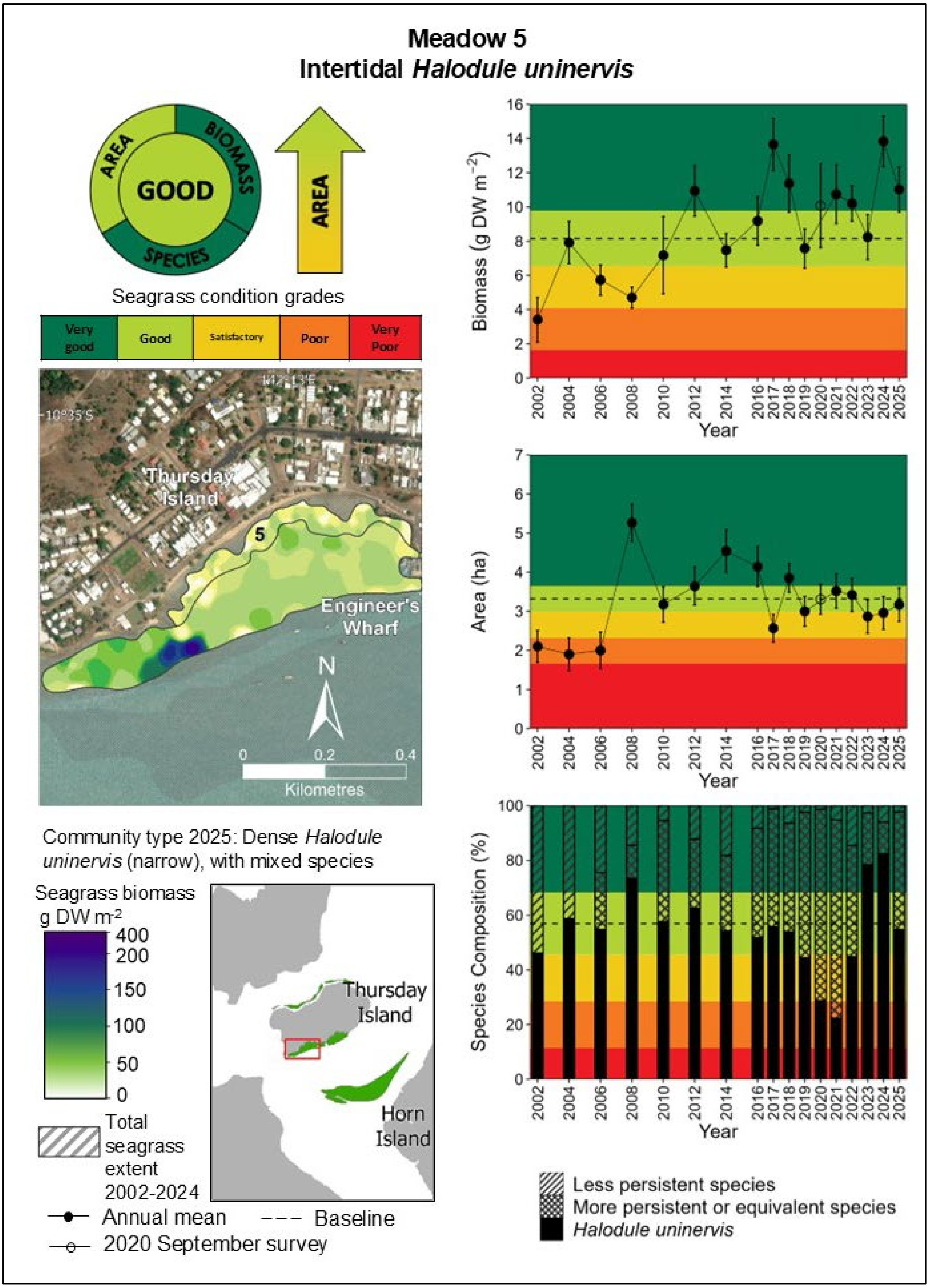



FIGURE 13 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE *HALODULE UNINERVIS* DOMINATED MONITORING MEADOW 5 AT THURSDAY ISLAND FROM 2002 TO 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

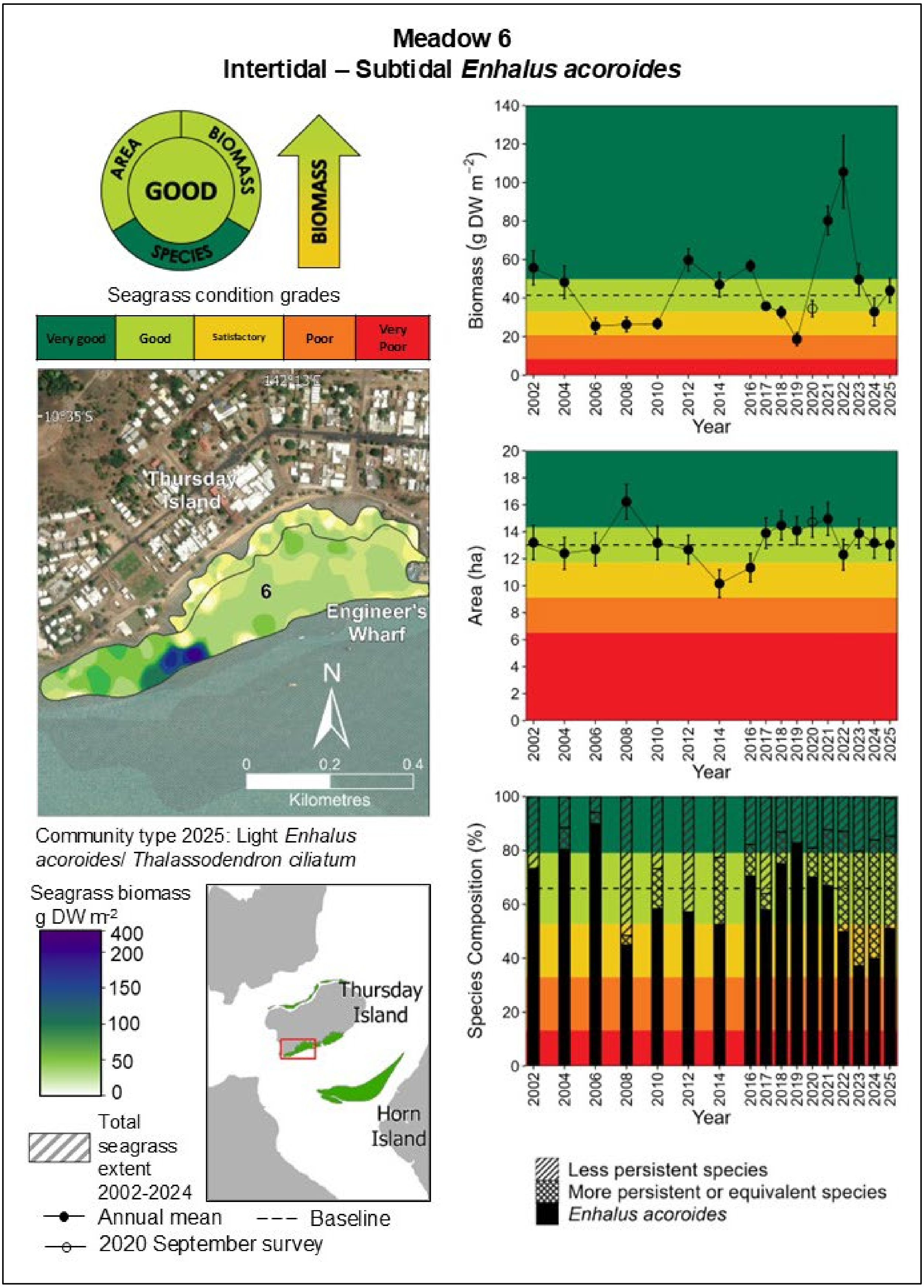



**Figure 14 Changes in biomass, area and species composition for the *Enhalus acoroides* dominated monitoring Meadow 6 at Thursday Island from 2002 to 2025 (biomass error bars = SE; area error bars = "R" reliability estimate).**

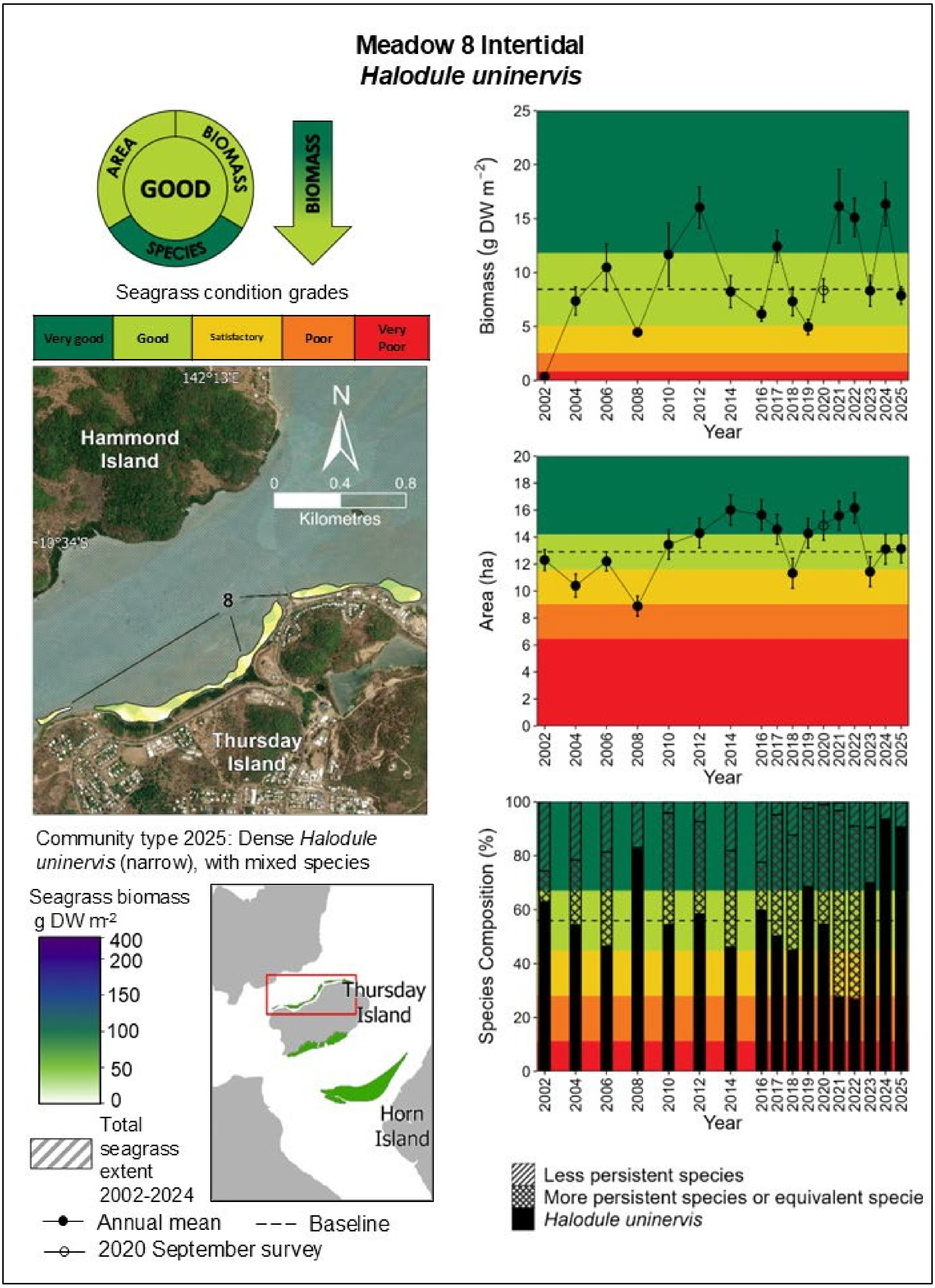



FIGURE 15 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE *HALODULE UNINERVIS* DOMINATED MONITORING MEADOW 8 AT THURSDAY ISLAND FROM 2002 TO 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

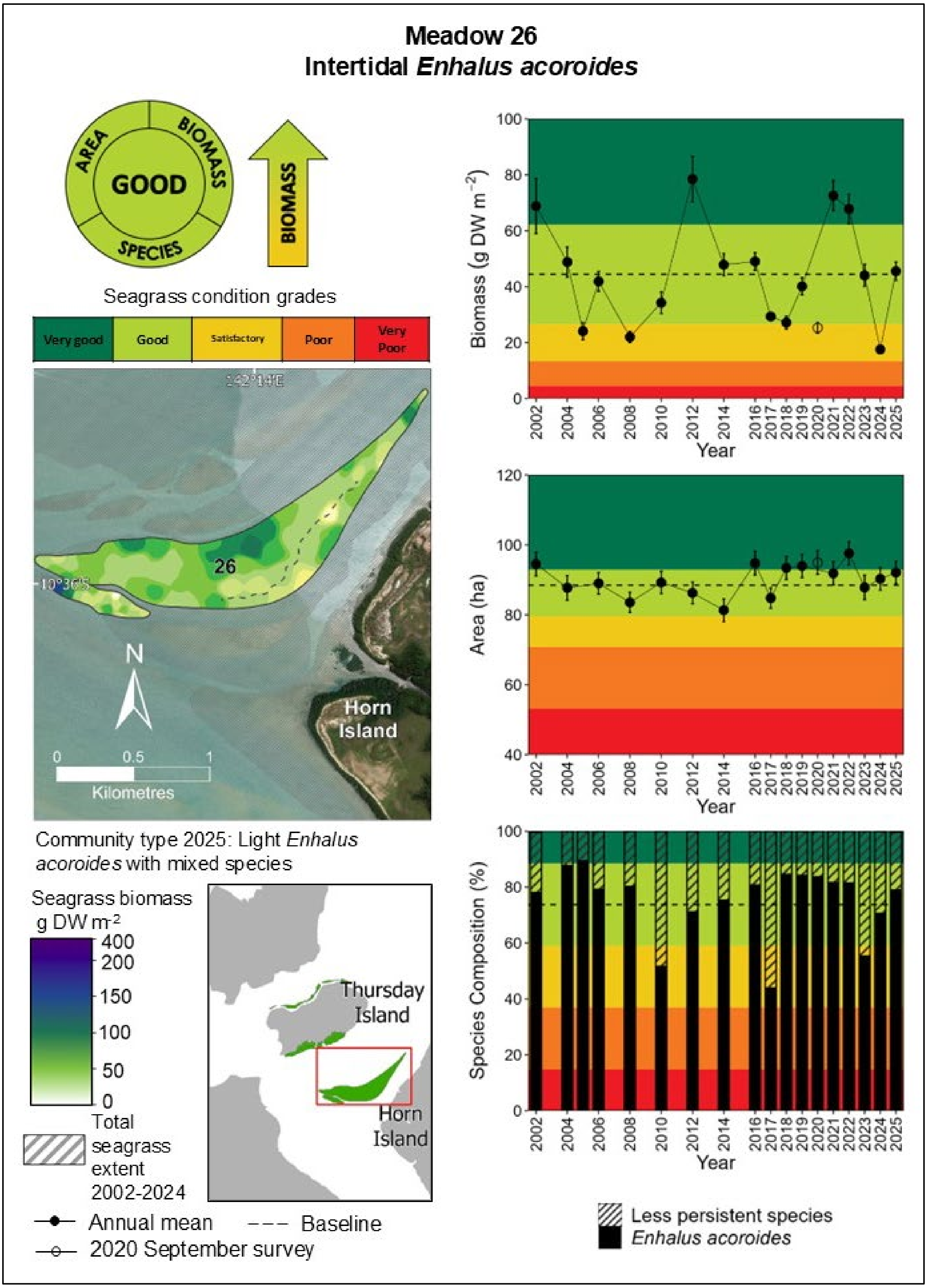



**FIGURE 16 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE *ENHALUS ACOROIDES* DOMINATED MONITORING MEADOW 26 AT MADGE REEFS FROM 2002 TO 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).**

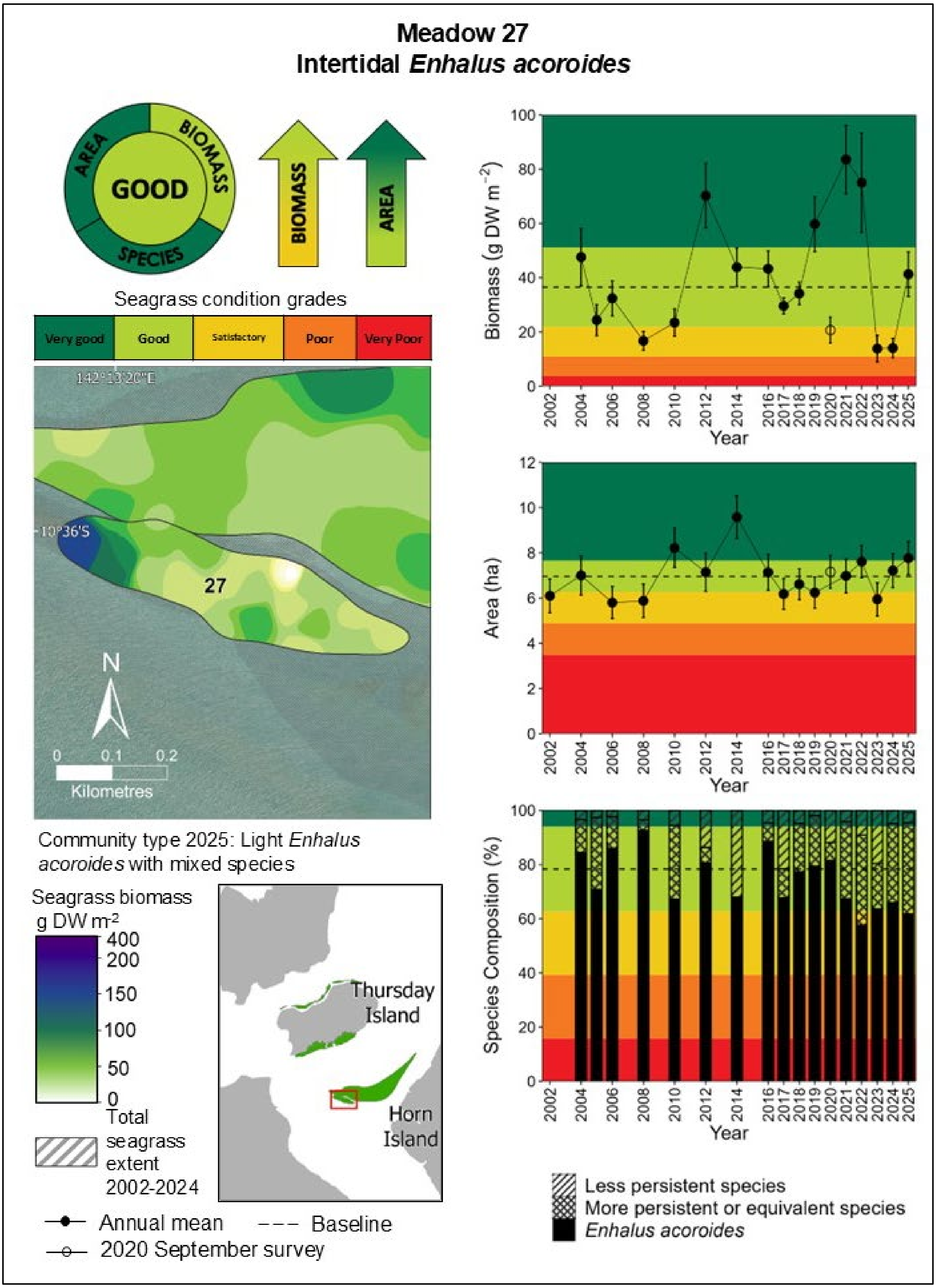



FIGURE 17 CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE *ENHALUS ACOROIDES* DOMINATED MONITORING MEADOW 27 AT MADGE REEFS FROM 2002 TO 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

## 3.1 SEAGRASSES IN THE WHOLE OF PORT AREA

The updated whole of port survey conducted concurrent to 2025 annual monitoring mapped 34 additional seagrass meadows outside of the annual monitoring survey. These meadows covered an additional 1259 ± 351 ha (Figures 8, 9 and 21). An additional three meadows were mapped outside of the survey limit towards Hammond Island, these covered a total area of 55.8 ha, as these were not included in previous whole of port surveys these meadows are not included in Figure 21. Meadow biomass peaked at 106 ± 12.3 g DW $m^{-2}$ in one of the small *T. ciliatum* with *E. acoroides* reef top meadow off Madge Reef; the lowest meadow biomass was 1.6 ± 1.5 g DW $m^{-2}$ for the *H. spinulosa* with *H. uninervis* meadow in the channel off Madge Reef (Figures 8 and 9). Most meadows had continuous cover, with seven meadows having isolated patches and seven with aggregated patches.

This updated mapping of all seagrasses in the port area found that the spatial footprint of seagrasses in the Thursday Island region had increased since last surveyed in 2022 and was the largest area recorded so far (Figure 21). Although the area of seagrass in the monitoring meadows is lower than mapped in 2022, this has been increasing in the past two years (Figure 1). Most of these meadows had a light or moderate cover of seagrass, similar to previous whole of Port surveys, but when these meadows were first surveyed in 2002 many had a dense cover. There was recovery in the deeper water seagrass meadows that had declined in 2022, with an increase in area, biomass and a shift towards the more persistent species *H. uninervis.*

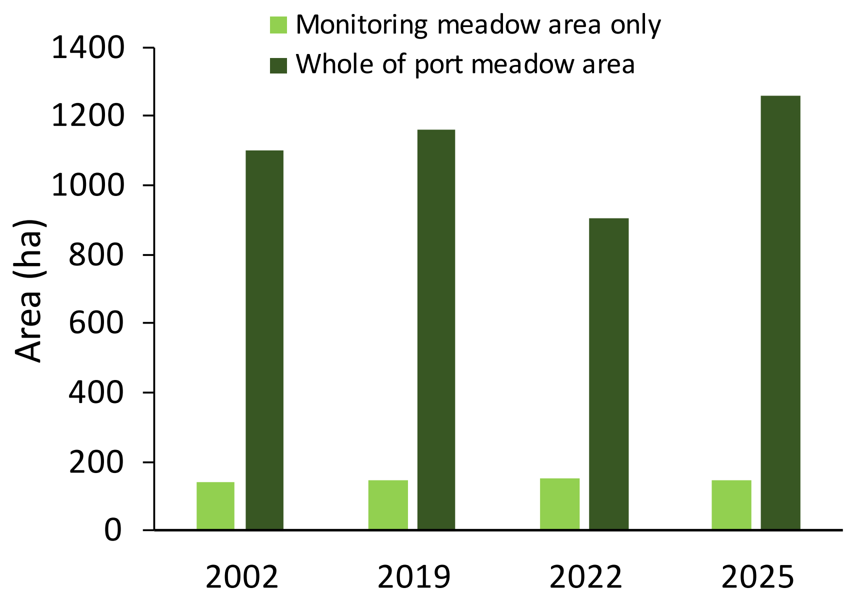



**FIGURE 21. COMPARISON OF SEAGRASS AREA (HECTARES) IN THE MONITORING MEADOWS ONLY AND THE WHOLE OF PORT MEADOW AREA EXCLUDING MONITORING MEADOWS IN THE THURSDAY ISLAND REGION, IN 2002, 2019, 2022 AND 2025.**

Only five meadows had a meadow biomass under 10 g DW $m^{-2}$ in 2025, representing 15% of the whole of port meadows. This represents a significant overall improvement in biomass compared to 2022 when just under half of the meadows had a meadow biomass under 10 g DW $m^{-2}$, compared to 64% in 2019 and just 14% in 2002.

## 3.2 THURSDAY ISLAND ENVIRONMENTAL CONDITIONS

### 3.2.1 RAINFALL

The total annual rainfall in the Thursday Island region in the 12 months leading up to the 2024 survey was above the long-term average, but lower than the 2023 survey year (Figure 20). January 2024 had the highest monthly rainfall in 20 years, with a total that was well above the monthly average. The survey month (March 2024) was also well above average, and the highest rainfall seen in March since the survey began in 2002 (Figure 21).

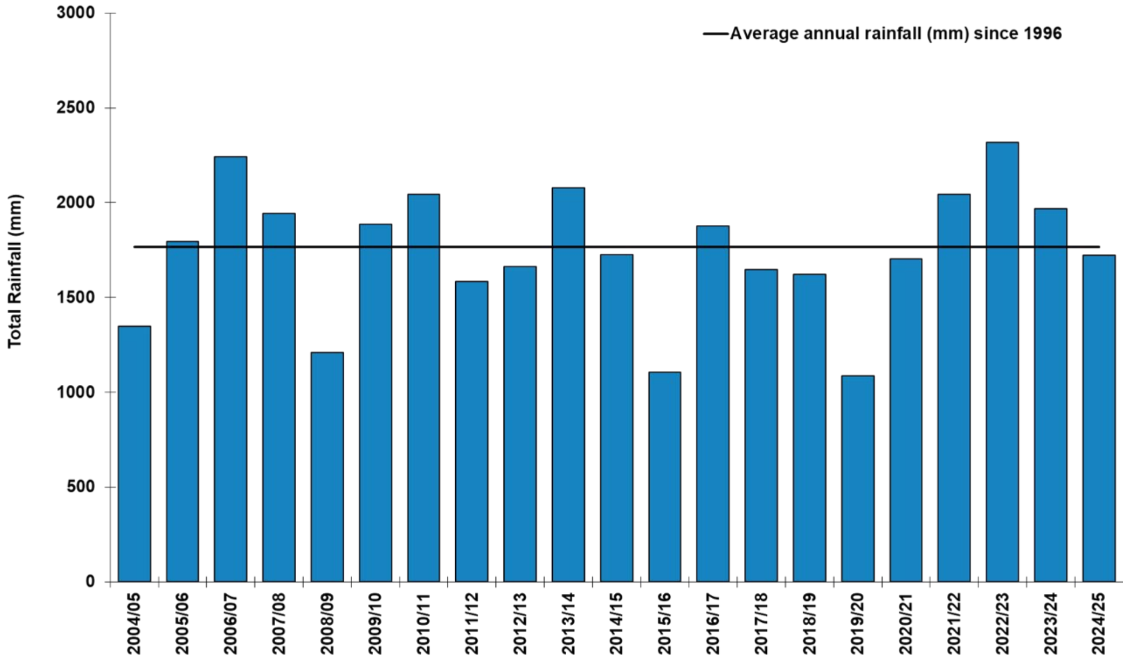



**FIGURE 18 TOTAL ANNUAL RAINFALL (MM) RECORDED AT HORN ISLAND, 2004/05 – 2024/25, IN EACH 12 MONTHS PRIOR TO SEAGRASS SURVEY.**

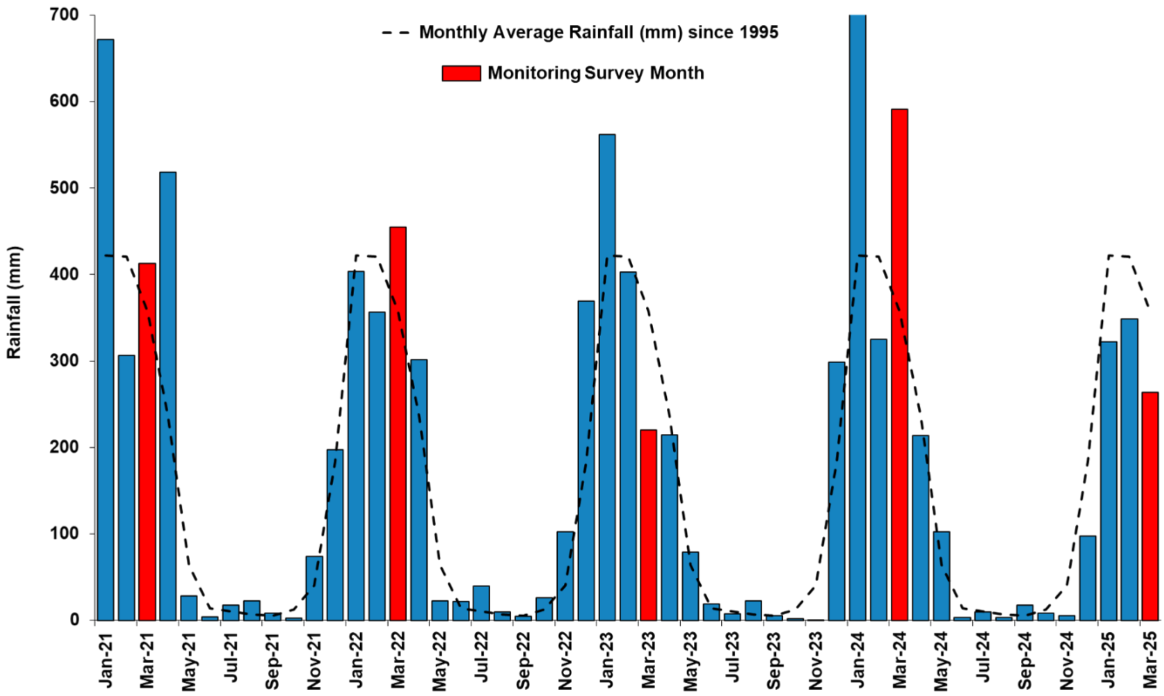



**FIGURE 19 TOTAL MONTHLY RAINFALL (MM) RECORDED AT HORN ISLAND, JANUARY 2021 - MARCH 2025.**

### 3.2.2 Air Temperature

The annual average maximum daily air temperature has remained above the long-term average of 30.48°C since 2015/16, and in 2025 was 31.05°C - well above average (Figure 22). In the year prior to the survey monthly average temperatures were above average, the highest temperature was 33.1°C in November 2024, this was one degree above average (Figure 23). There was an increase to well above average temperature leading up to the survey in January 2025, and remained slightly above average in the survey month (Figure 23).

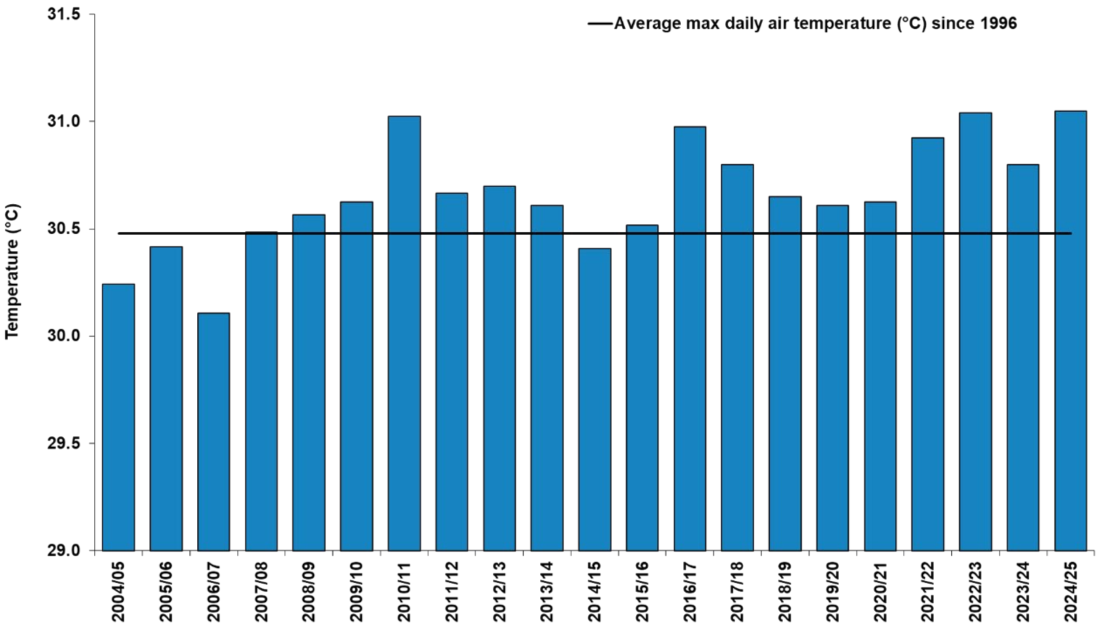



**Figure 20 Mean maximum daily air temperature (°C) recorded at Horn Island, 2004/05 – 2024/25. Twelve month year is twelve months prior to survey.**

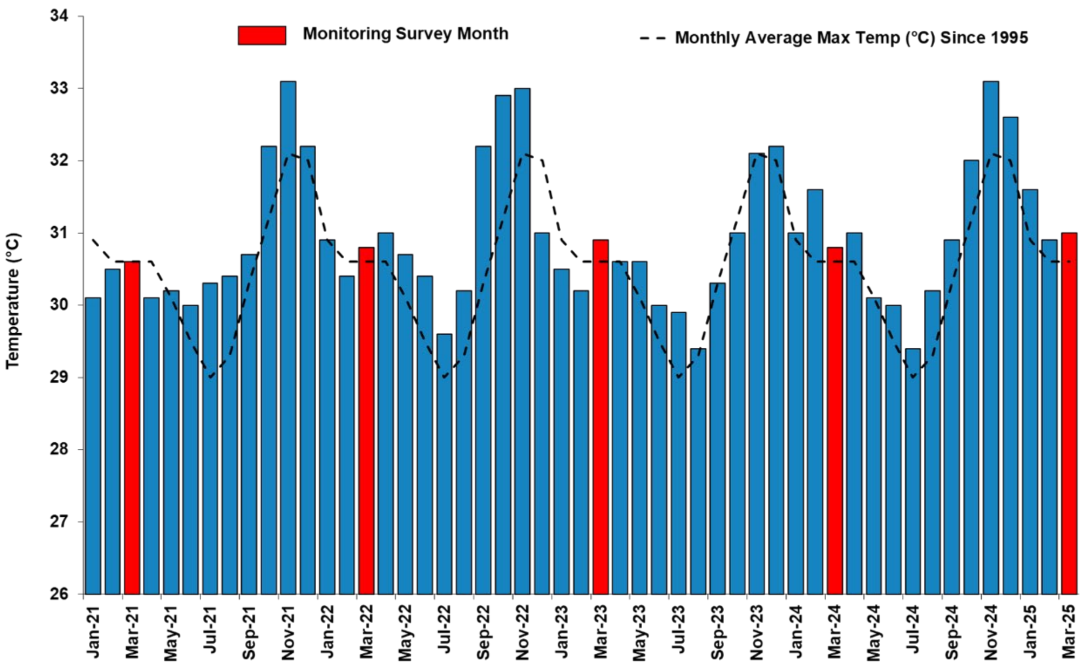



**Figure 21 Monthly mean maximum daily air temperature (°C) recorded at Horn Island, January 2021 – March 2025.**

### 3.2.3 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 slightly above average in 2024/2025 at 21 MJ $m^{-2}$ (MegaJoules $m^{-2}$) (Figure 24). The monthly values 12 months prior to the survey sat close to the average, only increasing well above average in November 2024 and February 2025 and were slightly above average for March 2025 (Figure 25).

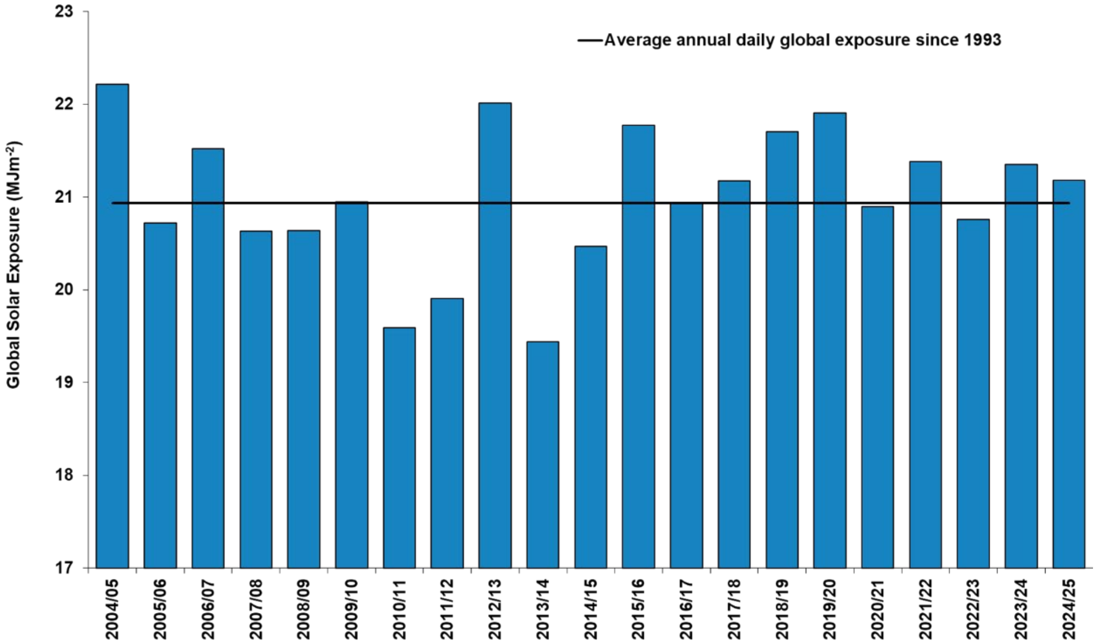



**Figure 22 Mean daily global exposure (MegaJoules $m^{-2}$) recorded at Horn Island, 2004/05 – 2024/25. Twelve month year is twelve months prior to survey.**

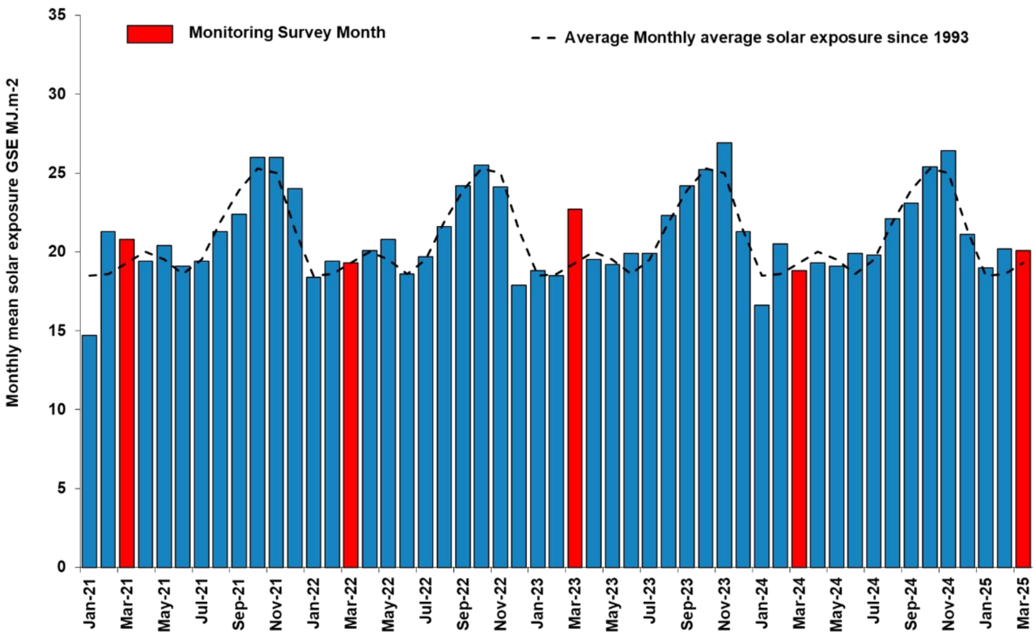



**Figure 23 Mean daily global solar exposure (MegaJoules $m^{-2}$) recorded at Horn Island, January 2021 - March 2025.**

### 3.2.4 Tidal Exposure of Seagrass Meadows

Annual daytime tidal exposure for intertidal seagrass was slightly above average in 2025 (Figure 26). The intertidal seagrass meadows were exposed for a total of 191 daytime hours in the 12 months prior to the survey (Figure 26). In the 12 months prior to the survey, including, the survey month (March 2025), the monthly daytime exposure stayed below-average, except for April, August and September 2024 (Figure 27), both April and August 2024 had the highest monthly exposures since surveys began.

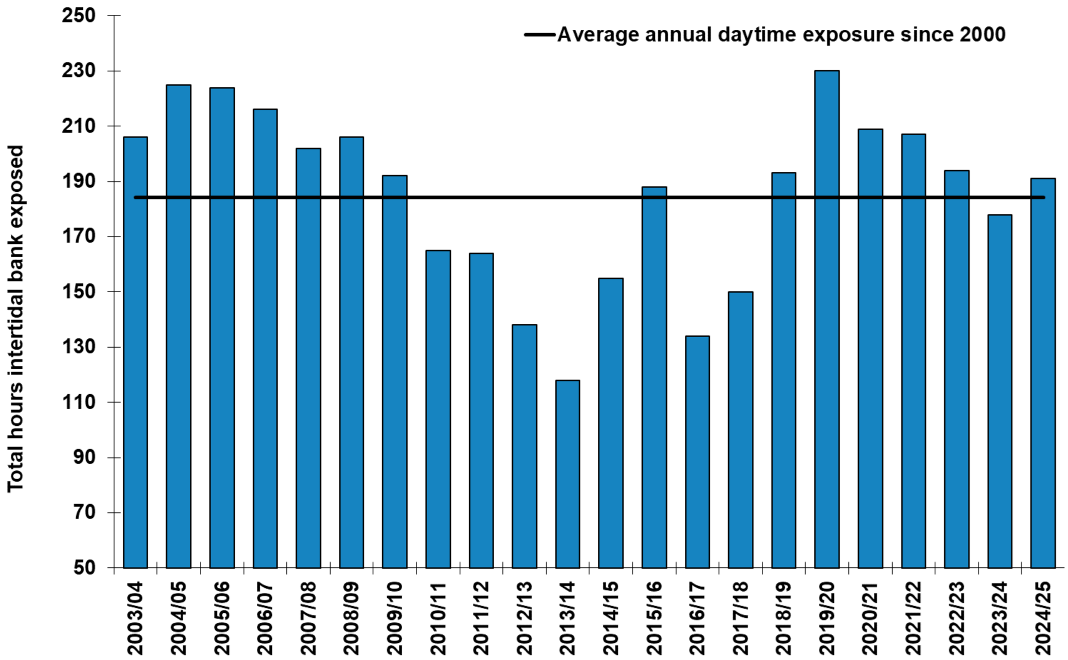



FIGURE 24 TOTAL HOURS DAYTIME EXPOSURE (ANNUAL) OF INTERTIDAL SEAGRASS IN THE PORT OF THURSDAY ISLAND; 2003/04 – 2024/25. TWELVE MONTH YEAR IS TWELVE MONTHS PRIOR TO SURVEY. *ASSUMES INTERTIDAL BANKS BECOME EXPOSED AT A TIDE HEIGHT <0.8M ABOVE LOWEST ASTRONOMICAL TIDE.

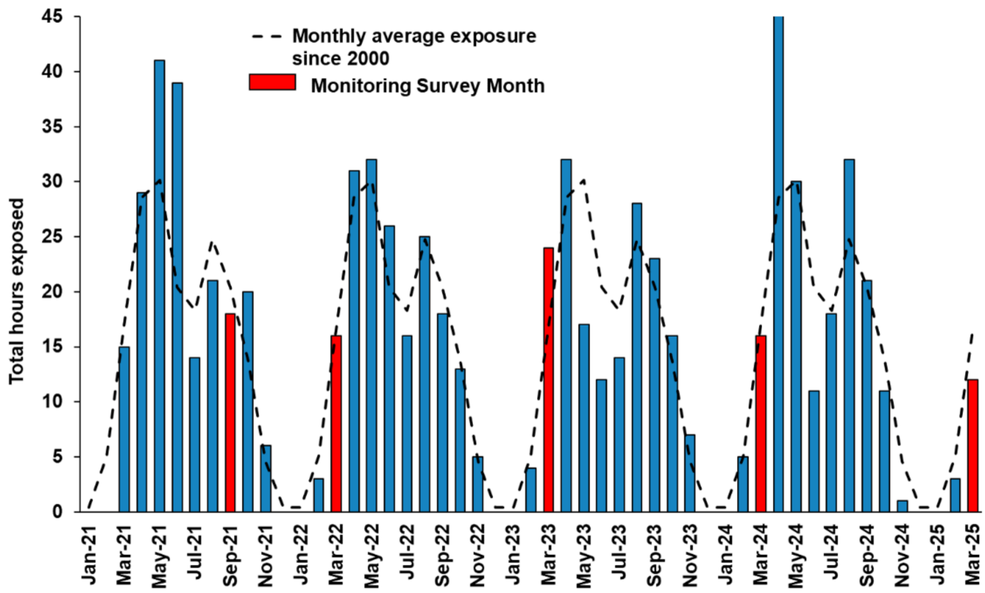



FIGURE 25 TOTAL HOURS OF DAYTIME EXPOSURE (MONTHLY), JANUARY 2021 TO MARCH 2025. *ASSUMES INTERTIDAL BANKS BECOME EXPOSED AT A TIDE HEIGHT <0.8M ABOVE LOWEST ASTRONOMICAL TIDE. PREDICTED DATA USED FOR JAN-MAR 2024 AS GAUGE WAS NOT OPERATIONAL.

# 4 DISCUSSION

Seagrasses in the Port of Thursday Island were in a good condition in 2025, an improvement from satisfactory condition in 2024. All meadows either maintained or improved their condition and the overall seagrass area in the Port increased. This recovery is a positive sign following the declines recorded in the previous whole of port survey and the drop in condition across many of the monitoring meadows seen in 2024.

In 2024, declines in biomass seagrass within *Enhalus acoroides* dominated meadows led to the overall condition of Thursday Island's seagrasses being downgraded from good to satisfactory after three consecutive years of good scores (Scott *et al*., 2024). In 2025, biomass in these meadows recovered, improving the condition of both individual meadows and the port as a whole. Although some intertidal *Halodule uninervis* dominated meadows had small declines in biomass, their biomass scores remained good or very good, and all other meadow indictors either maintained or improved their scores in 2025.

The recovery of the *E. acoroides* meadows highlights the resilience of this species. Despite its slow growth rates and high light requirements (Kilminster et al. 2015; Collier et al. 2016), *E. acoroides* stores large energy reserves in its below-ground rhizomes, providing resilience during periods of stress. However, if those reserves are depleted over longer time periods, the species becomes vulnerable. Although elsewhere in Torres Strait similar *E. acoroides* declines have preceded broader seagrass losses (Carter et al. 2020, 2021), the 2025 Thursday Island survey showed that recovery can be rapid when favourable conditions return.

Recent studies also suggest that heat and high light stress, particularly during low tide, can significantly reduce *E. acoroides* photosynthetic performance (Zhang et al., 2023). In the year leading up to the 2025 survey, environmental conditions were generally favourable for seagrass growth across all species. Most variables were close to average, except for higher-than-average air temperatures throughout the year and elevated tidal exposure in April and August 2024. Air temperatures have been above average since 2015/16 and have been very high in the previous few years, fortunately the periods of very high tidal exposure were during the winter months where air temperatures were cooler, limiting stress on the seagrass meadow. This pattern of favourable conditions supporting recovery is also reflected in Weipa, the nearest comparable port, where seagrass condition likewise improved from satisfactory to good following more optimal environmental conditions.

The seagrass recovery observed at Thursday Island is promising for the wider Torres Strait region. While the Torres Strait Seagrass Monitoring Program reported that all seagrass clusters were in satisfactory condition in 2024 (Carter *et al*., 2024), some areas—including the subtidal meadows within the dugong sanctuary that first declined in 2019—continue to show limited recovery.

The seagrasses around Thursday Island were reproducing sexually in 2025 and the survey team observed sexual reproduction in *E. acoroides*, including flowering and large aggregations of male flowers floating at the surface. Although asexual reproduction is often 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 maintaining resilience in a meadow (Rasheed 2004; Rasheed et al. 2014).

The seagrass in Torres Strait is an important feeding ground for dugongs and green turtles and the meadows around Thursday Island also support these herbivores. I In 2025, dugong feeding trails were recorded at three sites; however, no evidence of green turtle cropping was observed. Herbivory has contributed to declines elsewhere in the region (Carter et al, 2024, Scott et al., 2022), so maintaining healthy meadows in areas like Thursday Island is vital. Both dugongs and green turtles are known to travel large distances in search of food across Torres Strait (Cleguer *et al*., 2016; Gredzens *et al*., 2014), making local seagrass condition important on a regional scale.

Overall, the 2025 seagrass survey for Thursday Island shows a positive trajectory, with recovery in both monitoring meadows and broader port areas and an overall good condition. Seagrass condition in the Port of Thursday Island is a key indicator of overall marine environmental health and this year's results demonstrate the capacity of these ecosystems to rebound when environmental conditions are suitable. The results of this long-term monitoring 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. 2023).

# 5 REFERENCES

Bryant, C., Jarvis, J. C., York, P. and Rasheed, M. 2014. Gladstone Healthy Harbour Partnership Pilot Report Card; ISP011: Seagrass. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 14/53, James Cook University, Cairns, 74 pp.

Carter, A., Mellors, J., Whap, T., Hoffmann, L., and Rasheed, M. 2020. Torres Strait Seagrass 2020 Report Card. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 20/24, James Cook University, Cairns, 62 pp.

Carter, A. B., David, M., Whap, T., Hoffmann, L. R., Scott, A. L. and Rasheed, M. A. 2021. Torres Strait Seagrass 2021 Report Card Centre for Tropical Water & Aquatic Ecosystem Research Publication 21/13,. James Cook University, Cairns.

Carter A, Proctor M, David M, Scott A, Rasheed M and Torres Strait Regional Authority Land and Sea Rangers. 2024. Torres Strait Seagrass Report Card 2024. Centre for Tropical Water & Aquatic Ecosystem Research Publication 24/15, James Cook University, Cairns, 63 pp.

Carter, A., Taylor, H., McKenna, S., York, P. and Rasheed, M. 2014. The effects of climate on seagrasses in the Torres Strait, 2011-2014. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University, Cairns, 36 pp.

Carter, A. B., Jarvis, J. C., Bryant, C. V. and Rasheed, M. A. 2015. Development of seagrass indicators for the Gladstone Healthy Harbour Partnership Report Card, ISP011: Seagrass. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 15/29, James Cook University, Cairns, 71 pp.

Cleguer, C., Preston, S., Hagihara, R., Shimada, T., Udyawer, V., Hamann, M., Simpson, S., Loban, F., Bowie, G., Fujii, R., and Marsh, H. 2016. Working with the community to understand use of space by dugongs and green turtles in Torres Strait: A project in collaboration with the Mura Badulgal Registered Native Title Bodies Corporate. Report to the National Environmental Science Programme. Reef and Rainforest Research Centre Limited, Cairns (62pp.).

Coles, R. G., Lee Long, W. J., Watson, R. A. and Derbyshire, K. J. 1993. Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, Northern Queensland, Australia. Marine and Freshwater Research, **44**: 193-210

Collier, C. J., Chartrand, K., Honchin, C., Fletcher, A. and Rasheed, M. 2016. Light thresholds for seagrasses of the GBR: a synthesis and guiding document. Including knowledge gaps and future priorities. Report to the National Environmental Science Programme, Cairns, 41 pp.

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S. and Turner, R. K. 2014. Changes in the global value of ecosystem services. Global Environmental Change, **26**: 152-158

Fourqurean, J. W., Duarte, C. M., Kennedy, H., Marba, N., Holmer, M., Mateo, M. A., Apostolaki, E. T., Kendrick, G. A., Krause-Jensen, D., McGlathery, K. J. and Serrano, O. 2012. Seagrass ecosystems as a globally significant carbon stock. Nature Geoscience, **5**: 505-509

Gredzens, C., Marsh, H., Fuentes, M. M. P. B., Limpus, C. J., Shimada, T. and Hamann, M. 2014. Satellite tracking of sympatric marine megafauna can inform the biological basis for species co-management. PLoS One 9. doi:10.1371/JOURNAL.PONE.0098944.

Heck, K. L., Carruthers, T. J. B., Duarte, C. M., Hughes, A. R., Kendrick, G., Orth, R. J. and Williams, S. W. 2008. Trophic Transfers from Seagrass Meadows Subsidize Diverse Marine and Terrestrial Consumers. Ecosystems, **11**: 1198-1210

Heck, K. L., Hays, G. and Orth, R. J. 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows. Marine Ecology Progress Series, **253**: 123-136

Kilminster, K., McMahon, K., Waycott, M., Kendrick, G. A., Scanes, P., McKenzie, L., O'Brien, K. R., Lyons, M., Ferguson, A., Maxwell, P., Glasby, T. and Udy, J. 2015. Unravelling complexity in seagrass systems for management: Australia as a microcosm. Science of The Total Environment, **534**: 97-109

Lavery, P. S., Mateo, M.-Á., Serrano, O. and Rozaimi, M. 2013. Variability in the carbon storage of seagrass habitats and its implications for global estimates of blue carbon ecosystem service. PLoS ONE, **8**: e73748

Long, B. and Skewes, T. 1996. On the trail of seagrass dieback in Torres Strait. Professional Fisherman, **18**: 15-16, 18

Madsen, J. D., Chambers, P. A., James, W. F., Koch, E. W. and Westlake, D. F. 2001. The interaction between water movement, sediment dynamics and submersed macrophytes. . Hydrobiologia, **444**: 71-84

Marsh, H., Lawler, I. R., Kwan, D., Delean, S., Pollock, K. and Alldredge, M. 2004. Aerial surveys and the potential biological removal technique indicate that the Torres Strait dugong fishery is unsustainable. Animal Conservation, **7**: 435-443

McGlathery, K. J., Sundbäck, K. and Anderson, I. C. 2007. Eutrophication in shallow coastal bays and lagoons: the role of plants in the coastal filter. Marine Ecology Progress Series, **348**:

McMahon, K. and Walker, D. I. 1998. Fate of seasonal, Terrestrial Nutrient Inputs to a shallow seagrass dominated embayment. Estuarine, Coastal and Shelf Science, **46**: 15-25

Mellors, J. E., McKenzie, L. J. and Coles, R. G. 2008. Seagrass-Watch: Engaging Torres Strait Islanders in marine habitat monitoring. Continental shelf research, **28**: 2339-2349

Pendleton, L., Donato, D. C., Murray, B. C., Crooks, S., Jenkins, W. A., Sifleet, S., Craft, C., Fourqurean, J. W., Kauffman, J. B., Marba, N., Megonigal, P., Pidgeon, E., Herr, D., Gordon, D. and Baldera, A. 2012. Estimating global "blue carbon" emissions from conversion and degradation of vegetated coastal ecosystems. PLoS ONE, **7**: e43542

Rasheed, M. A. 2004. Recovery and succession in a multi-species tropical seagrass meadow following experimental disturbance: the role of sexual and asexual reproduction. Journal of Experimental Marine Biology and Ecology, **310**: 13-45

Rasheed, M. A., McKenna, S. A., Carter, A. B. and Coles, R. G. 2014. Contrasting recovery of shallow and deep water seagass communities following climate associated losses in tropical north Queensland, Australia. Marine Pollution Bulletin. **83:** 491-499

Reason, C. L., McKenna, S.A., and Rasheed, M.A. 2025. Port of Weipa Long-Term Seagrass Monitoring Program – 2024. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 24/71. James Cook University, Cairns, 33 pp.

Roelofs, A. J., Rasheed, M. A. and Thomas, R. 2003. Port of Weipa seagrass monitoring, 2000 - 2002. Ports Corporation of Queensland, Brisbane, 32 pp.

Scott, A. L., York, P. H., Duncan, C., Macreadie, P. I., Connolly, R. M., Ellis, M. T., Jarvis, J. C., Jinks, K. I., Marsh, H. and Rasheed, M. A. 2018. The role of herbivory in structuring tropical seagrass ecosystem service delivery. Frontiers in Plant Science, **9**:

Scott, A.L., Whap, T., Kris, J., Joe, S., Carlisle, M., David, M., Rasheed, M.A., York, P.H. and Carter, A.B. 2022. The role of dugong and turtle grazing in Torres Strait seagrass declines: Exclusion experiments show the role of green turtle and dugong grazing in structuring Torres Strait seagrass meadows. Report to the National Environmental Science Program. TropWATER.

Scott A, Jonson C, Reason C & Rasheed M. 2024. Seagrass habitat in the Port of Thursday Island: Annual seagrass monitoring report 2024, Centre for Tropical Water & Aquatic Ecosystem Research Publication Number 24/33, James Cook University, Cairns, 42 pp.

Unsworth, R. K. F., Rasheed, M. A., Chartrand, K. M. and Roelofs, A. J. 2012. Solar radiation and tidal exposure as environmental drivers of enhalus acoroides dominated seagrass meadows. PLoS ONE, **7**:

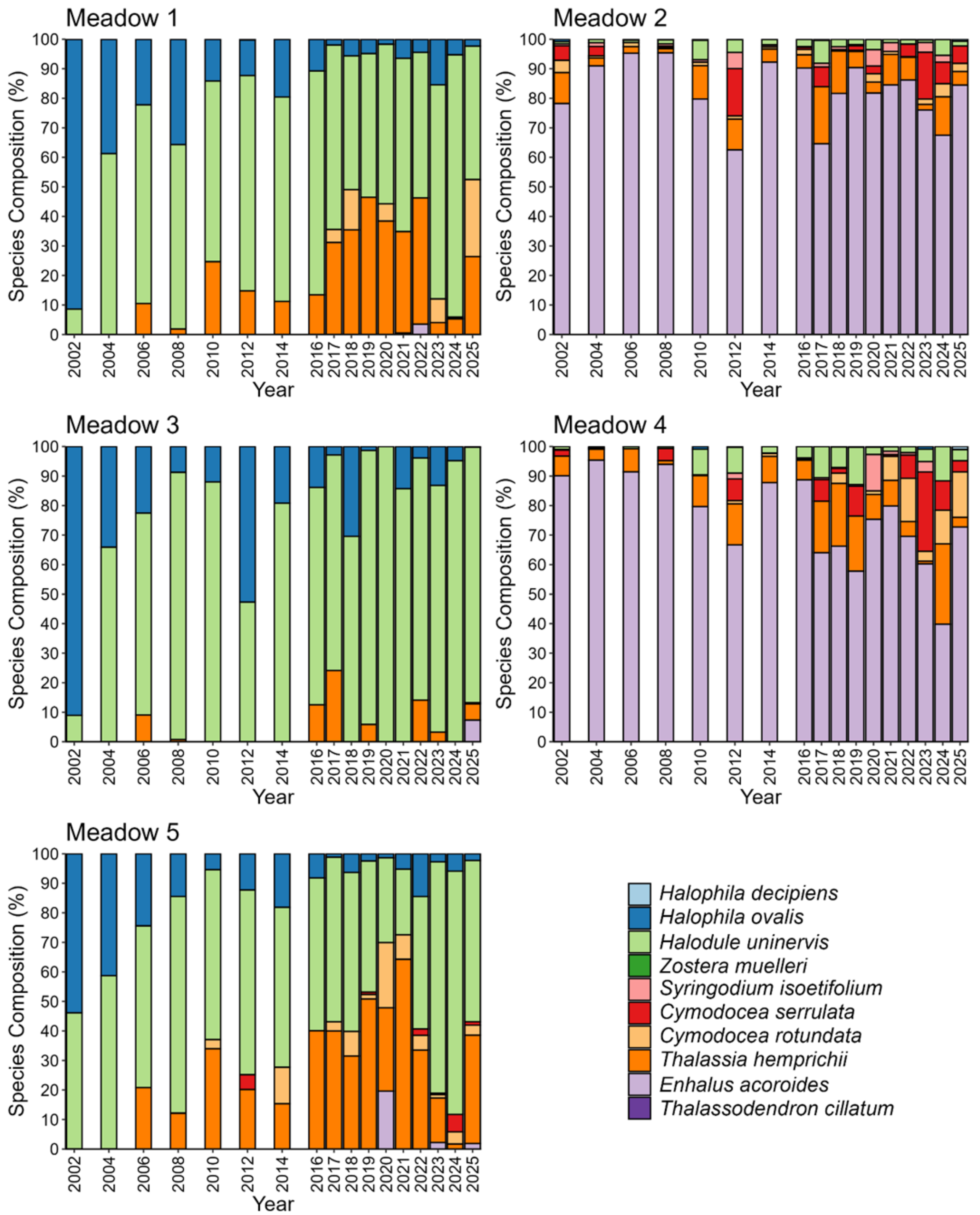
Unsworth, R. K. F., Collier, C. J., Mckenzie, L. J. and Cullen-Unsworth, L. C. 2015. A framework for the resilience of seagrass ecosystems. Marine Pollution Bulletin. **100:** 34-46.

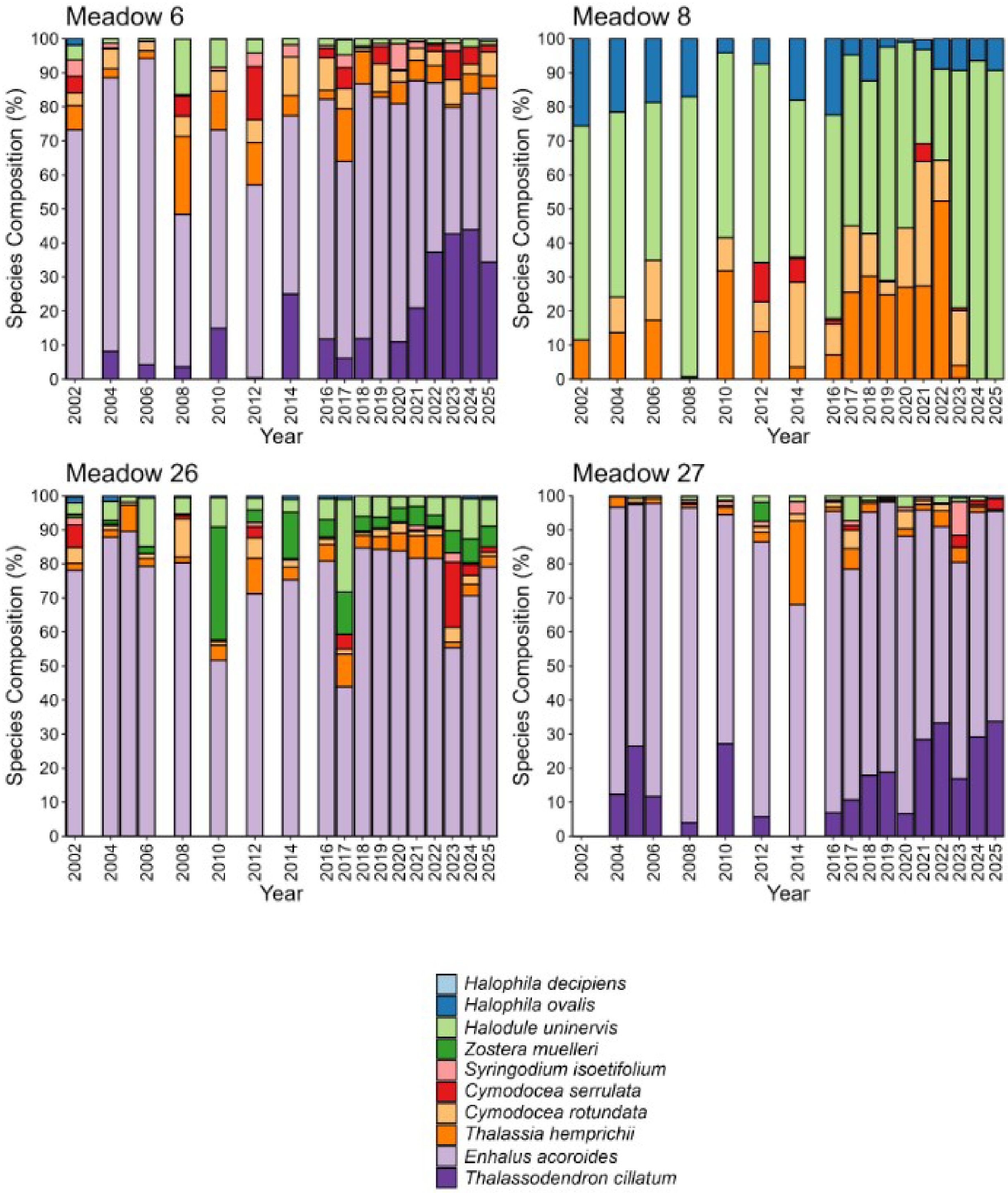
Wells, J., Reason, C. and Rasheed, M. 2019. Seagrass habitat of Mourilyan Harbour: Annual monitoring report - 2018. Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) Publication 19/14. James Cook University, Cairns, 36 pp.

Zhang, M., Li, H., Zhang, L. and Liu, J. 2023. Heat stress, especially when coupled with high light, accelerates the decline of tropical seagrass (*Enhalus acoroides*) meadows. Marine Pollution Bulletin. **192**:115043.

# 6 APPENDICIES

## APPENDIX 1. SPECIES COMPOSITION OF MONITORING MEADOWS IN THE PORT OF THURSDAY ISLAND; 2002–2025




Meadow 6
Meadow 8
Meadow 26
Meadow 27
Species Composition (%)
Year
Halophila decipiens
Halophila ovalis
Halodule uninervis
Zostera muelleri
Syringodium isoetifolium
Cymodocea serrulata
Cymodocea rotundata
Thalassia hemprichii
Enhalus acoroides
Thalassodendron cillatum

# 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, 2002–2025.

| Monitoring Meadow | Mean Biomass ± SE (g DW m$^{-2}$) (no. of sites) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **March 2002** | **March 2004** | **March 2005** | **March 2006** | **March 2008** | **Feb 2010** | **Feb 2012** | **Feb 2014** | **March 2016** | **March 2017** | **April 2018** | **March 2019** | **Sept 2020** | **March 2021** | **March 2022** | **March 2023** | **March 2024** | **March 2025** |
| **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) | 12.63 ± 1.34 (35) | 7.68 ± 2.27 (25) |
| **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) | 19.5 ± 1.89 (41) | 34.58 ± 4.10 (47) |
| **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) | 11.5 ± 3.24 (8) | 11.73 ± 3.58 (11) |
| **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) | 13.5± 2.45 (18) | 23.55 ± 4.71 (37) |
| **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) | 13.82 ± 1.46 (35) | 10.76 ± 1.31 (49) |
| **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) | 32.84± 7.21 (41) | 41.03 ± 5.71 (52) |
| **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) | 16.33 ± 2.01 (40) | 7.88 ± 0.82 (43) |
| **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) | 17.55 ± 1.2 (58) | 45.52 ± 3.28 (57) |
| **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) | 14.06 ± 3.5 (19) | 41.28 ± 8.18 (22) |

# APPENDIX 4B

Total meadow area ± R (ha) for each monitoring meadow within the Port of Thursday Island, 2002 – 2025.

| 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** | **Sept 2020** | **March 2021** | **March 2022** | **March 2023** | **March 2024** | **March 2025** |
| **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 | 2.99 ± 0.45 | 2.93 ± 0.42 |
| **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 | 11.87 ± 0.84 | 11.61 ± 0.84 |
| **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 | 0.35 ± 0.04 | 0.44 ± 0.043 |
| **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 | 1.81 ± 0.40 | 1.87 ± 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 | 2.95 ± 0.42 | 3.17 ± 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 | 13.17 ± 1.13 | 13.07 ± 1.18 |
| **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 | 13.11 ± 1.12 | 13.13 ± 1.06 |
| **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 | 90.26 ± 3.21 | 92.07 ± 3.20 |
| **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 | 7.21 ± 0.75 | 7.76 ± 0.73 |