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Seagrass Habitat of Cairns Harbour and Trinity Inlet: Annual Monitoring Report 2025

May 2026 | Report No. 26/17



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Seagrass Habitat of Cairns Harbour and Trinity Inlet: Annual Monitoring Report 2025

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The report may be cited as

Scott, A., Reason C.L., McKenna S., Smith, T. and Rasheed M. 2026. Seagrass habitat of Cairns Harbour and Trinity Inlet: Annual Monitoring Report 2025, Centre for Tropical Water & Aquatic Ecosystem Research, Publication Number 26/17, James Cook University, Cairns, 42 pp.

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Acknowledgements

This project was funded by Ports North. We wish to thank TropWATER staff including Paul Leeson and Luke Hoffmann for their invaluable assistance in the field, laboratory, and office.

We acknowledge the Australian Aboriginal and Torres Strait Islander peoples as the Traditional Owners of the lands and waters where we live and work.

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1. KEY FINDINGS

Cairns Harbour Seagrass condition 2025



Trinity Inlet Seagrass condition 2025



- This report presents results of the 25th annual survey in the Cairns long-term seagrass monitoring program.
- The overall condition of seagrasses in Cairns Harbour declined to poor in 2025 and Trinity Inlet remained poor. Only one meadow was in good condition with the rest satisfactory or below.
- Seagrass declines were linked to prevailing climate and weather patterns. This was the second year of very high rainfall in Cairns, following the record flooding after cyclone Jasper in December 2023. These multiple back-to-back events resulted in poor growing conditions for seagrasses.
- An extended period of low light was recorded at both Bessie and Ellie Point between November 2024 and April 2025, with benthic light below the minimum requirements for both *Zostera muelleri* and *Halodule uninervis*. This coincided with above average monthly rainfall during this time.
- While seagrasses declined in 2025, within Cairns Harbour this was largely driven by large declines in both biomass and area of the *H. uninervis* dominated meadow (Meadow 11) between Bessie Point and False Cape.
- The large *Z. muelleri* meadow adjacent to the Esplanade (Meadow 34) remained in a satisfactory condition with seagrasses covering much of the historical seagrass footprint.
- The smaller highly variable *Halophila* dominated meadows in Trinity Inlet collectively remained in a poor condition in 2025, however there was improvement in Meadow 33 to a good condition.
- Seed banks remained for meadows in Cairns Harbour, although density of *Z. muelleri* seeds declined and *H. uninervis* seed density remained stable in 2025.
- The poor condition of seagrass meadows indicates that repeated stressors are starting to erode resilience. However, monitoring history shows recovery can be rapid if conditions are favourable and when seagrasses maintain a presence within meadow footprints and have viable seed banks, which remained the case in 2025.

2. IN BRIEF

Seagrasses have been monitored annually in Cairns Harbour and Trinity Inlet since 2001. Each year six seagrass monitoring meadows representing the range of different seagrass community types found in Cairns are mapped and assessed for changes in area, biomass, and species composition. These metrics are then used to develop a seagrass condition index from very poor to very good (Figure 1). All seagrasses within the port limits are also remapped every three years as part of the long-term monitoring program.

Annual assessments of the seagrass seed bank density and viability are also conducted in the Esplanade and Bessie Point meadows. Benthic light and temperature (continuously logged) is also monitored in these meadows (Site E and B; Figure1) as well as at Trinity Inlet adjacent to the Redbank Creek meadow (Site R; Figure 1).

In 2025 the Cairns Harbour and Inlet seagrass meadows were in an overall poor condition, declining from satisfactory for the Harbour and maintaining condition for the Inlet. Total biomass and area in the monitoring meadows were both below baseline levels (Figure 2).

The large Bessie Point monitoring meadow (11) was in poor condition, while Meadow 13 and the large Esplanade meadow (34) were in an overall satisfactory condition, with all three condition indicators varying from poor to very good (Figure 1).

The three smaller Trinity Inlet estuarine monitoring meadows remained in a collective overall poor condition in 2025. Meadow 19 declined to a very poor condition due to a shift in species composition, while Meadow 33 improved to a good condition with increases in both biomass and area since 2024 (Figure 1). The small Redbank *Z. muelleri* meadow (20) was absent again in 2025.

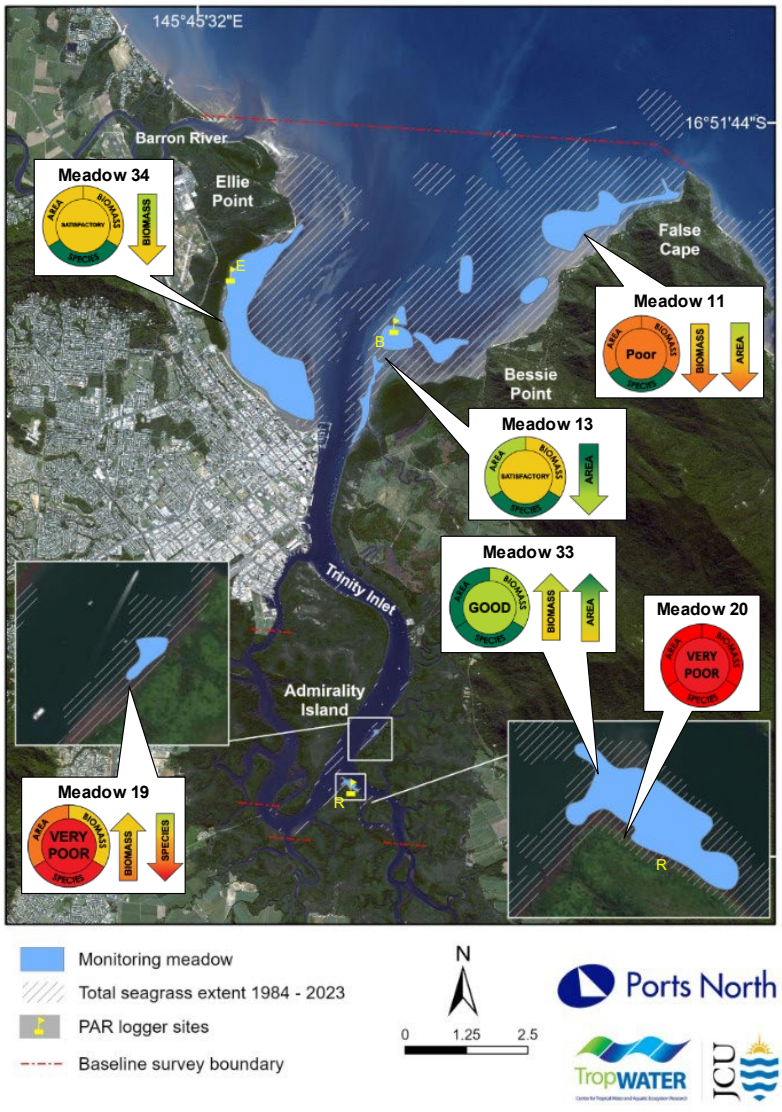


FIGURE 1: SEAGRASS MONITORING MEADOW CONDITION IN CAIRNS HARBOUR AND TRINITY INLET, 2025.

Sustained periods of low benthic light (benthic Photosynthetically Active Radiation (bPAR) at both Ellie and Bessie Point during 2025 was the likely cause of seagrass declines in the Cairns Harbour meadows. Low bPAR was associated with above average rainfall in the wet season (Figure 3). Daytime tidal exposure was slightly below average during 2024/25 (Figure 3). These conditions followed the record

rainfall and flooding in 2024 after Tropical Cyclone Jasper at the end of 2023, with the cumulative multi-year pressures likely contributing to the declines in 2025.

In 2025 seed banks remained present in both of the meadows. There was a decrease in *Z. muelleri* seed density in the Esplanade meadow from the previous year, but viable seeds were recorded for the first time since 2020. *H. uninervis* seeds were recorded in both meadows, with low numbers on the Esplanade but higher densities at Bessie point maintained at similar levels to the previous year.

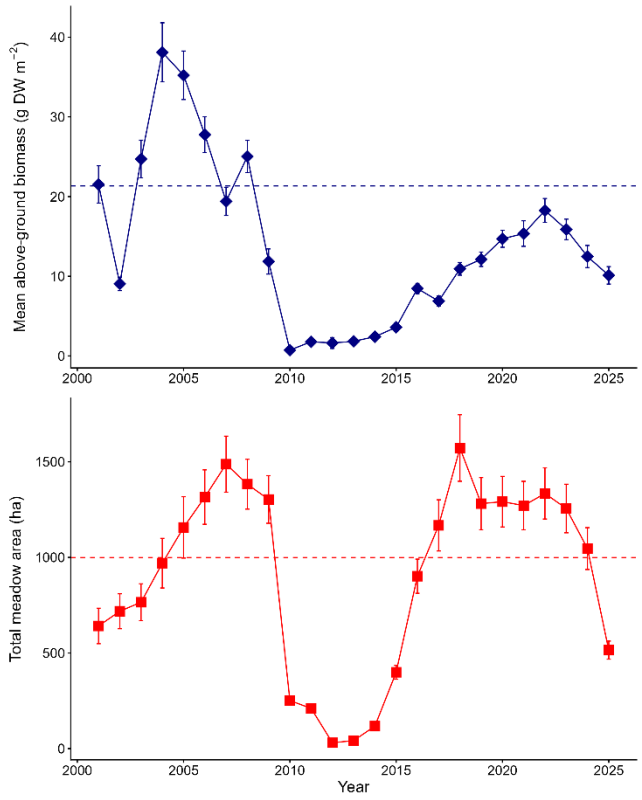


FIGURE 2: TOTAL A) BIOMASS AND B) AREA OF SEAGRASS WITHIN ALL CAIRNS MONITORING MEADOWS FROM 2001 TO 2025. DOTTED LINE INDICATES 10-YEAR (2001 – 2010) BASELINE MEAN.

The declines in seagrass condition in Cairns in 2025 are likely impacting the key seagrass ecosystem services provided by these meadows. These include food for dugong and green turtles, nursery habitat for juvenile fish and prawns, improved water quality through the trapping of suspended sediments and the capture and storage of carbon and nitrogen in plant tissues and sediments.

These declines likely reflect a reduction in resilience after multiple years of adverse growing conditions, and mean seagrasses may be more vulnerable to further declines if similar conditions persist.

However, historical declines in the monitoring program have shown seagrass recovery can be relatively rapid with the return of favourable growing conditions, and where propagules including remaining adult plants within the meadow footprint and viable seed banks remain, which was the case in 2025.

The Cairns Harbour and Trinity Inlet seagrass monitoring forms part of a broader program that examines condition of seagrasses in most Queensland commercial ports and areas of high cumulative anthropogenic risk. In Mourilyan Harbour, the nearest monitoring site to Cairns, seagrass has not recovered from the widespread losses between 2009 and 2011, largely due to the complete loss of the foundation species *Z. muelleri* (Shepherd et al. 2025). Across the wider Queensland seagrass monitoring network, seagrass condition has varied, with some areas showing signs of recovery while others declined. In general, these reflected local climate and weather conditions, similar to observations in Cairns. Seagrass in the Gulf of Carpentaria were in a good condition in Weipa with favourable climate and poor in Karumba where flooding locally impacted seagrasses (Reason et al. 2026; Scott and Rasheed 2026). On the east coast, Townsville seagrass was in a poor condition due to a range of unfavourable weather conditions over the past seven years (Tol et al. 2026).

For full details of the Queensland ports seagrass monitoring program see https://www.tropwater.com/project/management-of-ports-and-coastal-facilities/

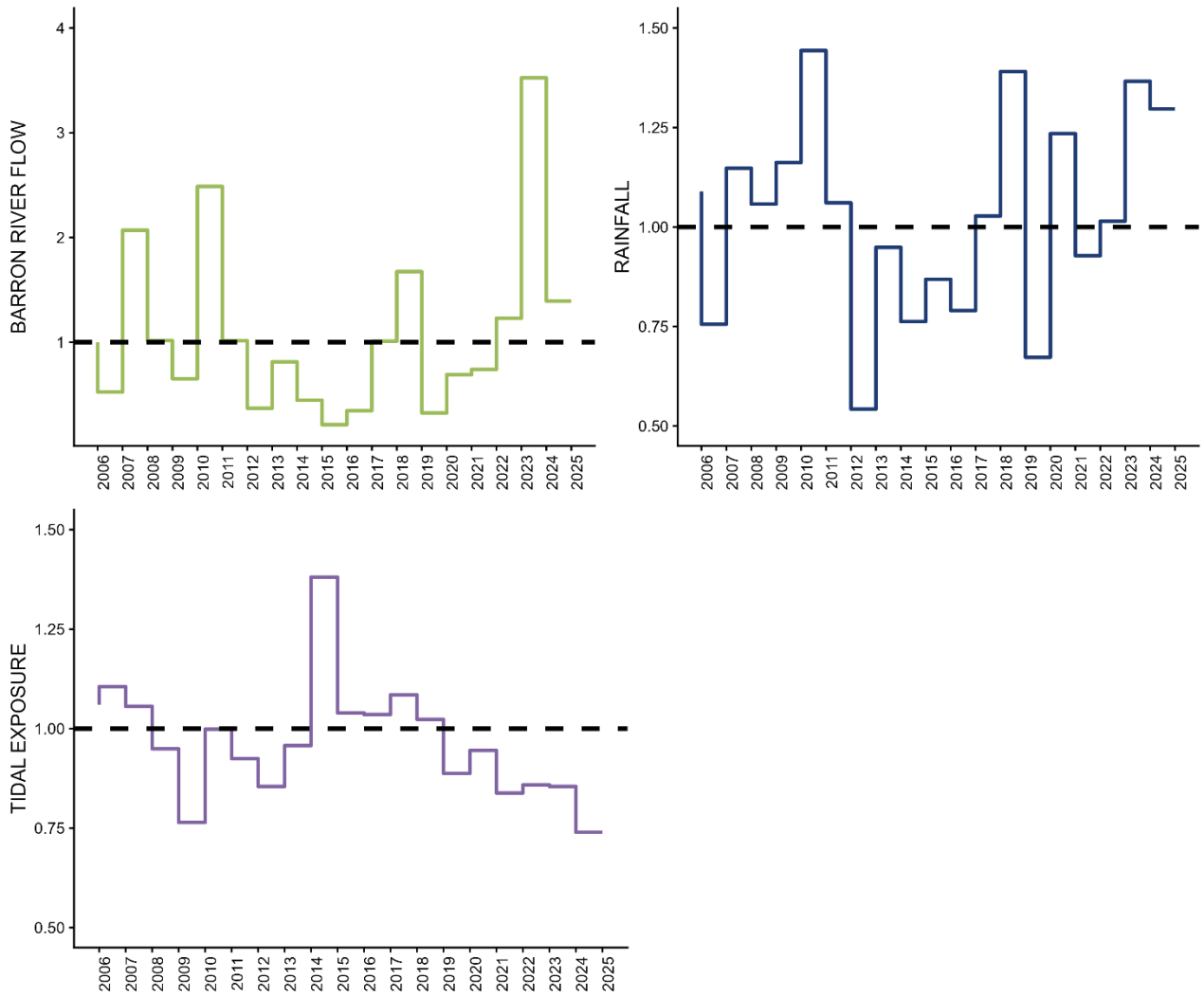


FIGURE 3: CLIMATE TRENDS IN CAIRNS: CHANGE IN CLIMATE VARIABLES AS A PROPORTION OF THE LONG-TERM AVERAGE.

3. INTRODUCTION

Seagrasses are one of the most productive marine habitats on earth and provide a variety of important ecosystem services worth substantial economic value (Costanza et al. 2014). These services include the provision of nursery habitat for economically important fish and crustaceans (Heck et al. 2003; Coles et al. 1993), and food for grazing mega herbivores like dugongs and sea turtles (Heck et al. 2008; Scott et al. 2018; Scott et al. 2020). Further, seagrasses play a major role in the cycling of nutrients (McMahon and Walker 1998), stabilisation of sediments (Christianen et al. 2013), improving of water quality (McGlathery et al. 2007) and studies suggest they are one of the most efficient and powerful carbon sinks in the marine realm (Fourqurean et al. 2012; Pendleton et al. 2012, York et al. 2018).

Globally, seagrasses have been declining at ever increasing rates due to both natural and anthropogenic causes (Waycott et al. 2009). Explanations for seagrass decline include natural disturbances such as storms, disease and overgrazing by herbivores as well as anthropogenic stresses including direct disturbance from coastal development, dredging, and trawling, coupled with indirect effects through changes in water quality due to sedimentation, pollution, and eutrophication (Short and Wyllie-Echeverria 1996; Dunic et al. 2021; Turschwell et al. 2021). In the tropical Indo-Pacific region industrial and urban run-off, port development, and dredging have all been identified as threats to seagrass (Grech et al. 2012). Locally in the Great Barrier Reef (GBR) coastal region, the highest threat areas for seagrasses all occur in the southern two thirds of the GBR, in areas where multiple threats accumulate including urban, port, industrial and agricultural runoff (Grech et al. 2011). These hot spots arise as seagrasses preferentially occur in the same sheltered coastal locations that ports and urban centres are established (Coles et al. 2015). In Queensland this has been recognised and a strategic monitoring program of these high-risk areas has been established to aid in their management and ensure impacts are minimised (Coles et al. 2015).

3.1 Queensland Ports Seagrass Monitoring Program

A long-term seagrass monitoring and assessment program has been established in most Queensland commercial ports. The program was developed by the Seagrass Ecology Group at 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 the key information to ensure that seagrasses and ports can co-exist. It is useful information for planning and implementing port development and maintenance programs so they have a minimal impact on seagrasses. The program also provides an ongoing assessment of many of the most threatened seagrass communities in the state.



FIGURE 4: LOCATION OF QUEENSLAND PORT SEAGRASS ASSESSMENT SITES (RED – LONG-TERM MONITORING AND BASELINE MAPPING; BLUE - BASELINE MAPPING ONLY).

The program not only delivers key information for the management of port activities to minimise impacts on seagrasses but has also resulted in significant advances in the science and knowledge of tropical seagrass ecology. It has been instrumental in developing tools, indicators and thresholds for the protection and management of seagrasses and 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/

3.2 Port of Cairns Seagrass Monitoring Program

The Port of Cairns is located within Trinity Bay and Trinity Inlet and operated by Ports North. It is one of Queensland's busiest ports and handles bulk and general cargo, cruise ships, fishing fleets and passenger ferries. Existing port infrastructure includes twelve operational wharves, commercial fishing bases, two barge ramps (CFB2 and the southern barge ramp), marina and mooring facilities, swing basins and a 10 km long channel which is subject to annual maintenance dredging.

Ports North have recognised that seagrasses make up an ecologically important and environmentally sensitive habitat in the Port of Cairns and recognise their value as a tool for monitoring water quality and the marine environmental health of the port.

In partnership with the James Cook University (JCU) - Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) and following the baseline survey conducted in 2001 (Campbell et al. 2002), Ports North established an annual seagrass monitoring program which helped define the natural variation for seagrass communities and some of the links between seagrass change and climate. The annual monitoring program conducted between October and December each year provides a regular update of the marine environmental health of Trinity Bay (Cairns Harbour) and Trinity Inlet and an assessment of seagrass condition and resilience to inform port management. As the annual monitoring program only examines a sub-set of representative seagrass meadows, an updated baseline survey of all of the seagrass in the system is conducted every 3 years. Annual assessments of the seagrass seed bank and the viability of buried seeds are conducted for the two main seagrass meadows in Cairns Harbour as a measure of the resilience to future impacts in March of each year.

In addition to the annual seagrass monitoring, benthic light (benthic Photosynthetically Active Radiation (bPAR) and temperature (continuously logged) data are recorded at three sites (Figure 1) to help assess the condition and resilience of seagrass and their associated benthic light (bPAR) levels.

The overall objectives of the 2025 annual seagrass monitoring were to:

1. Map and quantify the distribution, abundance and species composition of the selected long-term seagrass monitoring meadows.
2. Compare monitoring results with previous seagrass surveys and assess changes in relation to natural events, port and catchment activities.
3. Assess seagrass condition and examine seagrass change in relation to light (bPAR), and reproductive effort (seed banks).

4. METHODS

4.1 Sampling Approach

Survey and monitoring methods followed the established techniques for JCU's Queensland-wide seagrass monitoring programs. The application of standardised methods in Cairns and throughout Queensland allows for direct comparison of local seagrass dynamics with other seagrass monitoring programs in the broader Queensland region.

The annual seagrass survey was conducted during the seasonal peak of seagrass condition in October 2025.

Queensland seagrass communities are seasonal, with maximum distribution and abundance usually occurring in late spring/early summer.

4.2 Sampling Methods

Intertidal meadows were sampled at low tide using a helicopter. GPS was used to map the position of meadow boundaries and sites were scattered haphazardly within each meadow. Sites were surveyed as the helicopter hovered less than one metre above the substrate (Figure 5). Shallow subtidal meadows were sampled by boat using camera drops and van Veen grab (Figure 5). A Van Veen sediment grab (grab area 0.0625 m^{-2}) was used where required at each camera site to confirm sediment type and species viewed on the video screen. Subtidal sites were positioned at approximately 50 to 100 m intervals 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. Seagrass above-ground biomass was determined using a "visual estimates of biomass" technique (see Mellors 1991; Kirkman 1978).

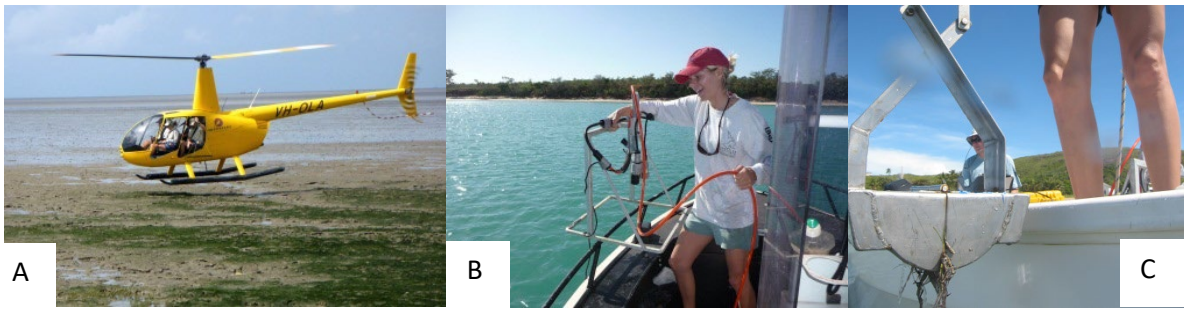


FIGURE 5: SEAGRASS MONITORING METHODS IN 2025. (A) HELICOPTER SURVEY OF INTERTIDAL SEAGRASS, (B AND C) BOAT-BASED CAMERA DROPS AND VAN VEEN GRAB FOR SUBTIDAL SEAGRASS.

Seagrass meadow boundaries were constructed using GPS marked meadow boundaries where possible, seagrass presence/absence site data, field notes, and aerial photographs taken during helicopter surveys. Meadow area was determined using the calculate geometry function in ArcPro 3.6.2®. Meadows were assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow (Table 1). 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 2). Community density was based on mean biomass of the dominant species within the meadow (Table 3). Seagrass meadows were also described using 'landscape categories' (Figure 6). Seagrass meadows were classified from meadows that contained isolated patches, through to meadows that had a continuous cover of seagrass.

TABLE 1: MAPPING PRECISION AND METHODOLOGY FOR SEAGRASS MEADOWS IN CAIRNS HARBOUR AND TRINITY INLET.

Mapping precision	Mapping methodology
1-10 m	• Meadow boundaries determined from a combination of helicopter and camera/grab surveys. • Exposed inshore boundaries mapped from helicopter. • Offshore boundaries interpreted from subtidal survey sites. • Relatively high density of mapping and survey sites. • Small subtidal meadows in Trinity Inlet.
10-50 m	• Subtidal meadow boundaries determined from camera/grab surveys only. • All meadows subtidal. • Patchy cover of seagrass throughout meadow. • Moderate density of survey sites. • Recent aerial photography aided in mapping.

TABLE 2: NOMENCLATURE FOR SEAGRASS COMMUNITY TYPES IN CAIRNS HARBOUR AND TRINITY INLET.

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 3: DENSITY CATEGORIES AND MEAN ABOVE-GROUND BIOMASS RANGES FOR EACH SPECIES USED IN DETERMINING SEAGRASS COMMUNITY DENSITY CAIRNS HARBOUR AND TRINITY INLET.

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

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.

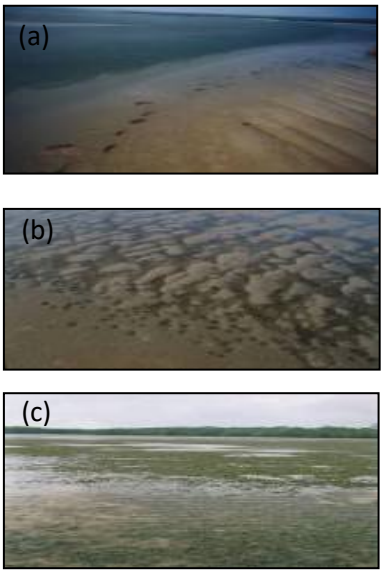


Figure 6: Seagrass meadow landscape categories: (a) Isolated seagrass patches, (b) aggregated seagrass patches, (c) continuous seagrass cover.

4.3 Seagrass Meadow condition index

A condition index was developed for seagrass monitoring meadows based on changes in the key indicators: mean above-ground biomass, total meadow area and species composition, relative to a long-term baseline (see Carter et al. 2023 for full details). Seagrass condition for each indicator in monitoring meadows 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).

4.4 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 2025, Tidal Data) for Cairns (https://www.msq.qld.gov.au/tides/tide-tables).
- 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) (Cairns Airport, Station #31011; http://www.bom.gov.au/climate/data/).
- River flow data (gigalitres; GL) was obtained from the Queensland Government (Barron River at Myola, Station #110001D; https://water-monitoring.information.qld.gov.au/).

4.5 Seed bank assessment & seed viability

Seed-bank density for *Z. muelleri* and *H. uninervis* is quantified around March each year for the two main seagrass meadows in Cairns Harbour (Bessie Point and Esplanade meadows). This timing is likely to capture a representative sample of the total pool of seeds in the sediment from the previous fruiting season that are available for germination in the subsequent growing season.

Approximately 30 sediment cores measuring 50 mm in diameter and 100 mm in depth were taken randomly within the boundary of each meadow (Figure 7). Each 100mm sediment core was separated into three depth categories (0 – 20 mm, 20 – 50 mm and 50 – 100 mm) then sieved with fresh water to separate out seagrass seeds from the sediment. For all samples, the 710 µm to 1 mm fraction of the sediment was inspected for *H. uninervis* and *Z. muelleri* seeds using a dissecting microscope. Seed density data were delineated by species and reported as mean number of seeds per m^{-2} per site.

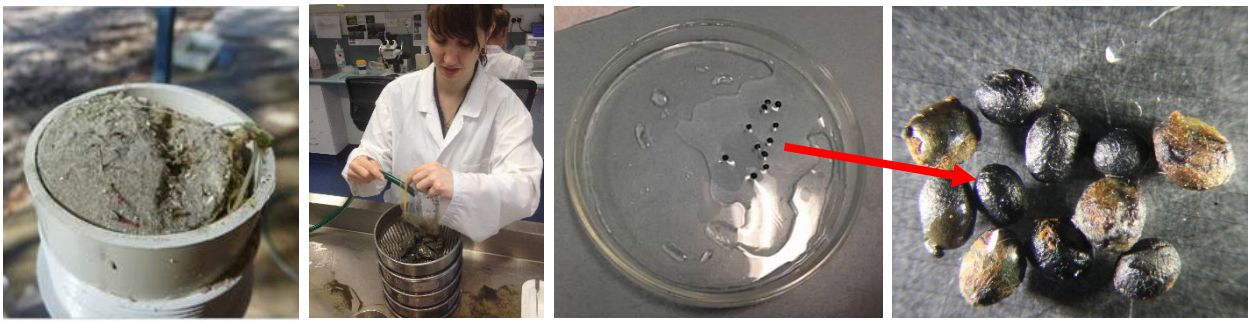
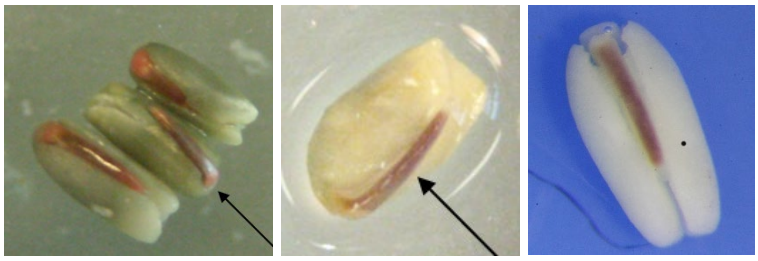


FIGURE 7: SEDIMENT SEED BANK CORES, SIEVING CORES IN THE LAB AND *HALODULE UNINERVIS* SEEDS FOUND IN THE SIEVED MATERIAL.

Once identified, collected, and recorded all seeds were stored in scintillation vials with mesh screening (<0.1 mm diameter) in 37 L tanks containing oxygenated salt water collected from Cairns Harbour at 8-10 °C until processing (Marion and Orth 2010). All intact seeds were tested for viability using tetrazolium chloride to stain respiring cells (Jarvis et al. 2021; Conacher et al. 1994) within 1 week of collection. Tetrazolium chloride was used due to increased accuracy and greater time efficiency compared to traditional germination tests (Jarvis and Moore 2010; Conacher et al. 1994). Seed embryos were removed from their seed coats and soaked in a 0.5 % tetrazolium chloride solution for 48 hours before examination on a dissecting microscope at 10 x magnification (Jarvis et al. 2021). Seeds with a red to brown stained cotyledon and axial hypocotyl were considered viable as this indicates living cells that can go on to germinate (Jarvis et al. 2021; Conacher et al. 1994; Harrison 1993) (Figure 8). Viability data were separated by species and reported as mean number of viable seeds per m^{-2} per site. Seed bank sampling reported here was conducted in March 2025.



Viable seagrass seeds (various shades of red/brown cotyledons)



Non-viable seagrass seeds (white cotyledons)

FIGURE 8: EXAMPLES OF STAINED VIABLE AND NON-VIABLE *ZOSTERA MUELLERI* SEEDS USING TETRAZOLIUM CHLORIDE.

4.5 Habitat mapping and Geographic Information System

All survey data was entered into a Geographic Information System (GIS) using ArcPro 3.6.2®. Satellite imagery of the Cairns area with information recorded during the monitoring surveys was combined to assist with mapping seagrass meadows. Three seagrass GIS layers were created:

4.5.1 Seagrass site layer

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

- Unique identifier
- Temporal details – Survey date and time.
- Spatial details – Latitude/longitude, depth below mean sea level (dbMSL; metres) for subtidal sites.
- Habitat information – Sediment type; seagrass information including presence/absence, above-ground biomass (total and for each species) and biomass standard error (SE).
- Sampling method and any relevant comments.
- Comments (e.g., dugong feeding trail (DFT) presence/absence.

4.5.2 Seagrass meadow layer

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

- Meadow unique identifier – 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) (Table 4), number of sites within the meadow, seagrass species present, meadow density and community type (Tables 2, 3), meadow landscape category (Figure 6).
- Sampling method
- Comments (e.g., dugong feeding trails present in meadow).

4.5.3 Seagrass biomass interpolation layer

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

4.6 Temperature and Light bPAR Loggers

Light (Benthic Photosynthetically Active Radiation or bPAR) and temperature are monitored continuously at three sites: The Esplanade/Ellie Point (Site E), Bessie Point (Site B) and Redbank (Site R) (Figure 1). Monitoring of within seagrass canopy temperature (°C) was recorded every 15 minutes using autonomous iBTag submersible temperature loggers. Temperature loggers were replaced at each location quarterly. Submersible OdysseyTM photosynthetic irradiance autonomous loggers (light loggers) were also deployed to assess bPAR. Continuous measurements were conducted and recorded by the logger every 15 minutes. Automatic wiper brushes cleaned the optical surface of the sensor every 15 minutes to prevent marine organisms fouling the sensors. Light loggers were replaced and downloaded quarterly.

5. RESULTS

5.1 Seagrass presence and species in monitoring meadows

A total of 539 habitat characterisation sites were assessed across the annual monitoring survey in 2025 (Figure 9). Seagrass was present at 47% of sites and a total seagrass area of 515 ± 88 ha was mapped in the annual monitoring meadows (Figure 10a and 10b).

Six species of seagrass were found in the monitoring meadows, a similar composition to previous years (Table 4). *Thalassia hemprichii* has only occasionally been recorded in Cairns Harbour and was not recorded for the third year in a row in the annual monitoring meadows in 2025.

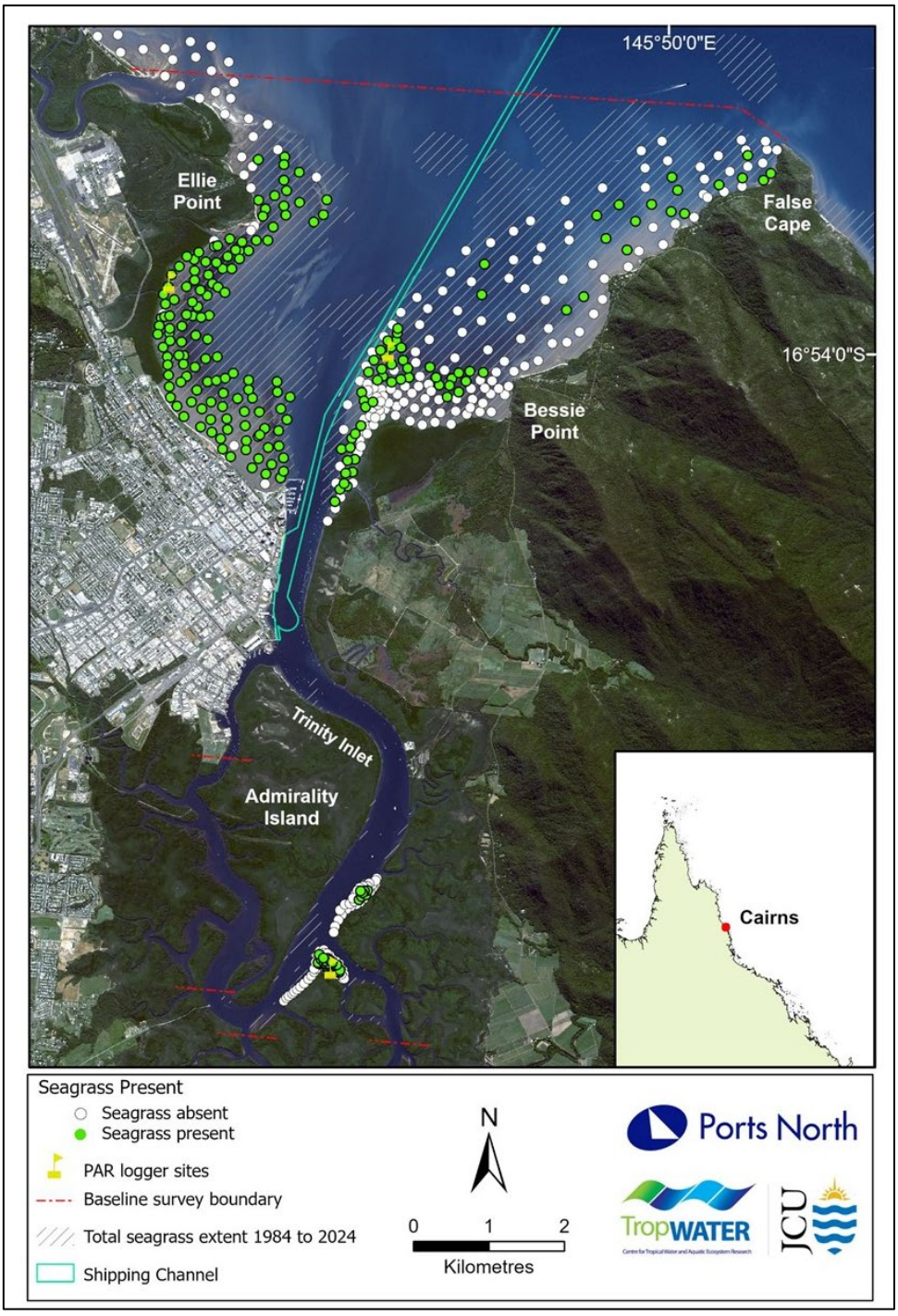


FIGURE 9: SEAGRASS PRESENCE/ABSENCE AT SITES SURVEYED WITHIN THE CAIRNS SURVEY AREA, 2025.

TABLE 4: SEAGRASS SPECIES PRESENT IN CAIRNS HARBOUR AND TRINITY INLET MONITORING MEADOWS IN 2025. PICTURES ARE NOT TO SCALE.



Cymodocea serrulata



Cymodocea rotundata



Zostera muelleri



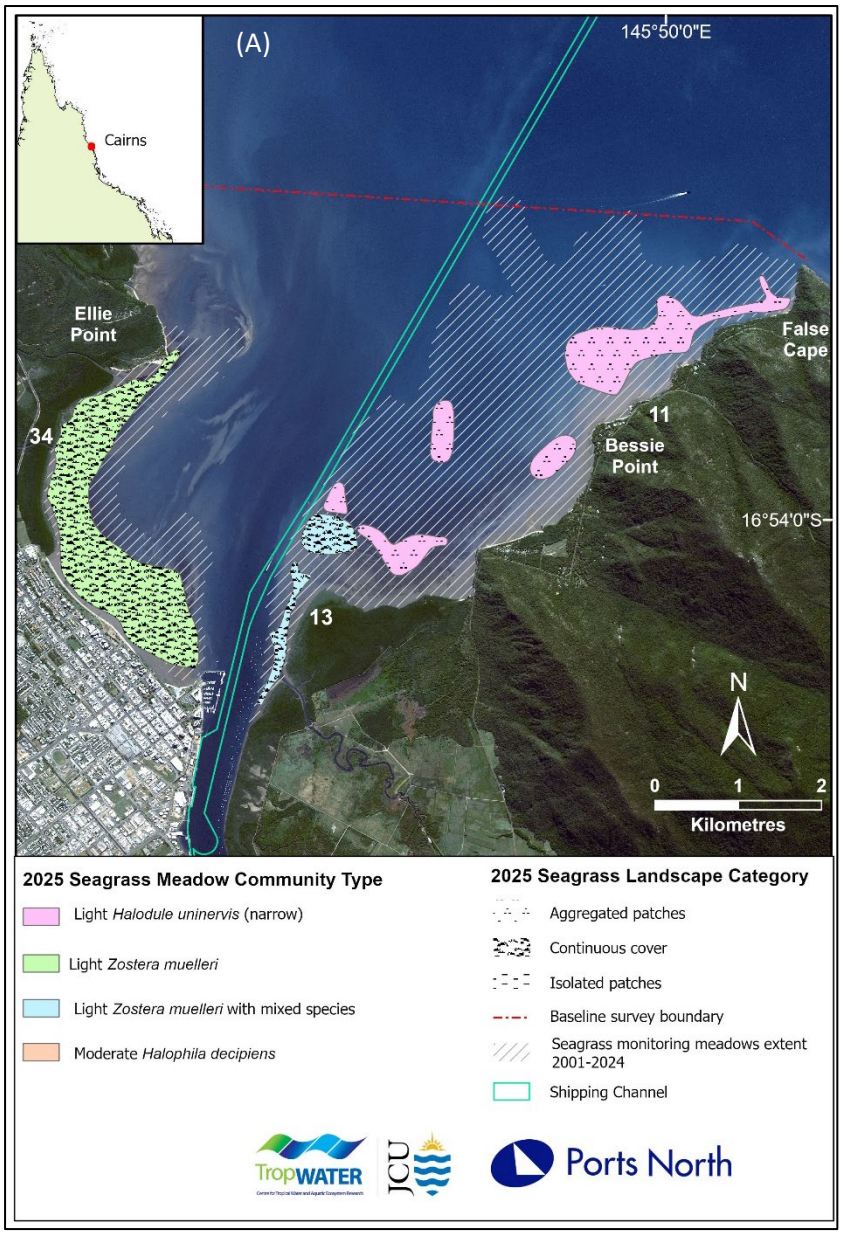
Halodule uninervis (narrow & wide form)



Halophila ovalis



Halophila decipiens



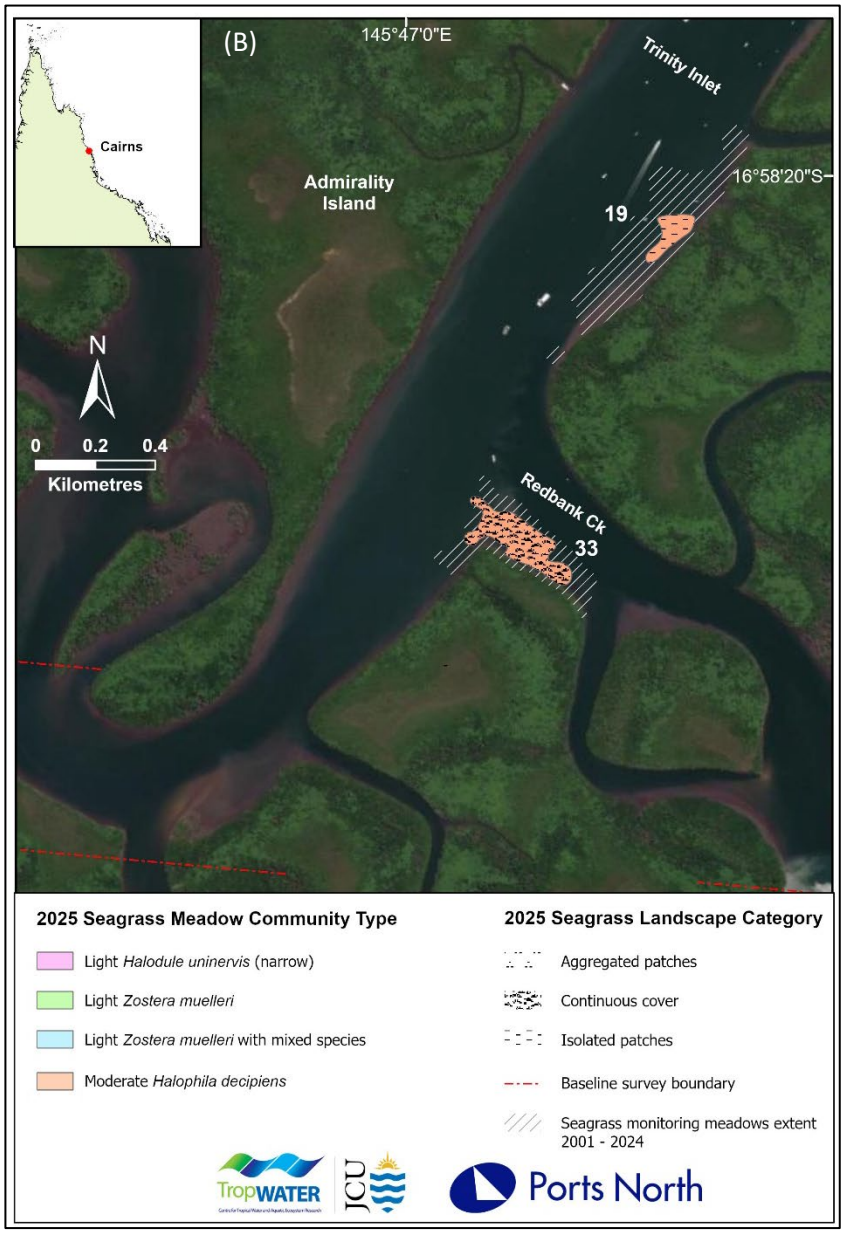


FIGURE 10: (A) CAIRNS HARBOUR MONITORING MEADOWS AND (B) TRINITY INLET MONITORING MEADOW DISTRIBUTION AND COMMUNITY TYPE IN 2025.

5.2 Seagrass condition in monitoring meadows

In 2025, the three large Cairns Harbour monitoring meadows (Meadows 11, 13 and 34) were collectively in a poor condition (Figure 10a; Table 5; Figures 12-14), a decline from a satisfactory overall condition the previous year. While all three meadows had declines in either area or biomass the majority of the decline in condition was due to the Bessie Point (11) monitoring meadow. The species composition remained unchanged for the Cairns Harbour meadows and in a very good condition (Table 5).

The three small Trinity Inlet meadows (Meadows 19, 20 and 33) remained in a poor overall condition, although meadow 19 did improve its biomass score and meadow 33 improved both biomass and area scores, however the low species composition score for meadow 19 and the absence of meadow 20 decreased the overall score (Figure 10b; Table 5; Figures 15-17). In 2025, the small intertidal Redbank Creek meadow (20) was once again absent with no *Z. muelleri* recorded (Figure 10b; Table 5; Figure 16). The subtidal Trinity Inlet meadow (19) remained in a poor condition due to a decline in species composition (Table 5; Figure 17). In contrast, the Redbank subtidal meadow (33) showed improvement, with its overall condition upgraded to good (Table 5; Figure 18).

The overall mean biomass of the six long-term monitoring meadows in 2025 was 10.11 ± 1.1 g DW m^{-2}, a 20% decline from the previous year (Figure 11a). While biomass steadily increased from 2010 to 2022, this marks the fourth consecutive year of decline, with current levels remaining well below the long-term average of 21.3 g DW m^{-2} (Figure 11a). In 2025, the total area of monitoring meadows was 515 ± 47 ha, this was almost a 50% decline from 2024 and is the first time the meadow area has dropped below the long-term average since 2017 (Figure 11b).

TABLE 5: GRADES AND SCORES FOR SEAGRASS INDICATORS (BIOMASS, AREA, AND SPECIES COMPOSITION) FOR THE LONG-TERM MONITORING MEADOWS IN CAIRNS; OCTOBER 2025 SURVEY.

Meadow	Biomass	Area	Species Composition	Overall Meadow Score
Cairns Harbour Meadows				
Esplanade to Ellie Pt. (34)	0.59	0.63	0.94	0.59
Bessie Point (11)	0.35	0.34	0.99	0.35
South Bessie Pt (13)	0.53	0.67	0.95	0.53
Overall Score for Cairns Harbour				0.49
Trinity Inlet Meadows				
Inlet (19)	0.64	0.41	0	0.21
Redbank Intertidal (20)	0.0	0.0	0.0	0.0
Redbank Subtidal (33)	0.69	0.89	1.00	0.69
Overall Score for Trinity Inlet				0.30

= very good condition = good condition = satisfactory condition

= poor condition = very poor condition

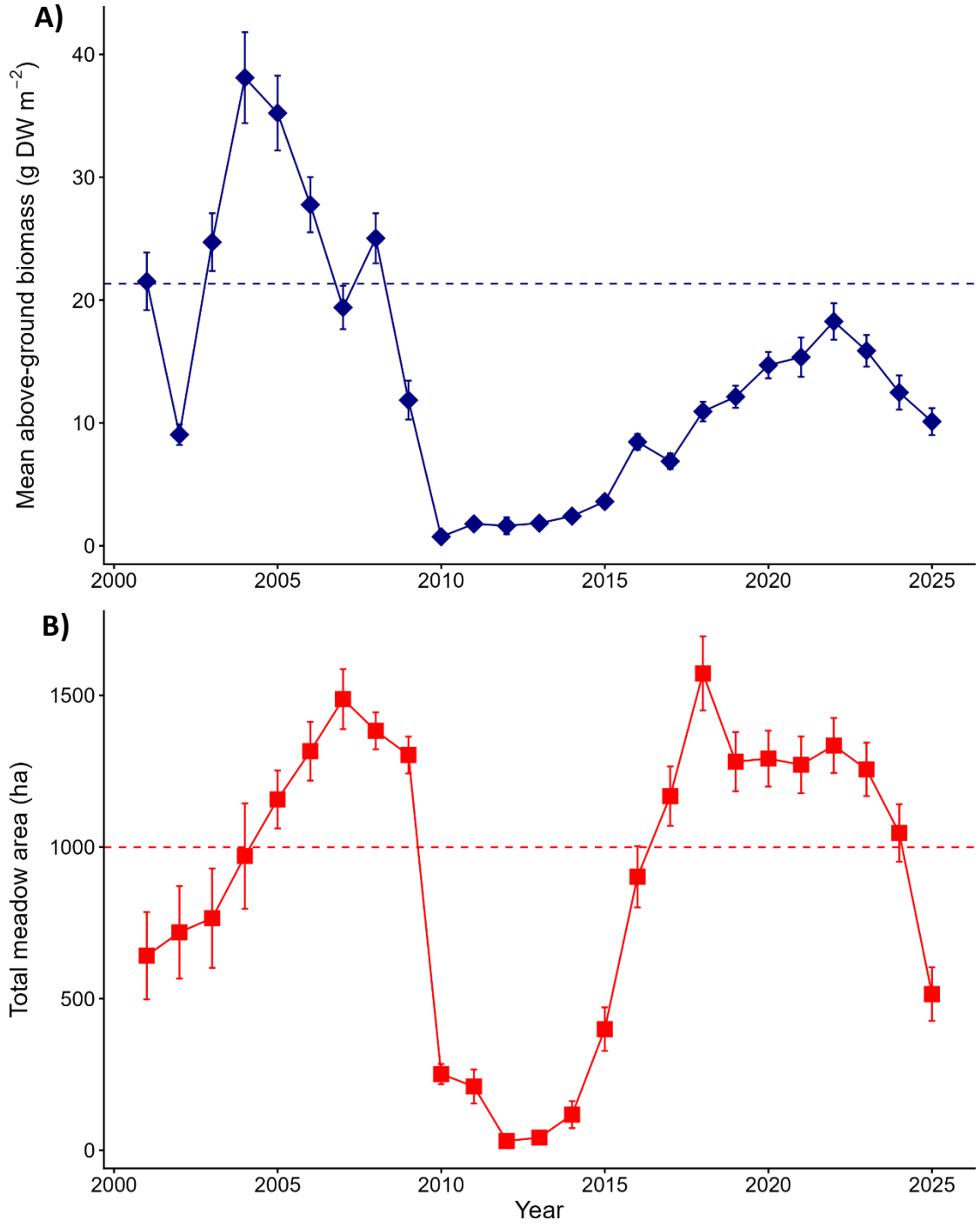


FIGURE 11: TOTAL A) BIOMASS ± SE AND B) AREA OF SEAGRASS ± R WITHIN ALL CAIRNS MONITORING MEADOWS FROM 2001 TO 2025. DOTTED LINE INDICATES 10-YEAR (2001 – 2010) BASELINE MEAN.

5.2.1 Coastal Cairns Harbour Meadows

Two of the three larger monitoring meadows in Cairns Harbour were all in a satisfactory condition in 2025 with the Bessie Point (11) meadow in poor condition (Table 5). This group of coastal meadows include the Esplanade to Ellie Point meadow (34), Bessie Point (11) and South Bessie Point (13).

The Esplanade meadow (34) remained in a satisfactory overall condition in 2025 (Figures 12 and 18). There was a decline in biomass from 27.6 ± 2.7 g DW m^{-2} in 2024 to 19.0 ± 1.9 g DW m^{-2} in 2025, resulting in a decline from good to satisfactory condition (Figure 12). Meadow area increased by 15% from the previous year, though it remained below the long-term baseline average of 308 ha and in satisfactory condition for the second consecutive year (Figures 12 and 18). This meadow is characterised by continuous, moderate-density *Z. muelleri* cover, with biomass hotspots less prominent in 2025 than in previous years (Figures 12 and 18). Species composition remained in a very good condition with an increase in the amount of *Z. muelleri* in the meadow making up 97% of the biomass in 2025 (Figure 12; Appendix 8.1).

The subtidal Bessie Point meadow (11) underwent a substantial decline from 2024 to 2025, the second consecutive year of declines, and was in an overall poor condition (Figure 13). Species composition remained stable and in a very good condition dominated by *H. uninervis*, while both area and biomass declined to poor condition (Figure 13; Appendix 8.1). Biomass declined for the third year in a row, from very good (9.8 ± 0.8 g DW m^{-2}) in 2023 to satisfactory (2.7 ± 0.4 g DW m^{-2}) in 2024 and poor (1.2 ± 0.3 g DW m^{-2}) in 2025 (Figure 13). The meadow previously had a continuous cover of seagrass but consisted of aggregated patches in 2025 (Figure 10a). Meadow area declined dramatically, contracting by over 70% from 687 ± 85 ha in 2024 to 190 ± 79 ha in 2025 (Figures 13 and 19) and had fragmented into five separate areas. This decline in area was well below the baseline average (619 ha) (Figure 13).

The intertidal South Bessie Point meadow (13) was in a satisfactory condition in 2025 (Figure 14). Biomass remained stable and in satisfactory condition, while species composition held its very good condition rating for the seventh consecutive year — dominated by *Z. muelleri* alongside *Cymodocea serrulata*, which together accounted for 83% of the meadow biomass (Figure 14; Appendix 8.1). Meadow area declined by 60% from the previous year, resulting in a downgrade of the area condition rating from very good to good (Figure 14).

5.2.2. Trinity Inlet Estuarine Meadows

The three small monitoring meadows in Trinity Inlet — Trinity Inlet (19), intertidal Redbank Creek (20), and subtidal Redbank Creek (33) — were collectively assessed as being in poor overall condition in 2025, for the third consecutive year (Figures 10b and 20). These meadows are characterised by high year-to-year variability, patchy distribution, and typically moderate to light-density seagrass cover (Figures 10b, 15- 17 and 20). Given their small size, even relatively minor changes in biomass, area, or species composition can shift the overall condition grade.

The Trinity Inlet meadow (19) declined from poor to very poor condition in 2025, driven by a shift in species composition away from the more stable *Halophila ovali*s to exclusively *Halophila decipiens* (Figure 15). Biomass more than doubled and improved from poor to satisfactory condition, though it remained below the baseline average for the fifth consecutive year — consistent with the high interannual variability historically observed at this site (Figure 15). Meadow area remained in poor condition, following seven consecutive years at or above the baseline average prior to 2024 (Figure 15).

The intertidal Redbank Creek *Z. muelleri* meadow (20) was absent for the second year in 2025 (Figure 16). This meadow occupies a narrow strip along the mangrove edge, where it historically connects with the subtidal Meadow 33. Historically, this meadow has shown substantial variability and was previously absent between 2011-2014 and again in 2016 (Figures 16 and 20).

The subtidal Redbank Creek meadow (33) improved in condition for the second consecutive year in 2025 with an upgrade to good due to increases in both biomass and area (Table 5; Figure 17). Seagrass biomass increased

by 50% from the previous year and improved to good condition (Figure 17). Meadow area more than doubled in 2025, resulting in an increase from satisfactory to very good condition, the meadow had been very fragmented in 2024 but now has a continuous seagrass cover across the meadow (Figure 17 and 20).

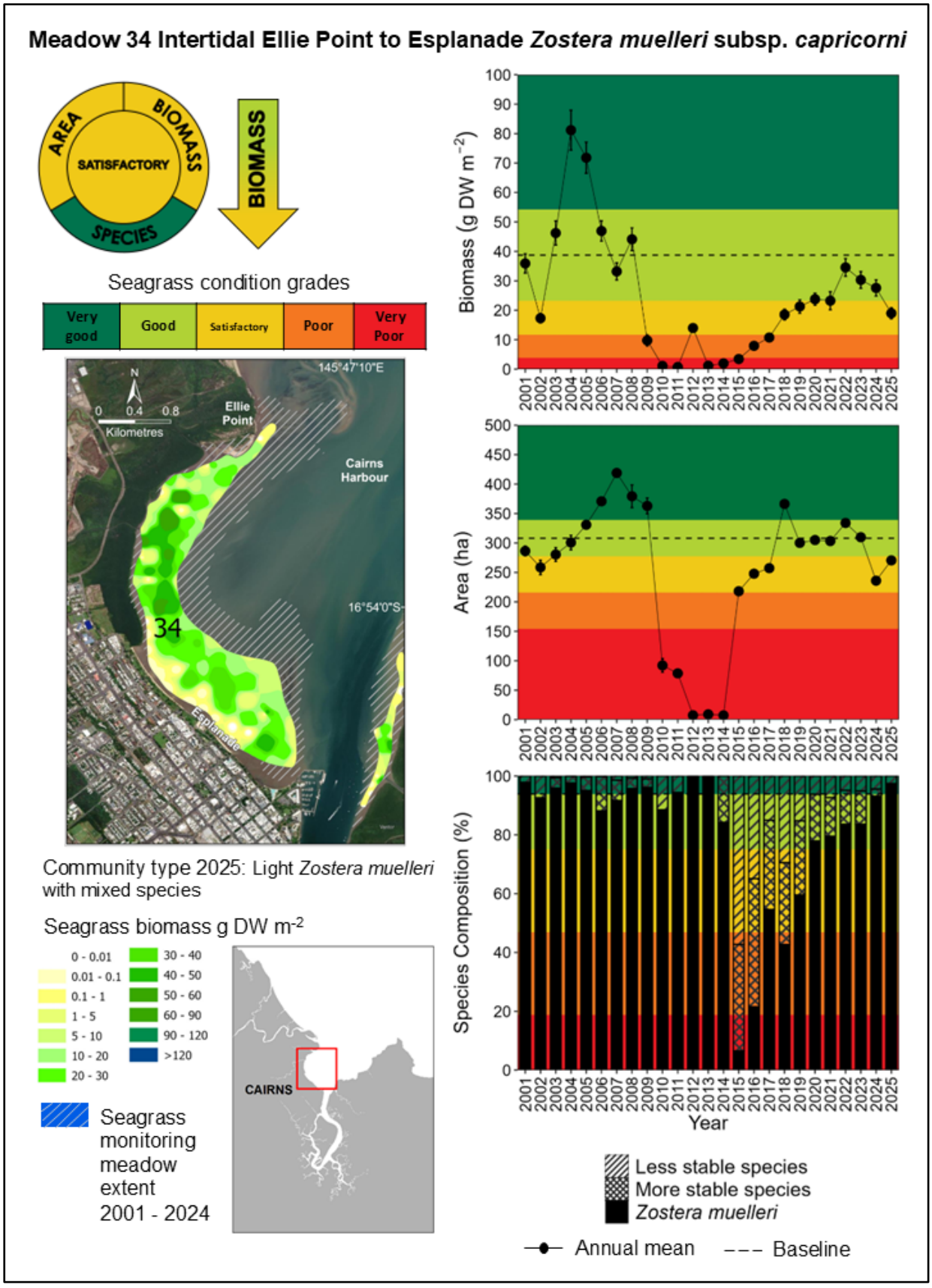


FIGURE 12: CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE ESPLANADE MEADOW (MEADOW NO. 34) FROM 2001 – 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

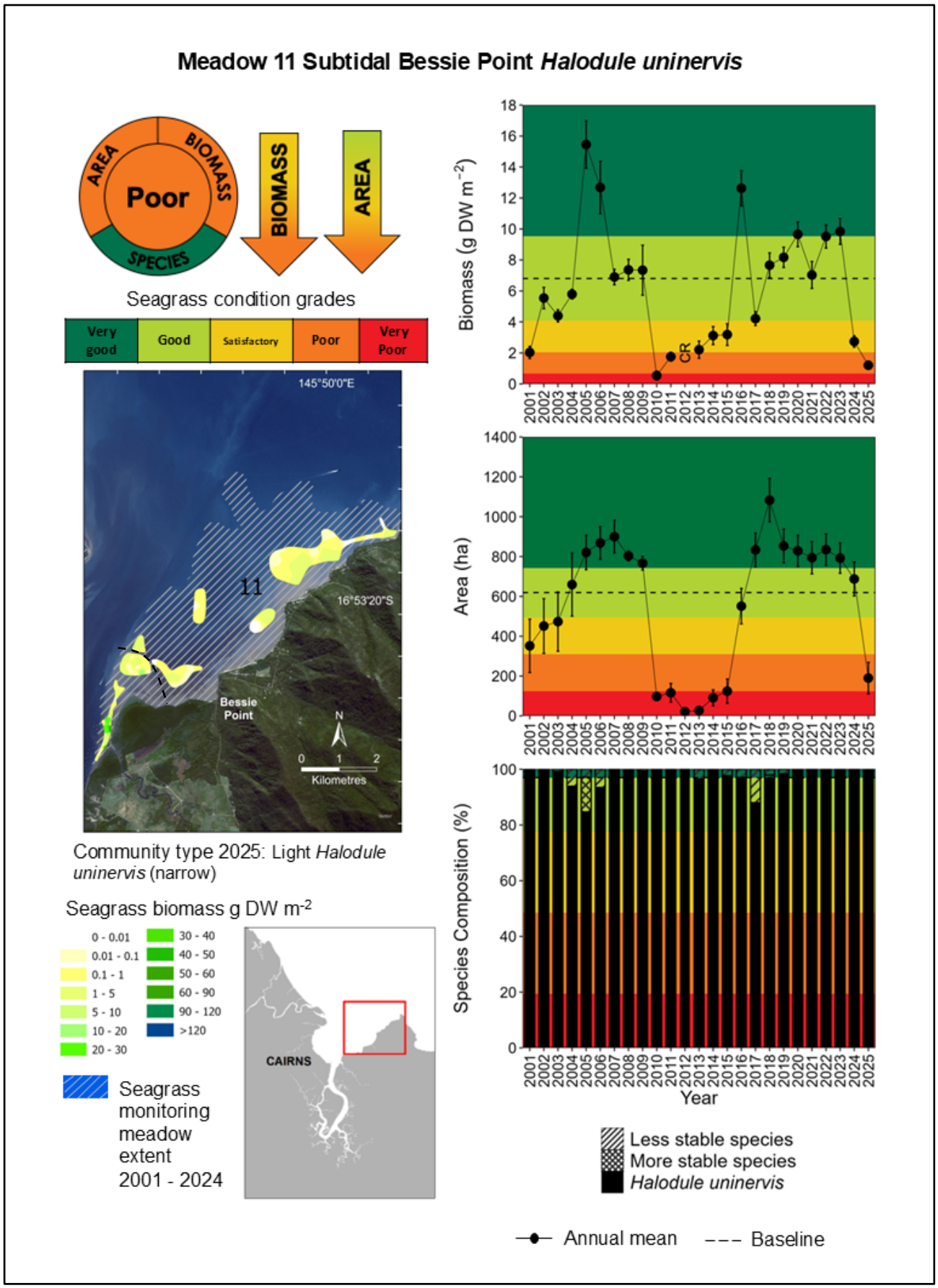


FIGURE 13: CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE BESSIE POINT (MEADOW NO. 11) MEADOW FROM 2001 – 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

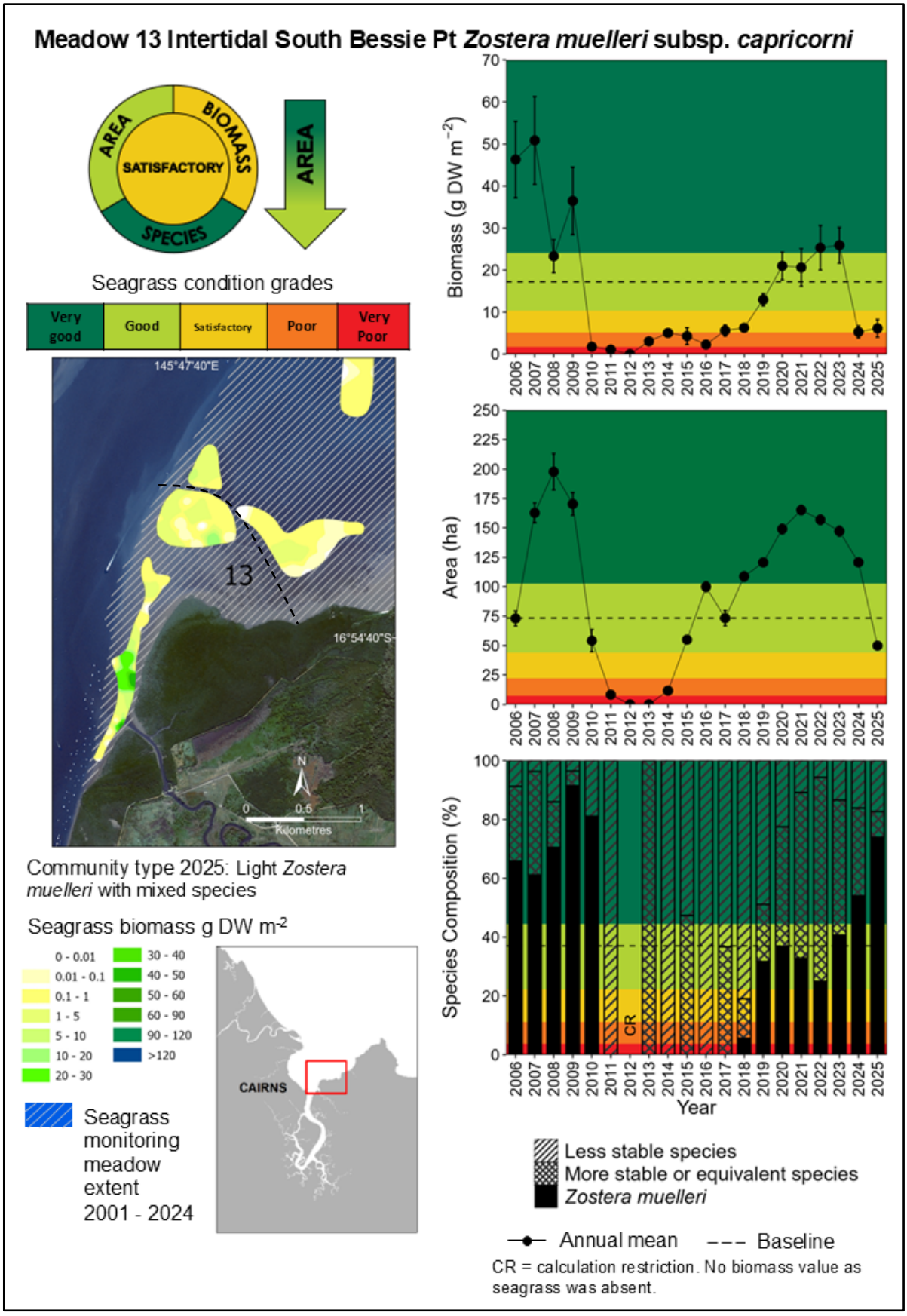


FIGURE 14: CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE SOUTH BESSIE POINT (MEADOW NO. 13) MEADOW FROM 2006 – 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

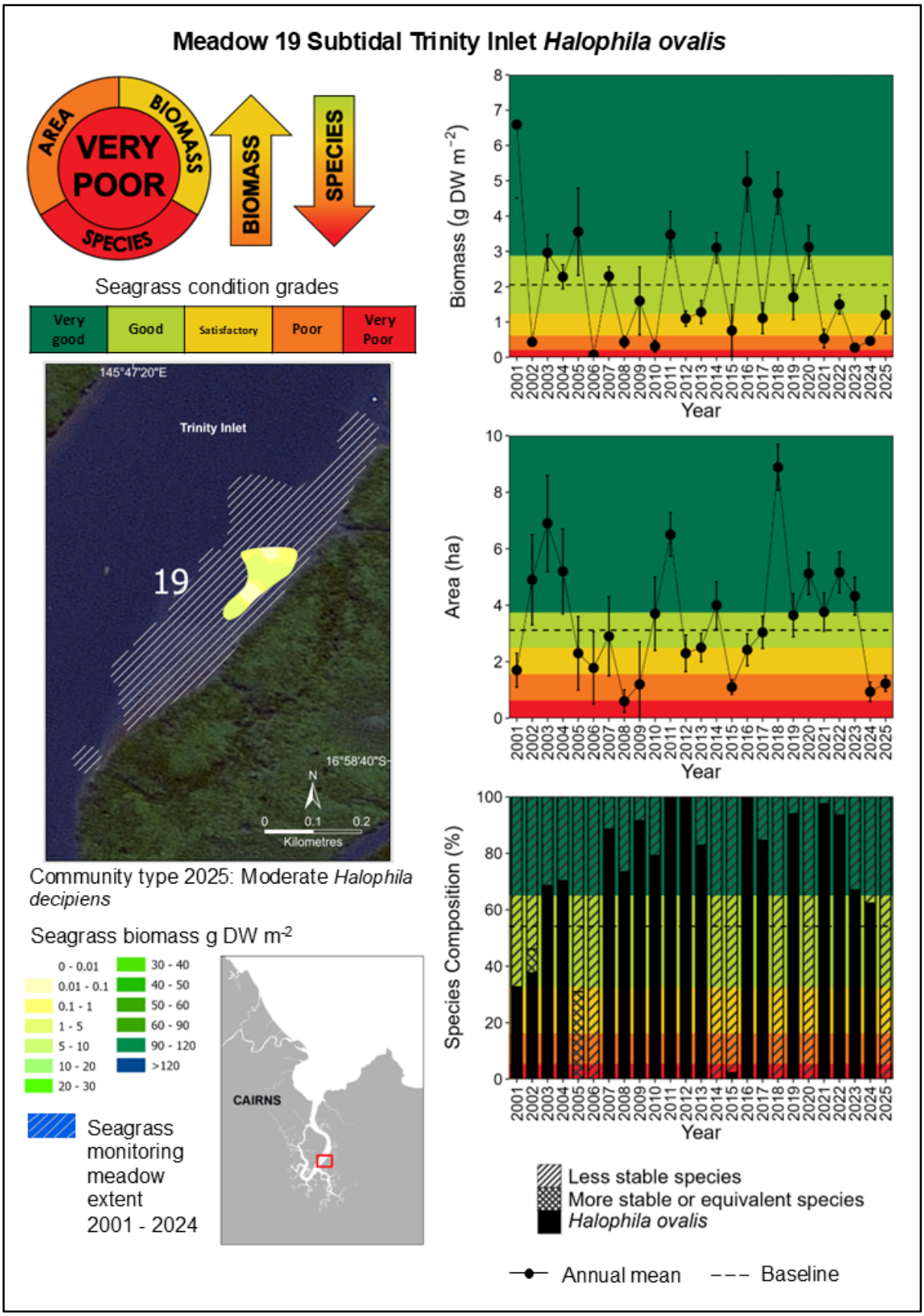


FIGURE 15: CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE TRINITY INLET *HALOPHILA* MEADOW (MEADOW NO. 19) FROM 2001 – 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

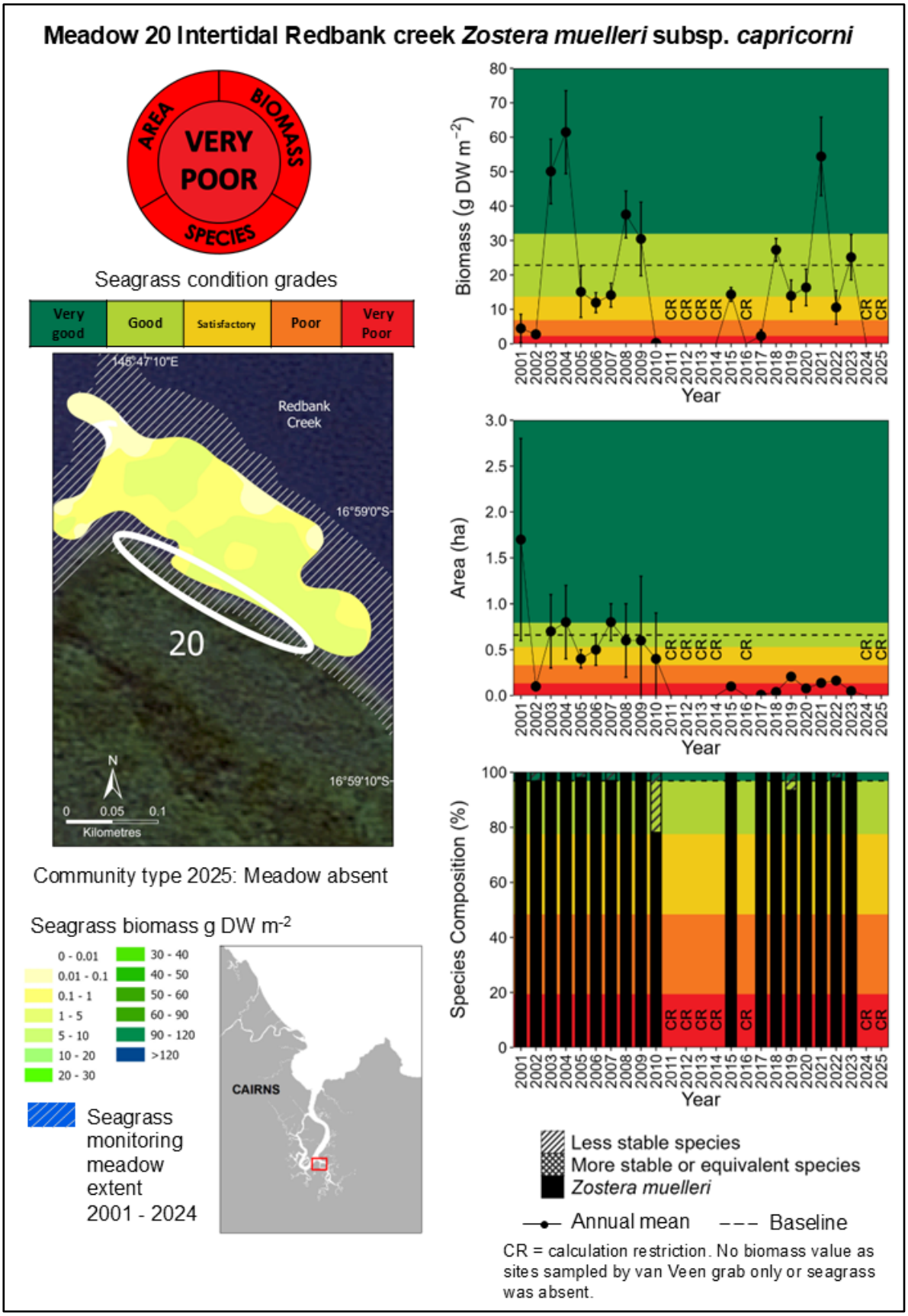


FIGURE 16: CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE TRINITY INLET *ZOSTERA* MEADOW (MEADOW NO. 20) FROM 2001 – 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

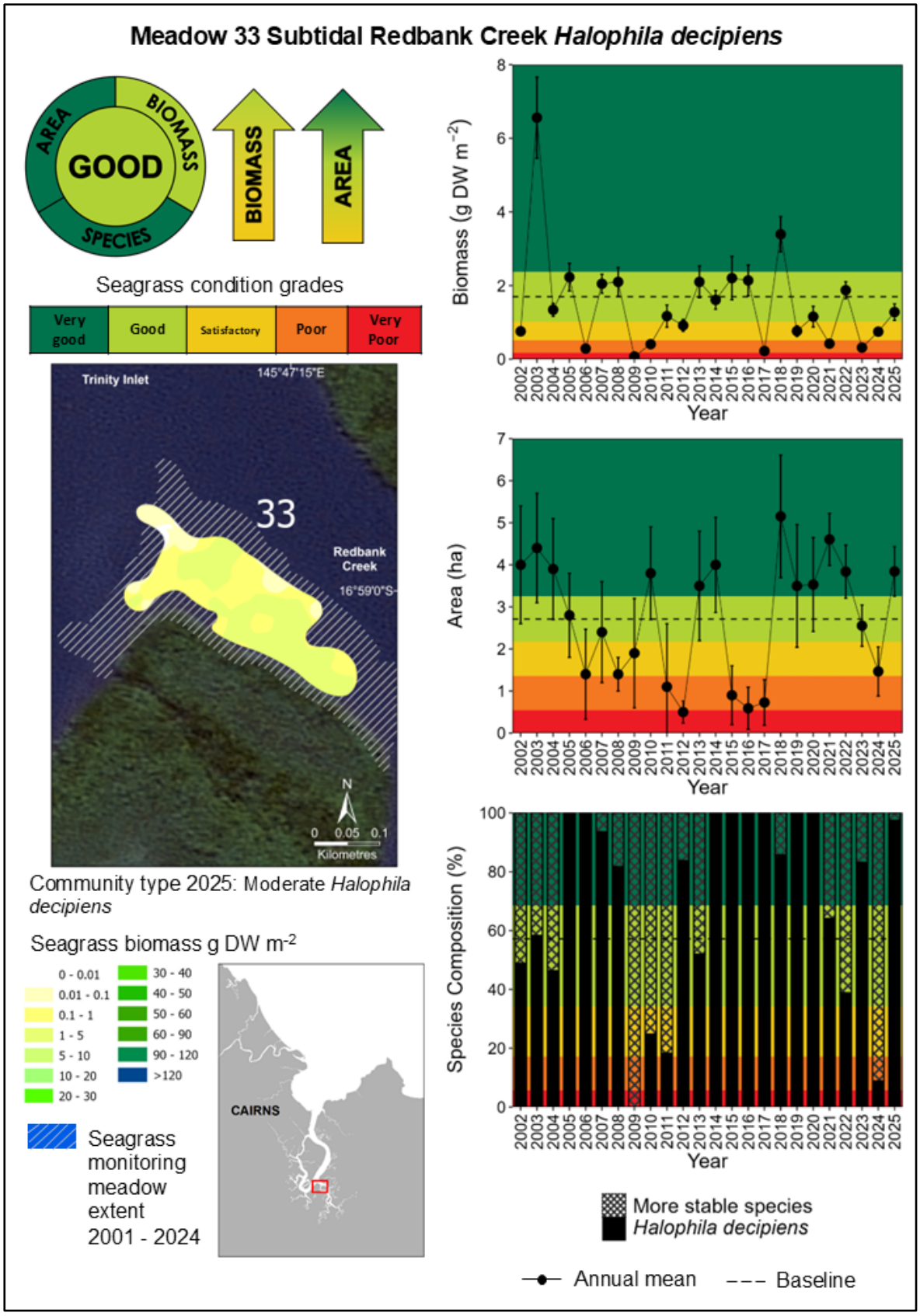


FIGURE 17: CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE TRINITY INLET *HALOPHILA* MEADOW (MEADOW 33) FROM 2002 – 2025 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE).

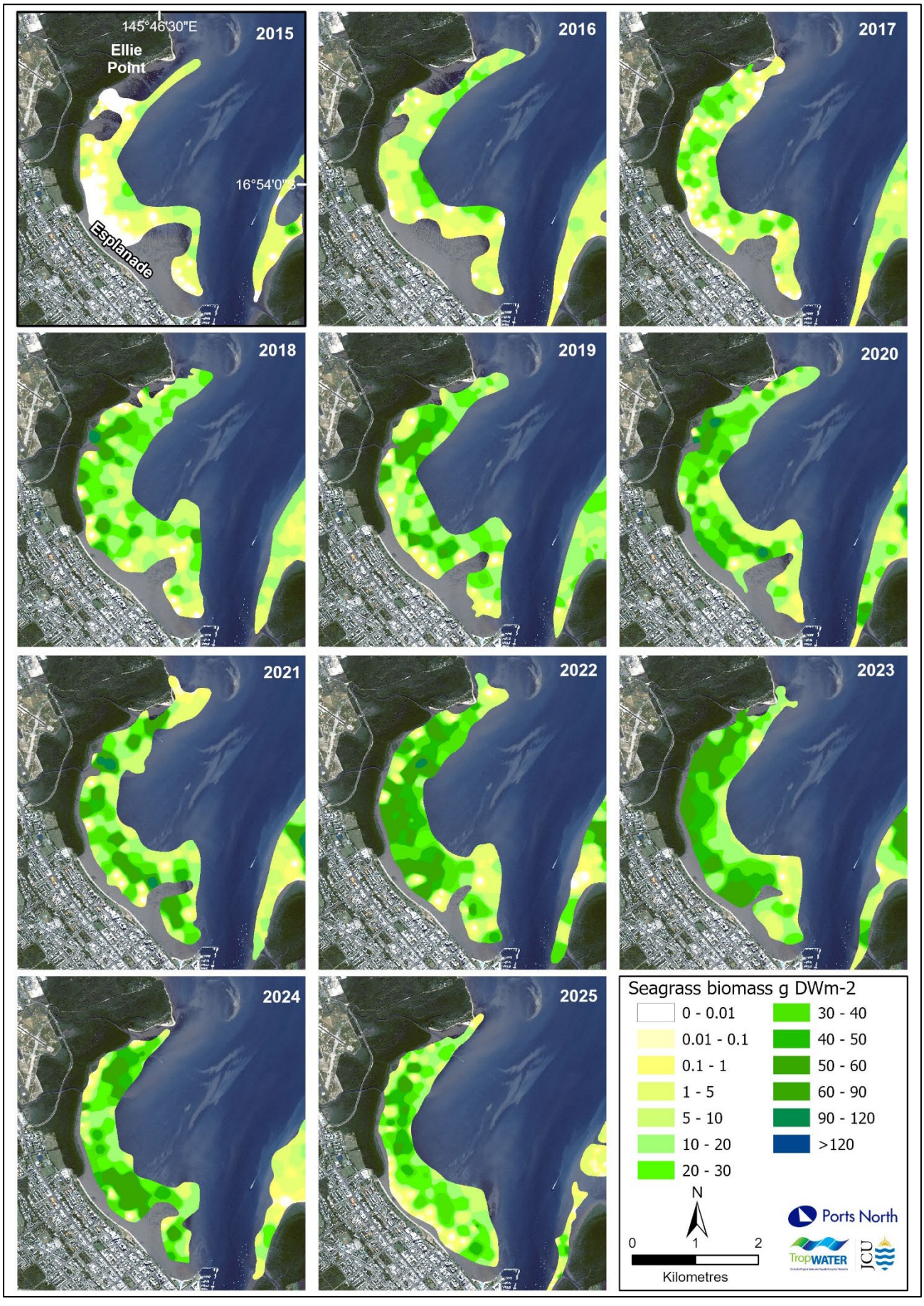


FIGURE 18: ESPLANADE TO ELLIE POINT SEAGRASS MONITORING MEADOWS FROM 2014 TO 2025.

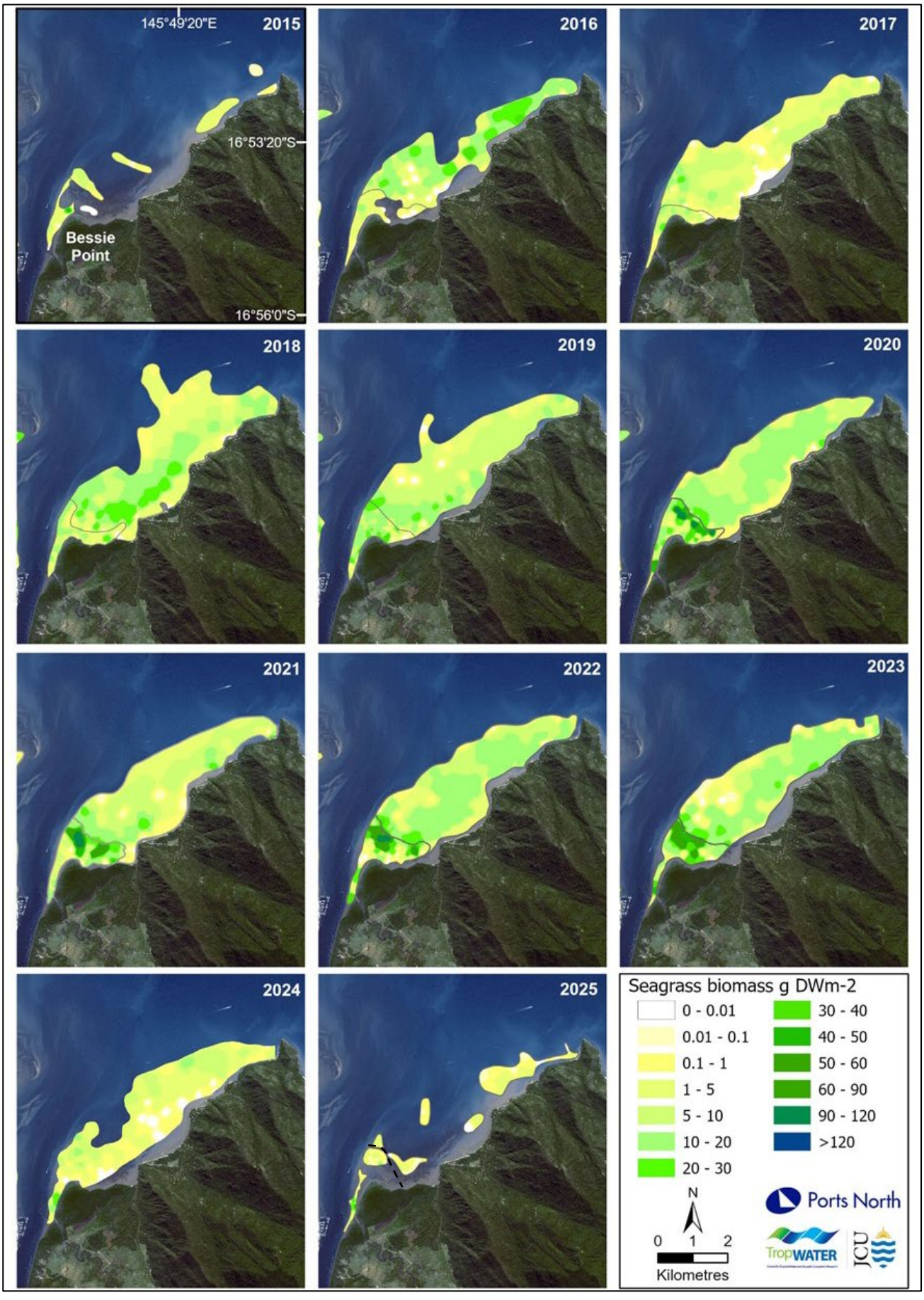


FIGURE 19: BESSIE POINT AND SOUTH BESSIE POINT SEAGRASS MONITORING MEADOWS FROM 2014 TO 2025.

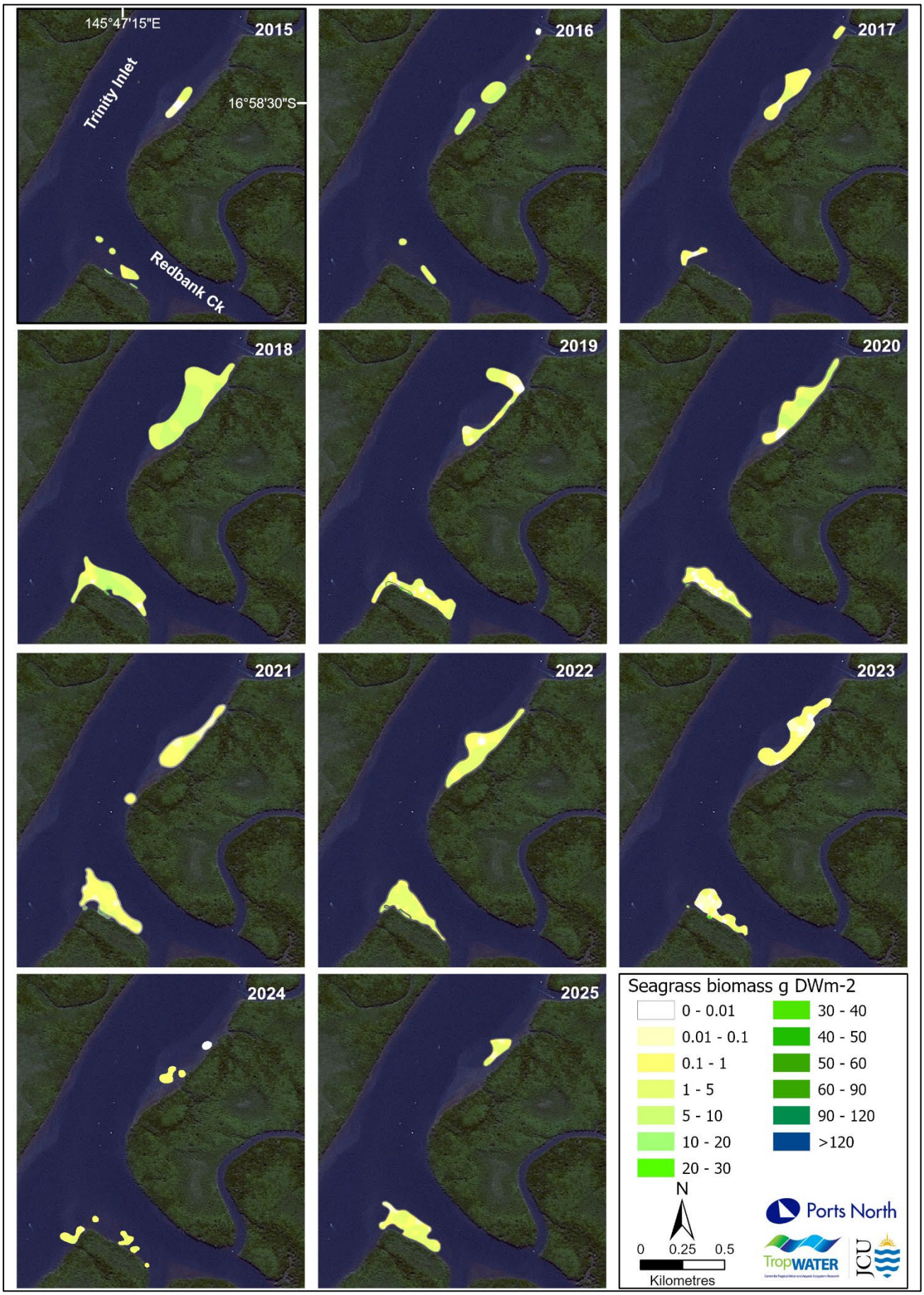


FIGURE 20: TRINITY INLET SEAGRASS MONITORING MEADOWS FROM 2014 TO 2025.

5.3 Seagrass Seed Banks

2025 marks the seventh consecutive year that seed bank assessments have been conducted at meadow scale in the two larger meadows, Esplanade (34) and Bessie Point (11) (Table 7; Figure 22). Seed densities across both meadows and species have ranged from 0 seeds m^{-2} in 2017 to 153 seeds m^{-2} in 2023 (see Reason et al. 2023 for historical seagrass seed densities). In 2025, *H. uninervis* seeds were present in both meadows, while *Z. muelleri* seeds continue to be recorded only on the Esplanade side of the Harbour (Table 6; Figure 22).

In the Esplanade meadow (34), total *Z. muelleri* seed density fell to 2.45 ± 1.22 seeds m^{-2}, the lowest recorded since no seeds were found in 2017, continuing a decline that began in 2021 and representing a 65% reduction from 2024 (Table 6; Figure 22). Notably however, viable seeds were recorded for the first time since 2020, albeit at a very low density of 0.65 ± 0.65 seeds m^{-2} (Table 6; Figure 22). *Halodule uninervis* seeds, absent from the Esplanade meadow in 2024, were also recorded again in 2025, though again at a very low density (0.61 ± 0.64 seeds m^{-2}) (Table 6; Figure 22).

At Bessie Point (11), *H. uninervis* seed density declined slightly in 2025 to 68.1 ± 29.7 seeds m^{-2}, continuing a downward trend from the peak of 153.1 ± 38.0 seeds m^{-2} recorded in 2023 (Table 6; Figure 22).

TABLE 6: CAIRNS HARBOUR 2013/2019-2025 MEAN ZOSTERA MUELLERI AND *HALODULE UNINERVIS* SEED BANK DENSITY AT THE MEADOW SCALE IN THE ESPLANADE MEADOW (34) AND BESSIE POINT MEADOW (11). *DATA FROM JARVIS ET AL. 2021 FOR COMPARISON.

Sampling Date	Esplanade *Zostera muelleri* mean total seeds m^{-2}	Esplanade *Zostera muelleri* mean viable seeds m^{-2}	Esplanade *Halodule uninervis* mean total seeds m^{-2}	Bessie Point *Halodule uninervis* mean total seeds m^{-2}
July 2013*	24 ± 4	5 ± 1	8 ± 2	13 ± 3
April 2019	9.81 ± 4.72	0	10.76 ± 10.9	105.1 ± 27.42
April 2020	3.80 ± 1.73	0.65 ± 0.65	4.58 ± 2.24	73.92 ± 21.12
April 2021	27.86 ± 7.39	0	15.05 ± 9.3	87.66 ± 23.76
March 2022	9.81 ± 3.39	0	3.17 ± 1.6	141.1 ± 34.39
March 2023	8.86 ± 3.85	0	7.85 ± 6.56	153.1 ± 38.04
March 2024	7.59 ± 2.39	0	0	75.23 ± 18.87
March 2025	2.45 ± 1.22	0.65 ± 0.65	0.61 ± 0.64	68.07 ± 29.66

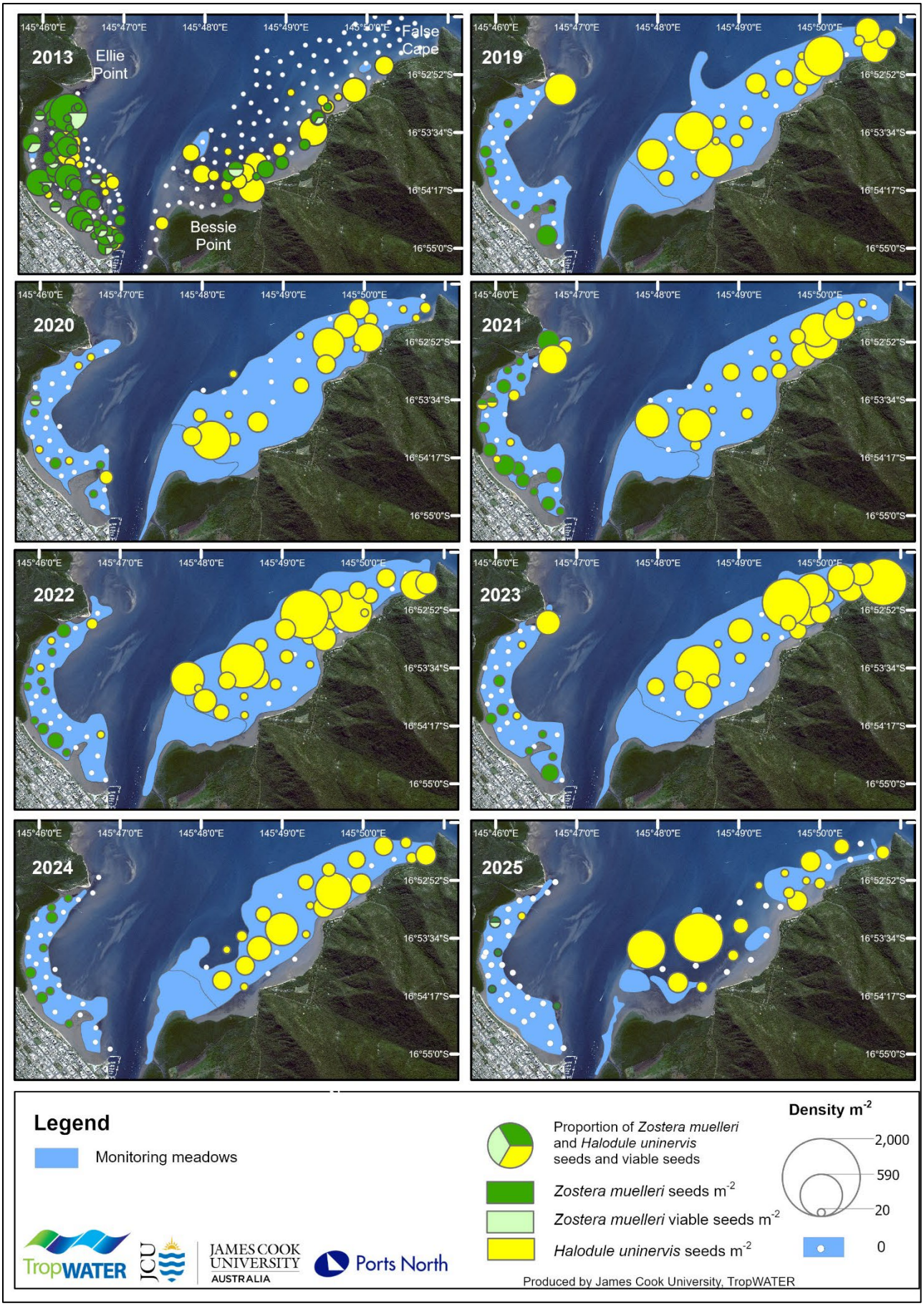


FIGURE 21: MEAN *ZOSTERA MUELLERI* SEED DENSITY AND VIABLE SEED DENSITY AT EACH SITE IN THE ESPLANADE (34) MEADOW AND MEAN *HALODULE UNINERVIS* SEED INFORMATION IN BOTH CAIRNS HARBOUR MEADOWS FROM 2019 TO 2025. 2013 SEED DATA PRESENTED FOR COMPARISON, SOURCE: JARVIS ET AL 2021

5.4 Cairns environmental conditions

5.4.1 Light (bPAR) and Temperature Assessment

The quantity and quality of light reaching the seabed is a limiting factor and critical to the persistence and growth of seagrass. Monitoring bPAR helps to understand seagrass change and potential causes of any observed change. Benthic light (bPAR) and temperature within the seagrass canopy is collected at three sites in the located within the mapped Cairns seagrass meadows; the Esplanade/Ellie Point (Site E), Bessie Point (Site B) and Redbank (Site R) (Figure 1). Published light requirement thresholds for seagrass species (i.e., Chartrand et al. 2016, Collier et al. 2016) are used to help understand the drivers of seagrass habitat change and condition. For the species found in Cairns, biologically relevant seagrass thresholds suggested in Collier et al. (2016) include:

- Seagrass meadows dominated by *Zostera muelleri* and *Halodule uninervis* – 6 mol/m^2/day for *Z. muelleri* and 5 mol/m^2/day for *H. uninervis*; 14 day rolling average; 28 consecutive days below threshold before impact.
- Seagrass meadows dominated by *Halophila* – 2.5 mol/m^2/day; 7 day rolling average; 28 consecutive days below threshold before impact.

In Cairns, benthic light (bPAR) generally drops below the thresholds for periods of time during the summer months usually coinciding with high rainfall (Figure 23). There was above average rainfall from December 2024 to March 2025 (Figure 25).

At Bessie Point, bPAR remained below the *H. uninervis* threshold for six months between November 2024 and April 2025, with an additional low-light period during a high-rainfall event in May 2025 (Figure 23). At the Ellie Point site (Esplanade meadow 34), light levels fell below the *Z. muelleri* threshold between December 2024 and April 2025 (Figure 23). This was the most extended period of sub-threshold light conditions recorded at both sites in the past six years (Figure 23). This follows an exceptionally stable period, during which the site maintained optimal light conditions for 20 consecutive months, with the previous threshold exceedance occurring in February 2023 (Figure 23). At Redbank Creek, bPAR data were recorded to April 2025, after which the loggers were lost. Levels were at or below the *Halophila* light requirement from January through April 2025 (Figure 23).

The maximum benthic water temperatures were variable between sites with a peak in temperature of 38.5^{o}C in November at the Bessie Point site and a minimum mean temperature of 21.5^{o}C in June at the Ellie Point site (Figure 23).

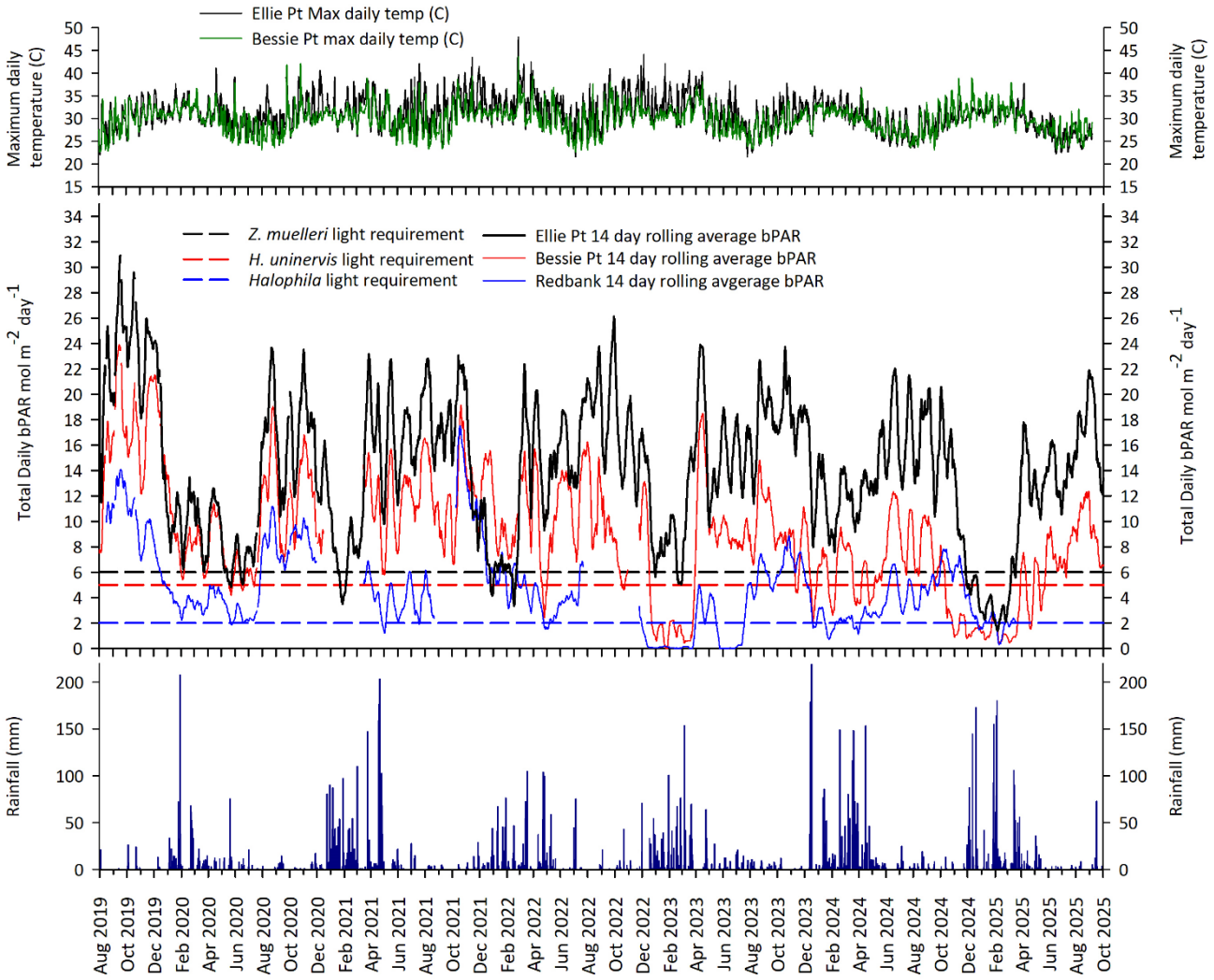


FIGURE 22: MAXIMUM TEMPERATURES (°C), TOTAL DAILY BPAR (MOL M^{-2} DAY^{-1}) DISPLAYED AS ROLLING AVERAGES, SEAGRASS LIGHT THRESHOLD AND RAINFALL (MM), AUGUST 2019 – OCTOBER 2025.

5.4.2 Rainfall

The Cairns region recorded a total annual rainfall of 2655 mm in 2024/25, well above the long-term average of 2048 mm (Figure 24). In the months leading up to the survey rainfall was above the long-term average in May and September (Figure 25).

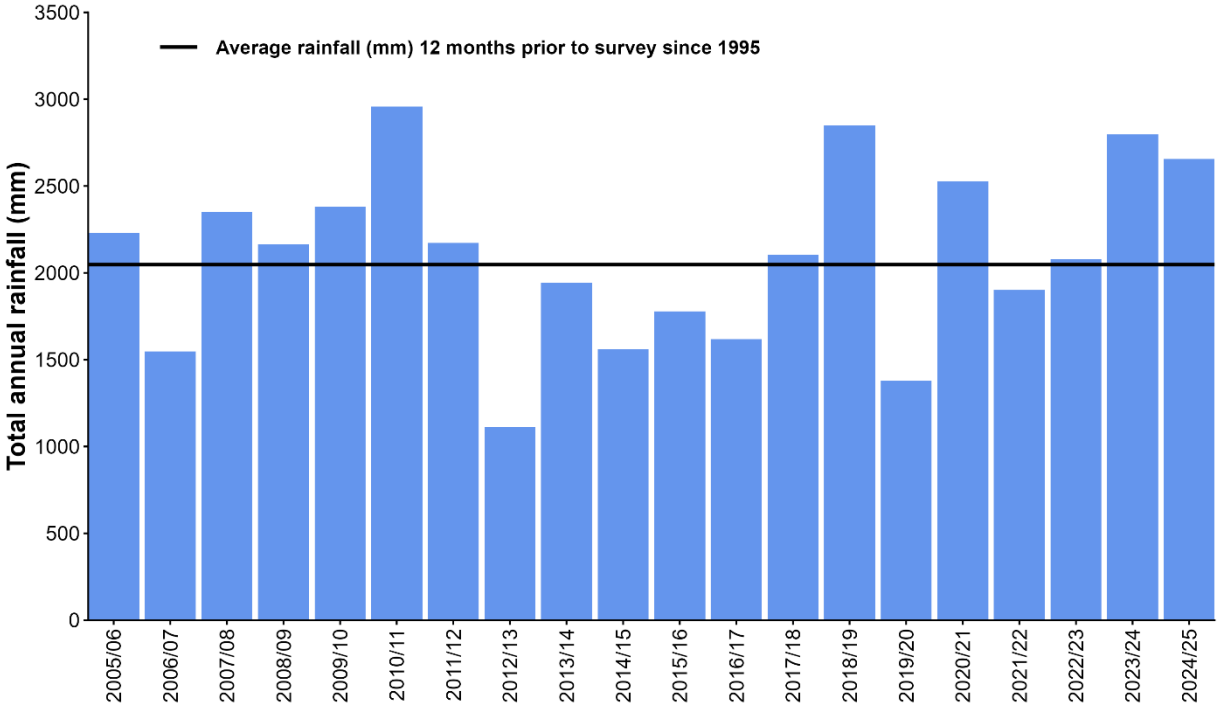


FIGURE 23: TOTAL ANNUAL RAINFALL (MM) RECORDED AT CAIRNS AIRPORT, 2005/6 – 2024/25, IN EACH 12 MONTHS PRIOR TO SEAGRASS SURVEY (NOVEMBER TO OCTOBER).

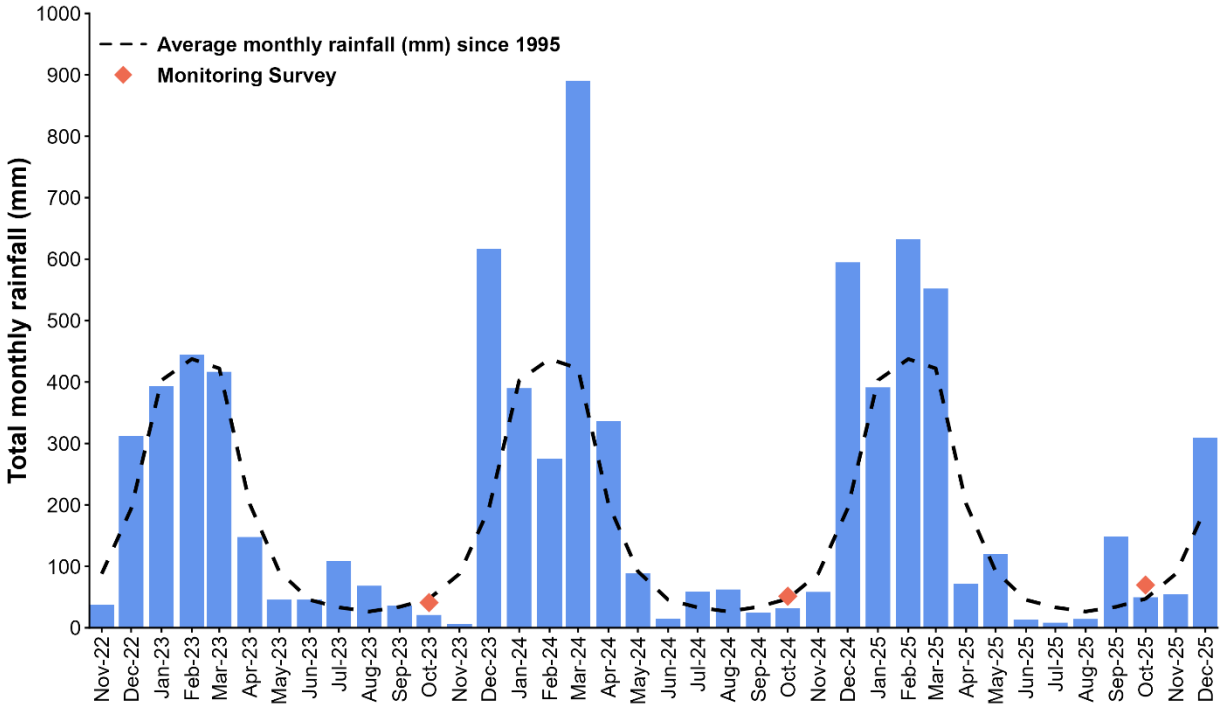


FIGURE 24: TOTAL MONTHLY RAINFALL (MM) RECORDED AT CAIRNS AIRPORT, NOVEMBER 2022 – DECEMBER 2024.

5.4.3 River Flow (Barron River)

River flow in the Barron River reached 1107 GL in 2024/25, this was higher than the long-term average of 794 GL (Figure 26). Most months throughout the year experienced flows that were close to the average, with the exceptions of December 2024 and February 2025 which were above average (Figure 27).

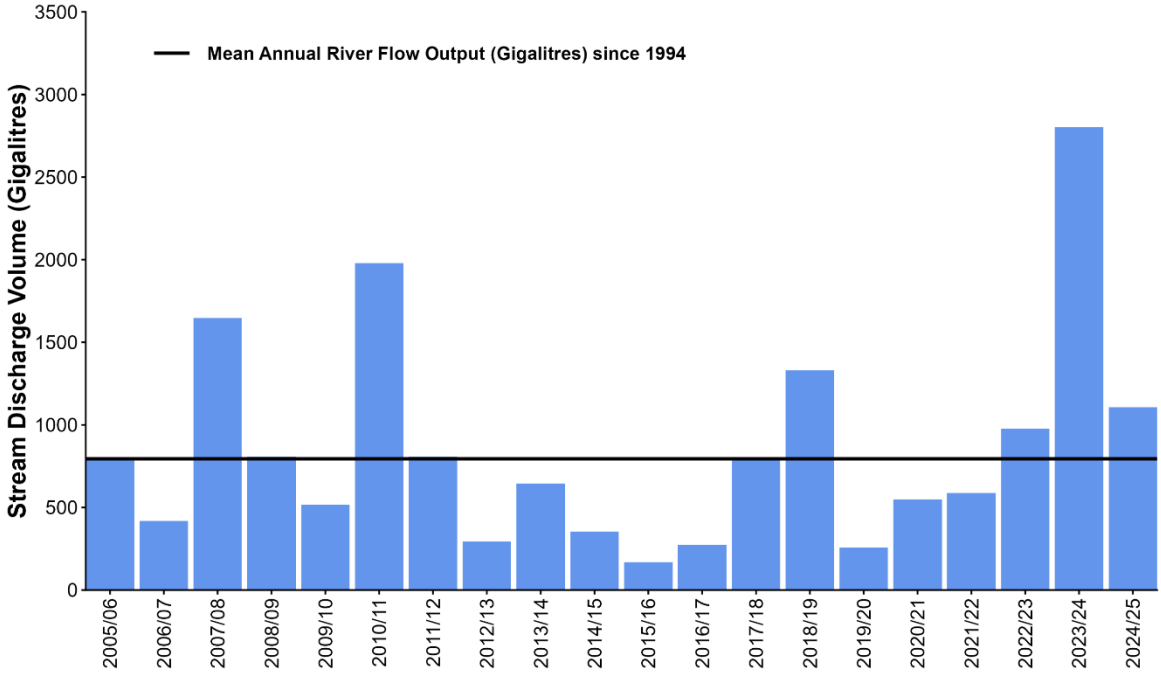


FIGURE 25: ANNUAL WATER FLOW (GIGA LITRES) FOR THE BARRON RIVER RECORDED AT MYOLA, 2005/6 – 2024/25, IN EACH 12 MONTHS PRIOR TO SEAGRASS SURVEY (NOVEMBER TO OCTOBER).

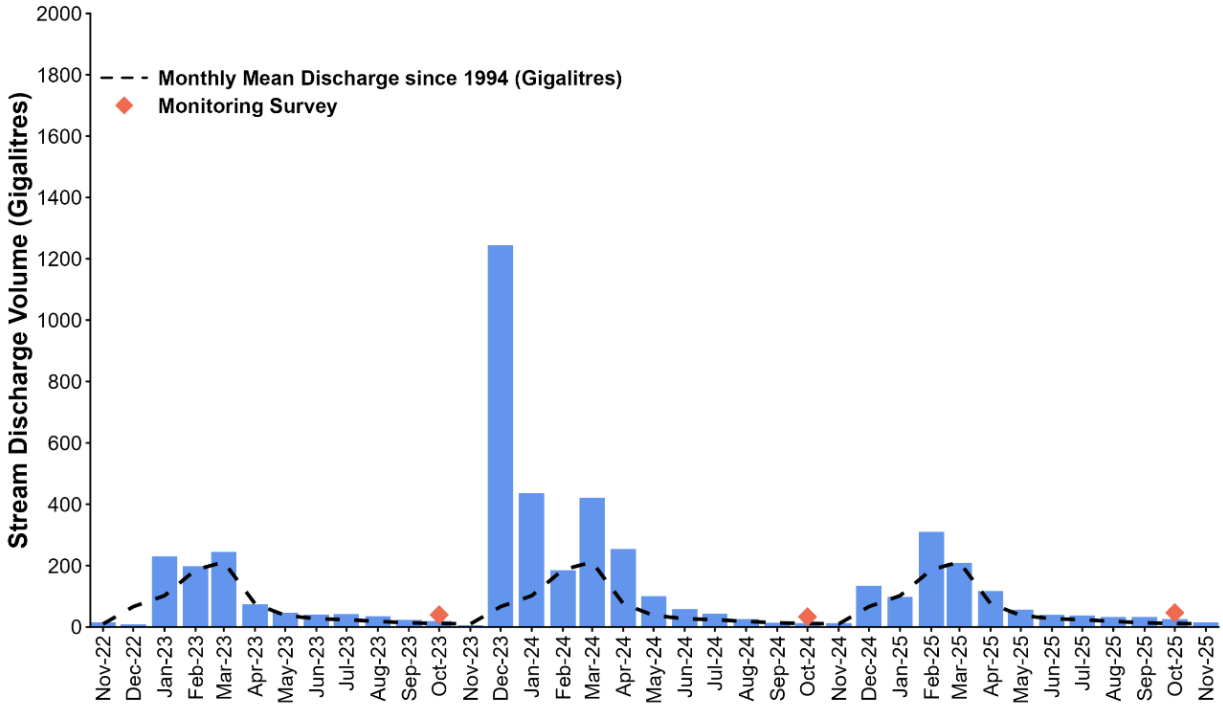


FIGURE 26: MONTHLY WATER FLOW (GIGALITRES) FOR THE BARRON RIVER RECORDED AT MYOLA, NOVEMBER 2022 TO NOVEMBER 2025.

5.4.4 Air Temperature

The annual maximum daily air temperature recorded at Cairns Airport in 2024/2025 was 30.17°C, an increase from the previous year and remaining above the long-term average (29.54°C) (Figure 28). Monthly maximum air temperatures were above the long-term average from November 2023 to February 2024, as well as in April, while the remaining months recorded below-average temperatures (Figure 29).

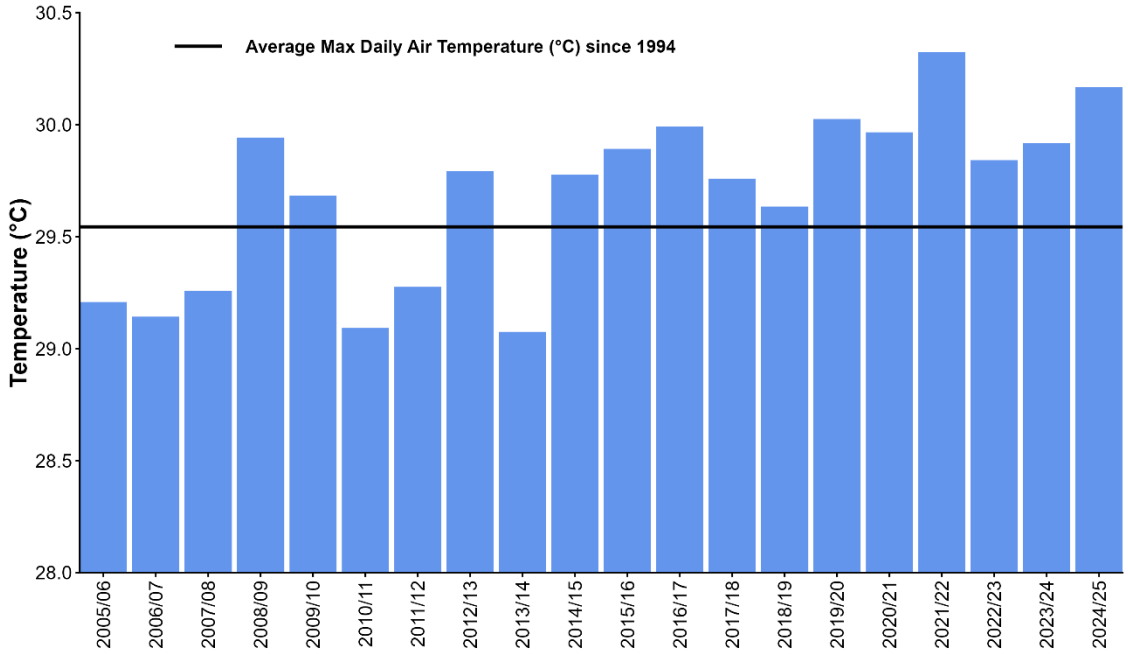


FIGURE 27: MEAN ANNUAL MAXIMUM DAILY AIR TEMPERATURE (°C) RECORDED AT CAIRNS AIRPORT 2005/06 – 2024/25 IN EACH 12 MONTHS PRIOR TO SEAGRASS SURVEY (NOVEMBER TO OCTOBER).

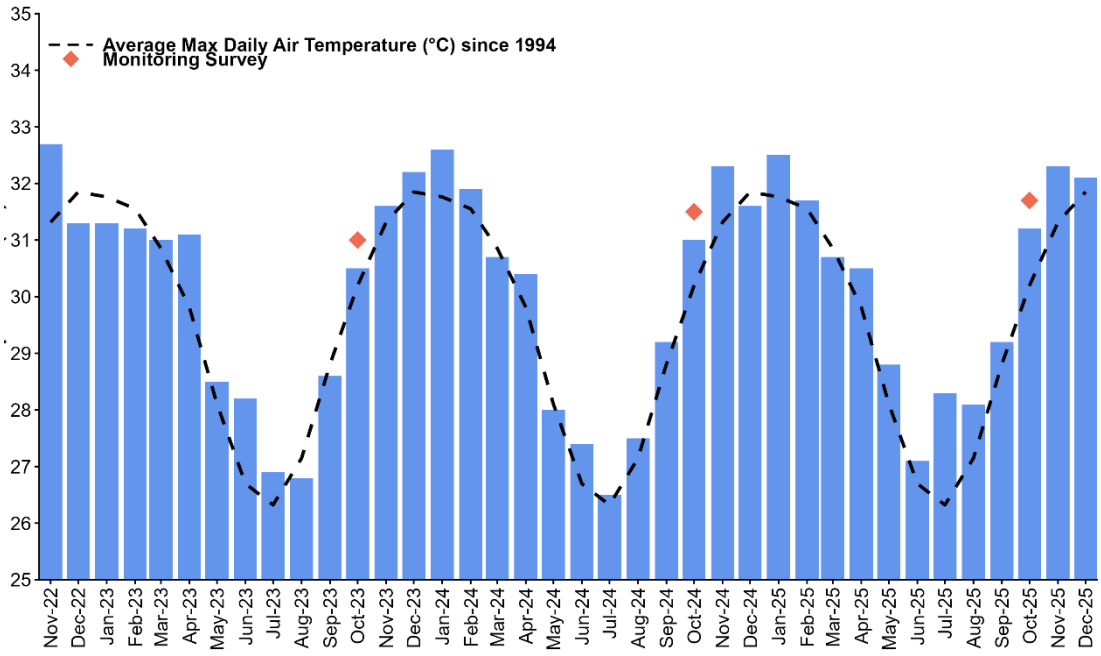


FIGURE 28: MEAN ANNUAL MAXIMUM DAILY AIR TEMPERATURE (°C) RECORDED AT CAIRNS AIRPORT 2005/06 – 2024/25 IN EACH 12 MONTHS PRIOR TO SEAGRASS SURVEY (NOVEMBER TO OCTOBER).

5.4.5 Tidal Exposure of Seagrass Meadows

In 2023/2024, intertidal seagrass meadows were exposed to air for a total of 183 hours, below the long-term average of 244 hours (Figure 30). This was driven by monthly tidal exposure close to or slightly below average throughout the year (Figure 31).

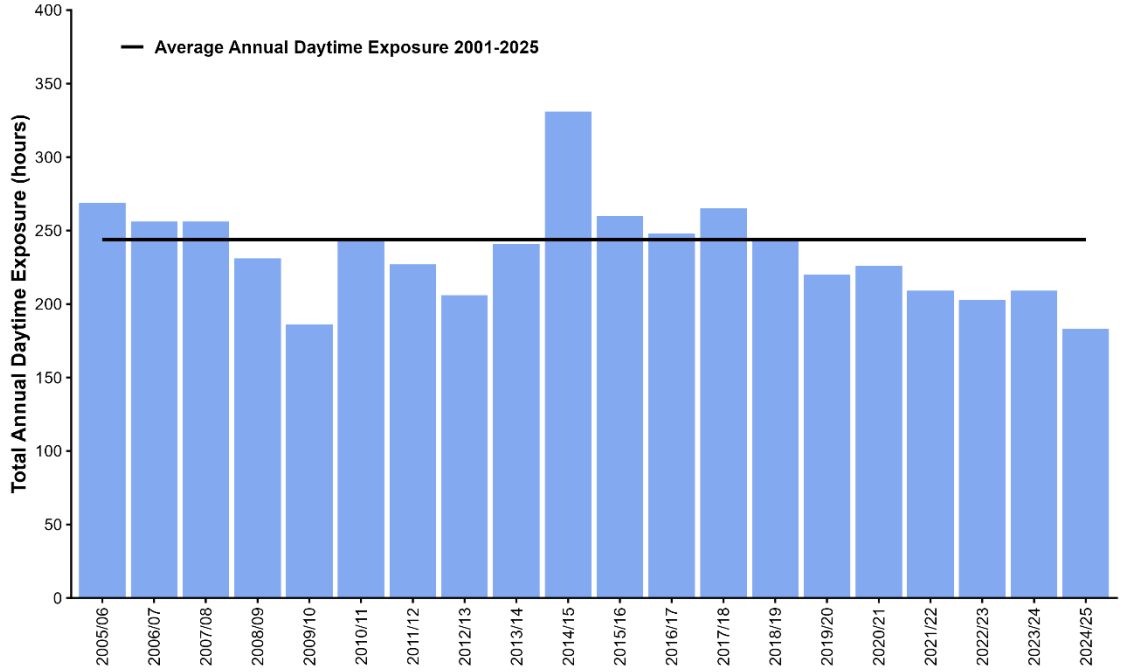


FIGURE 29: TOTAL ANNUAL DAYTIME TIDAL EXPOSURE OF SEAGRASS MEADOWS IN CAIRNS HARBOUR*; 2005/06 – 2024/25 IN EACH 12 MONTHS PRIOR TO SEAGRASS SURVEY (NOVEMBER TO OCTOBER). *ASSUMES INTERTIDAL BANKS BECOME EXPOSED AT A TIDE HEIGHT OF 0.8M ABOVE LOWEST ASTRONOMICAL TIDE

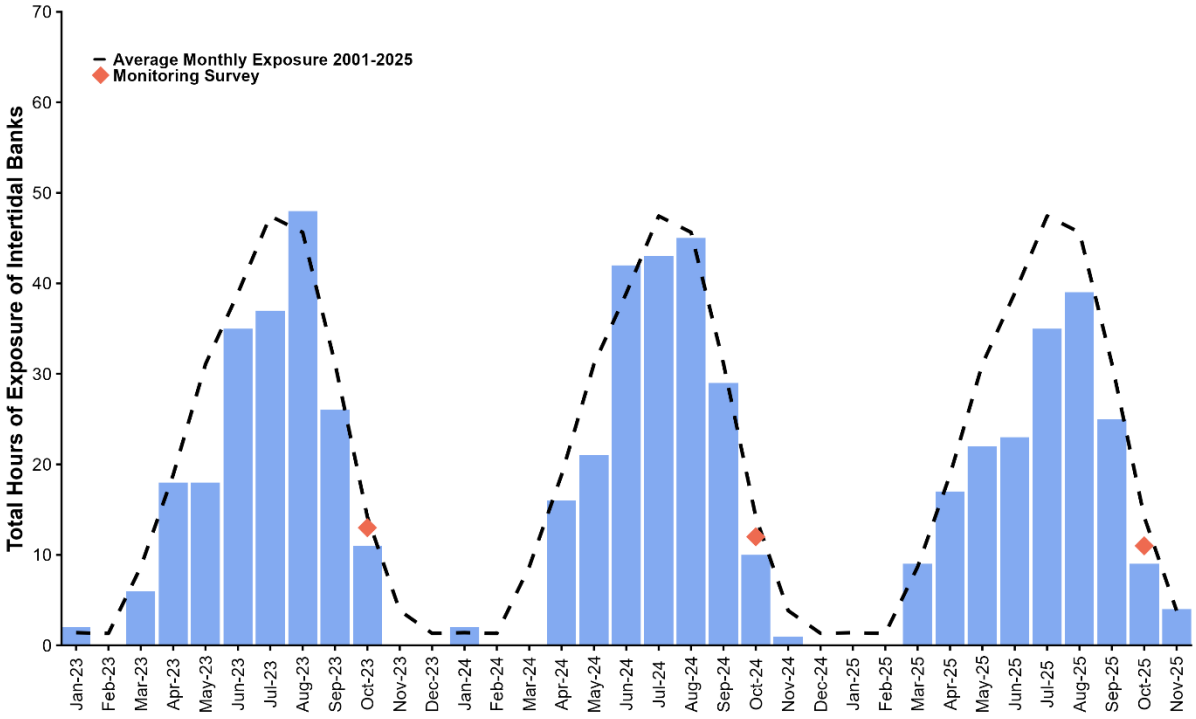


FIGURE 30: TOTAL MONTHLY DAYTIME TIDAL EXPOSURE OF SEAGRASS MEADOWS IN CAIRNS HARBOUR*; JANUARY 2023 – NOVEMBER 2025. *ASSUMES INTERTIDAL BANKS BECOME EXPOSED AT A TIDE HEIGHT OF 0.8M ABOVE LOWEST ASTRONOMICAL TIDE.

6. DISCUSSION

In 2025, the Cairns seagrass meadows in both the Harbour and Inlet were in a poor overall condition for the first time since 2016. The recorded declines in seagrass metrics and condition were driven by cumulative environmental stress after the record-breaking flooding associated with Tropical Cyclone Jasper in December 2023, which was followed by further heavy rainfall in early 2024. The 2024/25 wet season brought a second consecutive year of above-average rainfall and an extended period of reduced benthic light, prolonging the environmental stress on meadows after TC Jasper. These back-to-back years of cumulative stress may have progressively eroded the resilience the meadows had built over the preceding decade, ultimately driving the seagrass declines observed in 2025. In the Harbour the decline was principally due to the large *H. uninervis* meadow between Bessie Point and False Cape (meadow 11) that had declined significantly in area and biomass with the other two meadows remaining in satisfactory condition. In the Inlet, two meadows were in very poor condition, with just Meadow 33 improving to a good condition.

6.1 Cairns Harbour Meadows

Although Tropical Cyclone Jasper brought record-breaking flooding to Cairns, seagrass declines in the Harbour were not immediate — likely because the meadows had built substantial resilience over 13 consecutive years of improving condition, having been in good condition since 2019. This meant that the meadows had likely built-up substantial resilience to potential impacts, with extensive meadow footprints, high biomass and good energy stores. However, TC Jasper and the 2023/24 wet season were followed by a second consecutive year of above-average rainfall and low light levels, and this accumulation of adverse conditions created additional stress for the meadows. This mirrors previous large-scale losses in Cairns, where multiple consecutive years of La Niña conditions between 2009 and 2011 produced prolonged light limitation that drove seagrass declines, rather than any single disturbance event (McKenna et al. 2015). Cumulative stress from multiple years of poor environmental conditions is increasingly recognised as a driver of prolonged seagrass decline (Dunic et al. 2021; Turschwell et al. 2021), however this may have impacted the Harbour meadows in different ways. The Esplanade meadow (34) maintained its footprint with only a small drop in biomass, whereas the Bessie Point meadow (11) had a large decline in both area and biomass. In part this difference is likely due to the Bessie Point subtidal meadow being deeper than the intertidal Esplanade meadow hence more susceptible to turbidity/ runoff driven reductions of light.

Light is the primary limiting factor for seagrass growth and population maintenance in many coastal environments (Waycott et al. 2005). Benthic light levels at both the Esplanade and Bessie Point meadows fell well below species thresholds during the 2024/25 wet season. Prolonged light limitation causes a negative carbon balance as respiration exceeds photosynthesis, and if sustained, drives reductions in biomass and contraction of meadow extent (Collier et al. 2011; Chartrand et al. 2016; Anderson and Fourqurean 2003; Bass et al. 2025). Exposure to critically low light levels can also cause photoinhibition, where metabolic demands increase to the point that recovery becomes impaired even after light conditions improve (Collier et al. 2011; Chartrand et al. 2016; Bass et al. 2025). Numerous studies in the region have demonstrated strong relationships between bPAR, water temperature, and above-ground biomass in species such as *Z. muelleri* and *H. uninervis* (Collier et al. 2012; McKenna et al. 2025; Petus et al. 2014). In the 2024/25 wet season, there were multiple mechanisms that may have contributed to light limitation. Above average rainfall and river discharge over the previous two years increase sediment inputs, elevating turbidity (Lambrechts et al. 2010; Bainbridge et al. 2012). Strong winds in Townsville have been shown to promote wave-driven resuspension of fine sediments (Orpin et al. 2004; GHD 2022), further reducing water clarity. Waves are also the key driver of elevated turbidity in Cairns, although non cyclonic winds are usually below 25 knots and locally generated wave heights less than 1.4m (BMT, 2022). In combination, these processes can reduce the duration and intensity of available and usable benthic light.

While seagrass losses occurred across the Harbour, for the Esplanade meadow, seagrasses remained across the majority of the historical footprint, and for both the Bessie Point and Esplanade meadows viable seed banks remained both of which can facilitate rapid recovery. Seed bank assessments in 2025 confirmed that seed banks remained present in both Cairns Harbour meadows, although seed density declined compared to previous years. *H. uninervis* seeds remained widespread across the Bessie Point meadow, suggesting the persistent seed bank could support recovery in the coming year combined with vegetative spread from the remaining seagrass patches. For *Z. muelleri* a small number of seeds collected were viable after the previous four years of zero viability (no viability testing is conducted for *H. uninervis* seeds). The small number of overall *Z. muelleri* seed density may reflect germination of seeds prior to sampling, leaving only older, less viable seeds remaining in the sediment. Alternatively, low seed numbers may indicate limited flowering or fruiting success, as field observations suggest *Z. muelleri* did produce substantial numbers of reproductive shoots during the year (T. Smith, pers. obs.).

6.2 Trinity Inlet Meadows

The Trinity Inlet meadows were not impacted by TC Jasper and subsequent weather events in the same way as the Harbour meadows, partly due to their already poor condition prior to TC Jasper, and partly due to the seagrass community present. Although the light logger at Redbank was lost limiting data availability from 2024, light levels in the Inlet are historically much lower than in the Harbour and fall well below the threshold for higher-light-requiring species *Z. muelleri* (Chartrand et al. 2016). The Inlet meadows are dominated by faster growing *Halophila* species (*H. ovalis* and *H. decipiens*), these have similar morphology, life history strategies and ecological function, and are capable of growing in lower light environments than most other seagrass species (Chartrand et al. 2016, Josselyn et al. 1986, Erftemeijer and Stapel 1999). These small colonising *Halophila* species have relatively small energy reserves and can decline rapidly — in the order of days to a week — when light is limiting, but are also capable of fast recovery when light conditions improve (Kenworthy 2000). This community is therefore characterised by high interannual variability and susceptibility to disturbance.

The small Redbank *Z. muelleri* meadow (20) has a history of complete loss, having been absent from the monitoring program for multiple years between 2011 and 2016, suggesting this species is likely growing at the limits of its light and environmental requirements at this location. Having maintained only a satisfactory or poor condition since 2016, and with no extended period of recovery comparable to that seen in the Harbour meadows, the Trinity Inlet meadows did not carry the same level of accumulated resilience — in terms of meadow extent, biomass, or energy reserves — entering this period of adverse conditions. This sustained period of below-optimal condition, combined with the inherent variability of the *Halophila*-dominated community, means these meadows are likely to continue fluctuating in response to short-term environmental changes rather than showing the kind of recovery seen in the Harbour prior to 2025.

6.3 Conclusion and Implications for Management

In 2025, seagrass meadows in both Cairns Harbour and Trinity Inlet were in a poor overall condition for the first time since 2016, ending a 13-year period of sustained improvement in the Harbour. These declines were not the result of a single disturbance event, but rather the cumulative effect of successive years of adverse environmental conditions — most notably the record flooding associated with Tropical Cyclone Jasper in December 2023, followed by a second consecutive year of above-average rainfall and extended periods of reduced benthic light in 2024/25. The resilience accumulated by the Harbour meadows over more than a decade ultimately buffered them against immediate decline following TC Jasper, but was insufficient to withstand a second consecutive year of environmental stress. Despite these declines seagrasses in Cairns Harbour maintained a capacity for relatively rapid recovery with the return of favourable climate and environmental conditions. Previously when seagrass losses in Cairns occurred that resulted in longer term declines such as the period leading up to Cyclone Yasi in 2011, losses were far more extensive with the near

complete loss of meadows and propagules (McKenna et al 2015). This was not the case in 2025 with the large Esplanade covering most of its historical footprint and biomass although reduced still in a satisfactory condition. The other large meadow, Bessie Point, on the Western side of the harbour despite a large reduction in area maintained its seed banks. Under these circumstances we would expect seagrasses to have a relatively rapid return to good condition if climate in 2026 returns to more normal patterns.

These declines in 2025 have the potential to reduce the ecosystem services provided by Cairns's seagrass meadows, particularly for the meadows in a poor condition. These include food sources for herbivores such as dugongs and green turtles, nursery habitat for juvenile fish and prawns, and water quality improvements through sediment trapping and the capture and storage of carbon and nitrogen in plant tissues and sediments (Orth et al. 2020; Lefcheck et al. 2021).

Seagrass condition was variable in the broader long-term monitoring network in other parts of Queensland, and as in Cairns were related to local weather and climate conditions. In Mourilyan Harbour, the closest monitoring location to Cairns Harbour, seagrass was in a very poor condition in 2025, with no seagrass present in any of the monitoring meadows for only the second time in the 30 year monitoring history (Shepherd et al. 2026). Seagrass in Townsville remined in an overall poor condition in 2025, driven by multiple years of unfavourable climate conditions (Tol et al. 2026). Seagrass condition further to the south at Abbot Point has improved from satisfactory to good condition in 2025 following improved environmental conditions (Concannon et al. 2026). In the Gulf of Carpentaria, seagrasses in Weipa were in good condition linked to favourable weather but declined in Karumba related to high rainfall and flooding (Reason et al. 2026; Scott and Rasheed 2026).

The declines observed in Cairns in 2025 are concerning, however long-term monitoring data from this program demonstrate that these meadows are capable of recovery from climate-driven decline. Previous cycles of decline and recovery have been recorded across all monitoring meadows at some point over the past 25 years, indicating that even significant losses can be reversed under favourable conditions. The Harbour meadows in particular still retain much of their spatial footprint, foundation species, or seed banks — the key components of resilience — providing a strong basis for recovery should environmental conditions improve.

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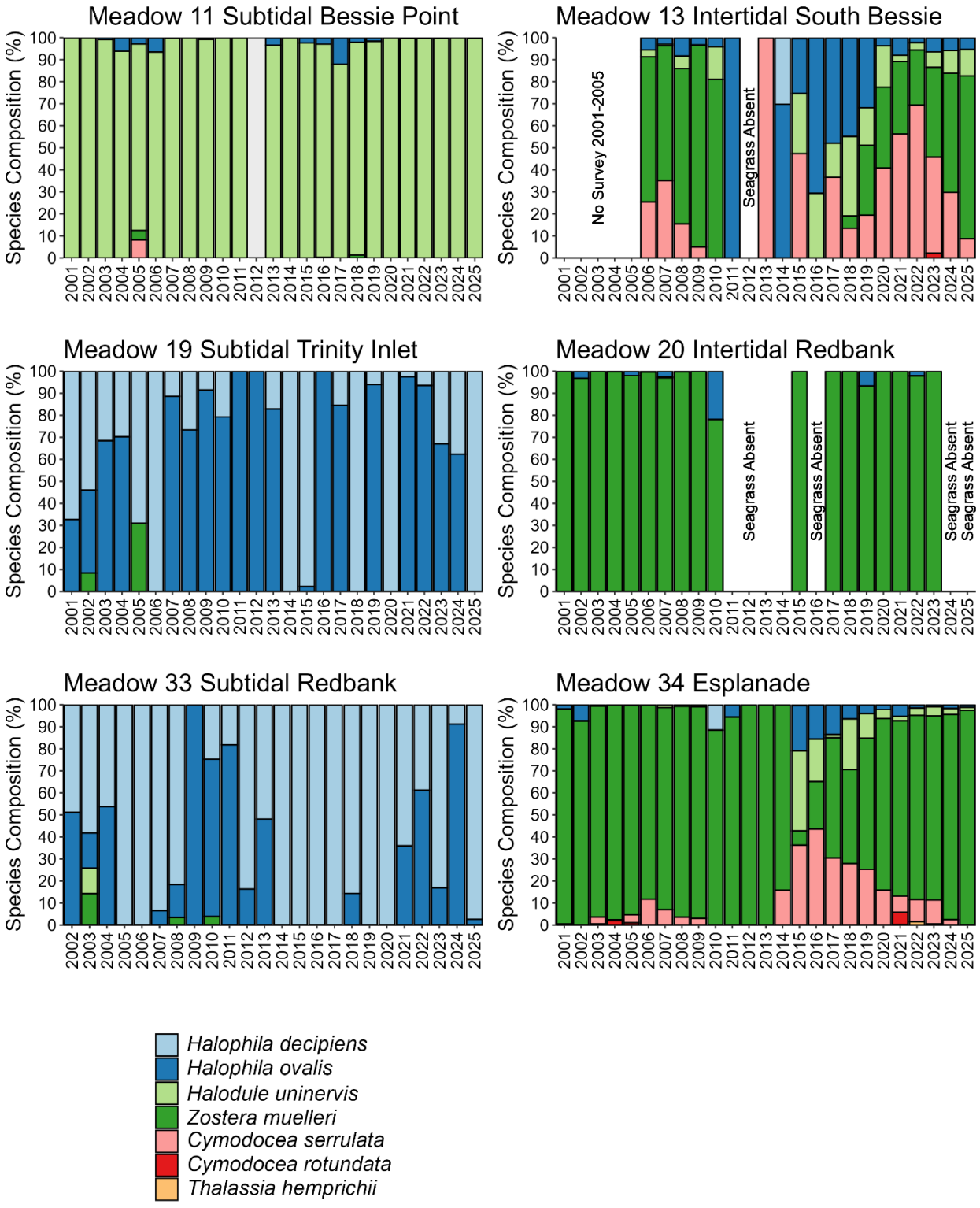
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8. APPENDICIES: SPECIES COMPOSITION, AREA AND ABOVE-GROUND BIOMASS

8.1 Species Composition changes: 2001 – 2025.



8.2 Seagrass monitoring meadow area (ha) in Cairns Harbour and Trinity Inlet, 2001-2025; ± R = reliability estimate.

Meadow	Area (ha) ± (R)																								
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Esplanade to Ellie Pt. (34)	286.4 ± 8.2	258.5 ± 12.2	280.4 ± 11.7	300.8 ± 12.3	330.9 ± 6.5	370.8 ± 6.5	418.9 ± 6.4	379.3 ± 19.2	362.9 ± 13.4	92.1 ± 11.5	78.6 ± 37.9	7.4 ± 0.4	9.0 ± 1.0	7.3 ± 1.5	218.1 ± 6.9	247.8 ± 6.7	257.2 ± 11.90	366.3 ± 6.8	300.1 ± 6.8	304.9 ± 7.1	303.3 ± 7.5	334 ± 6.6	310 ± 6.5	235 ± 5.8	270 ± 5.42
Bessie Pt. (11)	351.8 ± 133.9	451.2 ± 137.3	473.2 ± 148.8	659.3 ± 158.5	820.4 ± 86.6	868.1 ± 81.6	899.7 ± 81.3	803.3 ± 25.0	766.2 ± 34.1	97.2 ± 9.3	116. 1 ± 46.5	20.7± 0.5	27.1 ± 15.1	90.6 ± 40.2	124.2 ± 60.7	551.0 ± 88.9	833.2 ± 84.4	1083.1 ± 108.8	853.1 ± 84.8	828.74 ± 78.9	794 ± 80.7	834 ± 78.6	792 ± 76	687 ± 85	190 ± 79
South Bessie Pt. (13)	NA	NA	NA	NA	NA	73.0 ± 6.3	162.8 ± 8.4	197.7 ± 15.4	170.3 ± 9.6	54.2 ± 9.4	8.3 ± 3.4	NP	0.03 ± 0.02	11.8 ± 8.9	55.0 ± 3.3	100.0 ± 4.3	73.2 ± 6.4	108.7 ± 4.1	120.6 ± 3.9	149 ± 4.2	165.2 ± 4.0	156.9 ± 4.1	147 ± 4.3	121 ± 3.2	50 ± 3.0
Inlet (19)	1.7 ± 0.6	4.9 ± 1.6	6.9 ± 1.7	5.2 ± 1.5	2.3 ± 1.3	1. 8 ± 1.3	2.9 ± 1.4	0.6 ± 0.4	1.2 ± 1.5	3.7 ± 1.3	6.5 ± 3.2	2.3 ± 1.3	2.5 ± 2.2	4.0 ± 3.5	1.1 ± 0.5	2.4 ± 1.2	3.0 ± 3.9	8.88 ± 0.8	3.6 ± 0.7	5.12 ± 0.7	3.8 ± 0.7	5.16 ± 0.7	4.3 ± 0.7	0.94 ± 0.3	1.23 ± 0.3
Redbank (Zm) (20)	1.7 ± 1.1	0.1 ± 0.05	0.7 ± 0.4	0.8 ± 0.4	0.4 ± 0.1	0.5 ± 0.2	0.8 ± 0.2	0.6 ± 0.4	0.6 ± 0.7	0.4 ± 0.5	NP	NP	NP	NP	0.1 ± 0.1	NP	0.008 ± 0.006	0.04 ± 0.01	0.2 ± 0.03	0.07 ± 0.01	0.14 ± 0.02	0.16 ± 0.02	0.05 ± 0.01	NP	NP
Redbank (Ho) (33)	NA	4.0 ± 1.4	4.4 ± 1.3	3.9 ± 1.2	2.8 ± 1.0	1.4 ± 1.1	2.4 ± 1.2	1.4 ± 0.4	1.9 ± 1.3	3.8 ± 1.1	1.1 ± 1.5	0.5 ± 0.3	3.5 ± 2.7	4.0 ± 2.3	0.9 ± 0.7	0.6 ± 0.5	0.7 ± 1.1	5.15 ± 1.5	3.5 ± 1.5	3.5 ± 1.1	4.6 ± 0.6	3.83 ± 0.6	2.55 ± 0.5	1.47 ± 0.6	3.84 ± 0.6
TOTAL (monitoring meadows only)	641.6 ± 143.9	718.9 ± 152.6	765 ± 163.9	970 ± 173.9	1156.8 ± 95.5	1315. 6 ± 96.9	1487. 5 ± 98.9	1382.9 ± 60.8	1303.1 ± 60.6	251.4 ± 33.1	210.6 ± 55.8	30.9 ± 1.8	42.1 ± 17.9	117.7 ± 44.5	399.4 ± 71.8	901.8 ± 100.9	1167.5 ± 98	1572.2 ± 121.9	1281.2 ± 97	1291.4 ± 92	1271 ± 93.4	1334.44 ± 90.7	1255.8 ± 88.1	1046.3 ± 94.6	515 ± 47

NA = meadow not assessed, NP = meadow not present

8.3 Mean above ground biomass (g DW m^2) of seagrass for monitoring meadows in Cairns Harbour and Trinity Inlet, 2001-2025.

Meadow	Mean biomass ± SE (g DW m^{-2})																							
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Esplanade to Ellie Pt. (34)	5.9 ± 3.3	17.3 ± 1.6	46.2 ± 4.1	81.2 ± 6.8	71.8 ± 5.3	46.9 ± 3.4	33.2 ± 2.9	44.1 ± 3.8	9.8 ± 1.9	1.1 ± 0.4	0.7 ± 0.2	NA	1.2 ± 0.9	2.0 ± 0.9	3.4 ± 0.7	7.9 ± 0.7	10.7 ± 1.3	18.5 ± 1.8	21.2 ± 2.3	23.7 ± 2.0	3.2 ± 3.1	34.5 ± 3	30.3 ± 2.8	27.6 ± 2.7	19.0 ± 1.9
Bessie Pt. (11)	2.0 ± 0.4	5.5 ± 0.7	4.4 ± 0.4	5.8 ± 0.3^	15.5 ± 1.5	12.7 ± 1.7	6.9 ± 0.5	7.4 ± 0.7	7.3 ± 1.6	0.5 ± 0.3	1.8 ± 0.3	NA	2.2 ± 0.6	3.1 ± 0.6	3.2 ± 0.7	12.6 ± 1.1	4.2 ± 0.4	7.6 ± 0.7	8.2 ± 0.6	9.6 ± 0.8	7.0 ± 0.9	9.5 ± 0.7	9.8 ± 0.8	2.7 ± 0.4	1.27 ± 0.3
South Bessie Pt. (13)	NA	NA	NA	NA	NA	46.3 ± 9.1	50.9 ± 10.4	23.3 ± 3.9	36.5 ± 8.0	1.7 ± 0.8^	1.1 ± 0.4	NP	3.1 ± 0.0	5.1 ± 0.3	4.3 ± 2.0	2.3 ± 0.5	5.6 ± 1.3	6.2 ± 0.1	12.9 ± 1.5	20.9 ± 3.3	20.6 ± 4.8	25.3 ± 5.3	25.9 ± 4.2	5.3 ± 1.4	6.1 ± 2.1
Trinity Inlet (19)	6.6 ± 2.1	0.4 ± 0.1	3.0 ± 0.5	2.3 ± 0.3	3.6 ± 1.2	0.1 ± 0.02	2.3 ± 0.3	0.4 ± 0.2	1.6 ± 1.0	0.3 ± 0.2	3.5 ± 0.7	1.1 ± 0.2	1.3 ± 0.3	3.1 ± 0.4	0.8 ± 0.7	5.0 ± 0.8	1.1 ± 0.4	4.6 ± 0.6	1.7 ± 0.6	3.1 ± 0.6	0.53 ± 0.3	1.49 ± 0.3	0.28 ± 0.06	0.47 ± 0.10	1.21 ± 0.5
Redbank (Ho)* (33)	NA	0.8 ± 0.1	6.6 ± 1.1	1.3 ± 0.2	2.2 ± 0.4	0.3 ± 0.04	2.0 ± 0.3	2.1 ± 0.4	0.1 ± 0.1	0.4 ± 0.1	1.2 ± 0.3	0.9 ± 0.2	2.1 ± 0.4	1.6 ± 0.3	2.2 ± 0.6	2.1 ± 0.4	0.2 ± 0.02	3.4 ± 0.4	0.8 ± 0.1	1.1 ± 0.3	0.4 ± 0.1	1.87 ± 0.2	0.31 ± 0.1	0.75 ± 0.1	1.28 ± 0.2
Redbank (Zm) (20)	4.5 ± 4.1	2.8 ± 0.6	50.1 ± 9.4	61.5 ± 12.1	15.1 ± 7.4	11.9 ± 2.9	14.1± 3.1	37.5 ± 6.8	0.2 ± 0.02	30.4 ± 10.7	NP	NP	NP	NP	14.3 ± 2.0	NP	2.2 ± 1.8	27.2 ± 3.3	13.9 ± 4.5	16.4 ± 5.3	54.4 ± 11.4	10.54 ± 4.9	25.13 ± 6.6	NP	NP

^ The one site containing *Cymodocea serrulata* was omitted from Bessie Point biomass analysis and *Cymodocea rotunda* was omitted from South Bessie Point biomass analysis.
NP = meadow not present
NA = biomass values not available due to insufficient biomass samples
(Ho = *Halophila ovalis*; Zm = *Zostera muelleri*)