Port of Abbot Point Long-Term Seagrass Monitoring Program 2025

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Port of Abbot Point Long-Term Seagrass Monitoring Program 2025

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Acknowledgments

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 CONTENTS

2 KEY FINDINGS

Seagrass Condition 2025

GOOD

Likely causes of seagrass condition:

⬆ *Favourable climate conditions for seagrass growth in second half of year*

This report compiles findings of the annual Abbot Point long-term seagrass monitoring program conducted in October/November 2025. It also incorporates a broader-scale assessment of seagrasses conducted every three years in the program.

- Seagrass meadows in the Abbot Point region were in good overall condition in 2025 compared with the expected baseline conditions.
    - This is an improvement from the last two years where monitoring meadows were in satisfactory condition.
- Inshore *Halodule* and *Zostera* monitoring meadows ranged from satisfactory to very good condition in 2025.
- Offshore seagrass meadows dominated by *Halophila* species were in satisfactory condition in 2025.
- The 2025 broadscale survey mapped 13,789 ha of seagrass, with meadow locations and community types similar to previous broadscale surveys.
- Environmental conditions in the second half of the year were favourable for seagrass growth, likely contributing to the good condition of Abbot Point seagrass in 2025.
- The healthy state of Abbot Point seagrasses suggests they are likely to have reasonable resilience to potential disturbances over the coming year.

3 IN BRIEF

A long-term seagrass monitoring program and strategy were established in the Abbot Point region in 2008 following initial surveys of the area in 2004 and 2005. Annual monitoring occurs in representative monitoring meadows, with broadscale mapping occurring every third year. Annual monitoring is conducted at three inshore areas and a large region of the deeper offshore area (Figure 1 & 2). In addition to the established annual monitoring program, benthic light (Photosynthetically Active Radiation, PAR) and temperature (continuously logged) data is collected at two inshore sites and at offshore sites through the TropWATER/NQBP Ambient Water Quality Monitoring program (Figure 8 and 9; Section 4.5).

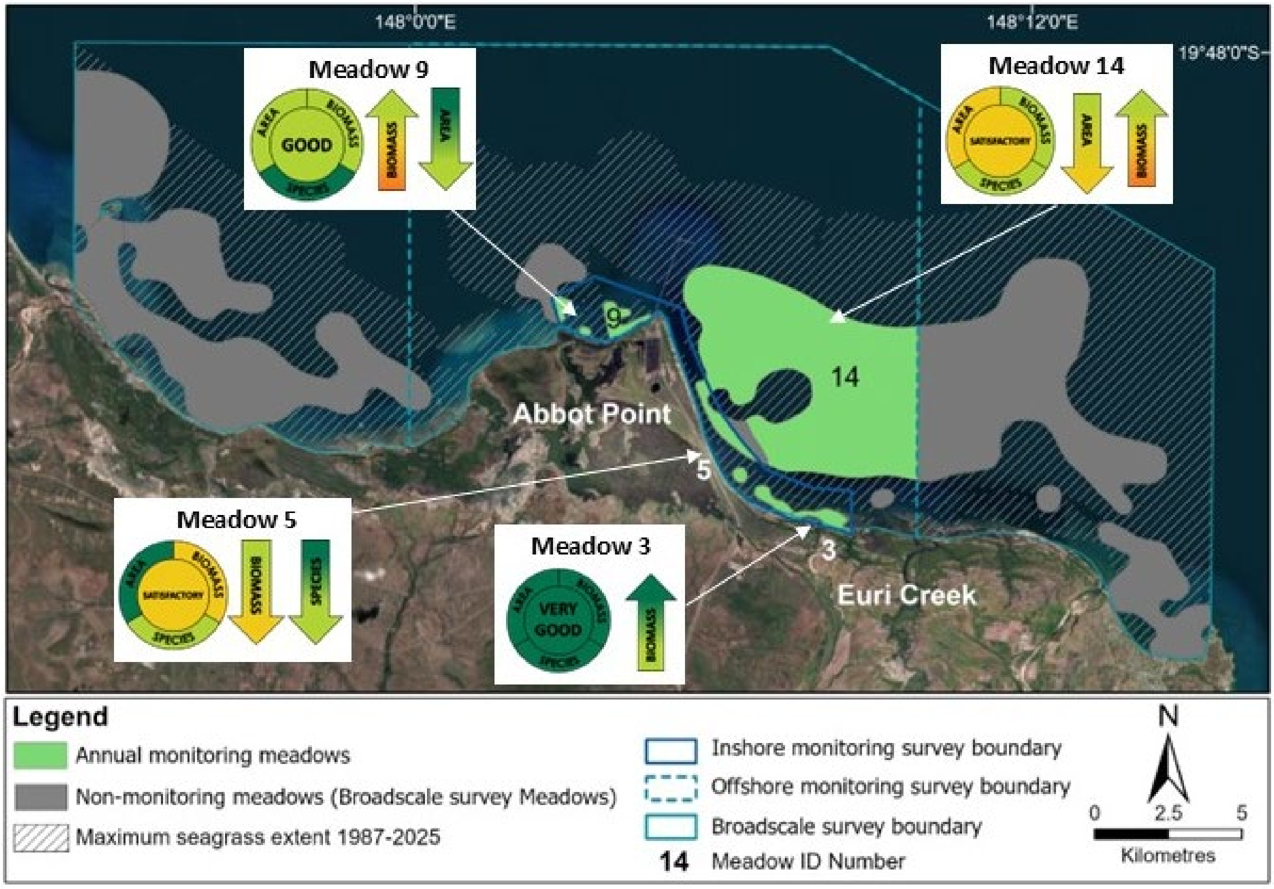

Figure 1. Seagrass condition for Abbot Point seagrass monitoring areas 2025.

The overall condition of Abbot Point seagrasses improved to good for the first time since the last broadscale survey in 2022. Seagrass condition indicators (biomass, area, and species composition) for all annual monitoring meadows ranged from satisfactory to very good (Figure 1). Annual monitoring results indicate that inshore seagrass meadows continue to be dominated by *Halodule uninervis*, except for Meadow 3 at Euri Creek, which is dominated by *Zostera muelleri*. The offshore monitoring area is dominated by deepwater species *Halophila spinulosa*, with *H. ovalis* and *H. decipiens* present at lower proportions. Five seagrass species were recorded in 2025, consistent with historical observations. Previously recorded species, including *Cymodocea rotundata*, *Cymodocea serrulata*, and *Syringodium isoetifolium,* were not observed during the survey. However, the persistence of foundation species across both inshore and offshore meadows suggests that the dominant regional seagrass community has remained relatively consistent.

Biomass increases were observed in three of the four monitored meadows, contributing to improved condition scores (Figure 1 & 2). Meadow 3 showed the largest improvement, with biomass increasing by 2.55 g DW m^{-2}, area by 21.7 ha, and the proportion of *Z. muelleri* rising from 56% to 89%. Meadow 9 also improved for the first time since 2022, increasing from poor to good condition, while Meadow 5 declined slightly to satisfactory due to reductions in biomass and species composition (Figure 1). Offshore Meadow 14 improved from poor to satisfactory, driven by a biomass increase despite a reduction in area (Figure 2).

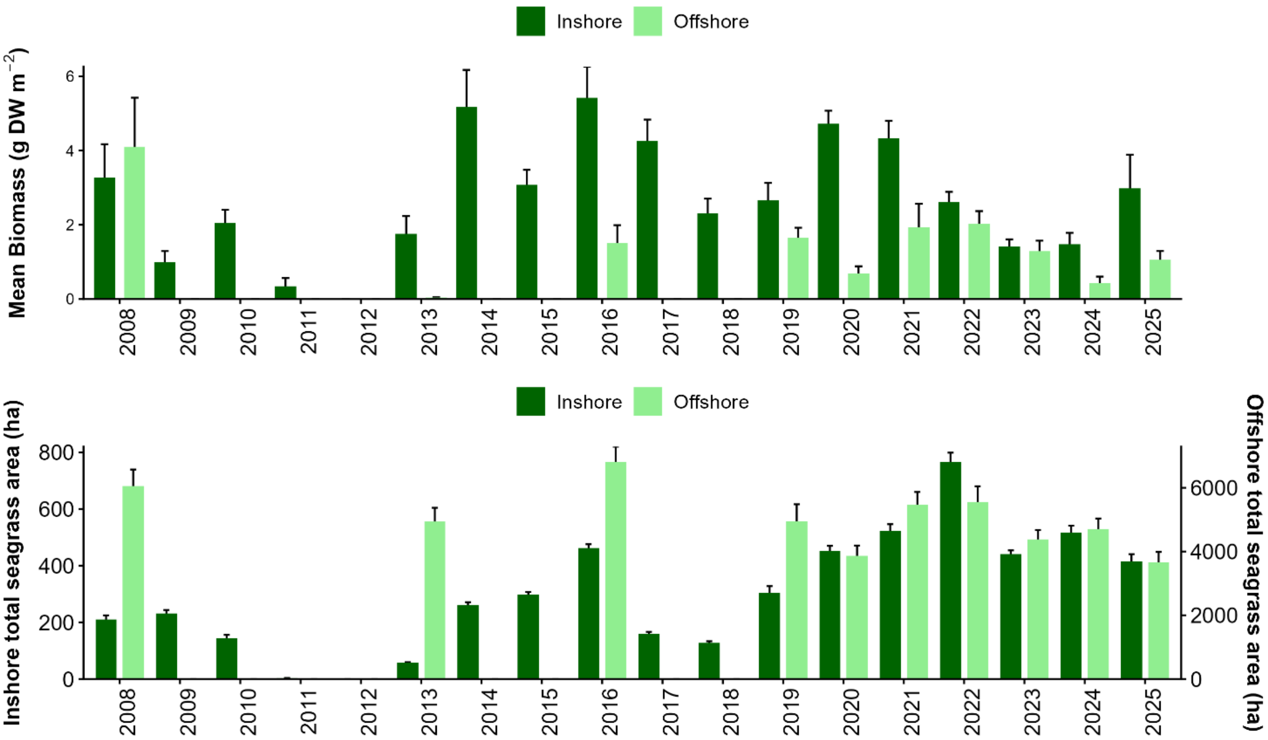

Figure 2. Comparison of mean biomass (g DW m^{-2}) and area (ha) for inshore and offshore seagrass monitoring meadows from 2008 to 2025.

Environmental monitoring over the 12 months prior to the survey indicated generally favourable conditions for seagrass growth (Figure 3). Benthic light (PAR) remained above species-specific growth thresholds for the majority of the year, with periods of consecutive low light below critical thresholds for growth limited to less than 40 days for *H. uninervis* and 28 days for *Halophila* species (Collier et al. 2016). Maximum benthic temperatures ranged from 21.1°C to 35.6°C, remaining within tolerable ranges for seagrass growth. Rainfall and river flows were above the long-term average earlier in the year, but below average in the months leading up to the survey. Wave stress (RMS) was lower and shorter in duration than in recent previous years. These conditions likely contributed to the observed increases in biomass across the monitoring meadows in 2025.

Comparison with the previous broader-scale survey conducted in 2022 shows that, although biomass and condition improved in the annual monitoring meadows in 2025, overall seagrass extent and biomass across the broader port limits remained well below levels recorded three years earlier (the last time broader scale assessments were completed) (Figure 2). This highlights the importance of periodic reassessments of the broader port limit area to understand regional seagrass condition.

The persistence of foundation species, combined with positive responses to favourable conditions, suggests that Abbot Point seagrasses are resilient and capable of recovery following episodic disturbances. Continued annual and broadscale monitoring will continue to track these dynamics and inform management strategies aimed at maintaining the ecological health of seagrass meadows in the region. The condition of seagrasses in 2025 indicates they should have reasonable levels of resilience to natural and anthropogenic stressors in the coming year.

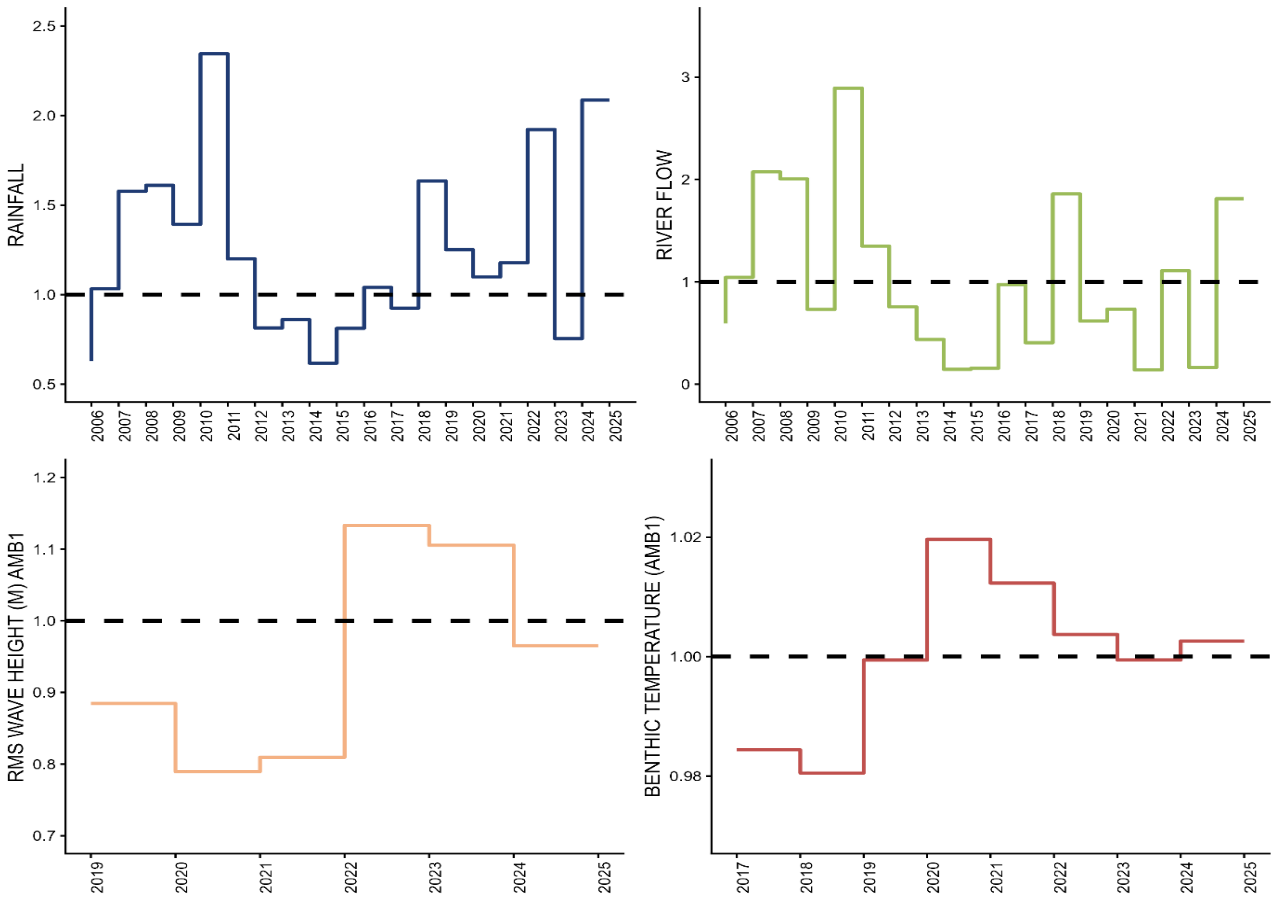

Figure 3. Climate trends for temperature and solar exposure (Bowen) and rainfall and river flow (Guthalungra/Elliot River) from 2006/07 to 2024/25: Change in climate variables as a proportion of the long-term average (LTA – dashed line). See section 5.4 for detailed climate data.

4 INTRODUCTION

Seagrasses are highly productive marine habitats that provide a range of ecosystem services important to human wellbeing, with their global value estimated at US$6.4 trillion annually (Costanza et al. 2014; Duarte et al. 2025; Forster et al. 2025). Services include nursery habitat for economically important fisheries species (Coles et al. 1993; Hayes et al. 2020), food for megaherbivores (e.g., dugongs and turtles) (Scott et al. 2018; Scott et al. 2021; Cleguer et al. 2026), sediment stabilisation (James et al. 2019), nutrient cycling across the coastal zone (McMahon and Walker 1998), and sequestration of atmospheric carbon (York et al. 2018; Rasheed et al. 2019; Macreadie et al. 2024; Gomis et al. 2025). Coastal communities and Traditional Owners rely on seagrass meadows for food and livelihoods (Hayes et al. 2020; Jänes et al. 2020a, 2020b). Seagrass meadows further contribute to coastal protection by dissipating wave energy and reducing sediment resuspension, a function of increasing importance under climate-driven sea-level rise and intensifying storm events (Duarte et al. 2025).

Globally there has been a net decline in seagrass meadows in recent decades due to natural and anthropogenic causes (Dunic et al. 2021; Turschwell et al. 2021; Waycott et al. 2009). Climate change stressors such as increases in water temperature and frequency and severity of tropical storms have the potential to exacerbate this decline (Strydom et al. 2020; Serrano et al. 2021; Carter et al. 2022; Shepherd et al. 2024; McKenna et al. 2025). In the Great Barrier Reef (GBR) coastal region, the hotspots with the highest threat exposure for seagrasses all occur in the southern two-thirds of the GBR, where multiple threats accumulate including urban development, ports, industrial and agricultural runoff (Grech et al. 2011). These hotspots arise as seagrasses occur in the same sheltered coastal locations where 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 (Coles et al. 2015).

4.1 Queensland Ports Seagrass Monitoring Program

A long-term seagrass monitoring and assessment program has been established in most Queensland commercial ports (Figure 4). The program was developed by James Cook University's Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) in partnership with Queensland port authorities. A common methodology and rationale are used to provide a network of seagrass monitoring locations throughout the state (Figure 4).

This program provides local information for individual ports and contributes to regional assessments of the status of seagrasses more broadly. The program further provides port managers and regulators with the key information necessary for planning and implementing port development and maintenance programs, to have minimal impact on seagrasses. The program provides an ongoing assessment of many of the most threatened seagrass communities in the state.

The program has resulted in significant advances in the science and knowledge of tropical seagrass ecology. It has been instrumental in developing tools, indicators, and

Figure 4. James Cook University's TropWATER and Queensland Ports long-term seagrass monitoring locations and baseline

thresholds for the protection and management of seagrasses, and an understanding of the causes 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/themes/seagrass-habitats.

4.2 Abbot Point long term seagrass monitoring program

North Queensland Bulk Ports Corporation (NQBP) in partnership with James Cook University (JCU) TropWATER has undertaken seagrass assessment and monitoring at Abbot Point since 2005. The annual long-term seagrass monitoring program has evolved over time as additional data have been collected and end-users have been expanded (i.e., Mackay Whitsunday Isaac Healthy Rivers to Reef Partnership). The current program consists of annual surveys of representative monitoring meadows, with broadscale mapping occurring every third year; including in 2025. The areas selected for annual monitoring represent the range of seagrass communities within the port and include meadows considered most likely to be influenced by port activity and development, as well as reference areas outside the zone of influence of port activity and development (Figure 5).

As part of the NQBP-JCU partnership, light (photosynthetically active radiation; PAR) and temperature assessments are also conducted within two of the inshore monitoring meadows. These assessments run in parallel with the companion Ambient Marine Water Quality Monitoring Program, which includes five additional water quality monitoring stations in the region (see Cartwright et al. 2025).

The long-term monitoring program, together with regular broadscale surveys and complementary monitoring and research by JCU in the Abbot Point region, aims to enhance understanding of water quality, seagrass, coral, and benthic habitat dynamics to support more effective management of marine habitats and port environments. The program contributes to Queensland’s network of long-term monitoring sites for important fish habitats in high-risk areas. It also provides a key input into the condition and trend assessment of seagrasses in the Mackay-Whitsunday-Isaac NRM region, an area that otherwise has limited spatial coverage for seagrass assessment and condition monitoring.

This report presents the findings of the annual long-term and broadscale monitoring for 2025. The objectives of this report are to:

- Assess and map seagrass to determine density (biomass), distribution (area), and community type (species composition) at representative long-term monitoring meadows.
- Assess and map the distribution and abundance of all seagrass in the broader Abbot Point region to provide an updated picture of seagrass at a broader scale (broadscale survey).
- Compare outcomes with previous monitoring surveys to interpret changes in seagrass in relation to natural events or human induced port and catchment activities.
- Discuss the implications of monitoring results for the overall health of the Port of Abbot Point marine environment.

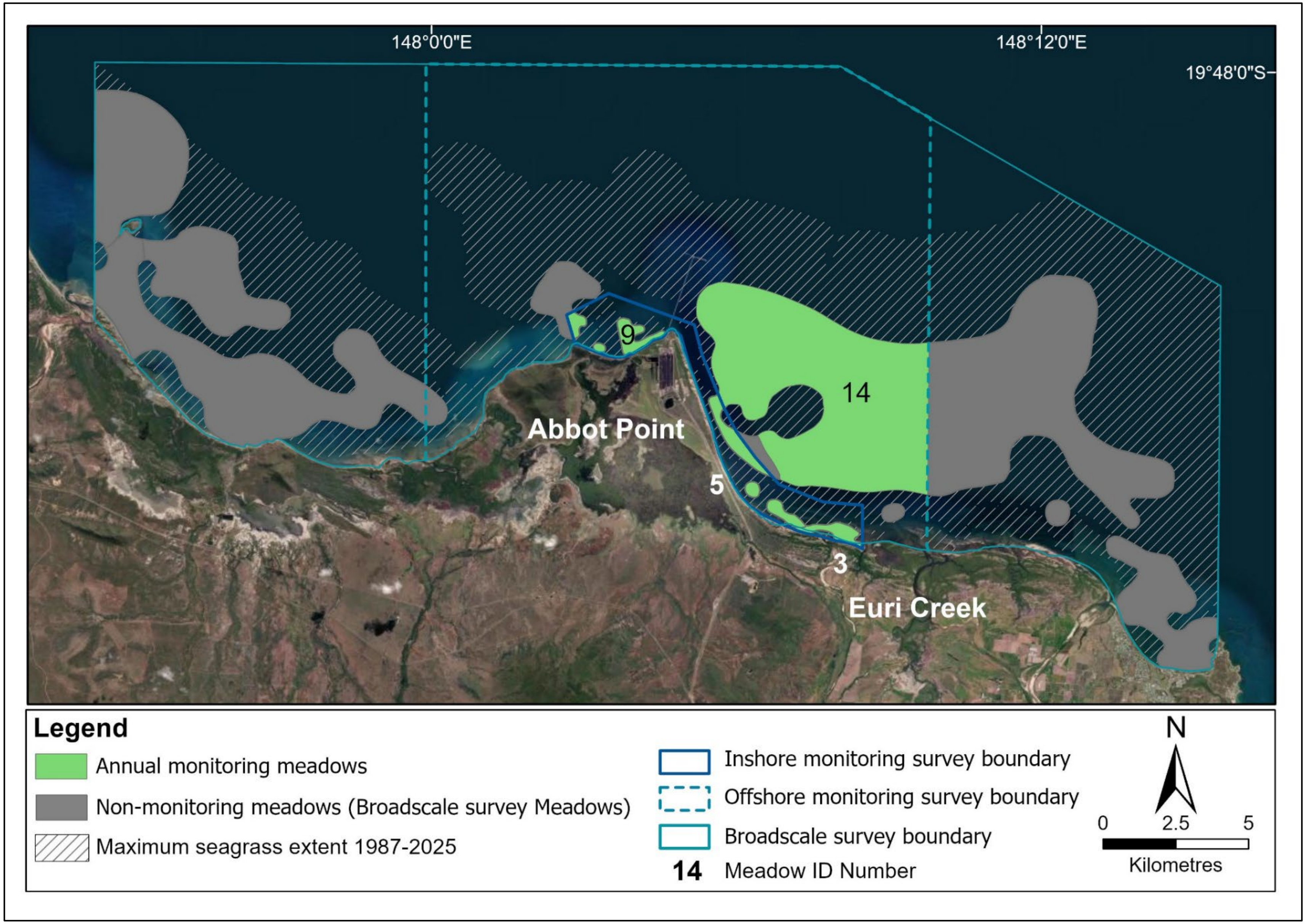

Figure 5. Location of survey limits and annual inshore and offshore long-term monitoring areas and seagrass outside the monitoring areas around Abbot Point.

5 METHODS

5.1 Sampling approach

In the initial 2008 baseline survey, five coastal meadows and four offshore areas were identified for long-term seagrass monitoring (McKenna et al. 2008). Monitoring meadows were selected for detailed annual assessment because they were representative of the range of seagrass meadow communities identified in the initial surveys. Surveys are conducted annually between September and December to assess seagrass at its expected seasonal peak in distribution and biomass, and to facilitate comparisons with previous surveys conducted in the area.

In 2019, three of the coastal meadows southeast of Abbot Point (Meadows 5, 7 and 8) were combined for analysis and reporting based on their proximity and similar species structure. These meadows have been referred to in reports from 2019 onwards as Meadow 5. Coastal monitoring meadows now comprise Meadows 3, 5, and 9 (Figure 5).

In 2020, changes were also made to the way the offshore seagrass meadows at Abbot Point were surveyed, analysed, and reported. This included a shift from assessing seagrass in fixed 'monitoring blocks' to a more extensive assessment of seagrass in a larger 'offshore' survey boundary (Figure 5). This allowed the full suite of seagrass meadow condition indicators (area, biomass, species composition) to be assessed and reported on, rather than just biomass and species composition in the offshore meadow. Ten survey years of data have now been collected covering this survey region (2008, 2013, 2016, 2019, 2020, 2021, 2022, 2023, 2024 and the current 2025 survey), resulting in a 10-year baseline for each condition indicator (Carter et al. 2023).

In 2023, a new survey area between Meadows 9 and 5 (around the Abbot Point Marine Offloading Facility (MOF)) was added to the program and reported on. This area is now incorporated into the inshore monitoring boundary and reported separately from the long-term monitoring meadows (Figure 5; Rasheed et al. 2025).

5.2 Sampling methods

Survey and monitoring methods for assessing seagrass in the Abbot Point region follow established techniques for Abbot Point and the JCU TropWATER Queensland-wide seagrass monitoring programs. The application of standardised methods at Abbot Point and throughout Queensland allows direct comparison of local seagrass dynamics with other seagrass monitoring programs in the broader Queensland region.

Site-appropriate methods were based on existing knowledge of benthic habitats and physical characteristics of the location such as depth, visibility, and logistical and safety constraints. Two sampling techniques were used for the survey:

1. Shallow subtidal areas <8m below MSL: Boat based underwater digital camera mounted to a drop frame (Figure 6A-B);
2. Offshore subtidal areas >8m below MSL: Boat based digital camera sled tows with sled net attached (Figure 6C-D).

At each survey site, seagrass habitat observations included seagrass species composition, above-ground biomass, percent algal cover, depth below mean sea level (dbMSL), sediment type, time, and position (GPS). The percent cover of other major benthos at each site was also recorded.

At sites where seagrass was present, seagrass above-ground biomass was measured using a "visual estimates of biomass" technique (Kirkman 1978; Mellors 1991). For camera drop sites, an observer ranked seagrass biomass within three randomly placed 0.25m^2 quadrats (Figure 6A-B). For digital camera sled tow sites, an observer ranked seagrass from ten random time frames along a 100m transect. For each frame, the video was paused, and advanced to the nearest point where the seabed was clearly visible and the sled was stable. A 0.25 m² quadrat, scaled to the camera lens, was then overlaid on the screen to standardise estimates.

Figure 6. (**A-B**) Shallow subtidal assessments of seagrass meadows using live-feed digital camera mounted on a 0.25m^2 drop frame, and (**C-D**) offshore underwater sled tows with digital camera.

5.3 Habitat mapping and Geographic Information System

All survey data were entered into a Geographic Information System (GIS) using ArcGIS PRO 3.5® software. Three GIS layers were created to describe seagrass in the survey area: a site layer, meadow layer and biomass interpolation layer.

- *Seagrass Site Layer:* The site (point) layer contains data collected at each site, including:
    - Site number
    - 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); site benthic cover (percent cover of algae, seagrass, benthic macro-invertebrates, open substrate); dugong feeding trail presence/absence.
    - Sampling method and any relevant comments.

- *Seagrass 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) (Table 3), number of sites within the meadow, seagrass species present, meadow density and community type (Tables 1 and 2), meadow landscape category (Figure 7).
    - Sampling method and any relevant comments.

- *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.

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 1. Nomenclature for seagrass community types in Queensland.

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

Table 2. Density categories and mean above-ground biomass ranges for each species used in determining seagrass community density in Queensland.

Density	Mean above-ground biomass (g DW m^{-2})				
	H. uninervis **(narrow)**	***H. ovalis H. decipiens***	***H. uninervis*** **(wide)** ***C. serrulata/rotundata***	***H. spinulosa H. tricostata***	***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

Most of the 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

Most of the meadow area consists of continuous seagrass cover with a few gaps of unvegetated sediment.

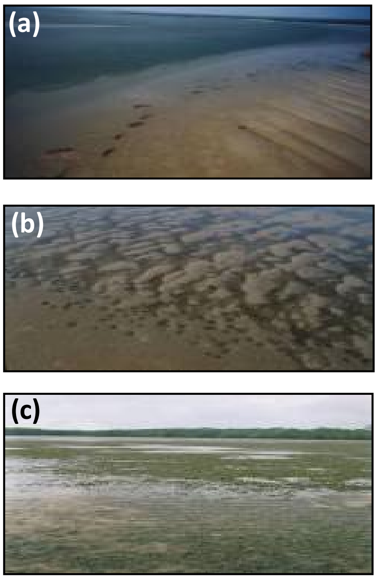

Figure 7. Seagrass meadow landscape categories: (a) Isolated seagrass patches, (b) aggregated seagrass patches, (c) continuous seagrass cover.

Seagrass meadow boundaries were determined from a combination of techniques. Subtidal boundaries were interpreted from a combination of subtidal survey sites, the distance between sites, field notes, depth contours and recent satellite imagery.

Once meadow polygons were delineated in ArcGIS Pro, area was calculated using the *Calculate Geometry* function. To account for spatial uncertainty, each meadow was assigned a mapping precision estimate (m) based on the survey method (Table 3). Precision ranged from 10-20 m inshore shallow subtidal meadows to 100 m for deeper subtidal meadows, where boundaries were inferred from distances between sites with and without seagrass. These estimates were used to generate buffers around each meadow to represent spatial error, with the buffered area expressed as a meadow reliability estimate (R; ha).

Table 3. Mapping precision and methodology for seagrass meadows in the Abbot Point region.

Mapping precision	Mapping methodology
10-20m	Subtidal meadow boundaries determined from digital camera with drop frame. Relatively high density of survey sites. Recent digital maps/ imagery aided in mapping. Distance between sites with/without seagrass aided in mapping.
100m	Subtidal meadow boundaries determined from digital camera with sled tows. Moderate density of survey sites. Recent digital maps/Landsat imagery aided in mapping. Distance between sites with/without seagrass aided in mapping.

5.4 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).

5.5 Environmental data

Available environmental data was collated for the twelve months preceding the 2025 survey. Total daily rainfall (mm) and river flow data were obtained by the Queensland Government's Water Monitoring Information Portal (station 121002A – Elliot River at Guthalungra).

Benthic light measured as photosynthetically active radiation (PAR; mol photons m^2 day^1), seabed water temperature, and wave stress were collected through this program and the companion TropWATER Ambient Marine Water Quality Monitoring Program (Figures 8 and 9).

At the inshore seagrass meadows (Meadows 5 and 9) PAR (water quality monitoring sites TW1 and TW2), was measured using submersible Odyssey cosine-corrected irradiance loggers fitted with automated wipers to minimise fouling (Figure 10). Loggers were calibrated against a cosine-corrected Li-Cor underwater quantum sensor (LI-190SA; Li-Cor Inc., Lincoln, Nebraska, USA) and corrected for immersion effects using a factor of 1.33 (Kirk 1994). Measurements were recorded at 15-minute intervals and used to estimate total daily irradiance reaching the seabed.

At the offshore meadow (Meadow 14; water quality monitoring site AMB1), PAR data were collected using a PAR sensor mounted horizontally on a multiparameter water quality logging instrument (MS9), which recorded measurements at ten-minute intervals (Cartwright et al. 2025).

Data are presented as 7-day and 14-day rolling averages of total daily PAR to allow comparison with modelled light requirements for regional seagrass species, primarily *Halophila* spp. and *Halodule* sp. (McKenna et al. 2015; Collier et al. 2016; Chartrand et al. 2017, 2018).

At inshore monitoring meadows seabed temperature was recorded using Tinytag Aquatic 2 TG-4100 – Submersible temperature data loggers, while at the offshore monitoring meadow, seabed temperature was recorded by the NTU-LPT logger (see Carwright et al. 2025 for more details).

Wave stress was measured using the root mean square water height (RMS water depth), which represents short-term variability in pressure over the 10-second burst interval and is therefore related to wave energy at the seabed (Cartwright et al. 2025). RMS water depth does not measure wave height at the sea surface but rather provides an index of near-bed orbital motion or wave shear stress relative to depth. Consequently, RMS water depth is a useful relative indicator of potential resuspension that is directly comparable between sites of different depths. For interpretation, higher RMS water height values indicate stronger wave action.

For the full suite of water quality monitoring stations and results, see Cartwright et al. 2025.

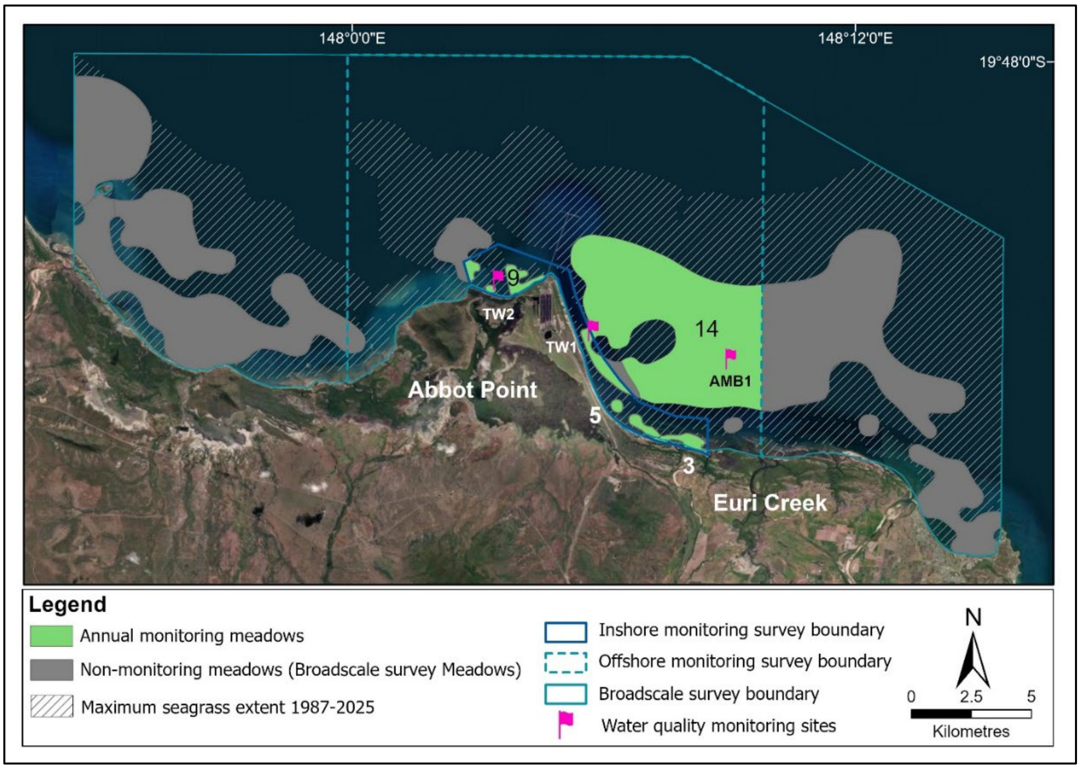

Figure 8. Location of light (photosynthetically active radiation (PAR)) and temperature loggers at Abbot Point.

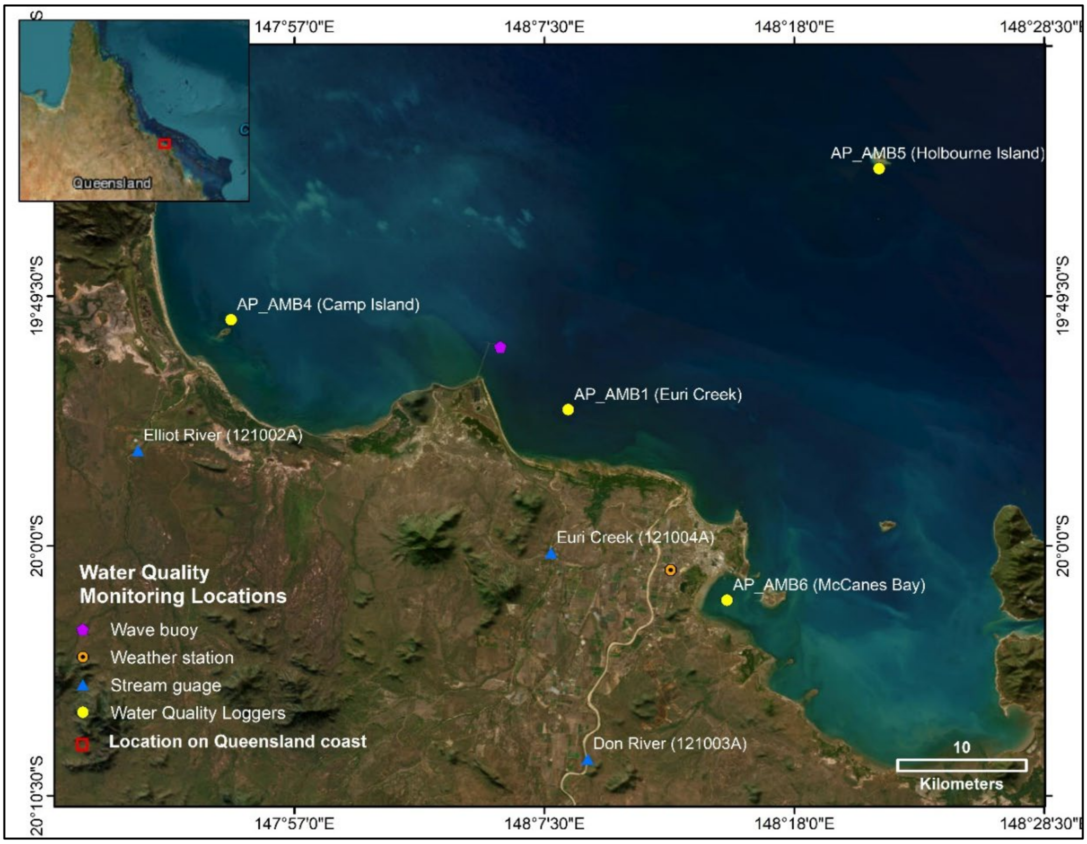

Figure 9. From Cartwright et al. 2025: Location of TropWATER water quality monitoring sites (yellow circles). Also shown are meteorological stations (orange square), and stream gauge stations (blue triangle).

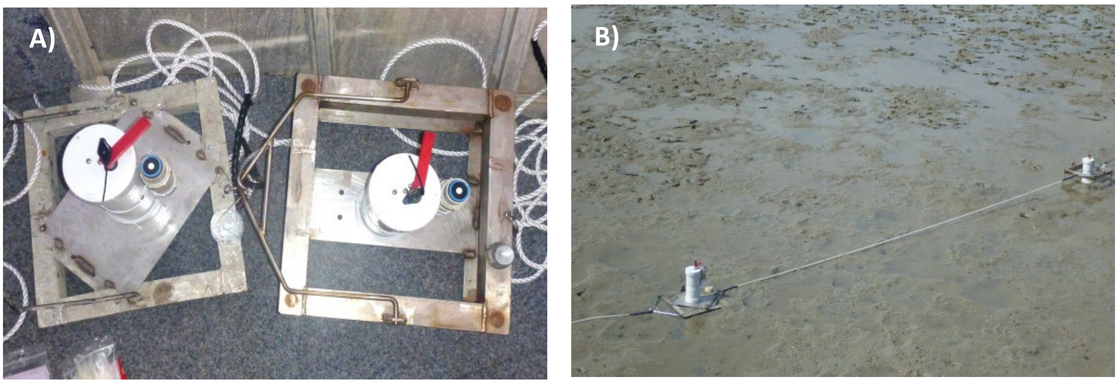

Figure 10. (**A**) Logging station consisting of a stainless-steel frame with PAR (Odyssey) loggers, temperature loggers and wiper units attached; (**B**) example of deployment of logging stations (Abbot Point stations are subtidal only).

6 RESULTS

6.1 Seagrass in the Abbot Point long term monitoring areas

The 2025 broadscale and annual monitoring survey was conducted between October and November 2025. Of the 359 assessments sites assessed in 2025, seagrass was present at 35% of these (Figure 12). Seagrass in the inshore annual monitoring areas covered approximately 415.1 ha while seagrass in the offshore monitoring area covered 3,662.03 ha (Figure 12 and 13; Appendix 8.2). Seagrass biomass was higher inshore and reduced offshore with increasing water depth (Figure 13, Appendix 8.2).

Five seagrass species were observed in the 2025 survey and were typical of those in the Abbot Point region and more broadly in Queensland (Figure 11). The offshore seagrass habitat was dominated by *Halophila spinulosa* with *H. ovalis*, *H. decipiens* and *Halodule uninervis* (wide form) also present (Appendix 8.1). Inshore meadows (5 and 9) were dominated by *H. uninervis* (narrow form) (Appendix 8.1). *Zostera muelleri* was the dominant species in the Euri Creek monitoring meadow (Meadow 3).

Cymodocea rotundata, Cymodocea serrulata, and *Syringodium isoetifolium* have been recorded in the region in past surveys but occurrences are uncommon, and they were not present in 2025 within the surveyed area. *Cymodocea serrulata* was last recorded in 2020, and *C. rotundata* and *S. isoetifolium* have only been recorded in the 2005 baseline survey. *Syringodium isoetifolium and C. serrulata* were recorded in the 2024 and 2025 Bowen (McCanes Bay) surveys, just to the south of the Abbot Point monitoring areas (Cleguer et al. 2026).

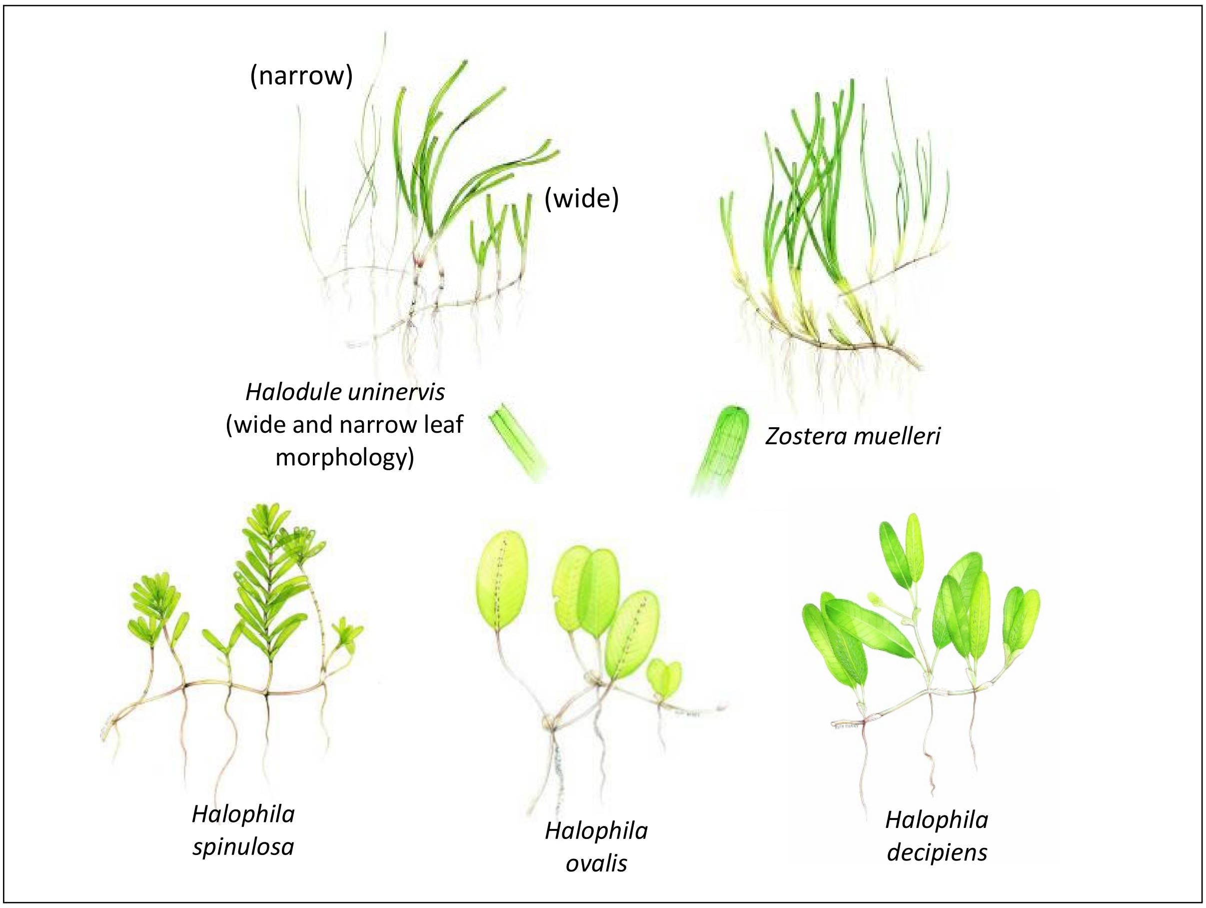

Figure 11. Seagrass species identified in the Abbot Point region assessment sites in 2025

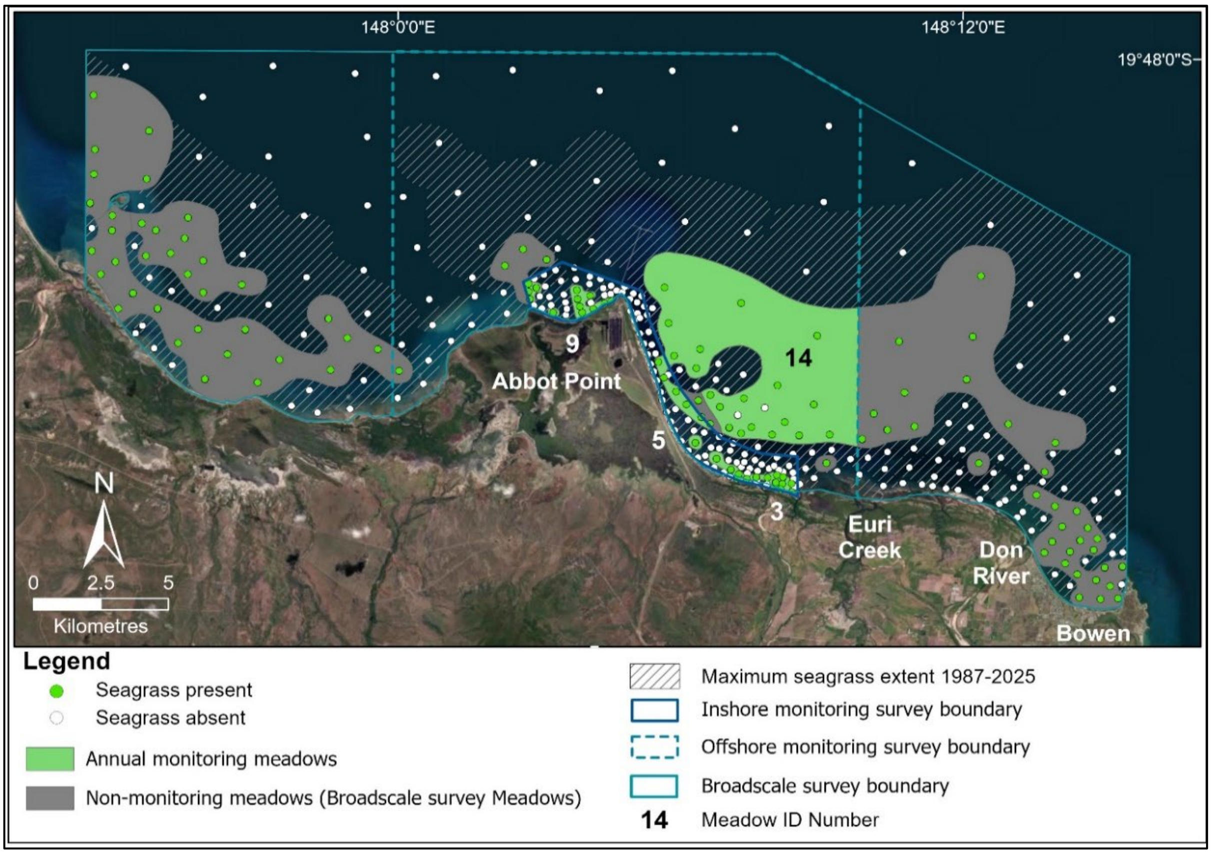

Figure 12. Location of seagrass assessment sites showing seagrass presence/absence, mapped meadows and survey boundaries in the 2025 annual monitoring and broadscale survey.

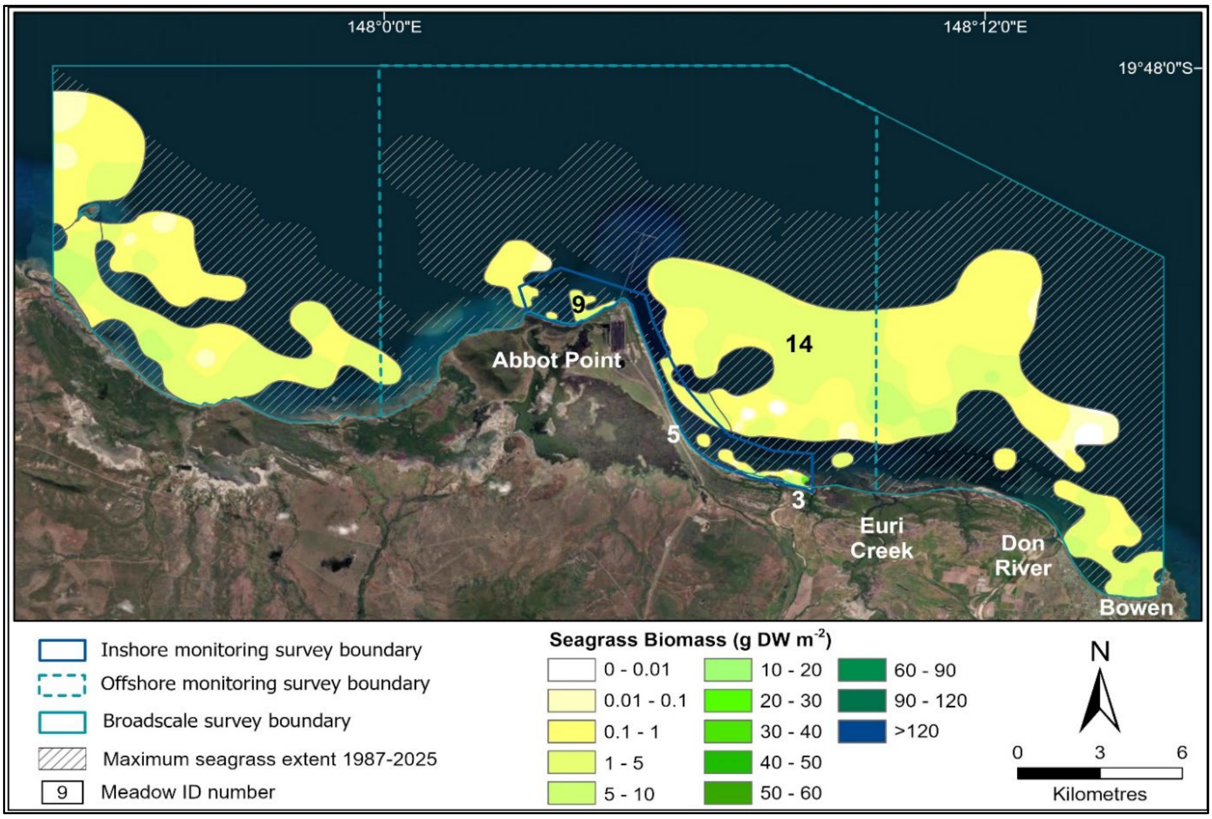

Figure 13. Mapped seagrass distribution and seagrass above-ground biomass (g DW m^{-2}) within mapped meadows for the Abbot Point region 2025.

6.2 Seagrass condition in the Abbot Point long term monitoring areas

In 2025 Abbot Point monitoring meadows were in a combined overall good condition (Table 4). This is an improvement on the previous two years when the meadows at Abbot Point were in satisfactory condition (Rasheed et al. 2025; McKenna et al. 2024). Individual meadows ranged in condition from very good to satisfactory, with two of the four meadows increasing in condition (Meadow 3 and 9), and two decreasing in condition due to a decrease in biomass and area respectively (Meadow 5 and 14).

Table 4. Condition scores for seagrass indicators (biomass, area and species composition) for the Abbot Point region 2025.

Meadow	Biomass	Species Composition	Area	Overall Meadow Score
Inshore meadow 3	0.89	0.97	0.97	0.89
Inshore meadow 5	0.54	0.77	1	0.54
Inshore meadow 9	0.65	1	0.81	0.65
Offshore meadow 14	0.68	0.70	0.52	0.52
Overall condition score for seagrass in the Port of Abbot Point				**0.65**

= very good condition = good condition = satisfactory condition

= poor condition = very poor condition

6.2.1 Inshore seagrass monitoring areas

There are three inshore annual monitoring meadows around Abbot Point. Meadow 3 and 5 are located to the southeast of Abbot Point while Meadow 9 is located on the western side of Abbot Point wharf (Figure 5). Meadows 5 and 9 are *H. uninervis* dominated meadows, while Meadow 3 at Euri Creek is a *Z. muelleri* dominated meadow (Figures 14-16; Appendix 8.1).

The Euri Creek *Z. muelleri* meadow (Meadow 3) was in very good condition at the end of 2025 for the first time since 2016 (Table 4; Figure 14). The above-ground biomass in the meadow increased from good in 2024 to very good in 2025, while the other condition indicators, area and species composition remained very good during this period (Figure 14). Condition indicators of this meadow have been on an upward trajectory since 2023. Between the 2024 and 2025 surveys, above-ground biomass increased by 2.55 g DW m^{-2}, area increased by 21.7 ha, and the contribution of the dominant species, *Z. muelleri*, increased from 56% to 89% of biomass.

The *H. uninervis* monitoring meadow on the south-eastern side of Abbot Point (Meadow 5) declined from good to satisfactory overall condition at the end of 2025 (Table 4; Figure 15). Biomass and species composition indicators declined in the meadow between 2024 and 2025. Despite this, the area of the meadow remained in very good condition and above the long-term baseline average for the seventh consecutive year. The decline in the species composition indicator was driven by a higher contribution of the less stable *Halophila* species. A relatively small change in above-ground biomass of 0.94 g DW m^{-2} was enough to cause a decrease in the biomass condition from good to satisfactory. In 2025 the meadow extended beyond the fixed inshore survey boundary for the long-term monitoring program (Figure 15). For the purposes of the long-term monitoring program and determining condition scores, meadow area, biomass, and species composition have only been calculated on the portion of the meadow that is within the annual fixed survey boundary.

The *H. uninervis* monitoring meadow on the western side of Abbot Point (Meadow 9) increased to an overall good condition in 2025, due to an increase in biomass of the meadow (Table 4; Figure 16). The above-ground biomass of the meadow increased from 0.48 g DW m^{-2} in 2024 to 1.39 g DW m^{-2} in 2025. The area of the meadow declined in condition to good after being in very good condition for the last four years. There was a 105.12 ha area reduction between 2024 and 2025 with the meadow becoming more fragmented compared to the previous year. The contribution of the meadow indicator species, *H. uninervis* increased from 78% to 99% between 2024 and 2025 remaining in very good condition. Meadow 9 also extended beyond the fixed inshore survey boundary for the annual long-term monitoring scope (Figure 16). Calculations for condition scores for each indicator were based on the portion of the meadow that was within the annual survey area boundary.

No seagrass was found in the vicinity of the Marine Offloading Facility area in 2025 (Figures 12 and 13).

6.2.2 Offshore seagrass monitoring area

The offshore monitoring area encompasses the seafloor from ~5 m to 26 m below mean sea level. The shallowest section of the offshore monitoring area is located on the north-western side of Abbot Point on Clark Shoal. Seagrass around Clark Shoal has been intermittently present throughout the monitoring program and has typically been dominated by *H. uninervis*. The deeper areas generally consist of low light adapted *Halophila* species; dominated by *H. spinulosa*.

Seagrass condition in the offshore monitoring area (Meadow 14) improved from poor to satisfactory condition between 2024 and 2025 (Table 4; Figure 17). This improvement in condition was a result of the biomass of the meadow increasing for the first time since 2022 from poor (0.42 g DW m^{-2}; 2024) to good (1.06 g DW m^{-2}; 2025). Meadow area decreased by 1047 ha between 2024 and 2025, resulting in a reduction of the area condition score from good to satisfactory. The species composition of the offshore monitoring meadow remained good with *H. spinulosa* (41%), *H. ovalis* (33%), and *H. decipiens* (26%), making up the species composition of the meadow. Meadow 14 also extended beyond the fixed annual monitoring offshore survey boundary, forming part of the broadscale offshore meadow (Figure 13). Condition assessments and scores for each indicator were based on the portion of the meadow that was within the annual survey area boundary.

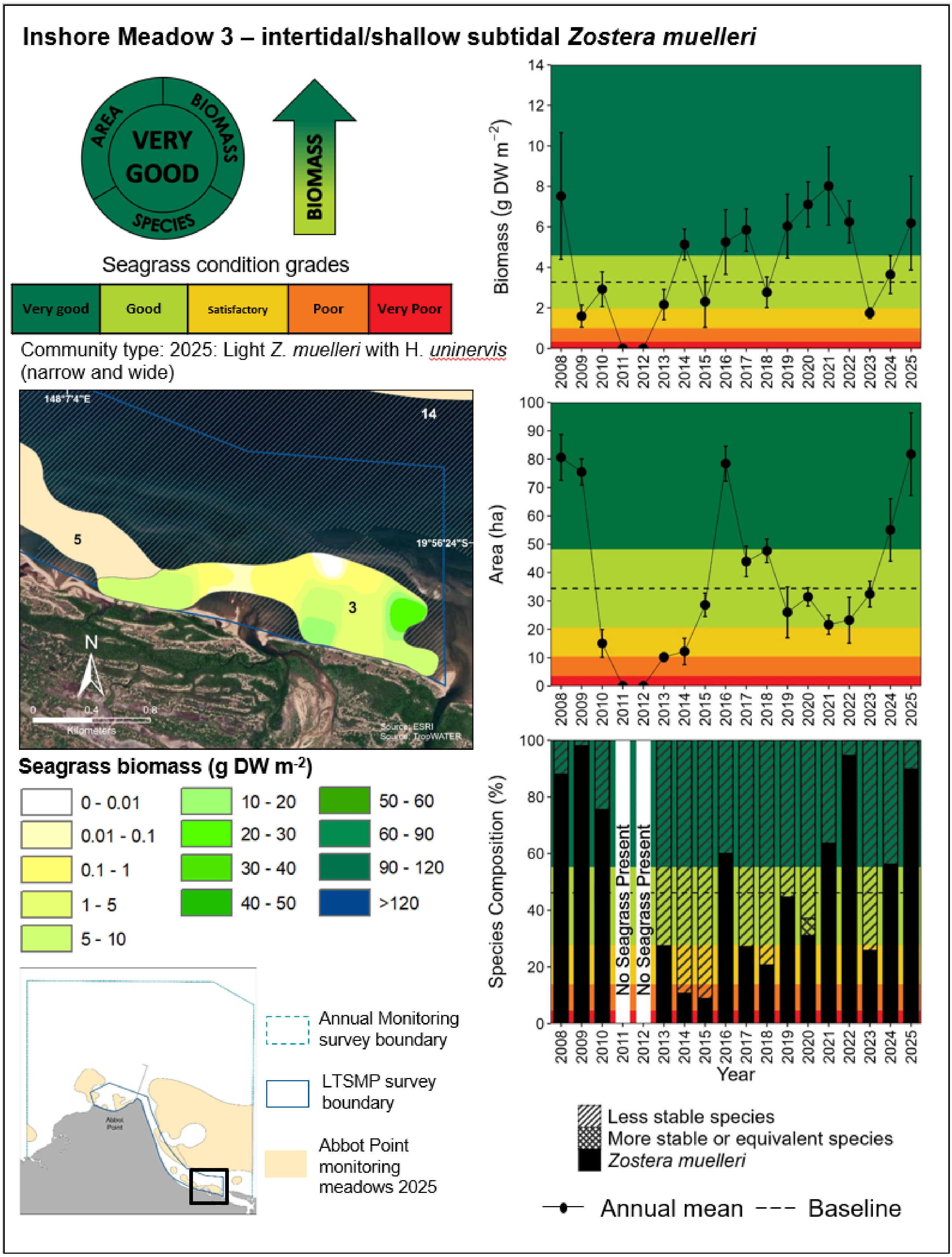

Figure 14. Changes in mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 3. Lack of arrows indicates no change in condition index from the previous year.

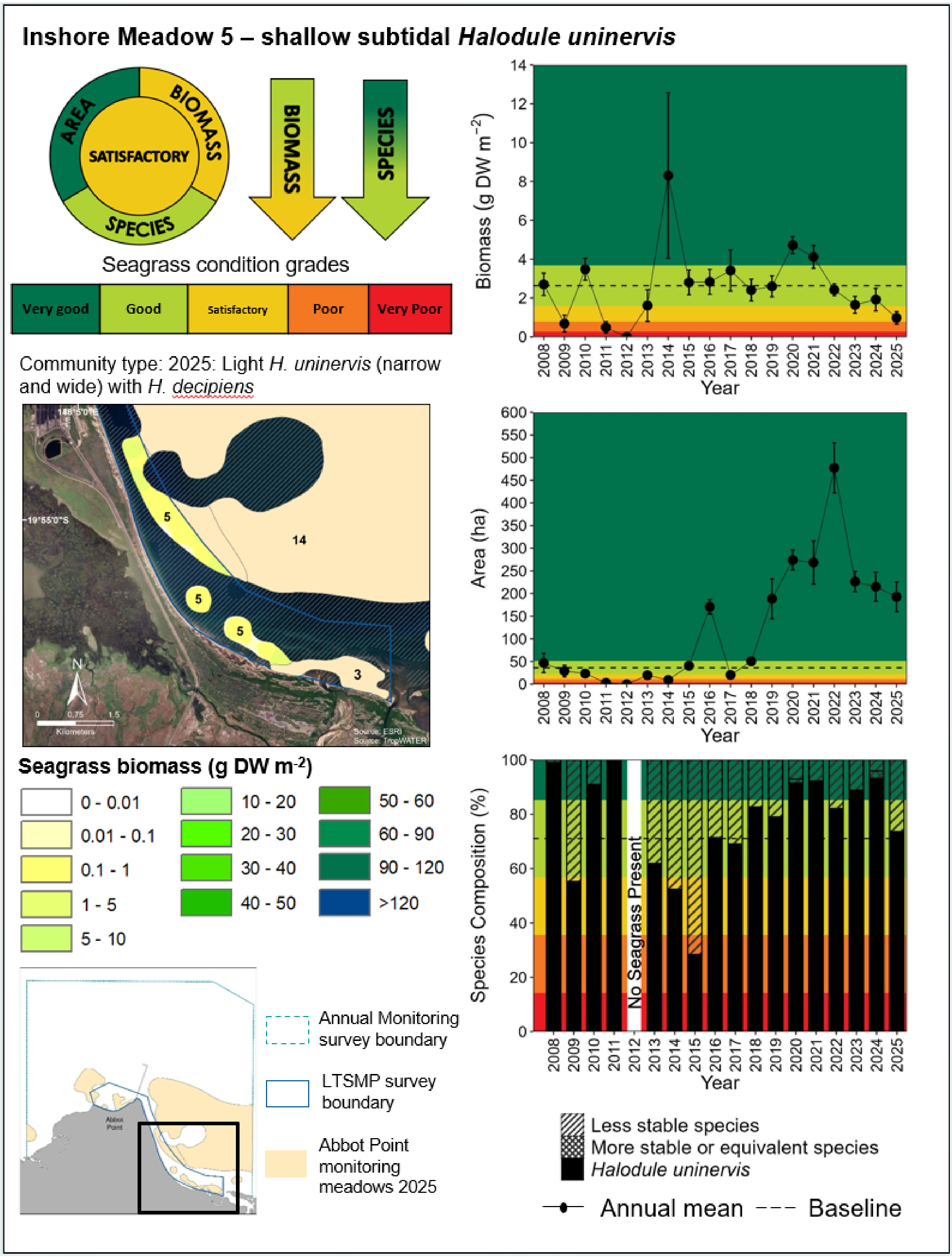

Figure 15. Changes in mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 5. Lack of arrows indicates no change in condition index from the previous year.

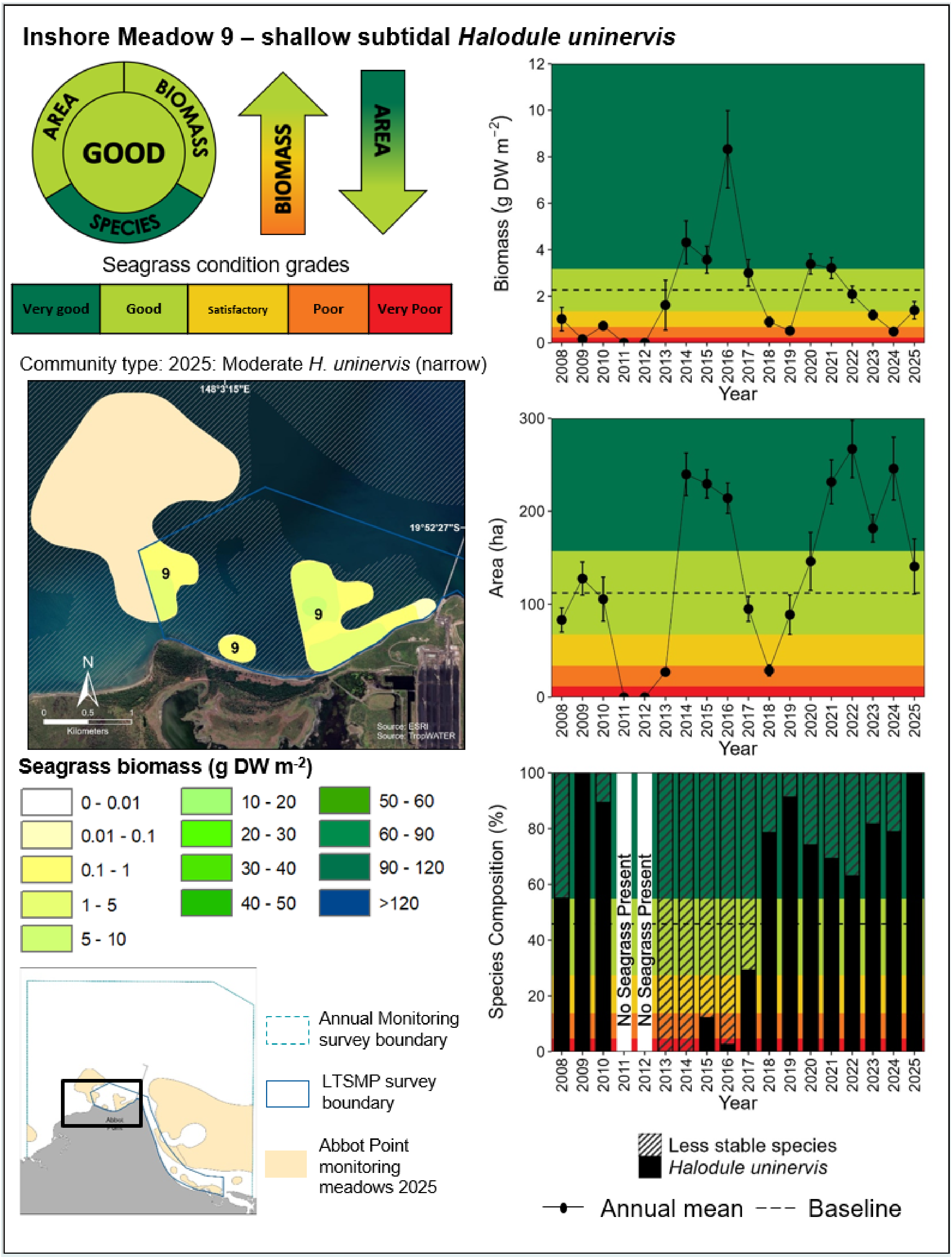

Figure 16. Changes in mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 9. Lack of arrows indicates no change in condition index from the previous year.

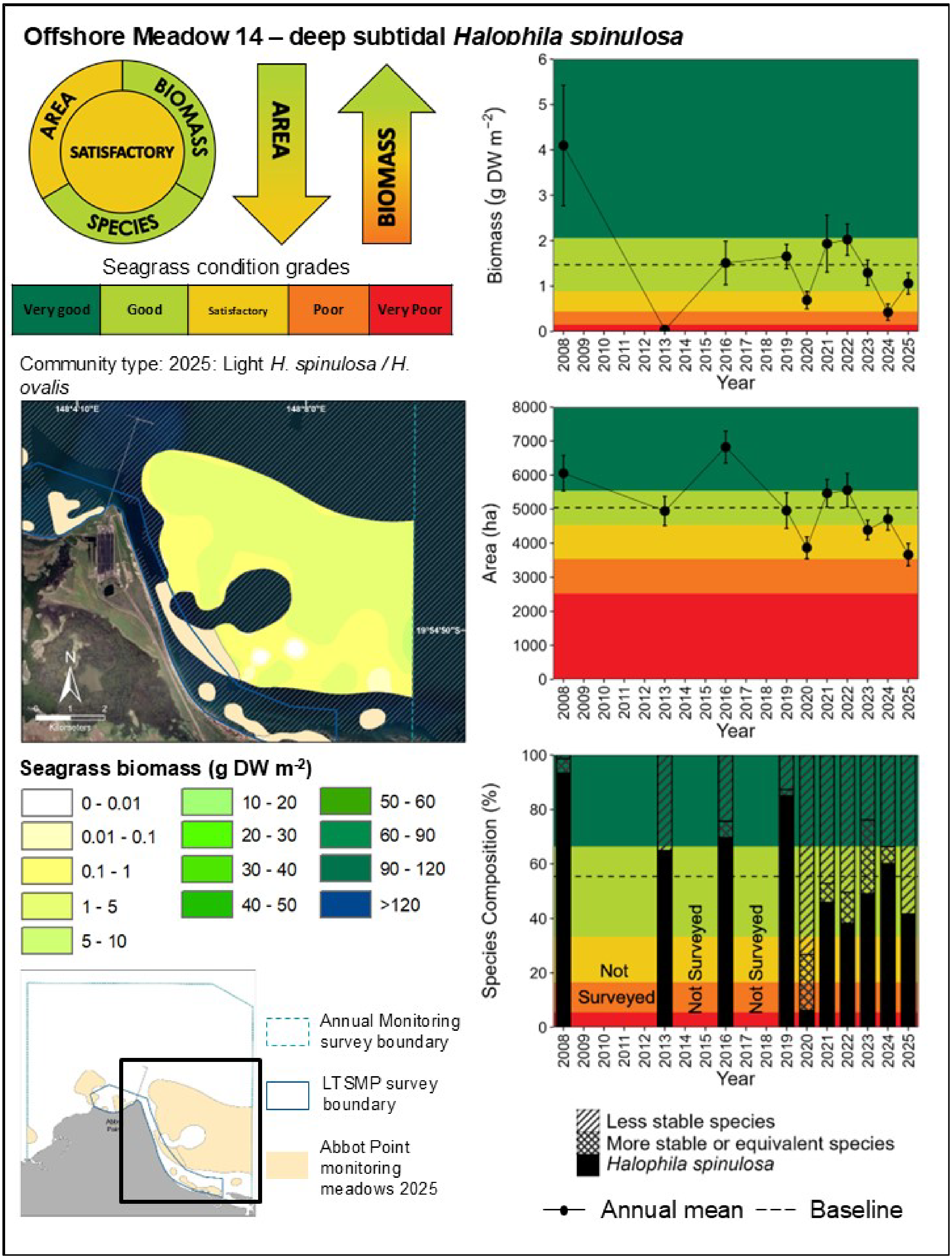

Figure 17. Changes in mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at offshore monitoring Meadow 14. Lack of arrows indicates no change in condition index from the previous year.

6.3 Whole-of-port broadscale surveys

Seagrass habitat across the broader port region is assessed every three years to improve understanding of regional seagrass distribution and condition (Figures 12 and 20). In 2025, a total of 13,789 ha of seagrass was mapped within the broadscale survey boundary (Figures 18–20). In general, the area and biomass of the mapped inshore seagrass meadows were comparable to the previous broadscale survey in 2022. However, the offshore meadow was at its lowest biomass since 2013, and smallest area since the program began. Species composition remained similar to the 2022 broadscale survey (Reason et al. 2023). Offshore meadows have been dominated by *H. spinulosa* and inshore meadows throughout the region have been dominated by *H. uninervis,* except for Meadow 3, which is dominated by *Z. muelleri* (Figure 19). *Halophila ovalis* and *H. decipiens* are the next most prevalent species throughout both inshore and offshore areas.

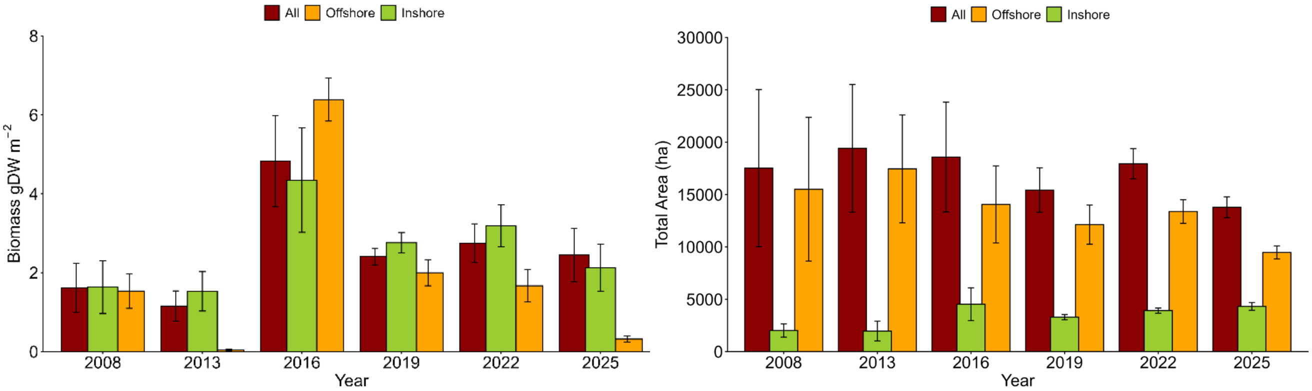

Figure 18. Temporal comparison of mean above-ground biomass (g DW m^{-2}) and total area (ha) of seagrass meadows during the broadscale surveys in Abbot Point for 2008, 2013, 2016, 2019, 2022 and 2025.

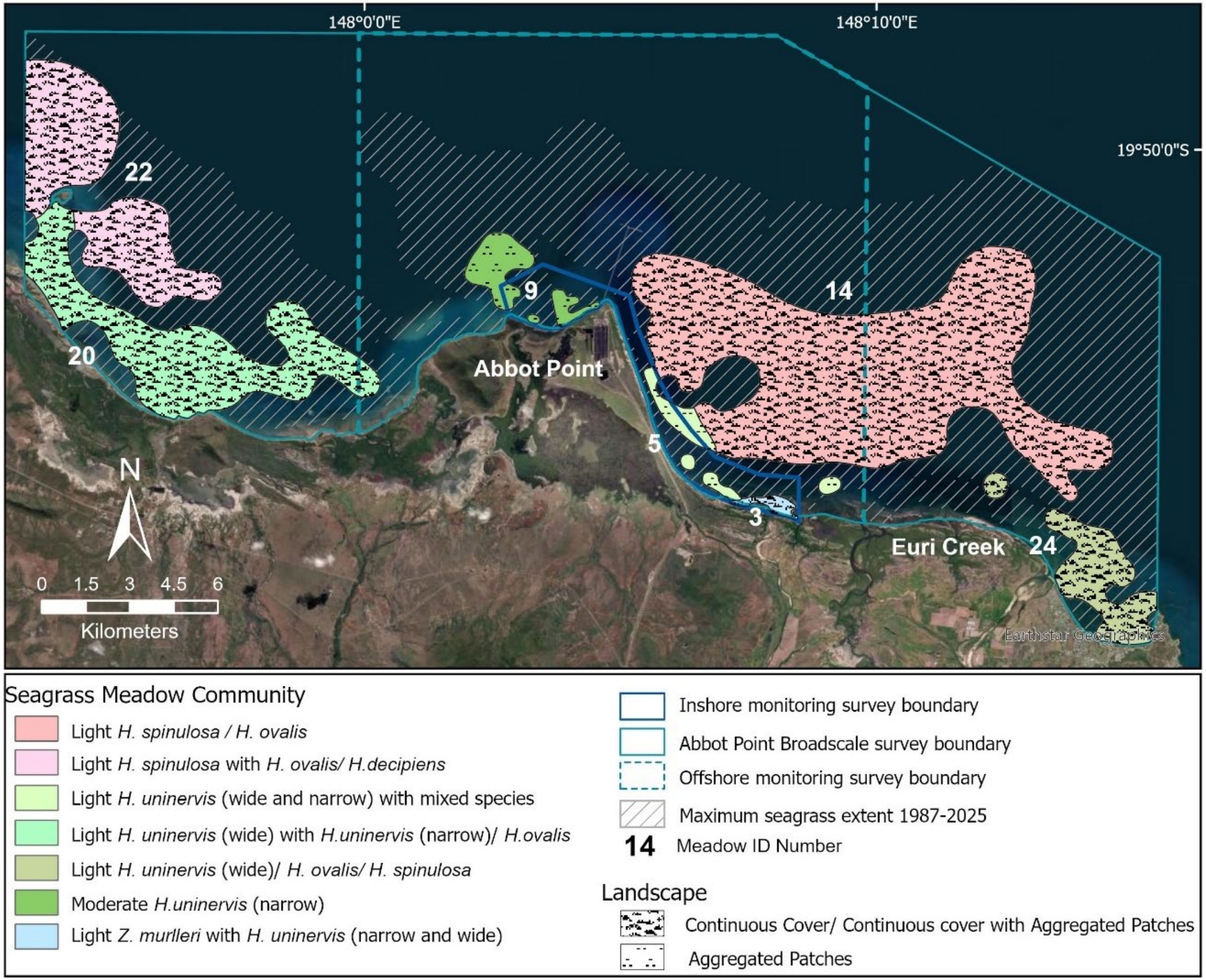

Figure 19. Comparison of seagrass meadow community and landscape type for the broadscale surveys in Abbot Point in 2025.

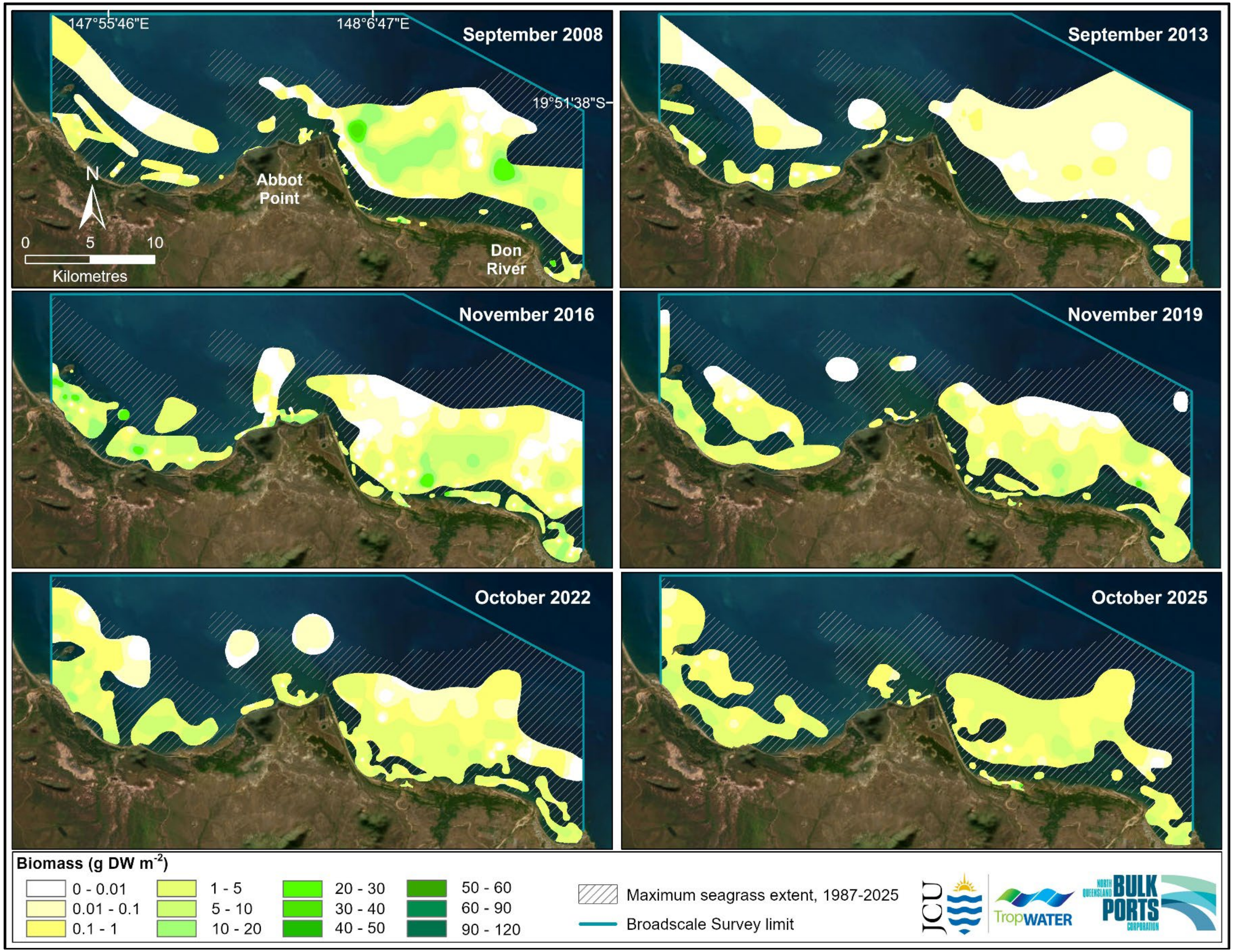

Figure 20. Temporal comparison of mean seagrass above-ground biomass (g DW m^{-2}) and total area (ha) of monitoring meadows during the broadscale surveys in Abbot Point for 2008, 2013, 2016, 2019, 2022 and 2025.

6.4 Abbot Point environmental data

6.4.1 Benthic daily light – photosynthetically active radiation (PAR)

Light available to seagrass generally changes seasonally, with lower light levels during the wet season due to higher rainfall, increased cloud cover, river flow, and wind events, with higher light levels during the dry season supporting seagrass growth (Figures 21b and 22b). In addition, semi-regular fluctuations between low and high PAR are often overridden by larger episodic events caused by storms, rainfall, or wind events (Cartwright et al. 2025). Low PAR often corresponds with periods of high turbidity at Abbot Point (Cartwright et al. 2025).

Locally derived light requirements for the maintenance of seagrass biomass were previously developed for seagrass around Abbot Point (McKenna et al. 2015). For offshore areas dominated by *Halophila* species, 1.5 mol m^{-2} day^{-1} over a rolling 7-day average described light conditions supporting the maintenance of deep-water *Halophila* species. For shallow inshore areas dominated by *H. uninervis,* a threshold of 3.5 mol m^{-2} day^{-1} over a rolling 14-day average was required. These values are indicative of conditions that support seagrass growth in the area.

The inshore PAR logging stations, TW1 and TW2, are at different depths and represent the depth gradient over which inshore seagrasses occur at Abbot Point (Figure 8). As a result, total daily light at each of these logging stations differs in range. TW2, on the western side of the Abbot Point wharf, located in Meadow 9, is the shallowest of the three PAR logging stations and therefore has the highest PAR overall (Figures 21b and 22b). This is followed by inshore TW1 (Meadow 5), then offshore AMB1 (Meadow 14).

In the twelve months preceding the 2025 survey, PAR (7-day (AMB1) and 14-day (TW1 and TW2) rolling averages) ranged as follows (see Figures 21b, 22b):

- TW2 (Meadow 9): shallow subtidal inshore *H. uninervis* meadow:
  - 0.007 (June 2025) – 10.97 (Nov 2024) mol m^{-2} day^{-1}.
  - A total of 136 days were recorded below the *Halophila* light threshold for Abbot Point, and 110 below the *H. uninervis* threshold
  - A total of 138 days had no readings due to logger issues and lost equipment.
- TW1 (Meadow 5): shallow subtidal inshore *H. uninervis* meadow:
  - 0.29 (April 2025) – 7.8 (Nov 2024) mol m^{-2} day^{-1}.
  - 27 days in total recorded below the *Halophila* light threshold, and 270 below the *H. uninervis* threshold,
  - No days were missing readings
- AMB1 (Meadow 14) subtidal offshore *Halophila* meadow:
  - 0.05 (Feb 2025) – 8.4 (Sept 2025) mol m^{-2} day^{-1}.
  - 57 days in total recorded below the *Halophila* light threshold, and 144 below the *H. uninervis* threshold,
  - There were 35 days without a reading.
- Control logger (land)
  - 3.84 (June 2025) – 41.87 (Dec 2024) mol m^{-2} day^{-1}
  - Daily maximum temperature: 19.6°C (July 2025) – 54.5°C (April 2025)

There were some periods in the twelve months prior to the annual survey when light fell below seagrass maintenance thresholds for consecutive days, which can affect the distribution and biomass of seagrass. TW2 (Meadow 9) recorded 210 consecutive days below the *H. uninervis* threshold (Dec 2024 – July 2025). TW1 (Meadow 5) recorded 48 consecutive days below the *H. uninervis* threshold (April 2025 – May 2025). AMB1 (Meadow 14) recorded 20 consecutive days when light fell below the *Halophila* maintenance threshold (Feb 2025).

For TW2 and AMB1, PAR data loss occurred sporadically throughout the 12 months prior to the 2025 survey, with 138 consecutive days of data loss occurring in TW2. This was due to equipment malfunctions, including wiper units flooding or stopping, resulting in sensor fouling, and Odyssey logger failure. Affected data were flagged as poor-quality data and removed.

6.4.2 Benthic water temperature

Maximum daily benthic temperatures at monitoring sites in the twelve months preceding the survey ranged from 21.1 °C (TW1) – 37.9 °C (TW2) (Figures 21a and 22a). The daily maximum temperature on land (control logger) ranged from 19.6 °C – 54.5 °C (Figure 22a). The reading of 54.5°C (control) and 37.9 °C (benthic loggers) are both considered to be a false reading that occurred during logger change-out and maintenance. Daily maximum benthic temperatures at the control and benthic sites are 36.6°C and 35.6°C, respectively. Data from the companion Marine Water Quality Monitoring Program has shown that the variation in benthic temperature in the Abbot Point region is smaller than in many other regions along the east coast of Queensland and that the water column is mostly well mixed, with depth profiles for temperature showing only minor gradients of change (Cartwright et al. 2025).

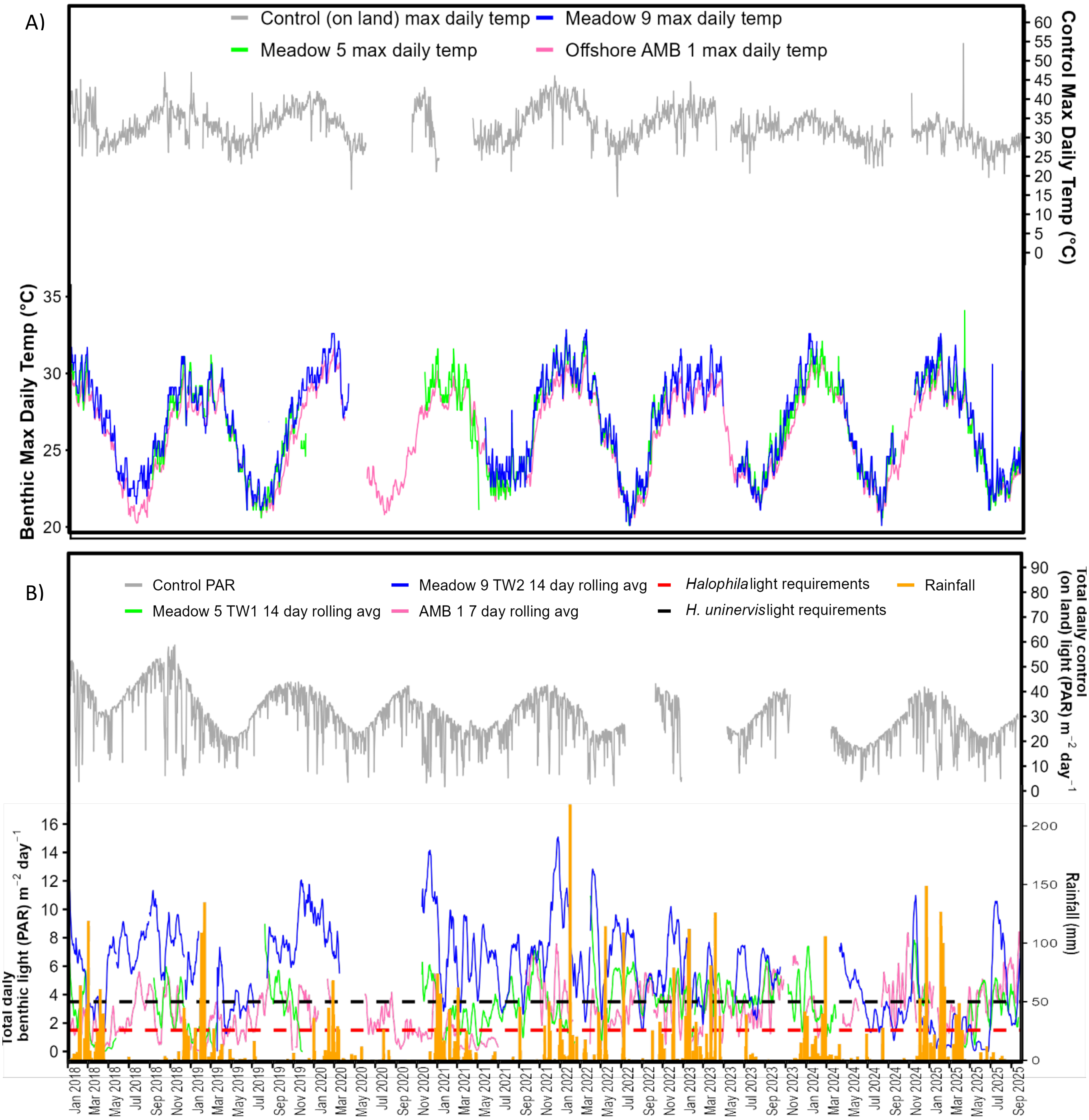

Figure 21. (A) Total daily maximum temperatures at in water and control (on land) logging stations; (B) Total daily PAR (mol photons m^{-2} day^{-1}) at sites expressed as 14- and 7-day rolling averages, *Halodule uninervis* and *Halophila* light requirement thresholds and total daily rainfall January 2018 – September 2025. Data gaps are due to equipment malfunction or loss.

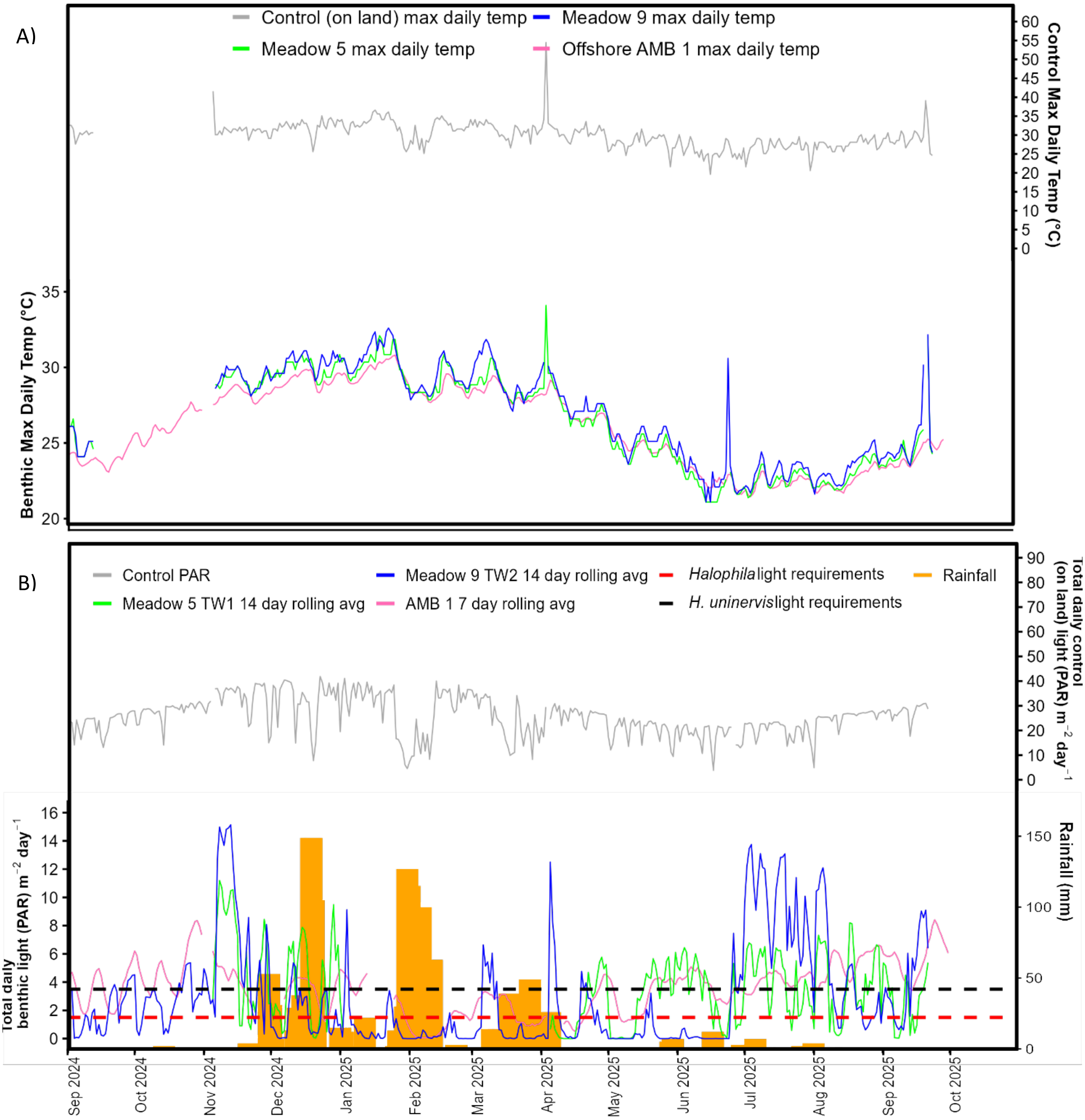

Figure 22. (A) Total daily maximum temperatures at in water and control (on land) logging stations; (B) Total daily PAR (mol photons m^{-2} day^{-1}) at sites expressed as 14- and 7-day rolling averages, *H. uninervis* and *Halophila* light requirement thresholds and total daily rainfall in the 12 months prior to the survey: September 2024 – October 2025. Data gaps are due to equipment malfunction or loss.

6.4.3 Rainfall

Total annual rainfall in the 12 months preceding the 2025 survey was 1,534 mm which was above the long-term average (Figure 23a). Monthly patterns showed that rainfall occurred primarily from December to March with a peak of 510 mm in February 2025. The five months leading up to the 2025 survey were all below the average monthly rainfall (Figure 23b).

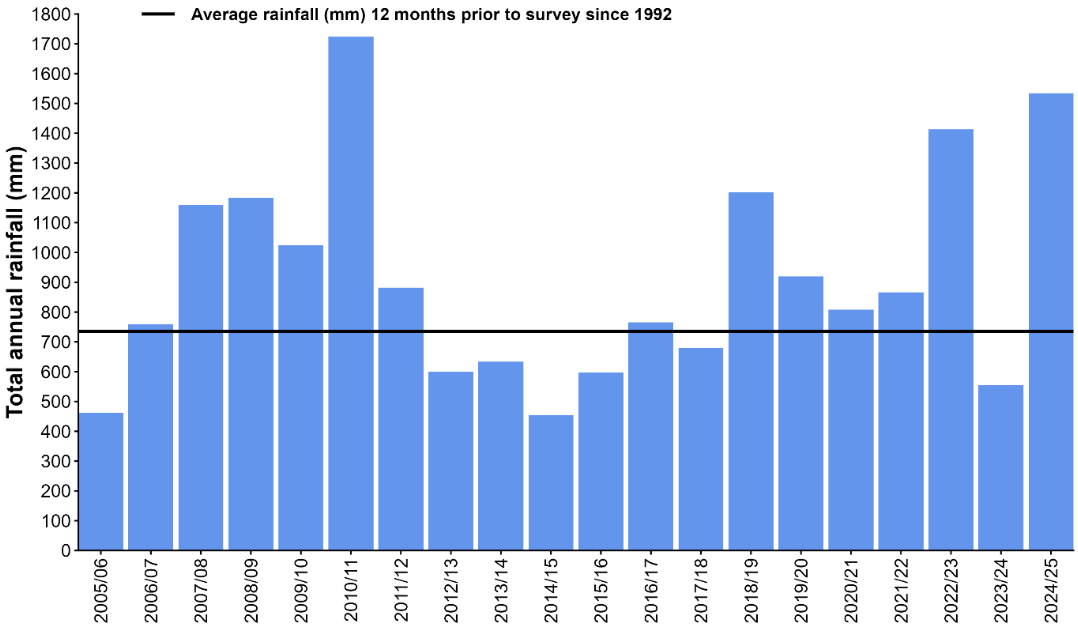

Figure 23a. Long-term trends in total annual rainfall (mm) from 2005/06-2024/25. Year represented in columns is twelve months prior to the survey. Source: Queensland Government's Water Monitoring Information Portal (station 121002A – Elliot River at Guthalungra

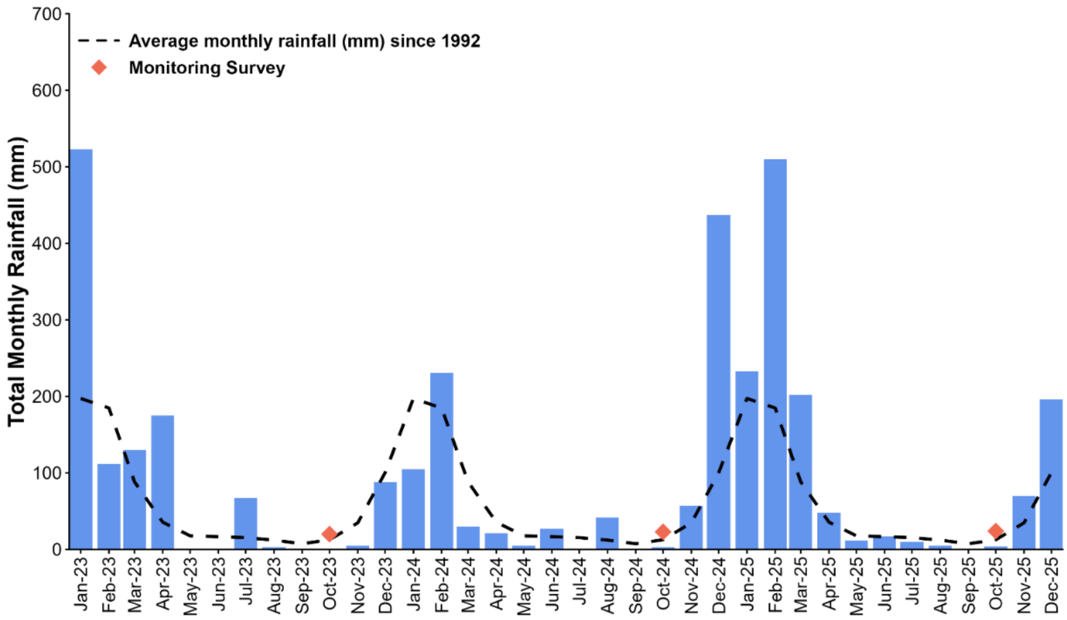

Figure 23b. Total monthly rainfall (mm) over the past three years (January 2023 – December 2025). Source: Source: Queensland Government's Water Monitoring Information Portal (station 121002A – Elliot River at Guthalungra.

6.4.4 River flow - Elliot River

River flow volume for the Elliot River was 128.47 gigalitres in the 12 months preceding the annual seagrass survey, exceeding the long-term average (Figure 24a). This volume was comparable to levels recorded in 2018/19. River flow exceeded the monthly mean discharge volume in December 2024 and from February to April 2025 before tracking average levels in subsequent months (Figure 24b).

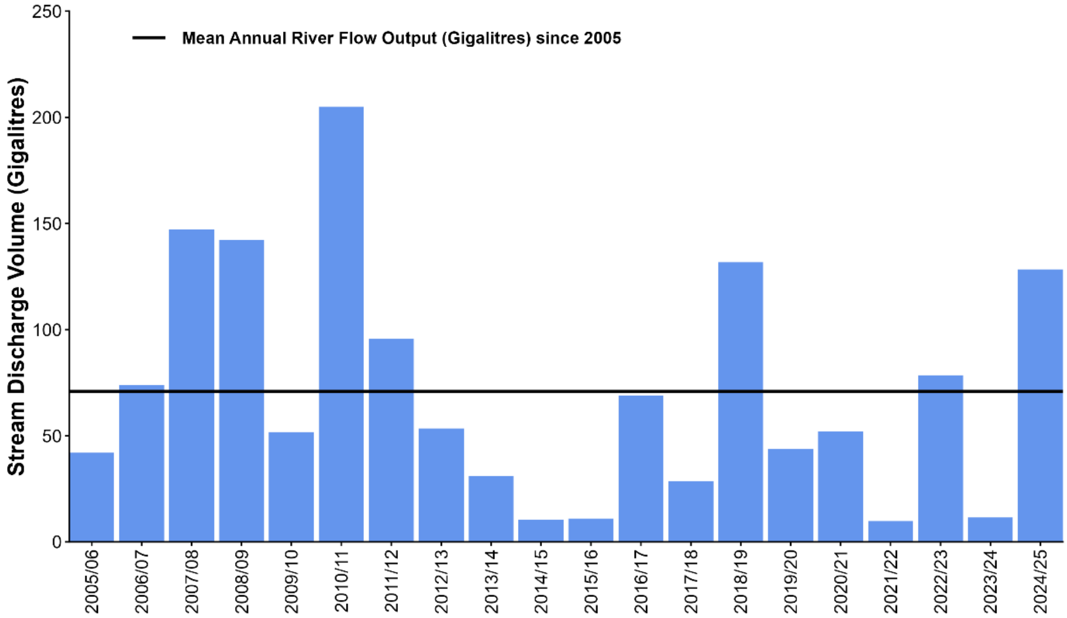

Figure 24a. Total annual river discharge (gigalitres) of the Elliot River from 2005/06 to 2024/25. Year represented in columns is twelve months prior to the survey. Source: Queensland Government's Water Monitoring Information Portal (station 121002A – Elliot River at Guthalungra.

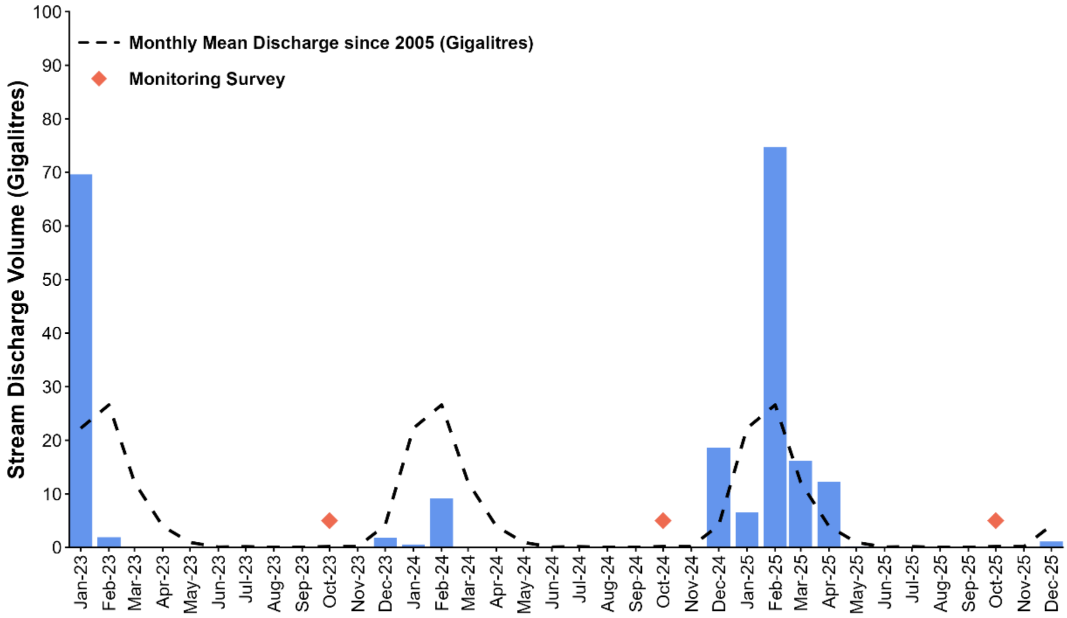

Figure 24b. Total monthly river discharge (gigalitres) of the Elliot River over the past three years (January 2023 to December 2025). Source: Queensland Government's Water Monitoring Information Portal (station 121002A – Elliot River at Guthalungra).

6.4.5 RMS water depth

Mean daily RMS in the twelve months prior to the survey ranged from 0.0097 m (June 2025) to 0.14 m (February 2025) (Figure 25a). RMS generally stayed within the low-energy range with short-lived peaks such as in February 2025, coinciding with periods of increased wind, energetic tidal conditions (Cartwright et al. 2025), low PAR and/or high rainfall. Peaks throughout 2025 were generally recorded over short periods of a day or two, reducing the likelihood of resuspension events. Cartwright et al. (2025) have established that there are low but consistent positive correlations (r = 0.20–0.28) between NTU and RMS in the offshore seagrass meadow, indicating that short-period water-column motion contributed modestly to turbidity variability. RMS values were generally lower in 2025 than in 2024 and remained low for longer periods (Figure 25a and 25b).

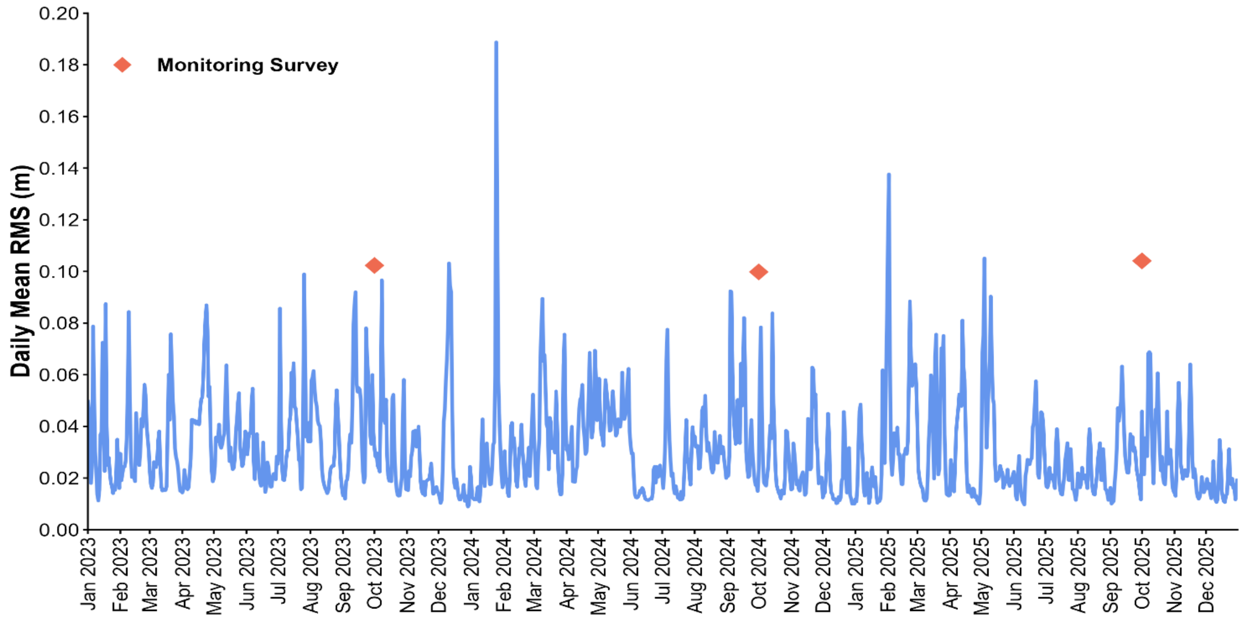

Figure 25a. Daily mean RMS water depth measured in the offshore monitoring meadow (meadow 14) from January 2023 – December 2025 (data provided by the TropWATER Marine Water Quality Monitoring Program site AMB1).

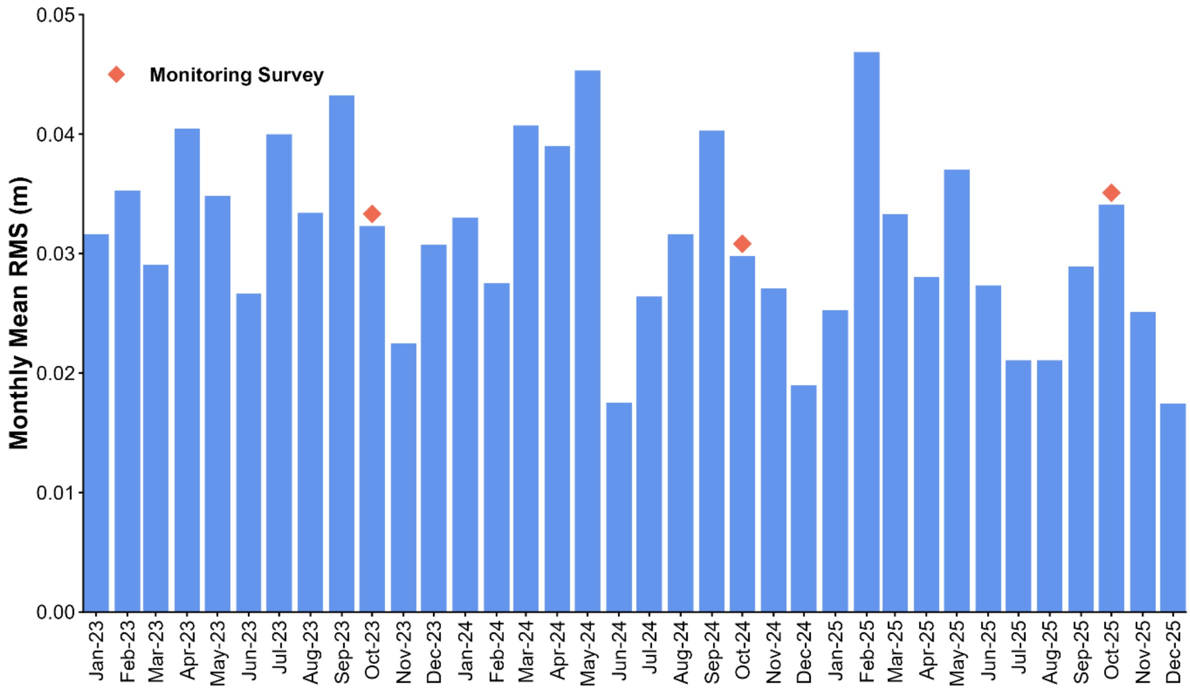

Figure 25b. Mean monthly, RMS water depth recorded at Abbot Point water quality site AMB 1 January 2023 – July 2025.

7 DISCUSSION

Annual seagrass monitoring meadows around Abbot Point were in overall good condition at the end of 2025, following two years of satisfactory condition. The inshore seagrass monitoring meadows ranged from satisfactory (Meadow 5) to very good (Meadow 3) in overall meadow condition. The large offshore meadow was in satisfactory condition, despite a decline in area and species composition. Improved condition scores were primarily driven by increases in meadow biomass. Biomass increases were likely driven by favourable growing conditions in the lead-up to the 2025 survey, with benthic light above minimum maintenance and persistence thresholds, as well as lower river flow and rainfall in the months prior to the survey. The mixed responses observed among meadows likely reflect poorer growing conditions at the start of the year, with high rainfall and river flows potentially contributing to temporary seagrass declines prior to recovery later in the year.

In the broader Abbot Point region, substantial areas of seagrass were mapped in both coastal and offshore areas, in addition to the annually monitored meadows. These areas are assessed every third year in the program to provide an update on broader seagrass status within the port of Abbot Point. The biomass and area of inshore seagrass meadows were comparable to previous surveys. However, for offshore meadows, these indicators were lower compared to previous surveys indicating that across the broader region seagrasses may not have fully recovered from recent seagrass stressors and climate conditions.

The increase in biomass observed across most annual monitoring meadows suggests that environmental conditions in the months leading up to the 2025 survey were favourable for seagrass growth. Unfavourable conditions in the first half of the year including high rainfall, river discharge and wave energy (RMS), likely reduced photosynthetically active radiation (PAR) and led to limited conditions for seagrass growth during that period. However, these impacts were not sustained through the second half of the year.

Periods of benthic light exceeding the minimum thresholds required for seagrass growth likely supported recovery in the months prior to the 2025 survey, particularly in shallow inshore meadows dominated by *Halodule uninervis*. Reduced wave-driven sediment resuspension, indicated by generally lower and less persistent RMS wave stress compared to 2024, would have further enhanced water clarity and light penetration to the benthos. While periods of low PAR were still recorded, their ecological impact depends on when they occur, and how long they persist. Previous research indicates that seagrass biomass begins to be adversely affected after approximately 40 consecutive days below light thresholds for *H. uninervis* and 28 consecutive days for *Halophila* species (Collier et al. 2016). Although extended periods below thresholds were recorded at some sites in early 2025, these occurred outside peak growing periods, so negative impacts on seagrass were not sustained. Previous seasonal studies at Abbot Point (Unsworth et al. 2010) show that seagrass meadows in the Abbot Point region follow a broad seasonal pattern of higher seagrass biomass in the late dry season. Therefore, poor growing conditions (i.e., low light) in the first half of the year were unlikely to strongly affect overall annual growth and establishment. The exception would be areas where seagrass was completely lost, in which case inshore and deepwater seagrasses may not have recruited or grown rapidly enough (Rasheed et al. 2014) to be in good condition by the end of 2025.

The improvement in condition at the Euri Creek *Zostera muelleri* meadow (Meadow 3) was driven by increases in all three-indicator metrics, biomass, area, and the increased presence of *Z. muelleri*. The persistence and increased dominance of *Z. muelleri* in Meadow 3 suggests this meadow has increased resilience and was able to recover strongly with the improved growing conditions late in 2025. Results for the other two inshore monitoring meadows were more mixed, with these *Halodule uninervis* meadows declining in only some indicators, which may reflect species differences in their ability to respond to improving conditions and local-scale differences in environmental conditions. Similarly, results for the offshore meadow (Meadow 14), were mixed with the biomass of the deepwater *Halophila* meadow increasing but a reduction in meadow area, particularly at the deeper offshore margin of the meadow occurring. These *Halophila* species are typically associated with variable or disturbed conditions and exhibit lower resistance to environmental stress (Kilminster et al. 2015; York et al. 2015). It is possible that the poorer light conditions at the start of the year particularly affected seagrass recruitment in deeper areas where light attenuation would be greatest, leaving a legacy of a reduced spatial footprint at the time of the survey.

At a broader scale, total seagrass area and biomass have remained similar since the 2022 broadscale survey, with notable decline recorded only in the offshore Meadow 14. This highlights the dynamic nature of seagrass ecosystems in the region and reflects the patterns in the annually monitored section of this meadow described above. While monitoring meadows showed signs of recovery in 2025, offshore declines suggest that environmental pressures, including variability in rainfall, river discharge, and turbidity, may have had some impact on the ability of deepwater species to recruit (Grech et al. 2011; Coles et al. 2015). These species are recognised as colonisers with high temporal variability and rapid recovery potential following disturbance, often supported by sediment seed banks (Rasheed et al. 2014; Kilminster et al. 2015). They are also highly seasonal and in the case of *H. decipiens* likely to be annual in their recruitment and senescence (York et al. 2018). The reduction in area particularly in deeper sections of the meadows, where light limitation would be more pronounced, suggests that environmental conditions may have impeded seagrass recruitment. Above-average rainfall and river flow earlier in 2025 likely contributed to periods of reduced water clarity and light limitation. While conditions later in the year were more favourable, the initial establishment for the seasonally recruiting deepwater species may have been sufficiently impeded to leave a legacy of reduced seagrass area by the time of the survey. A high level of interannual and intra-annual variability is typical for these deepwater *Halophila*-dominated meadows.

At the end of 2025, seagrasses around Abbot Point followed trends similar to those recorded at other ports within JCU's long-term seagrass monitoring program, with seagrass meadows in Bowen, Hay Point, and Gladstone to the south, similarly in overall good condition at the end of 2025 (Cleguer et al. 2026; Myers et al. 2026; Reason et al. 2026). Overall, at the end of 2025, seagrass meadows at Abbot Point showed improvements in biomass and overall condition across most monitoring meadows, suggesting that seagrass meadows in the Abbot Point region were in a relatively good position to resist and recover from potential disturbances in the coming year. Continued variability in environmental drivers, particularly light availability, highlights the susceptibility of these systems to changing conditions. The monitoring program provides critical insights into seagrass trends, and an understanding of the drivers of change, to support effective management of this important coastal ecosystem.

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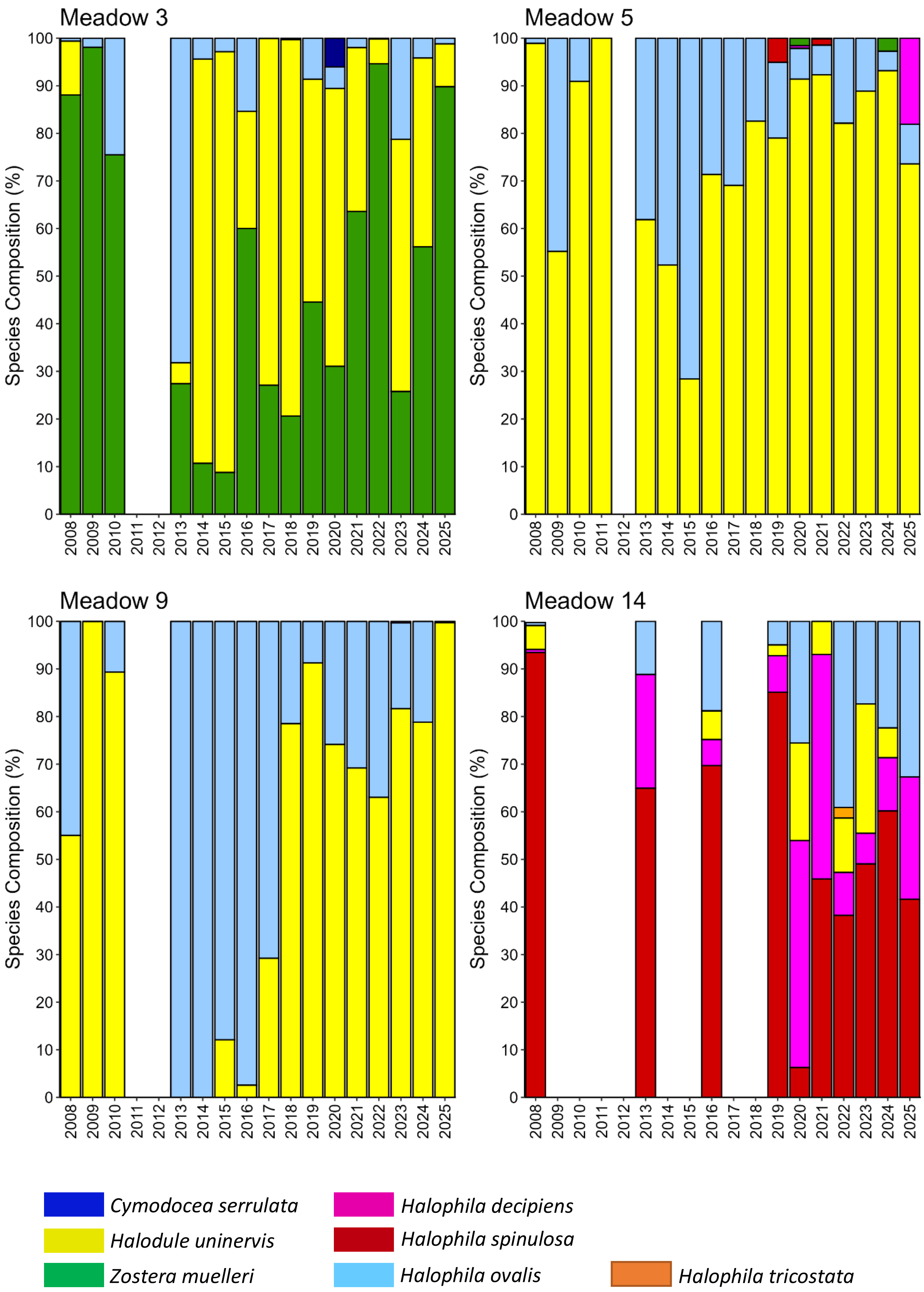
9 APPENDICES

9.1 Species composition of inshore and offshore long-term monitoring meadows



9.2 Above-ground biomass and area of long-term monitoring meadows

9.2.1 Mean above-ground biomass of monitoring meadows in the Abbot Point region 2005 - 2025

Mean Biomass ± SE (g DW m^{-2}) (no. sites present in meadow)				
	Inshore meadow 3	**Inshore meadow 5**	**Inshore meadow 9**	**Offshore meadow 14**
2005	36.1 ± 16.07 (6)	0.06 ± 0.02 (6)	1.45 ± 0.50 (16)	NS
2008	8.91 ± 4.17 (11)	2.7 ± 0.57 (18)	0.40 ± 0.15 (17)	4.10 ± 1.33 (32)
2009	2.76 ± 0.99 (14)	0.68 ± 0.43 (19)	0.63 ± 0.30 (23)	NS
2010	2.92 ± 0.86 (5)	3.48 ± 0.29 (8)	0.73 ± 0.16 (12)	NS
2011	NP	0.48 ± 0.10 (5)	NP	NS
2012	NP	NP	NP	NS
2013	NP	1.61 ± 0.81 (6)	3.07 ± 1.55 (3)	0.04 ± 0.010 (31)
2014	1.67 ± 0.34 (3)	8.3 ± 4.26 (5)	4.36 ± 0.91 (8)	NS
2015	4.21 ± 3.96 (3)	2.8 ± 0.64 (13)	2.80 ± 0.50 (20)	NS
2016	5.25 ± 1.59 (10)	2.83 ± 0.65 (15)	8.32 ± 1.66 (14)	1.51 ± 0.48 (68)
2017	5.85 ± 1.05 (13)	3.42 ± 1.06 (10)	3.0 ± 0.57 (20)	NS
2018	2.77 ± 0.76 (12)	2.41 ± 0.57 (13)	0.90 ± 0.20 (5)	NS
2019	6.04 ± 1.58 (8)	2.6 ± 0.54 (27)	0.52 ± 0.13 (12)	1.65 ± 0.27 (48)
2020	7.11 ± 1.11 (14)	4.72 ± 0.44 (42)	3.39 ± 0.44 (25)	0.69 ± 0.19 (13)
2021	8.02 ± 1.93 (10)	4.12 ± 0.59 (50)	3.22 ± 0.45 (23)	1.93 ± 0.63 (14)
2022	6.25 ± 1.03 (10)	2.42 ± 0.31 (27)	2.09 ± 0.35 (18)	1.86 ± 0.33 (25)
2023	1.74 ± 0.57 (5)	1.65 ± 1.49 (12)	1.19 ± 0.91 (19)	1.29 ± 0.28 (12)
2024	3.64 ± 0.94 (6)	1.92 ± 0.58 (13)	0.48 ± 0.11 (19)	0.42 ± 0.18 (12)
2025	6.19 ± 2.32 (12)	0.98 ± 0.32 (9)	1.39 ± 0.38 (13)	1.06 ± 0.23 (21)

NP – No seagrass present in meadow; NS – Seagrass meadow not surveyed (offshore meadows have only been annually surveyed since 2019. Before then the offshore area of Abbot Point was only surveyed in tri-annual broadscale surveys.

9.2.2 Total area (ha) of long-term monitoring meadows in the Abbot Point region 2005 – 2025.

	Area ± R (ha)			
	Inshore meadow 3	Inshore meadow 5	Inshore meadow 9	Offshore meadow 14
2005	25.6 ± 6	46.6 ± 15.9	125.8 ± 41	NS
2008	56.95 ± 8.06	45.3 ± 20.29	83.96 ± 10.26	6056.14 ± 518.09
2009	44.2 ± 9.3	16.2 ± 3.3	22.9 ± 5.1	NS
2010	15.04 ± 4.9	23.47 ± 8.69	105.38 ± 85.44	NS
2011	NP	3.12 ± 2.66	NP	NS
2012	NP	NP	NP	NS
2013	NP	28.86 ± 13.86	35.11 ± 15.47	4944.41 ± 426.88
2014	12.19 ± 3.84	10.49 ± 2.48	92.42 ± 71.5	NS
2015	8.84 ± 4.55	25.24 ± 19.58	180.27 ± 62.26	NS
2016	78.40 ± 6.17	191.71 ± 35.74	214.02 ± 41.28	6821.67 ± 468.29
2017	43.91 ± 5.33	20.38 ± 3.13	94.91 ± 16.76	NS
2018	47.67 ± 5.15	50.56 ± 8.27	28.80 ± 6.02	NS
2019	25.98 ± 8.98	188.46 ± 44.09	88.75 ± 21.1	4959.81 ± 523.70
2020	31.4 ± 3.25	274 ± 31.19	146.04 ± 21.82	3865.81 ± 321.55
2021	21.62 ± 3.40	268.45 ± 47.75	231.45 ± 23.63	5464.70 ± 406.24
2022	23.22 ± 8.10	477.32 ± 55.27	266.85 ± 30.91	5555.54 ± 489.35
2023	32.41 ± 4.58	226.52 ± 22.33	181.55 ± 14.72	4386.31 ± 285.31
2024	55.04 ± 11.01	215.1 ± 31.81	245.69 ± 33.78	4709.35 ± 327.34
2025	81.75 ± 14.58	192.78 ± 32.79	140.57 ± 29.68	3662.03 ± 327.52