Port of Abbot Point Long-Term Seagrass Monitoring Program 2022

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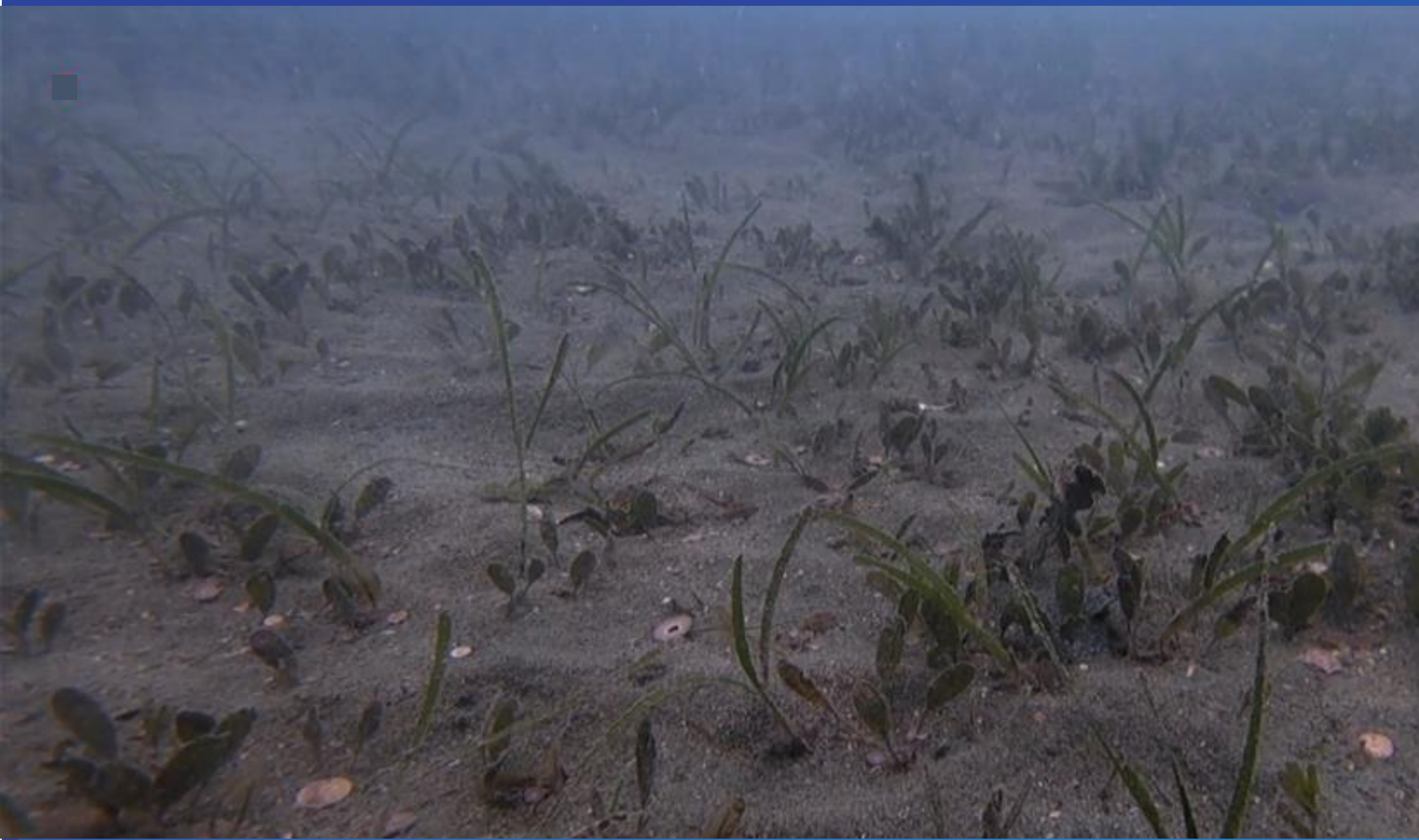

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Port of Abbot Point Long-Term Seagrass Monitoring Program 2022

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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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CONTENTS

1 KEY FINDINGS

Seagrass Condition 2022

GOOD

Likely causes of seagrass condition:

- ↑ *Favourable climate conditions for seagrass growth*
- ↑ *Expanded footprint for inshore meadows*
- ↑ *Indicator species continue to thrive*

- Abbot Point annual monitoring meadows were in a good overall condition in 2022. This is the third consecutive year that seagrass has been in a good condition.
- Inshore *Halodule* and *Zostera* monitoring meadows were in a good condition in 2022. The area of the two *H. uninervis* monitoring meadows on either side of Abbot Point was the largest it has been in the program to date.
- Offshore seagrass meadows dominated by *Halophila spinulosa* and *H. ovalis* were also in good condition in 2022. Of note was the presence of *H. tricostata* in offshore areas, last recorded in 2016.
- The 2022 broadscale survey mapped 17,945 ha of seagrass with the location and community types similar to previous broadscale surveys.
- Environmental conditions over the last three years have been favourable for seagrass growth, likely contributing the sustained good condition of Abbot Point seagrass in 2022.
- The healthy state of Abbot Point seagrasses means they are likely to have high levels of resilience to future natural and anthropogenic pressures.

2 IN BRIEF

A long-term seagrass monitoring program and strategy was established in the Abbot Point region in 2008 following initial surveys of the area in 2004 and 2005. The program has evolved to consist of annual surveys of representative monitoring meadows with broader whole-of-port mapping occurring every third year; completed again in 2022. Annual monitoring is conducted at three inshore areas and a large region of the deeper offshore area (Figure 1). Prior to 2020 the offshore seagrasses were assessed at several smaller monitoring blocks. The shift to assessing a more extensive offshore region in 2020 allows the full suite of seagrass indicators (area, biomass, species composition) to be assessed and reported on for offshore seagrass.

The overall condition of Abbot Point seagrasses remained good for the third consecutive year. Seagrass condition indicators (biomass, area and species composition) for all annual monitoring meadows were in a good or better condition (Figure 1). The past few years have seen a trend of improved seagrass condition after lows recorded in 2017 associated with impacts from Tropical Cyclone Debbie. In 2022 the biomass, area, and species composition of inshore *Halodule uninervis* and *Zostera muelleri* meadows were in good or better condition (Figure 1). The area of the two *H. uninervis* monitoring meadows on either side of Abbot Point was the largest it has been in the program to date. All seagrass indicators for the offshore monitoring meadow (Meadow 14) were also in good condition. *Halophila tricostata* was recorded for the first time in the offshore monitoring area since 2016.

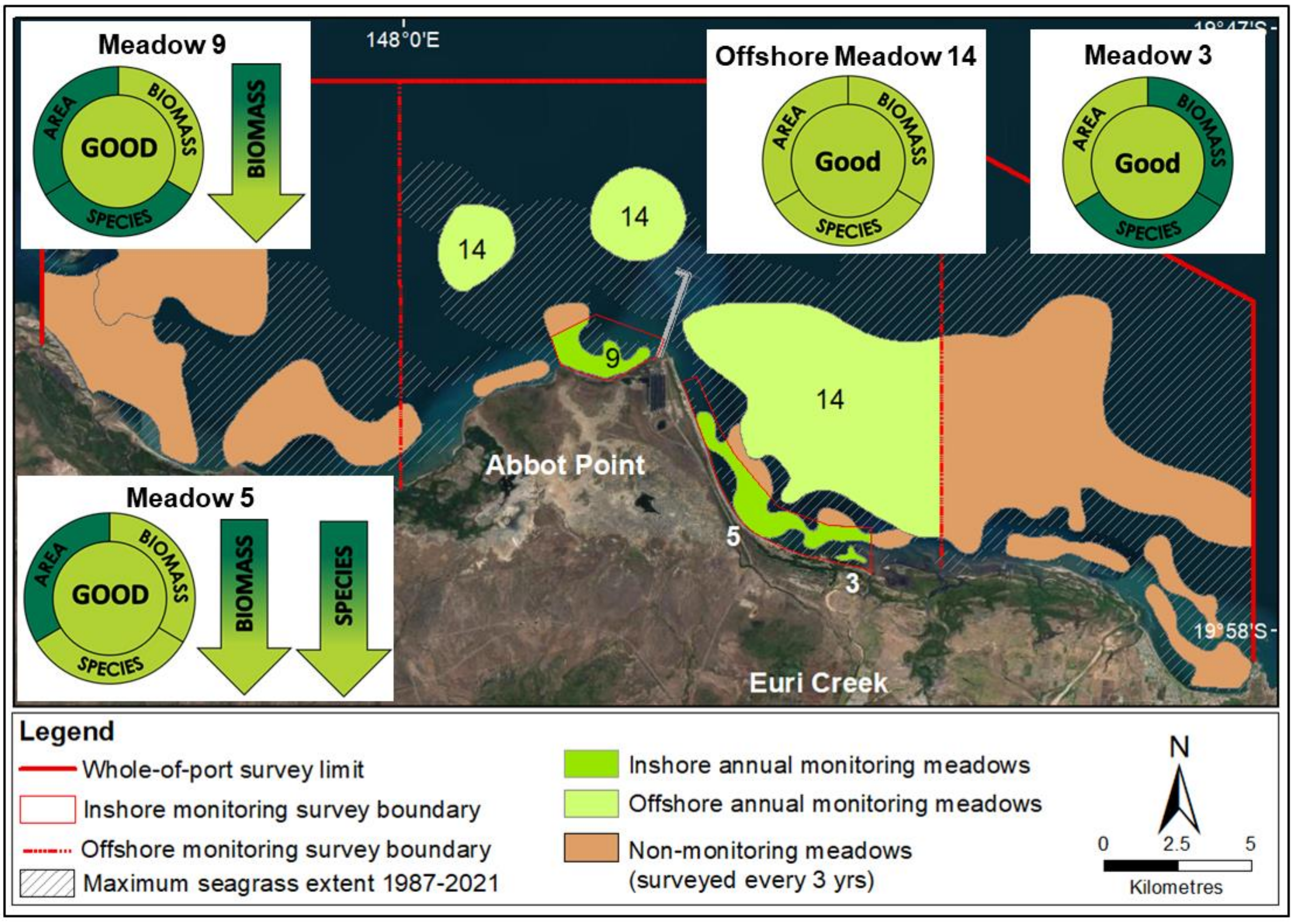

Figure 1. Seagrass condition for Abbot Point seagrass monitoring areas 2022.

Between 2017 and 2019 seagrasses around Abbot Point were recovering from successive years of climate impacts, particularly following large reductions in seagrass area and biomass due to TC Debbie. The seagrass meadows around Abbot Point have now recovered to levels recorded before TC Debbie (Figure 2). Favourable growing conditions for seagrass over the last three years have likely contributed to the improved condition and expansion of Abbot Point seagrass meadows (Figure 3 & Section 5.3). Favourable growing conditions include for example below average river flows, high light conditions for significant periods of time and the lack of any recent damaging weather and climate events that were prevalent from 2017-2019. In 2022, periods of weather conditions considered unfavourable for seagrass growth were short lived and unlikely to have occurred for long enough to cause impacts to seagrasses.

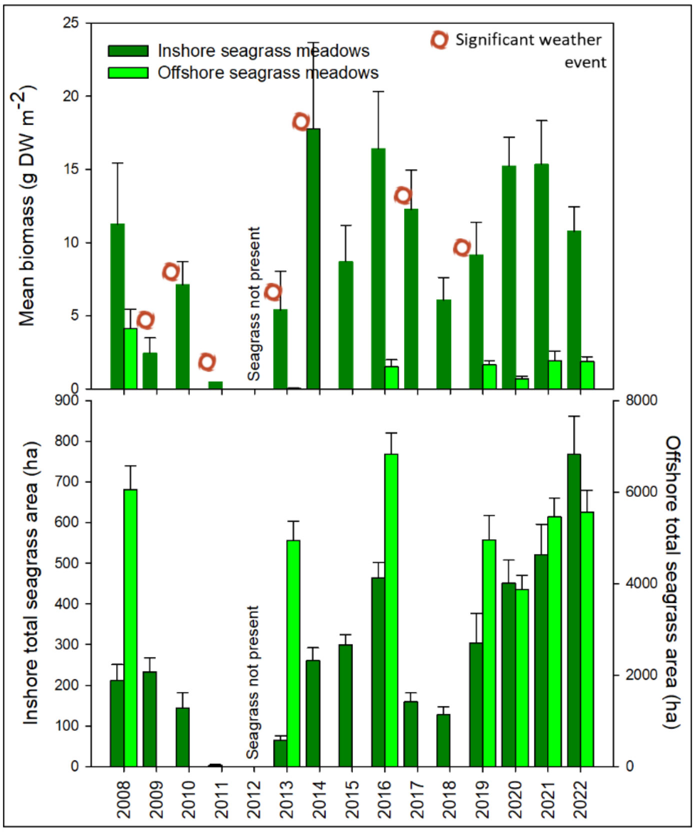

Figure 2. Comparison of mean biomass (g DW m^{-2}) and area (ha) for inshore and offshore seagrass monitoring meadows from 2008 to 2022.

The whole-of-port broadscale survey mapped 17,945 ha in 2022 (Figure 1). Seagrass meadow location and species composition has been similar in the region across all broadscale surveys.

The Abbot Point long-term monitoring program is incorporated into the broader Queensland Ports seagrass monitoring program using a consistent state-wide monitoring methodology (see https://www.tropwater.com/project/management-of-ports-and-coastal-facilities/). This enables direct comparisons with regional and state-wide trends to put local changes into context. It also provides a key input into the condition and trend of seagrasses in the Mackay Whitsunday Isaac NRM region, an area which otherwise has a poor coverage for seagrass assessment and condition. Monitoring at other sites in the network has shown a range of results during 2022. North of Abbot Point seagrass was in good condition in Cairns Harbour and Townsville, (Reason et al. 2023; McKenna et al. 2023). South of Abbot Point seagrass was in satisfactory condition in Hay Point and Gladstone (York et al. 2023; Smith et al 2023). In Weipa and Karumba seagrasses were in a good and very good condition also due to favourable climate conditions (Reason et al. 2022; Scott et al. 2023).

The continued healthy state of Abbot Point seagrasses in the annual monitoring meadows and the greater port region means they are likely to be resilient to future natural and anthropogenic pressures.

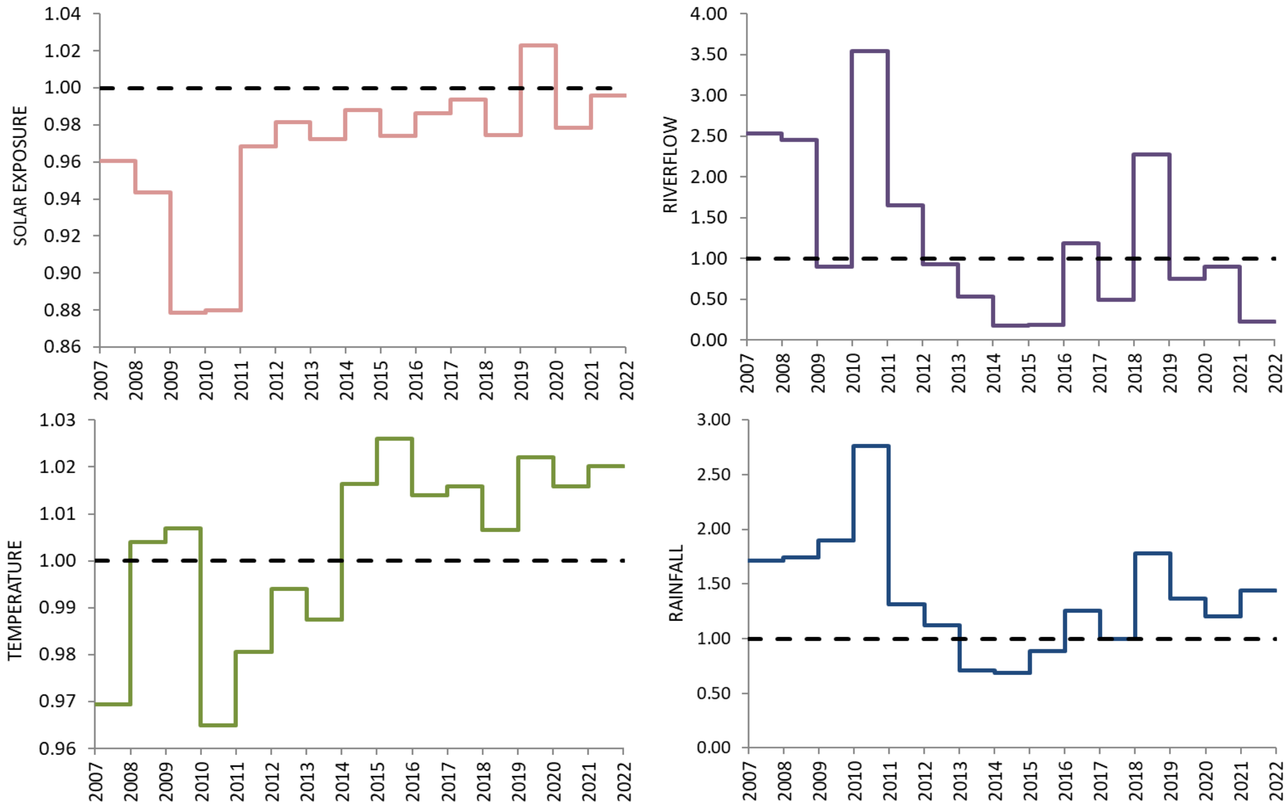

Figure 3. Climate trends for temperature and solar exposure (Bowen) and rainfall and river flow (Gathulungra/Elliot River) from 2006/07 to 2021/22: Change in climate variables as a proportion of the long-term average (LTA – dashed line). See section 5.3 for detailed climate data.

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 (Barbier et al. 2011; Costanza et al. 2014). These services include the provision of nursery habitat for economically important fish and crustaceans (Coles et al. 1993; Heck et al. 2003, Hayes et al. 2020), and food for grazing megaherbivores like dugongs and sea turtles (Heck et al. 2008; Scott et al. 2018). Seagrasses also play a major role in the cycling of nutrients (McMahon and Walker 1998), sequestration of carbon (Fourqurean et al. 2012; Lavery et al. 2013; York et al. 2018, Rasheed et al. 2019), stabilisation of sediments (James et al. 2019), and the improvement of water quality (McGlathery et al. 2007).

Globally, seagrasses have been declining due to natural and anthropogenic causes (Dunic et al. 2021; 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). In the Great Barrier Reef (GBR) coastal region, the hot spots with the highest threat exposure 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 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).

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 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).

Figure 4. Location of Queensland port seagrass monitoring sites.

A strategic long-term assessment and monitoring program for seagrasses provides port managers and regulators with the key information to ensure effective management of seagrass resources. It is useful information for planning and implementing port development and maintenance programs, so they 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 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/project/management-of-ports-and-coastal-facilities/.

3.2 Abbot Point Seagrass Monitoring Program

North Queensland Bulk Ports Corporation (NQBP) in partnership with James Cook University's TropWATER Centre have been engaged in a seagrass assessment and monitoring program at Abbot Point since 2005. The annual long-term seagrass monitoring program has evolved over time as more data has 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 broader whole-of-port mapping occurring every third year; completed again in 2022. 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 areas outside the zone of influence of port activity and development (Figure 5).

In 2019, three of the coastal meadows to the southeast of Abbot Point (Meadows 5, 7 and 8) were combined for analysis and reporting based on their proximity and similar species structure and have since been referred to as Meadow 5 (Figure 5). In 2020 the annual monitoring of offshore seagrass shifted from assessing fixed monitoring blocks to a more extensive assessment of seagrass habitat within a larger survey area, to be able to incorporate changes in seagrass area into the offshore monitoring design (Figure 5). This new assessment strategy for offshore seagrasses allows for the full suite of seagrass indicators used in the meadow condition index (area, biomass, species composition) to be assessed and reported on for offshore meadows. This is an improved way to quantify change in these highly variable, deep-water seagrass meadows that have large changes in their spatial footprint from year to year.

As part of a NQBP/JCU partnership, light (Photosynthetic Active Radiation (PAR)) and temperature assessments within two of the inshore monitoring meadows are also conducted and run parallel to other water quality monitoring stations in the region (5 stations) (see Waltham et al. 2022 for the full NQBP/JCU partnership water quality program).

Information collected in the strategic monitoring program aims to assist in planning and managing future developments in coastal areas in the region. The monitoring program forms part of Queensland's network of long-term monitoring sites of important fish habitats in high-risk areas. It also provides a key input into the condition and trend of seagrasses in the Mackay-Whitsunday-Isaac NRM region, an area which otherwise has a poor spatial coverage for seagrass assessment and condition.

This report presents the findings of the annual seagrass and broader whole-of-port monitoring for 2022. Objectives include:

- Assess and map seagrass to determine seagrass density (biomass), distribution (area) and community type (species composition) at representative long-term monitoring meadows.
- Map and quantify the distribution and abundance of all seagrass in the Abbot Point region to provide an updated picture of seagrass at a broader scale (whole-of-port survey).
- Compare results of monitoring surveys to baselines (long-term averages) for each meadow to determine their condition and assess any changes in seagrass habitat 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's marine environment.

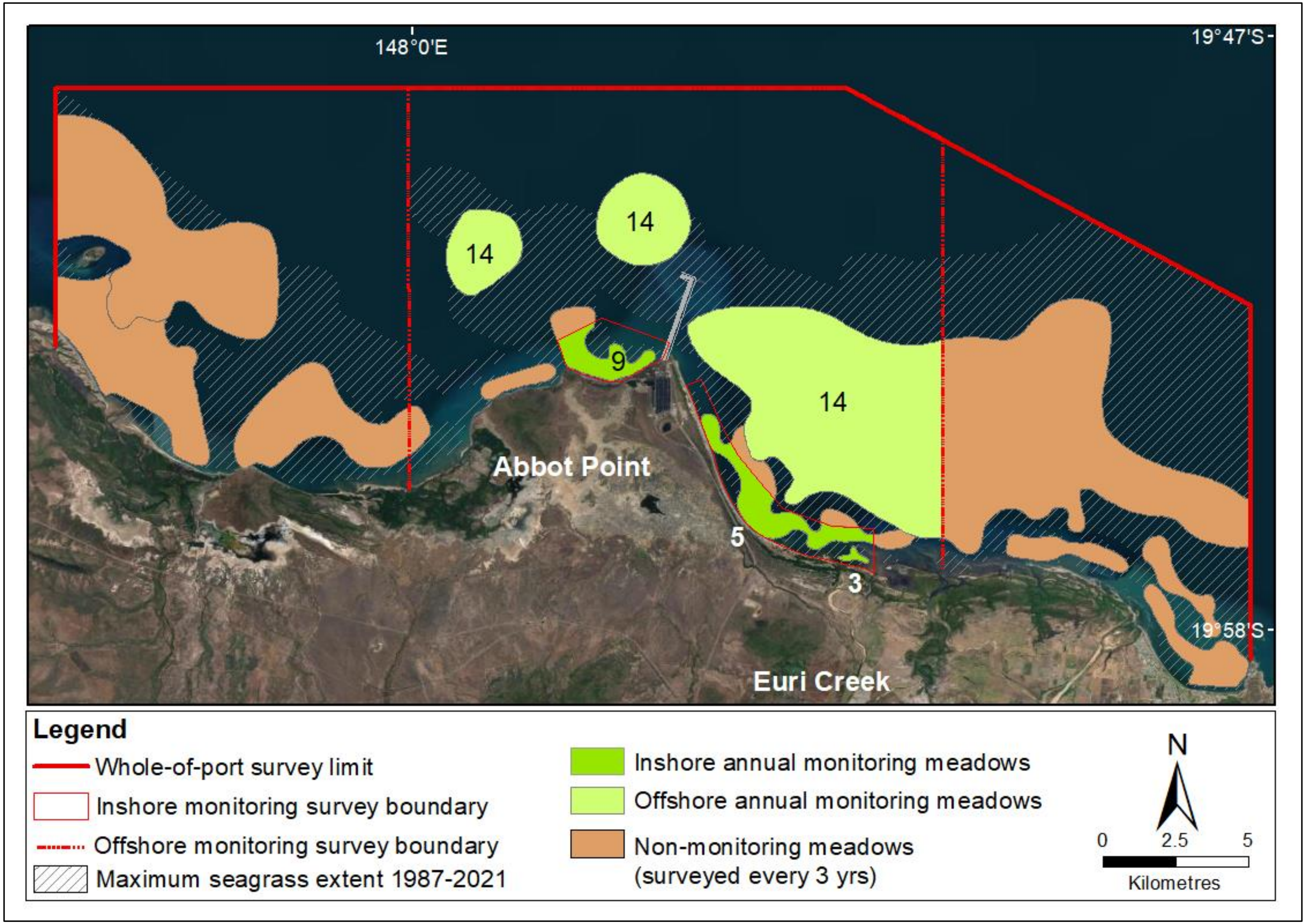

Figure 5. Location of annual inshore and offshore monitoring areas and seagrass meadows outside the monitoring areas around Abbot Point

4 METHODS

4.1 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 initial surveys. Annual surveys are conducted between September and December when tropical seagrass species are at their peak distribution and biomass. The Abbot Point Long-Term Monitoring Program has occurred annually since 2008 during that peak seagrass season.

In 2019, three of the coastal meadows to the southeast of Abbot Point (Meadows 5, 7 and 8) were combined for analysis and reporting based on their proximity and similar species structure and referred to in this report as Meadow 5. Coastal monitoring meadows now encompass 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 on. The change included a shift from assessing seagrass in fixed 'monitoring blocks' to a more extensive assessment of seagrass in a larger survey boundary (Figure 5) to allow for the full suite of seagrass health indicators used in the meadow condition index (area, biomass, species composition) to be assessed and reported on for offshore meadows. An interim baseline for each seagrass indicator has been calculated from the historical data available that covered the same survey region which now consists of seven years (2008, 2013, 2016, 2019, 2020, 2021 and 2022). The interim baselines for Meadow 14 will continue to be adjusted with additional years of monitoring data until ten years of baseline data is reached.

4.2 Sampling methods

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

Sampling methods were chosen 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. Intertidal and subtidal areas <8m below MSL: Boat based underwater digital camera mounted on 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).

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

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, and 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). At camera drop sites this technique involved an observer ranking seagrass biomass within three randomly placed 0.25m^2 quadrats at each site (Figure 6A-B). At digital camera sled tow sites this technique involved an observer ranking seagrass at ten random time frames allocated within the 100m of footage for each site (Figure 6C-D). The video was paused at each of the ten time frames then advanced to the nearest point on the tape where the bottom was visible and sled was stable on the bottom. From this frame an observer ranked seagrass biomass and species composition. A 0.25m^2 quadrat, scaled to the video camera lens used in the field, was superimposed on the screen to standardise biomass estimates.

4.3 Habitat mapping and Geographic Information System

All survey data were entered into a Geographic Information System (GIS) using ArcGIS 10.8®. Three GIS layers were created to describe seagrass in the survey area: a site layer, seagrass meadow layer and seagrass biomass interpolation layer.

- *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.

- *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

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.

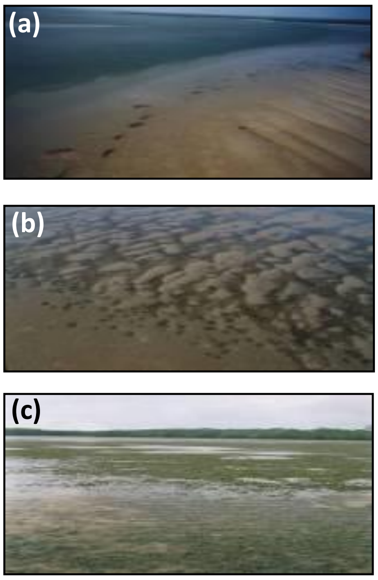

Figure 7. Seagrass meadow landscape categories: (a) Isolated seagrass patches, (b) aggregated seagrass patches, (c) continuous seagrass cover.

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

Meadow area was determined using the calculate geometry function in ArcGIS®. Meadows were assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow (Table 3). 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 area reliability estimate (R) in hectares.

Table 3. Mapping precision and methodology for seagrass meadows in the Abbot Point region 2022.

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.

4.4 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).

4.5 Environmental data

Available environmental data was collated for the twelve months preceding the 2022 survey. Temperature and solar exposure were obtained for the nearest weather station from the Australian Bureau of Meteorology (station 033327; Bowen Airport AWS). Total daily rainfall (mm) and river flow data was obtained by the Queensland Governments' Water Monitoring Information Portal (station 121002A – Elliot River at Guthalungra). Root Mean squared (RMS) wave height data has been collected by JCU at Abbot Point site AMB1 as part of the NQBP/JCU partnership since 2017 (Figure 10).

Three logging stations (two inshore stations (TW1 and TW2) and one offshore station (AMB 1) collect water temperature and light (PAR) at the seabed within the seagrass monitoring areas (Figure 9). This data has been used to represent the availability of light and temperature in the monitored seagrass meadows.

As part of the NQBP/JCU partnership, the team has water quality loggers deployed in the greater Abbot Point region since late 2017 (Figure 10). Detailed data from the water quality monitoring program can be found in Waltham et al. (2022).

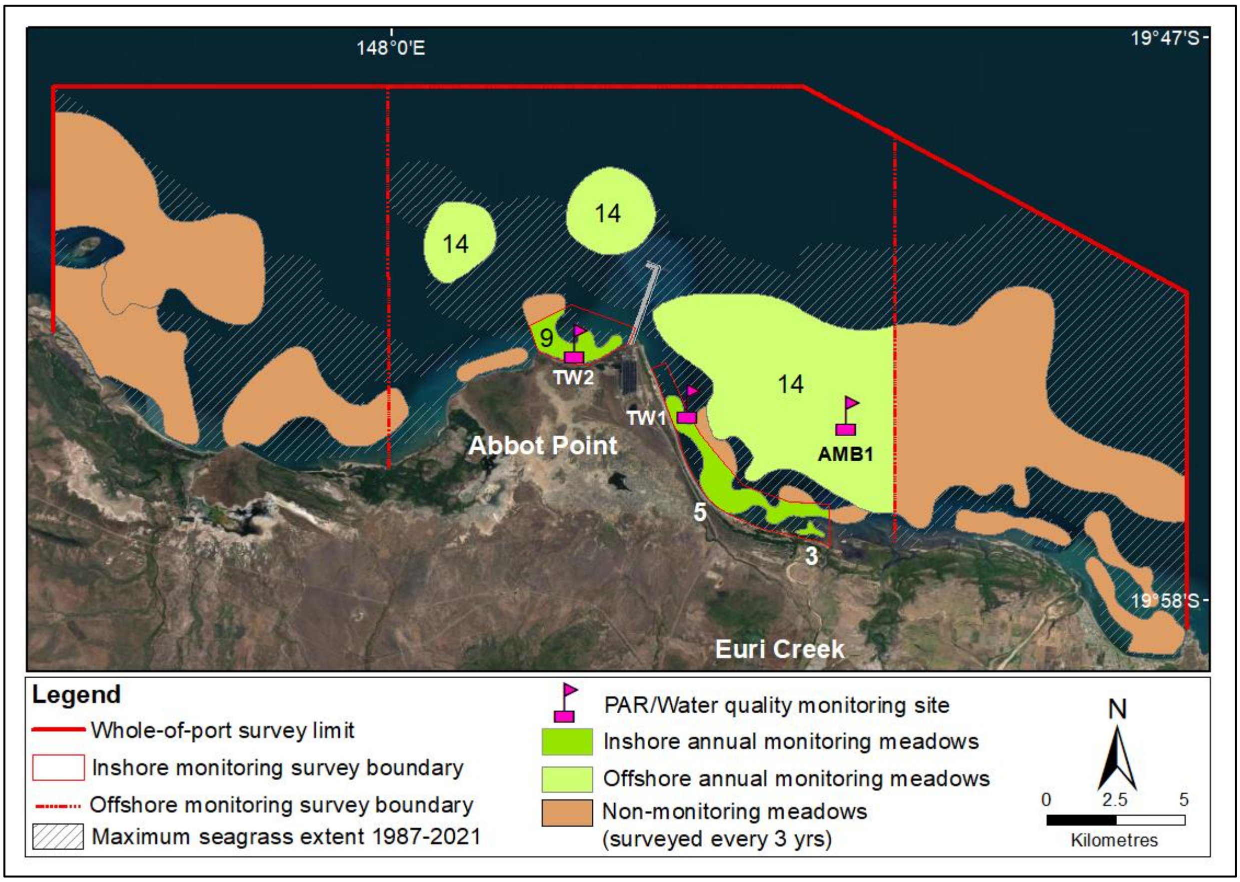

Figure 9. Location of TropWATER, James Cook University light (PAR) loggers at Abbot Point.

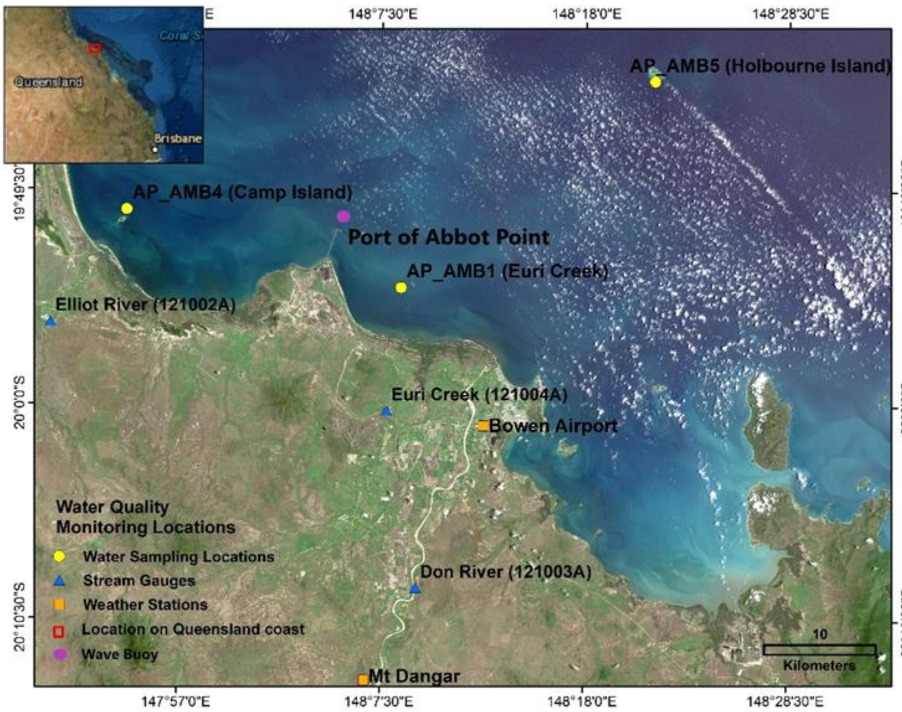

Figure 10. From Waltham et al. (2022): Location of TropWATER water quality monitoring sites (yellow circles). Also shown are meteorological stations (orange square), and stream gauge stations (blue triangle).

At the two inshore logging stations (TW1 & TW2), each independent logging station within the meadows consists of 2π cosine-corrected irradiance loggers (Submersible Odyssey Photosynthetic Irradiance Recording Systems) with supporting electronic wiper units (Figure 11). Irradiance loggers were calibrated using a cosine corrected Li-Cor underwater quantum sensor (LI-190SA; Li-Cor Inc., Lincoln, Nebraska USA) and corrected for immersion effect using a factor of 1.33 (Kirk 1994). Readings were made at 15-minute intervals and used to estimate total daily irradiance (PAR) reaching seagrass. The electronic wiper unit fitted to each irradiance logger automatically cleaned the optical surface of the sensor every 15 minutes to prevent marine organism fouling.

Autonomous Thermodata® iBTag submersible temperature loggers recorded seabed temperature every 30 minutes.

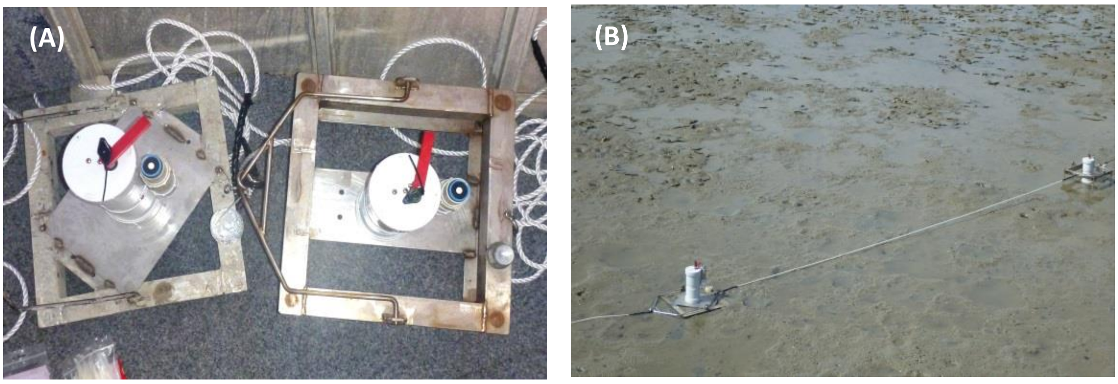

Figure 11. (**A**) Logging station consisting of a stainless steel frame with PAR loggers, temperature loggers and wiper units attached; (**B**) example of deployment of logging stations (Abbot Point stations are subtidal only).

5 RESULTS

5.1 Seagrass in the Abbot Point monitoring areas

The 2022 whole-of-port and annual monitoring survey was conducted between October and November 2022 and assessed 344 sites in the Abbot Point region (Figure 13). Seagrass was present at 50% of the survey sites. Seagrass in the inshore annual monitoring areas covered 767.4 ha while seagrass in the offshore monitoring area covered 5,555.5 ± 489.3 ha (Figure 13; Appendix 8.2). Seagrass biomass was higher closer to the shoreline reducing offshore with increasing water depth (Figure 14).

Five seagrass species were observed in the 2022 survey and were typical of those in the Abbot Point region and more broadly in Queensland (Figure 12). The offshore seagrass habitat was dominated by *H. spinulosa* with *H. ovalis*, *H. decipiens, H. uninervis* (both narrow and wide forms) and *H. tricostata* also present (Appendix 8.1). This is the first time *H. tricostata* was recorded since the 2016 broadscale survey. Inshore meadows (5 and 9) were dominated by *H. uninervis* (narrow form) (Appendix 8.1). Z*ostera muelleri* was the dominant species in the Euri Creek meadow (Meadow 3).

Cymodocea rotundata, Cymodocea serrulata, and *Syringodium isoetifolium* have been recorded in the region in the past but occurrences are uncommon, and they were not present in 2022 within the surveyed area. *C. serrulata* was last recorded in 2020, and *C. rotundata* and *S. isoetifolium* have only been recorded in the 2005 baseline survey.

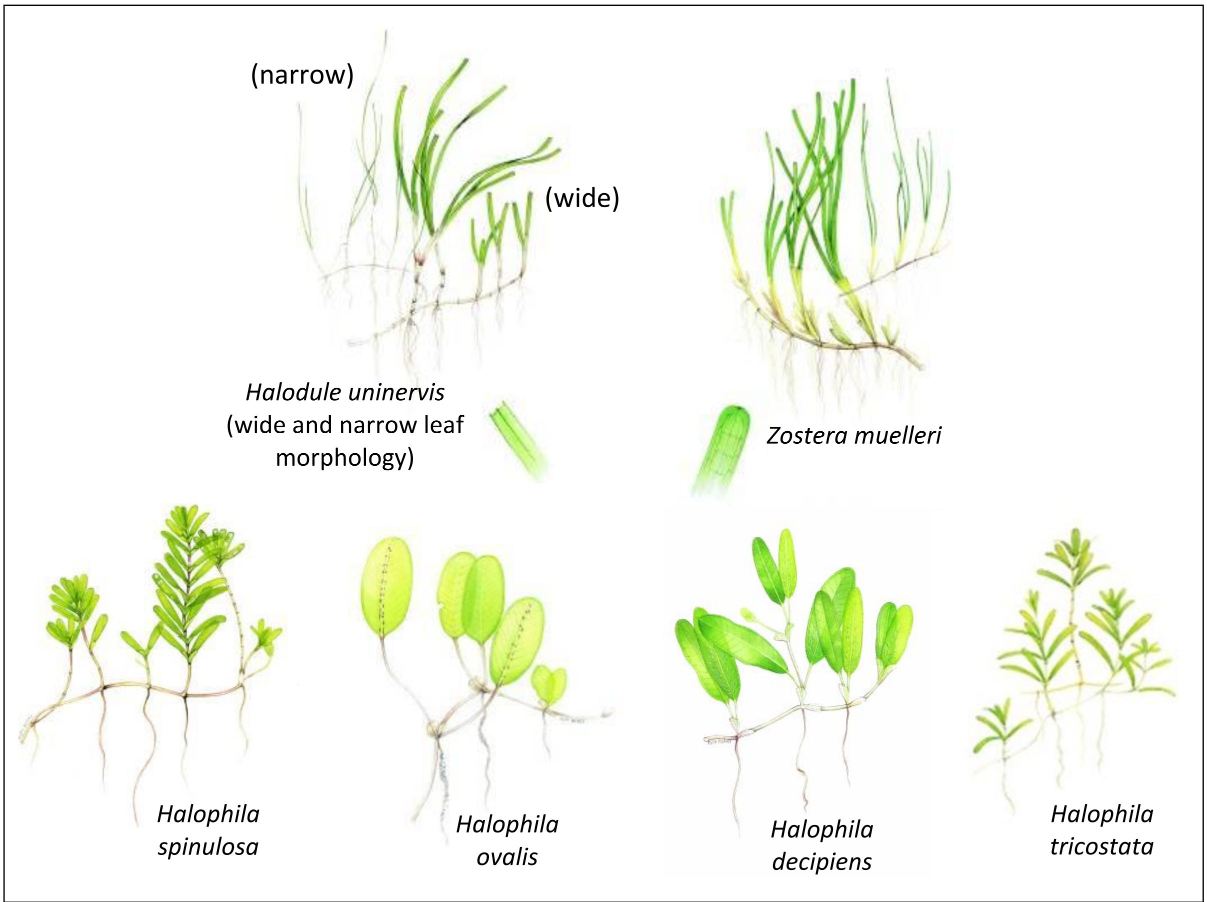

Figure 12. Seagrass species identified in the Abbot Point region in 2022.

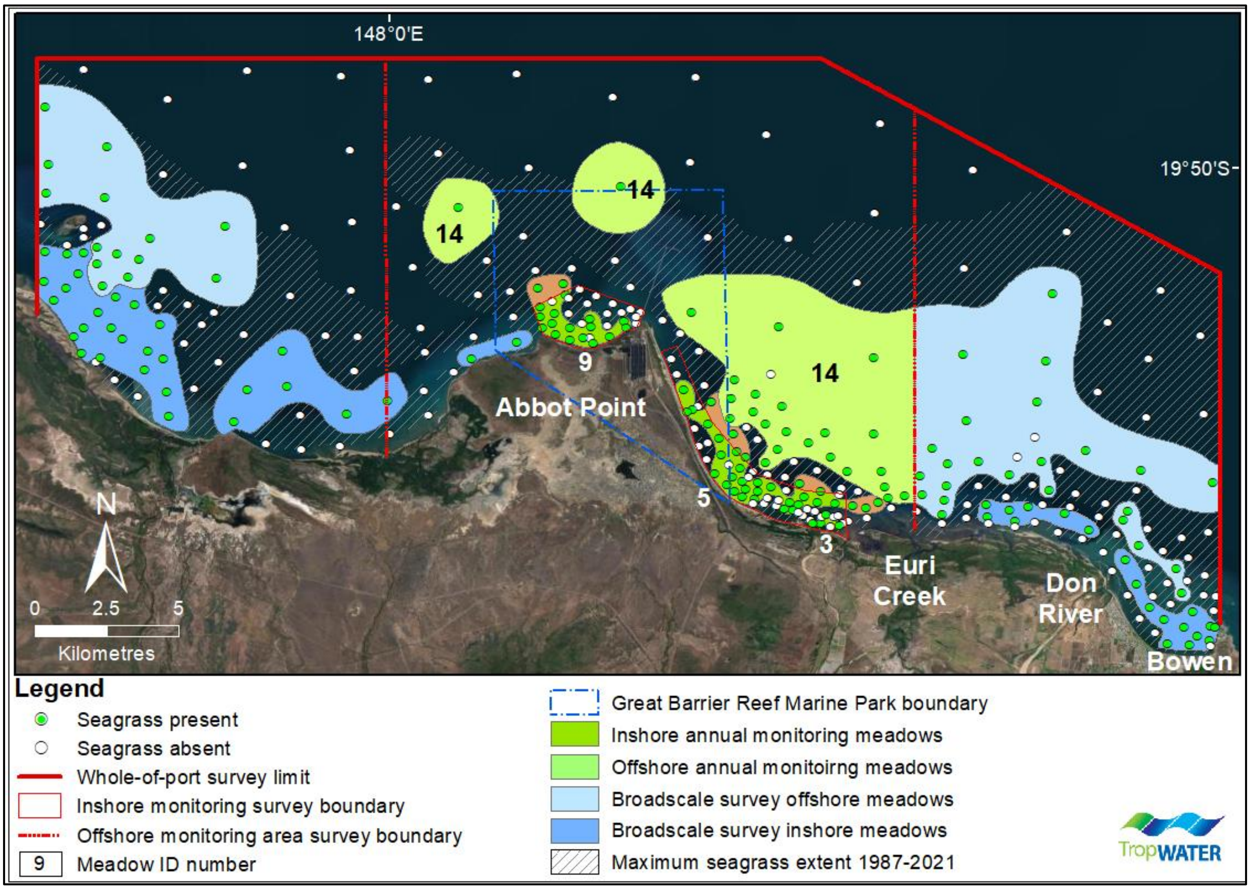

Figure 13. Location of seagrass meadows and assessment sites in the 2022 annual monitoring and broadscale survey.

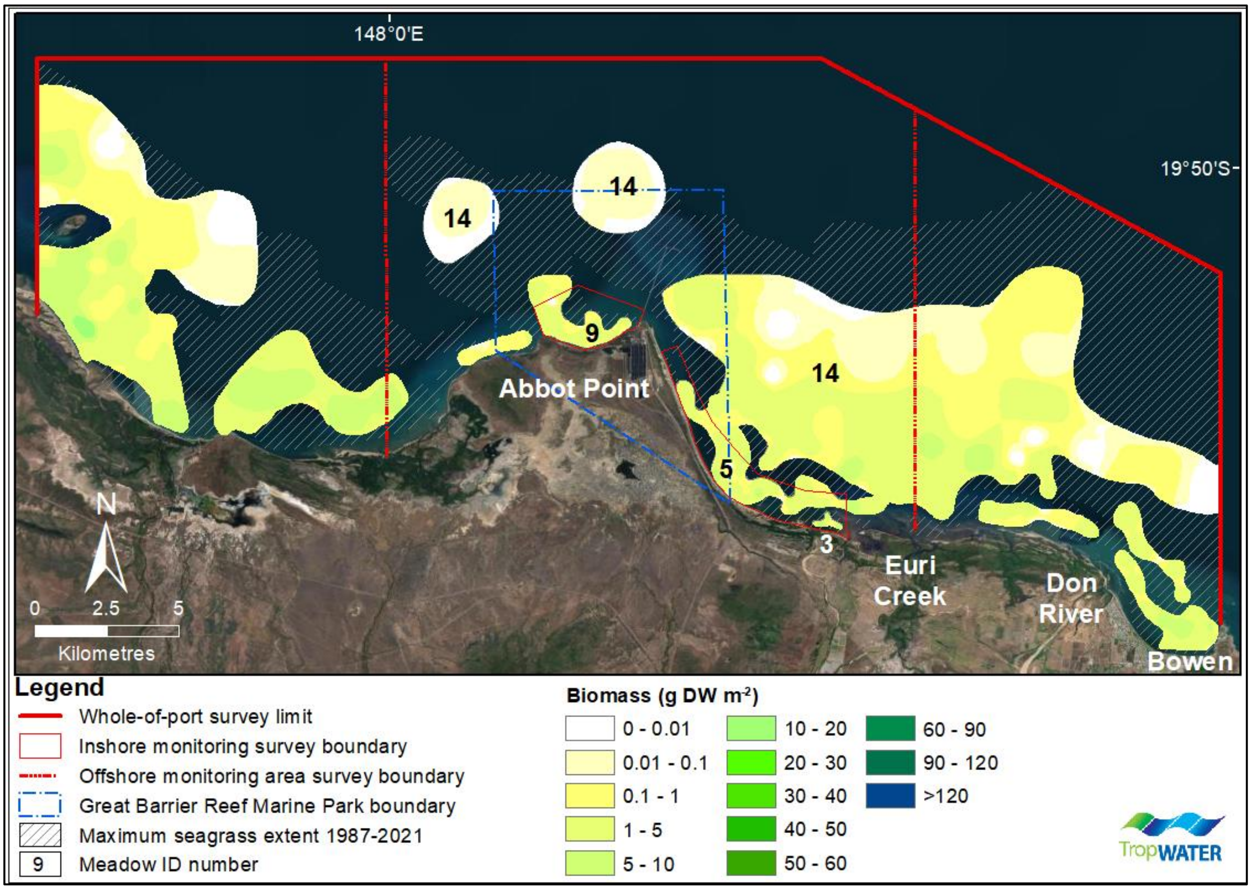

Figure 14. Seagrass biomass (g DW m^{-2}) and distribution for Abbot Point survey 2022.

5.2 Seagrass condition in the Abbot Point monitoring areas

In 2022 Abbot Point monitoring meadows were in good condition (Table 4). This is the third consecutive year seagrass meadows in the Abbot Point region have been in good or better condition after impacts from multiple climate related events between 2017 and 2019 that reduced the condition of seagrass meadows to poor.

Table 4. Condition scores for seagrass indicators (biomass, area and species composition) for the Abbot Point region 2022.

Meadow	Biomass	Species Composition	Area	Overall Meadow Score
Inshore meadow 3	0.89	0.88	0.67	0.67
Inshore meadow 5	0.73	0.83	1	0.73
Inshore meadow 9	0.73	0.88	1	0.73
Offshore meadow 14	0.80	0.75	0.78	0.76
Overall condition score for seagrass in the Port of Abbot Point				**0.72**

= very good condition = good condition = satisfactory condition

= poor condition = very poor condition

5.2.1 Inshore monitoring meadows

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 the only inshore monitoring meadow located on the western side of Abbot Point (Figure 9). Meadows 5 and 9 are *H. uninervis* dominated meadows, while Meadow 3 at Euri Creek is a *Z. muelleri* dominated meadow (Figure 15-17; Appendix 8).

The Euri Creek *Z. muelleri* meadow (Meadow 3) was in good condition in 2022 for the fourth consecutive year (Table 4; Figure 15). The three condition indicators; biomass, area and species composition have remained relatively stable during this time (Figure 15). The biomass of this meadow has been above the long-term average and in very good condition for the last four years (Figure 15). The area of the meadow in 2022 (23 ha) was similar to 2021. On a very positive note, the indicator species of the meadow, *Z. muelleri*, contributed much more to the species composition of the meadow in 2022 compared to recent years and was back to being at similar levels seen before TC Yasi (Figure 15; Appendix 8.2).

The *H. uninervis* monitoring meadow on the south-eastern side of Abbot Point (Meadow 5) was also in good condition in 2022 (Table 4; Figure 16). The mapped area of this meadow in 2022 was the largest recorded in the program to date (477 ha) (Figure 16; Appendix 8.2.2). Meadow biomass has been near to or above the long-term average for the past nine years (Figure 16). In 2022 the meadow had a higher proportion of the less stable *Halophila* species, resulting in the species composition condition for the meadow decreasing from very good in 2021 to good in 2022 (Figure 16; Appendix 8.2.2). In 2022 the meadow extended beyond the fixed survey boundary for annual monitoring (Figure 16). For the purpose of the annual monitoring program and determining condition scores, meadow area, biomass and species composition have only been calculated on the portion of the meadows that is within the fixed survey boundary.

The *H. uninervis* monitoring meadow on the western side of Abbot Point (Meadow 9) was in good condition in 2022 (Table 4). Similar to the other *H. uninervis* monitoring meadow, the area of this meadow (267 ha) in 2022 was the largest it has been in the program to date 2022 (Figure 17). The biomass of this meadow has historically been variable throughout the monitoring program ranging from being absent and in very poor condition to being in very good condition (Figure 17). For the last three years however, the density of this meadow has been in good or better condition (Figure 17). The species composition of the meadow has been in very good condition for the last five years with the indicator species *H. uninervis* dominating the meadow throughout this period (Figure 17; Appendix 8.1). Meadow 9 also extended beyond the fixed survey boundary for annual monitoring (Figure 17). Calculations for condition assessments and scores for each indicator was based on the portion of the meadow that was within the survey area boundary.

5.2.2 Offshore monitoring area

The offshore monitoring area encompasses seafloor from ~5m to 26m below mean sea level. The shallowest offshore area is located on the north-western side of Abbot Point on Clark Shoal. Seagrass in this area has been intermittent in its presence 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 remained in good condition in 2022 (Table 4; Figure 18). The density, area and species composition of the meadow has been similar for the past two years and remains near the respective long-term averages (Figure 18). The total extent of seagrass present in the offshore survey area was 5,555.5 ± 489.3 ha and similar to 2021 (5464.7 ha). The offshore meadow had a greater presence of *H. ovalis* in 2022 than previous years. *Halodule uninervis* and *H. tricostata* were also present in the meadow. *Halophila tricostata* has not been recorded in the annual monitoring program since 2016 (Figure 19; Appendix 8.1). Seagrass was recorded to a depth of 21m below mean sea level in the offshore area.

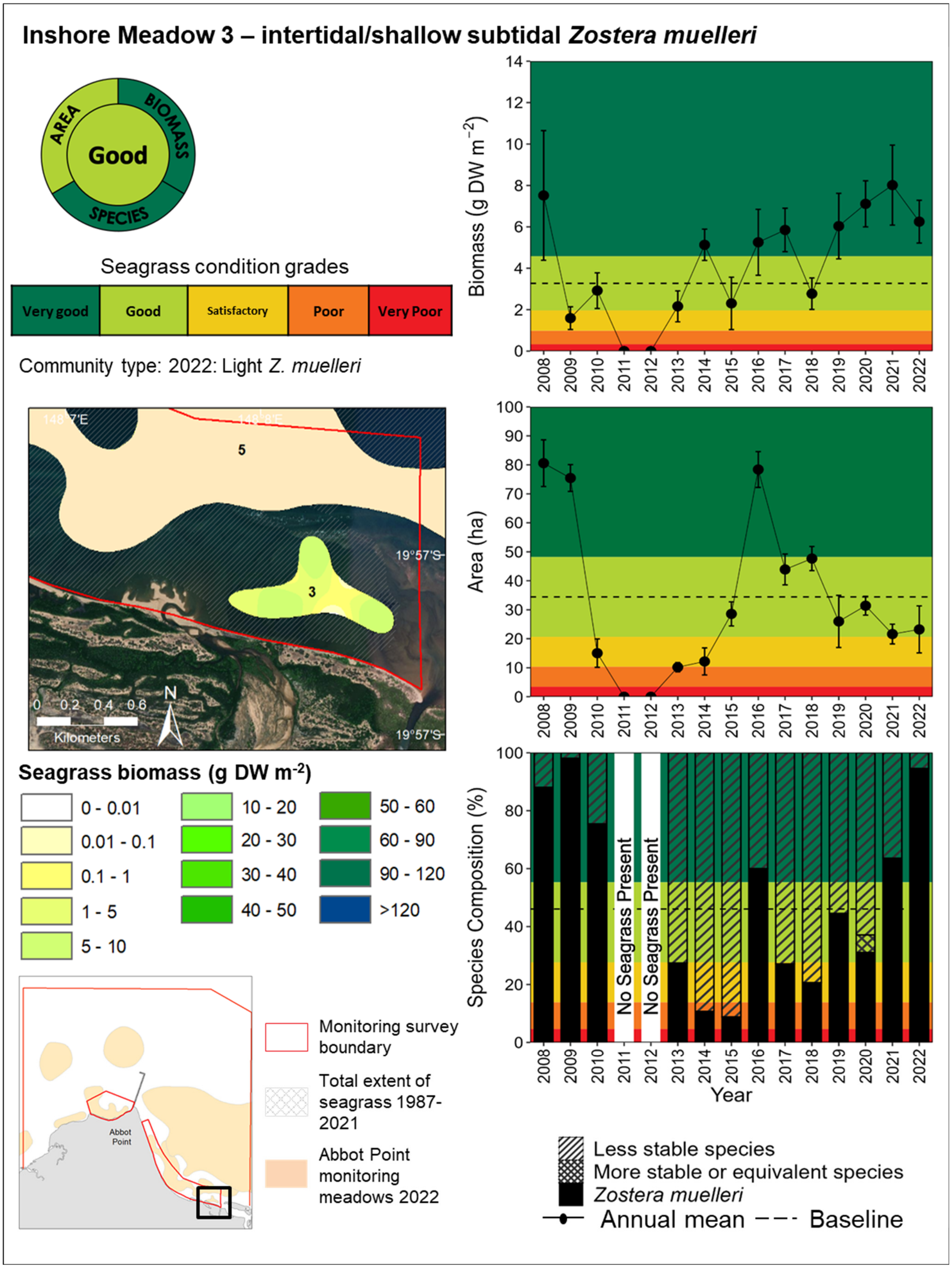

Figure 15. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 3. *Lack of arrows indicates no change in condition index from the previous year.

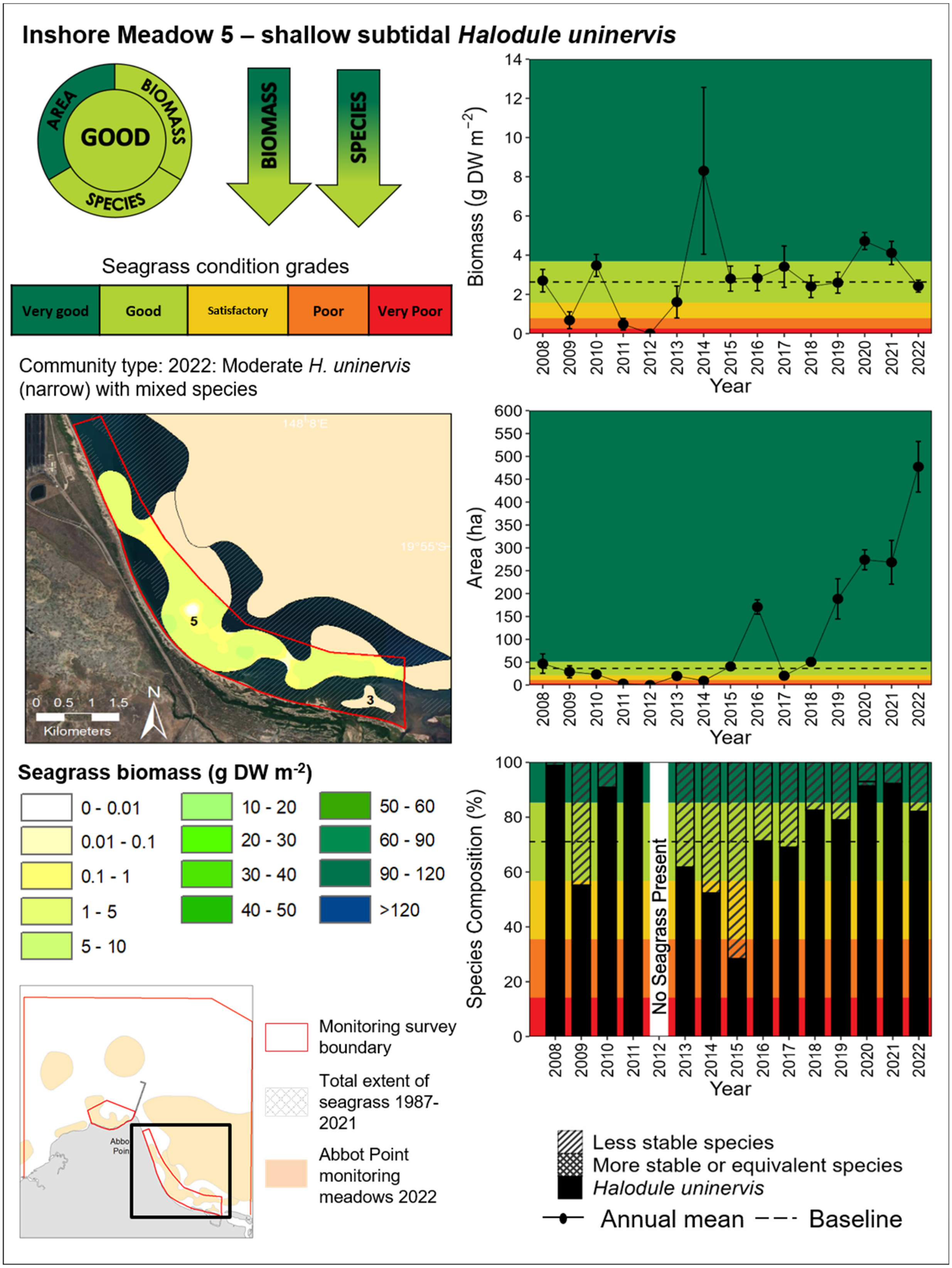

Figure 16. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 5. *Lack of arrows indicates no change in condition index from the previous year.

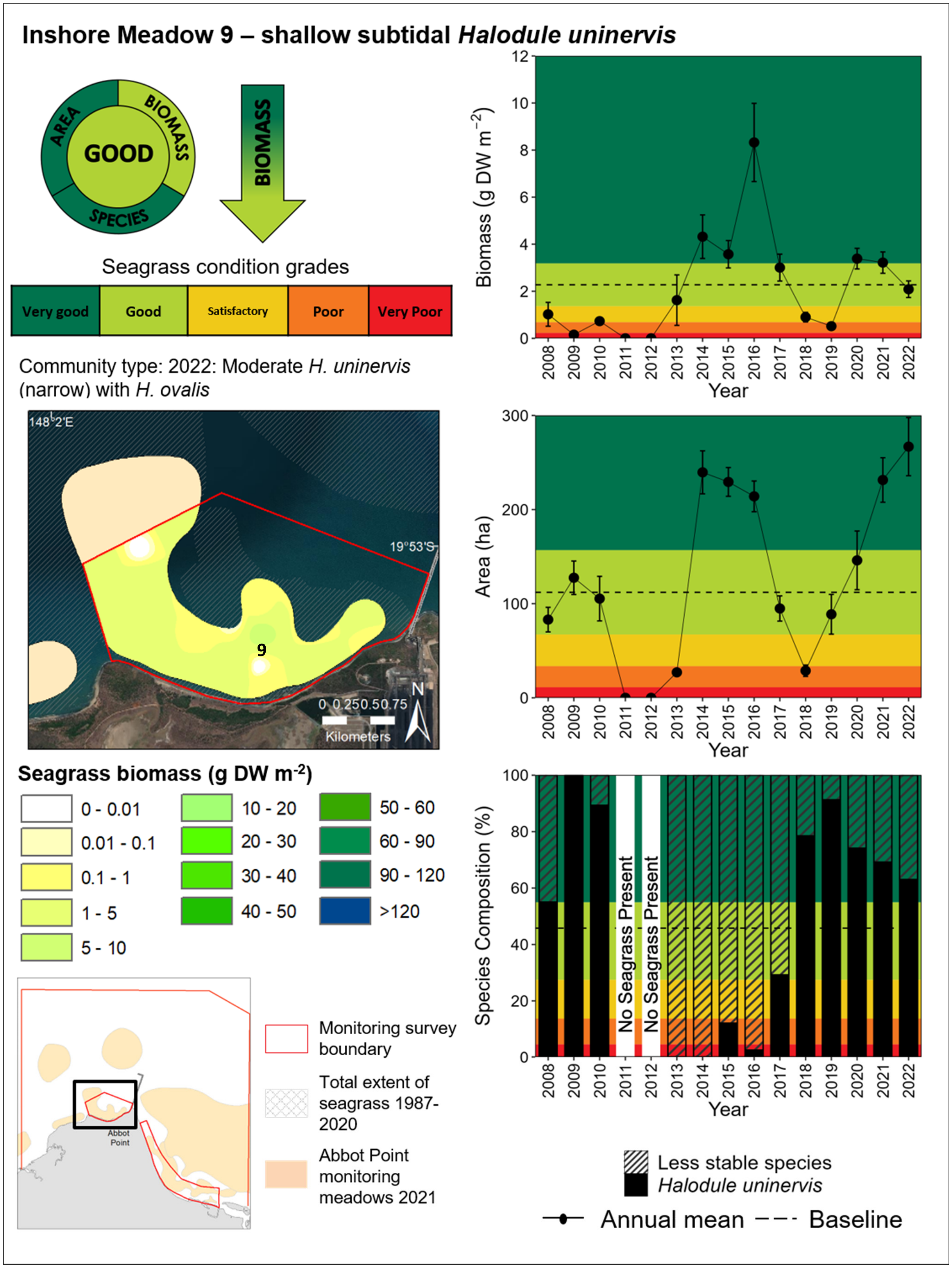

Figure 17. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 9. *Lack of arrows indicates no change in condition index from the previous year.

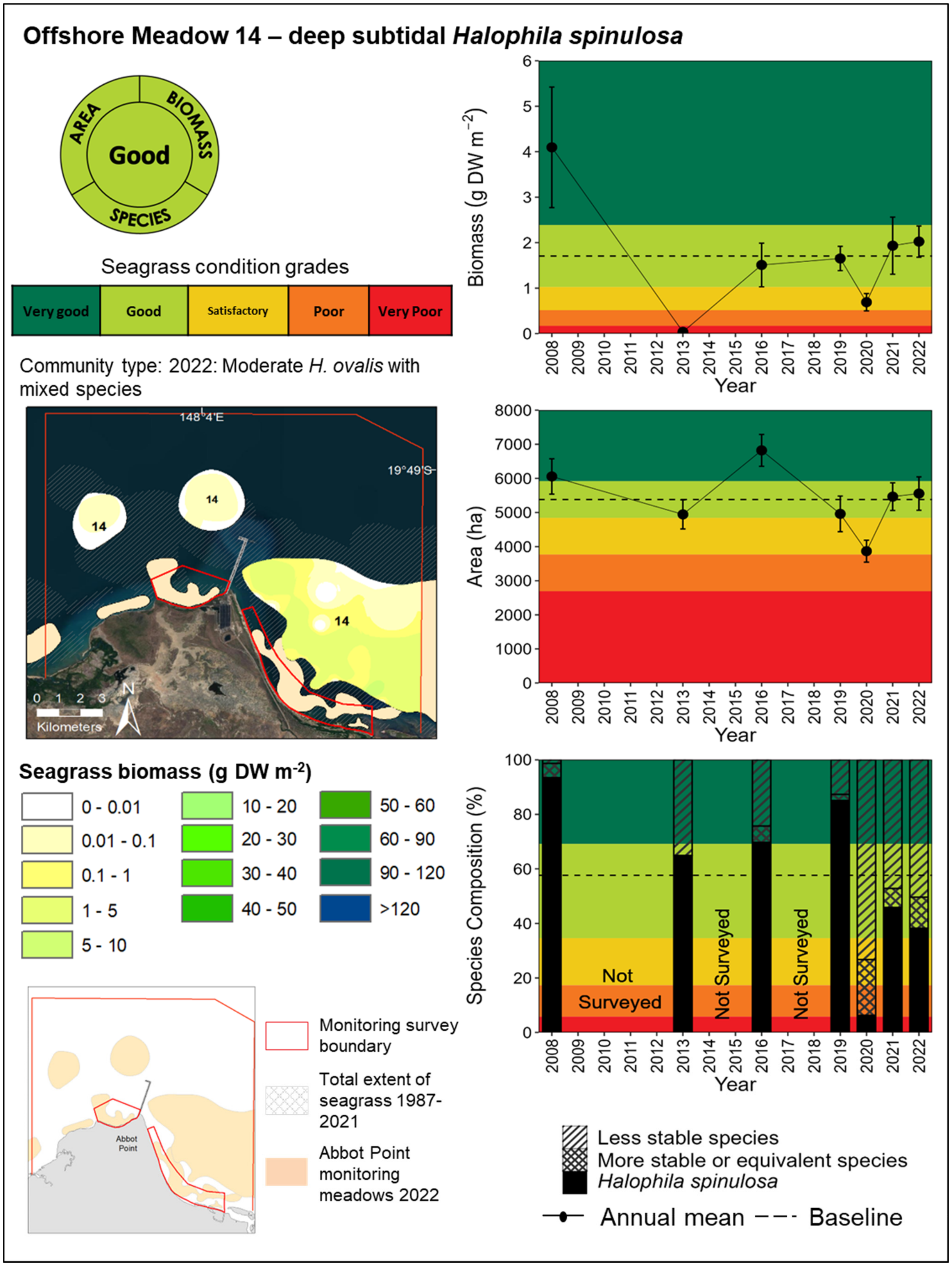

Figure 18. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at offshore monitoring Meadow 14. *Lack of arrows indicates no change in condition index from the previous year.

5.2.3 Comparison with previous whole-of-port surveys

The entire seagrass habitat is mapped in the broader port region every three years to get a better understanding of seagrass habitat in the region (Figure 20). In 2022 17,945 ha of seagrass was mapped within the broadscale survey boundary (Figure 19 & 20). Overall seagrass biomass, area, species composition and the location of meadows across the region was similar to the previous broadscale survey completed in 2019 (Figure 19 & 20). Offshore meadows have been dominated by *H. spinulosa* and inshore meadows throughout the region have been dominated by *H. uninervis*. *Halophila ovalis* and *H. decipiens* are the next prevalent species throughout both inshore and offshore areas.

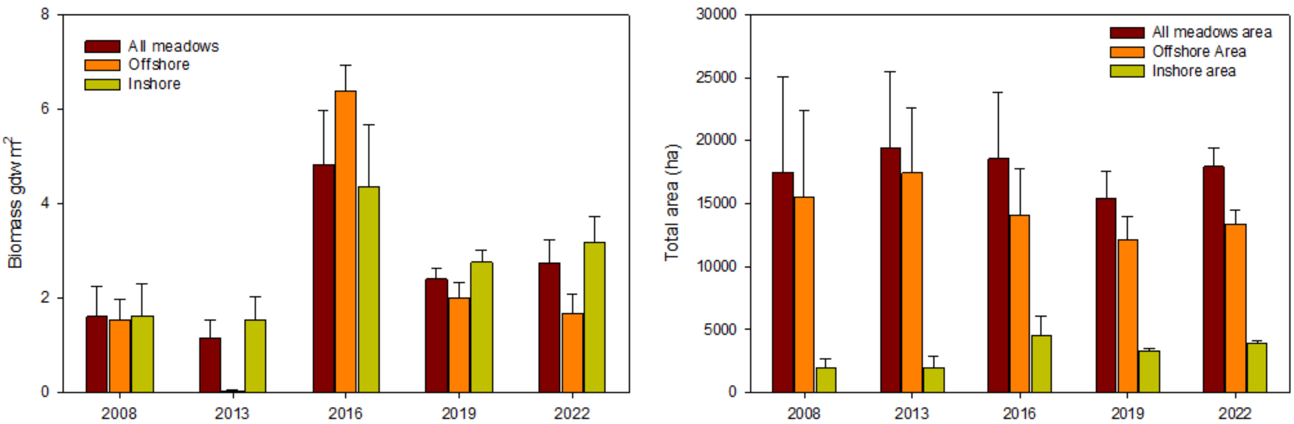

Figure 19. Comparison of biomass (g DW m^{-2}) and total area (ha) of meadows during the whole of port surveys in Abbot Point for 2008, 2013, 2016, 2019, 2022.

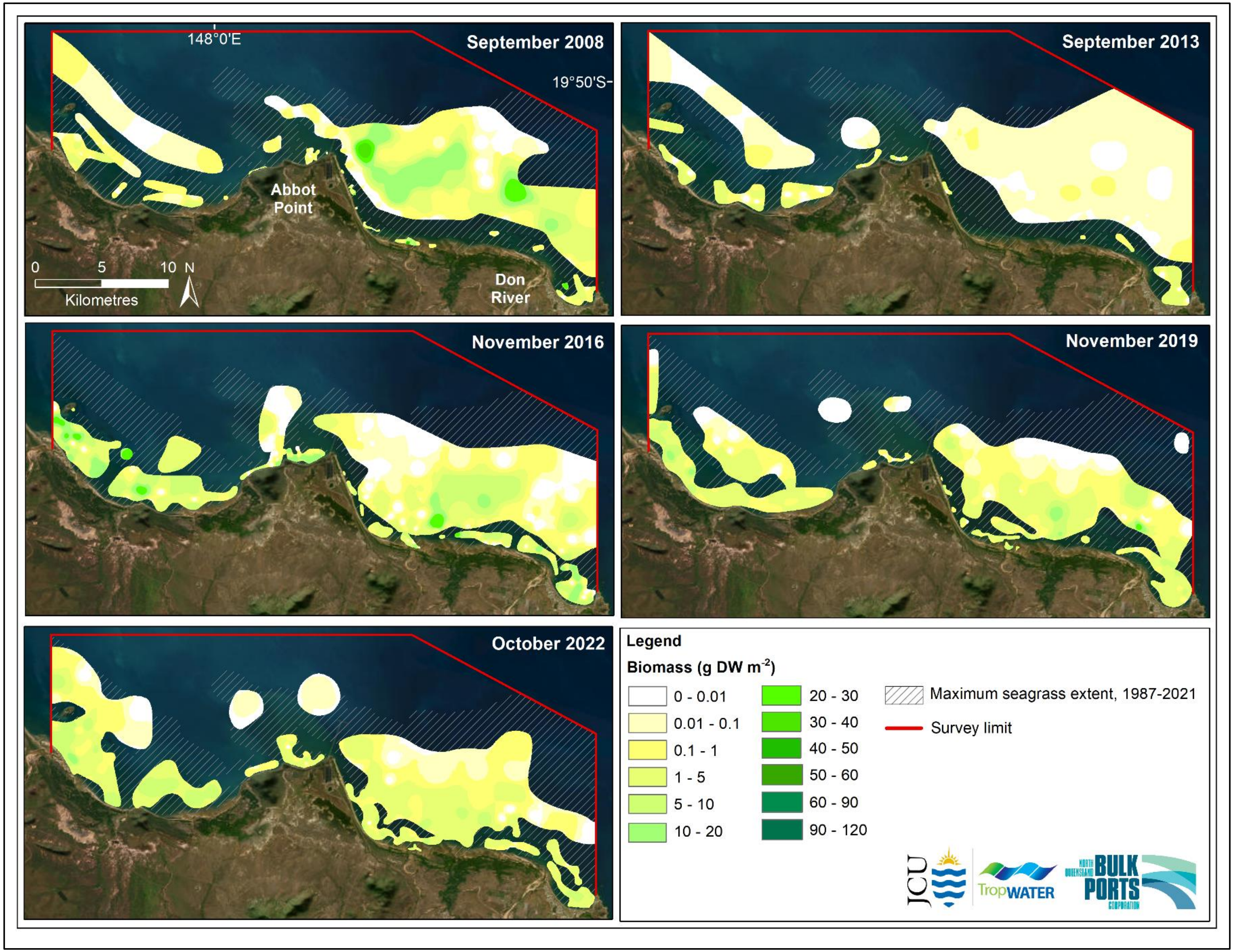

Figure 20. Comparison of biomass (g DW m^{-2}) and total area (ha) of monitoring meadows during the broadscale surveys in Abbot Point for 2008, 2013, 2016, 2019 and 2022.

5.3 Abbot Point environmental data.

5.3.1 Benthic daily light – photosynthetically active radiation (PAR)

Light available to seagrass changes with season; lower light levels during the wet season associated with higher rainfall, higher cloud cover, river flow and wind events, followed by higher light levels supporting seagrass growth during the dry season (Figure 21a). In addition, semi-regular fluctuations between low and high PAR are often overridden by larger episodic events caused by storms, rainfall, or wind events (Waltham et al. 2022).

The inshore PAR sites: TW1 & TW2 are at different depths and represent the depth gradient where coastal seagrasses can be found at Abbot Point (Figure 9). Because of this the total daily light at each of these logging stations differs in range. TW2 on the western side of the Abbot Point wharf is the shallowest site, followed by TW1 then AMB 1 located offshore.

Locally derived light thresholds for the Abbot Point region were determined in 2015 (McKenna et al. 2015) and based on local data collected by this monitoring program. Analysis of the data collected at Abbot Point indicated that for the offshore areas dominated by *Halophila* species a 1.5 mol m^{-2} day^{-1} over a rolling 7-day average described light conditions that supported maintenance of deep-water *Halophila* species. For the shallow inshore areas dominated by *H. uninervis* a threshold of 3.5 mol m^{-2} day^{-1} over a rolling 14-day average was recommended.

PAR levels vary at the two inshore logging sites with light at TW1 (the deeper site inshore site) generally lower than TW2 (shallower site) (Figure 21a & b). For the data available at TW1 light levels were below the threshold for inshore seagrass maintenance for a maximum of 48 days over the 2021/22 wet season. Light at TW2 on the western side of Abbot Point remained above the threshold throughout most of the year with very brief dips below the threshold in May and September. PAR data at AMB1 is currently only available until 31st July 2022 for this report. The complete dataset for this site will be published within Ambient Marine Water Quality 2023 report. For the available data, light at AMB1 was above the offshore seagrass threshold for most of the time. Light fell below the threshold towards late April for 10 days and in early May for 8 days (Figure 21b).

5.3.2 Benthic water temperature

At inshore seagrass meadows (e.g., Meadow 9 and 5) temperature followed a similar trend and ranged from highs of 31.8°C in January/March 2022 and lows of 19.4°C in June 2022 (Figure 22). The temperature around the time of sampling in October 2022 was on average 28°C. Water temperature within the offshore seagrass canopy at AMB 1 showed a similar trend and temperature range to inshore data. Temperature data was only available up until June 2022 (Figure 22).

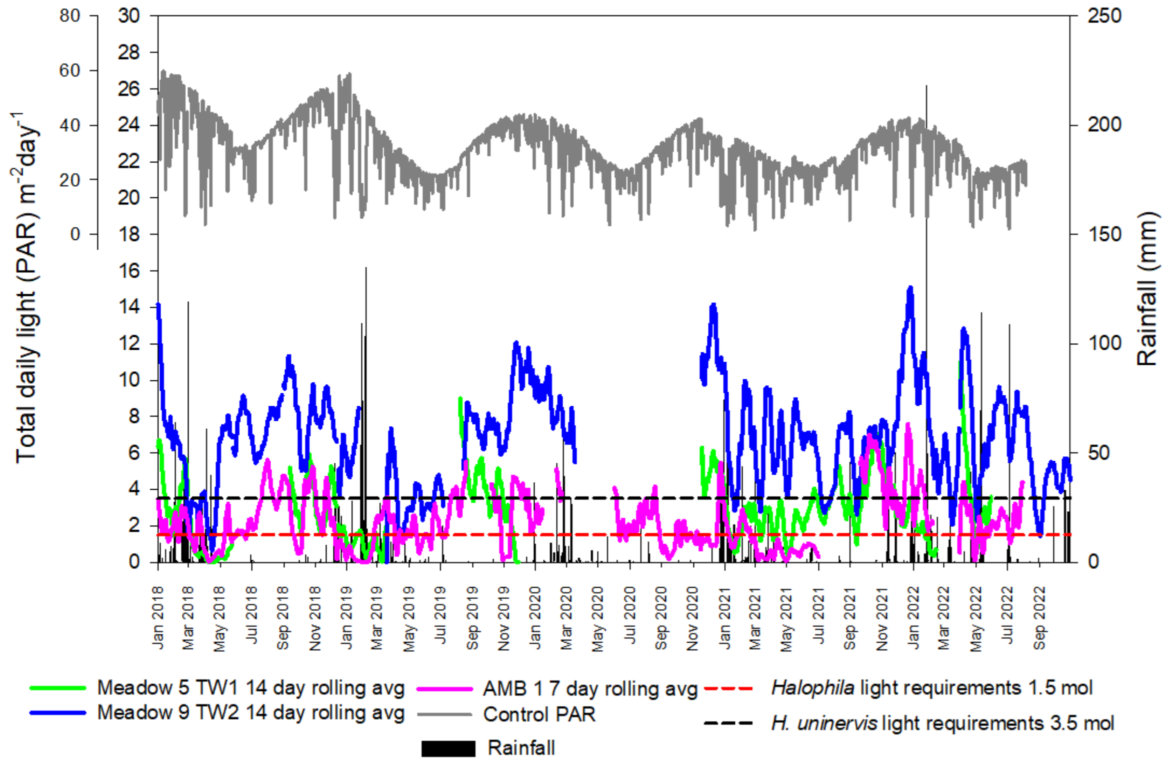

Figure 21a. Fourteen- and seven day rolling average total daily PAR (mol photons $m^{-1}day^{-1}$), total daily rainfall, and *H. uninervis* and *Halophila* light requirement thresholds January 2018 – October 2022. Data gaps are due to equipment malfunction or loss.

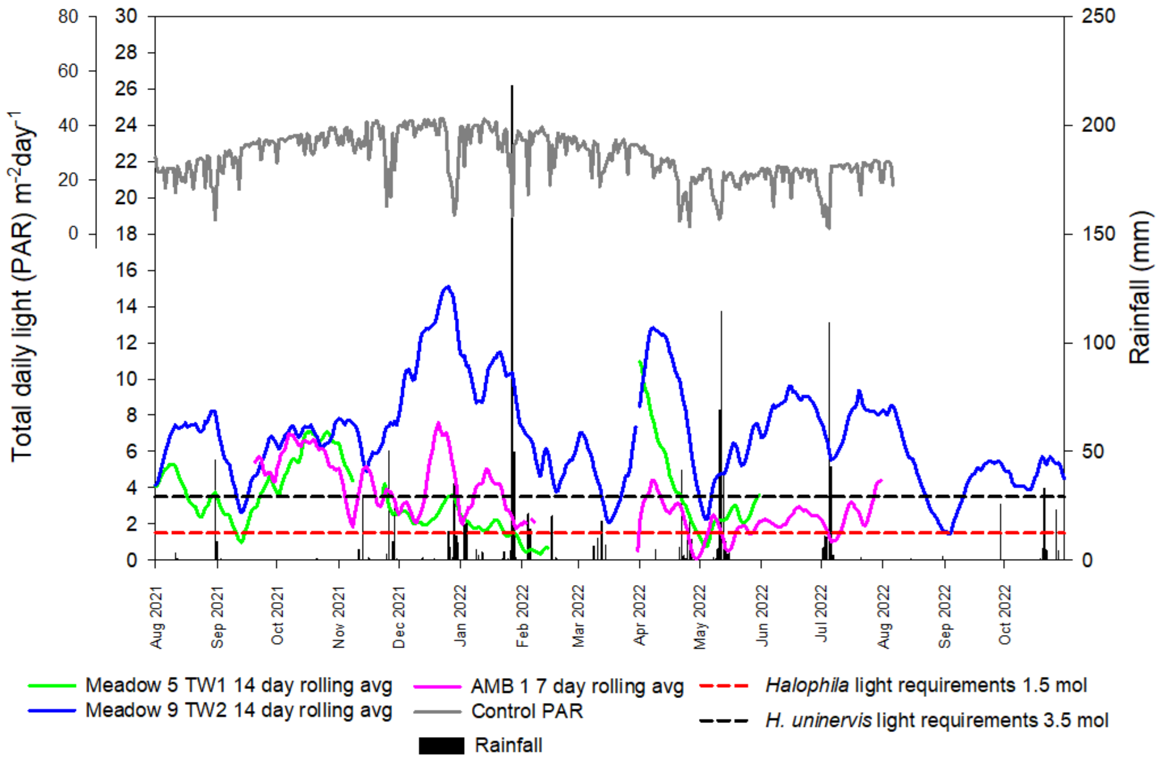

Figure 21b. Fourteen- and seven day rolling average total daily PAR (mol photons $m^{-1}day^{-1}$), total daily rainfall, and *H. uninervis* and *Halophila* light requirement thresholds August 2021 – October 2022. Data gaps are due to equipment malfunction or loss.

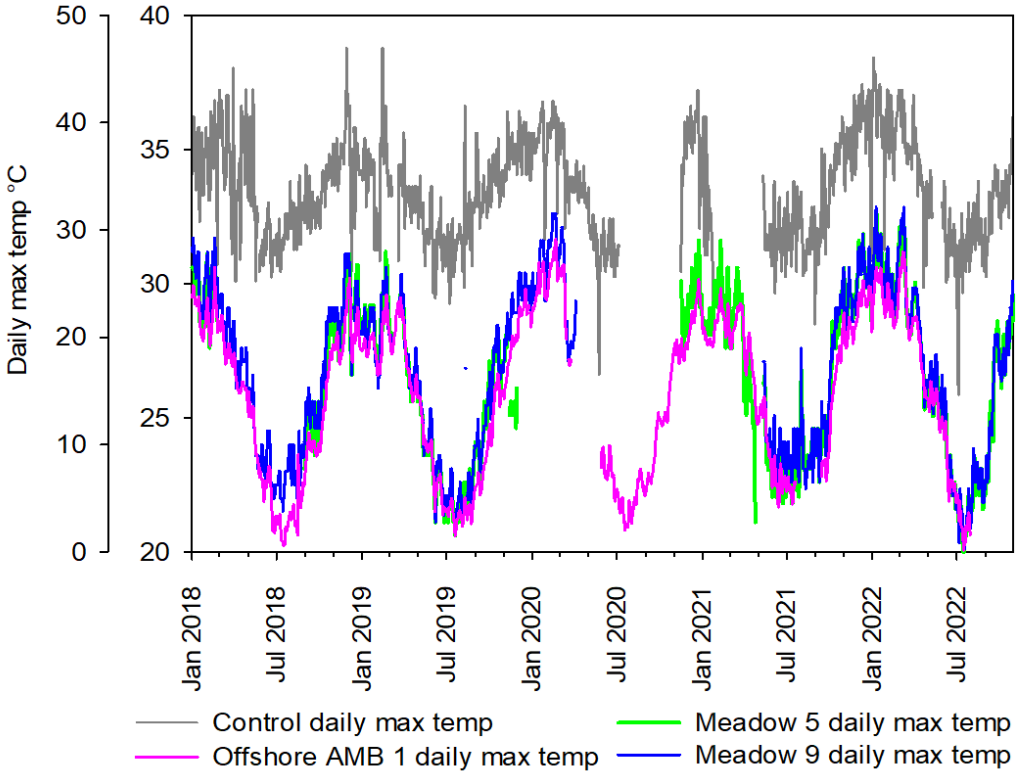

Figure 22. Maximum daily water temperature (°C) within the seagrass canopy at the two inshore monitoring sites and one offshore monitoring site January 2018 – October 2022. Control daily maximum temperature was from a temperature logger on land in the Port of Bowen.

5.3.3 Rainfall

Total annual rainfall in the 12 months proir to the 2022 survey was 1090 mm and above the long term average (Figure 23a). January recorded the highest rainfall (239mm) in 2022 with above average rainfall also recorded in April, May, July, October and November 2022 (just before the survey) (Figure 23b).

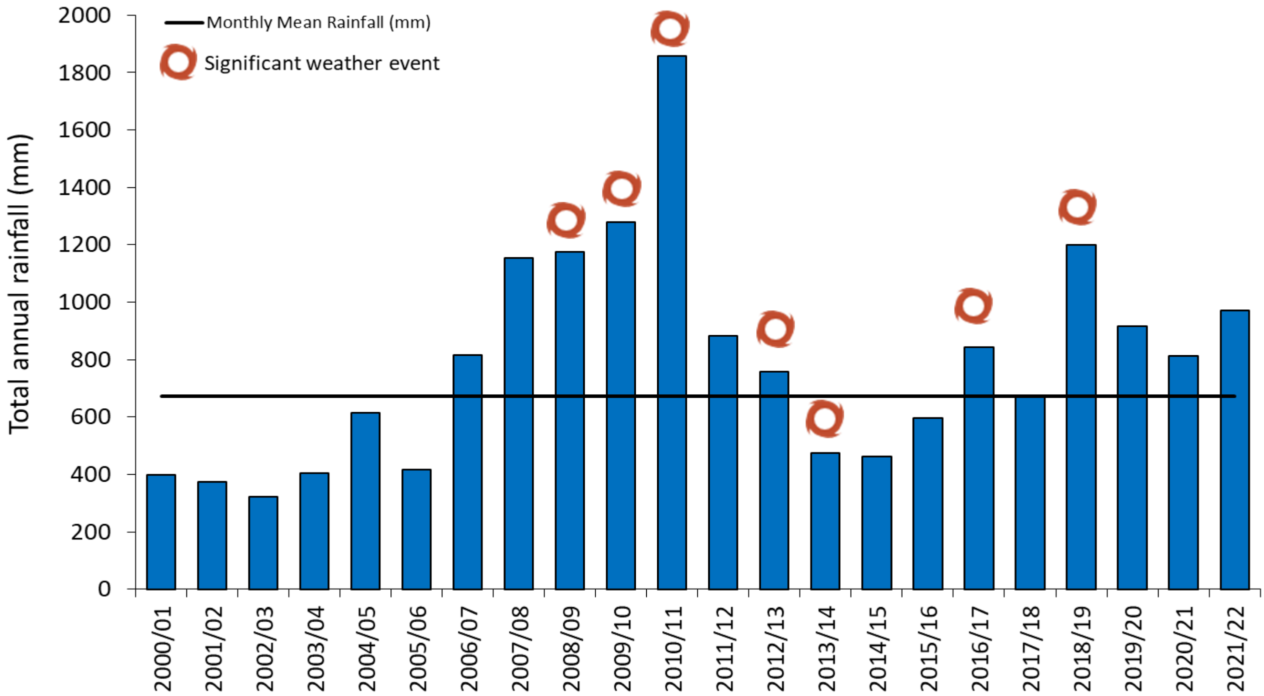

Figure **23a**. Total annual rainfall (mm) recorded at Guthalungra, 2000/01-2021/22. Year represented in columns is twelve months prior to the survey.

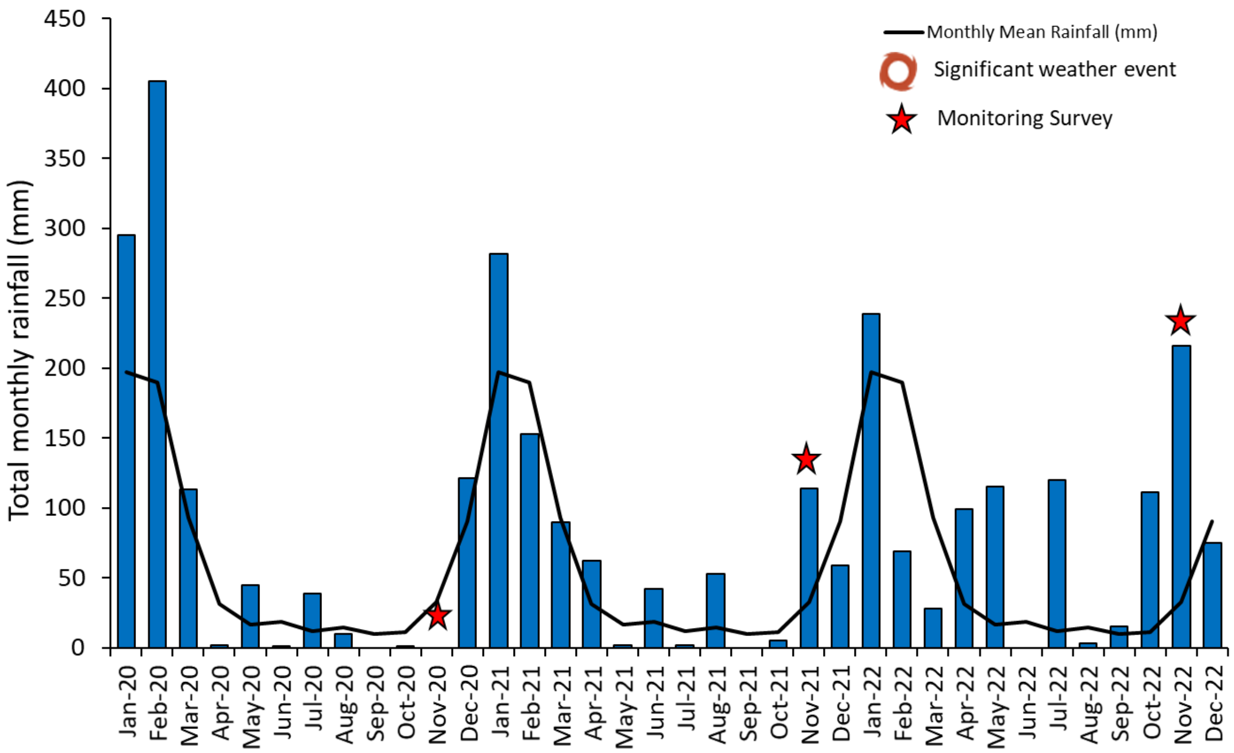

Figure 23b. Total monthly rainfall (mm) recorded at Guthalungra, January 2020 – December 2022.

5.3.4 River flow - Elliot River

River flow for the Elliot River was below the long-term annual average in 2021/22 for the third consecutive year (Figure 24a). Above average monthly flows were recorded in May, July, October and November (Figure 24b).

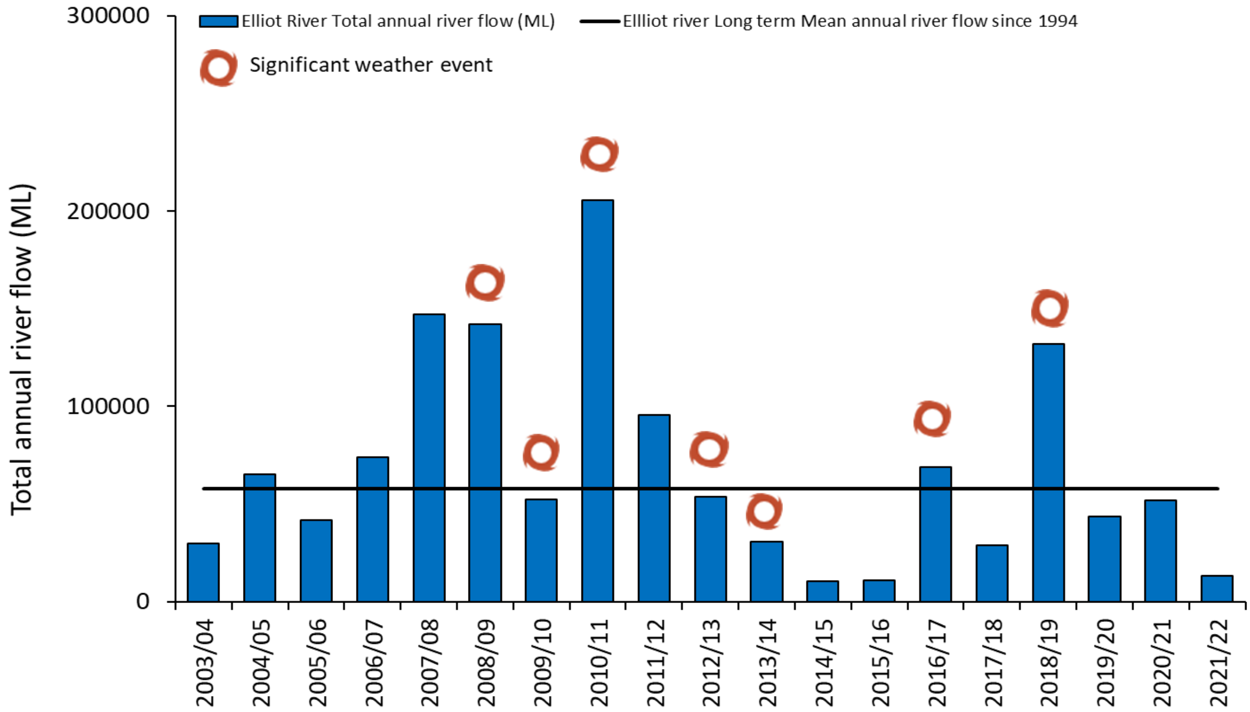

Figure 24a. Total annual river discharge of the Elliot River from 2003/04 to 2021/22. Year represented in columns is twelve months prior to the survey.

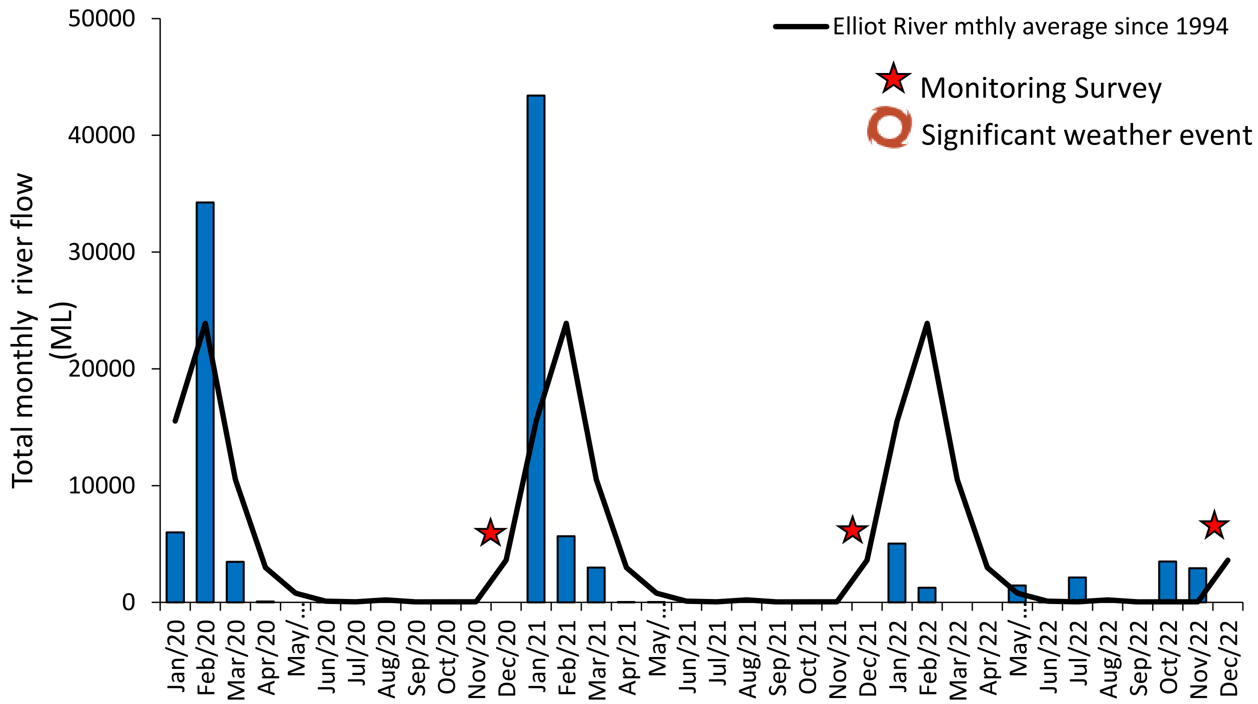

Figure 24b. Total monthly river discharge of the Elliot River from January 2020 to December 2022.

5.3.5 Root mean square – wave stress

Root mean square (RMS) is a relative indication of wave shear stress at the sea floor that is directly comparable between sites of different depths. RMS water height is not a measurement of wave height at the sea surface (Waltham et al. 2022). The summary data presented below is RMS water height at monitoring station AMB 1, within the offshore seagrass monitoring area. For the full suite of water quality monitoring stations and results see Waltham et al. (2022).

RMS at AMB 1 was recorded up until July 2022 by the ambient water quality monitoring program, five months before the seagrass survey. There were several peaks in maximum RMS (red line) in November 2021 and April 2022, however they were of a lower magnitude to those seen in the wet season in previous years (Figure 25). Peaks in RMS wave height can cause peaks in turbidity and sediment deposition (Waltham et al. 2022), however, the average monthly RMS was similar to the long-term average during 2022.

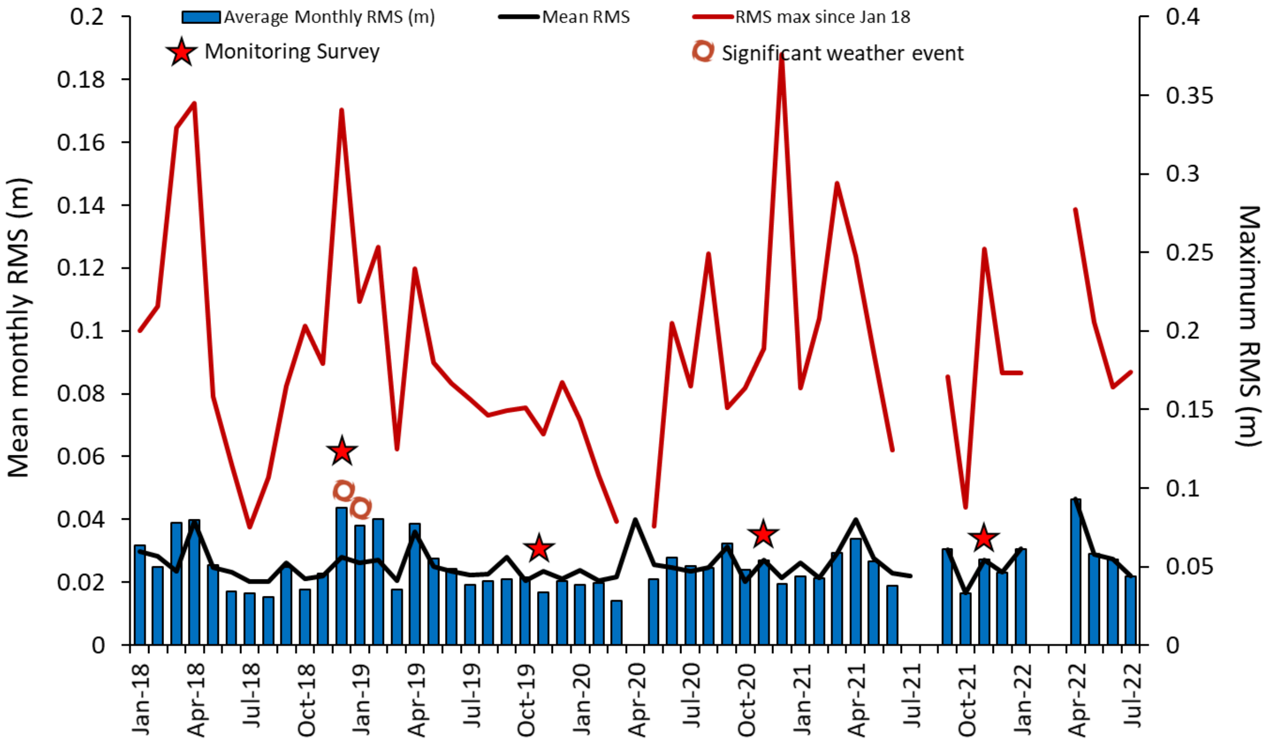

Figure 25. Mean monthly, long-term monthly mean, and maximum RMS recorded at Abbot Point water quality site AMB 1 January 2018 – July 2022.

6 DISCUSSION

In 2022 the Abbot Point annual seagrass monitoring meadows remained in a good condition for the third consecutive year. Seagrass condition indicators (biomass, area and species composition) for all annual monitoring meadows were in a good or better condition. An extensive footprint of seagrass was found in the greater port region and was similar to the previous broadscale survey conducted in 2019. Favourable environmental conditions for seagrass growth through most of 2022, as well as the healthy condition of seagrass leading into 2022 are likely to have contributed to seagrass remaining in good condition in the Abbot Point region in 2022.

The area of the two inshore *H. uninervis* monitoring meadows on either side of Abbot Point was the largest it has been in the program to date. Much of the increase in area has been due to the meadow landscape changing from patches of seagrass to are more continuous cover of seagrass throughout each area. The extent and biomass of the Euri Creek *Z. muelleri* meadow (Meadow 3) was similar to the previous year. This meadow has now fully recovered from the complete loss recorded following TC Yasi, with the key indicator species *Z. muelleri* returning to its highest level since the meadow was lost.

The offshore annual monitoring meadow has been similar across all condition indicators (biomass, area, and species composition) for the last two years. The most notable change in 2022 was the presence of *H. tricostata*. This species was last recorded in the 2016 broadscale survey. The annual monitoring in Townsville also recorded *H. tricostata* in the deeper meadows in 2022 (McKenna et al. 2023). These deeper meadows and their species are highly variable, and many are only present for part of the year (Chartrand et al. 2017; York et al 2015). *Halophila* species generally germinate and grow from a recruitment of seeds, or a sediment seed bank that can remain dormant in the sediment for parts of the year or between years until environmental conditions are suitable for growth (Chartrand et al. 2017; York et al 2015; Rasheed et al. 2014; Hammerstrom et al. 2006; Hammerstrom and Kenworthy 2003; McMillan 1991). *Halophila* fruits were found in abundance in the 2022 survey.

Seagrass in the broadscale survey area was of similar density, extent, and location to the previous broadscale survey in 2019. The community types of the meadows found in the greater region have also been similar between surveys with offshore meadows dominated by *H. spinulosa* and inshore meadows dominated by *H. uninervis*.

Local environmental conditions are a key factor in determining seagrass distribution, biomass, and health. The Abbot Point region has not experienced any damaging weather and climate events over the last three years that were prevalent from 2017-2019. For the most part, the region has experienced favourable conditions for seagrass growth over the last three years. Although there were some periods where rainfall and river flow were above long-term averages in the couple of months leading up to the 2022 survey, adverse effects from these events (i.e., low light) were not sustained long enough to be likely to have an impact on seagrass in the area. For example, in October when rainfall and river flow were above monthly averages, the light only fell below the threshold for *H. uninervis* for a maximum of six days allowing seagrass to maintain survival and growth.

Weather driven events that bring heavy rainfall, high river flow and flooding and wind-driven re-suspension of sediment are important environmental factors that can have a negative effect on seagrass as they can negatively impact water quality. These large events, particularly TC Debbie resulted in a decline in seagrass condition to very poor in 2017. Since then, both offshore and inshore meadows have been constantly improving in condition. Clearer water, particularly during the growing season from June to December results in seagrasses receiving light above their growing requirements allowing them to increase in condition

(Chartrand et al. 2017). The fact that both offshore and coastal seagrass meadows were in good condition indicate that light was above the minimum requirements (McKenna et al. 2015) throughout the growing season and this was supported by the inshore PAR levels recorded in the program.

The Queensland Ports seagrass monitoring program uses consistent state-wide monitoring methodology. Abbot Point is part of this broader Queensland Ports program, and this enables comparisons with regional and state-wide trends to put local changes into context. It also provides a key input into the condition and trend of seagrasses in the Mackay Whitsunday Isaac NRM region, an area which otherwise has a poor coverage for seagrass assessment and condition. Monitoring at other sites has shown a range of results during 2022. Coastal areas to the north of Abbot Point had seagrass in good condition (e.g., Cairns Harbour - Reason et al. 2023; and Townsville – McKenna et al. 2023). Coastal areas to the south had seagrass in a satisfactory condition such as Hay Point and Gladstone Harbour (York et al. 2023; Smith et al. 2023). These were the only ports that had a decline in condition between 2021 and 2022. Seagrass in the Gulf of Carpentaria in Weipa and Karumba were in a good and very good condition also due to favourable climate conditions (Reason et al. 2022; Scott et al. 2023).

The good condition of seagrasses in the Abbot Point region for the past few years was likely due to ongoing favourable growing conditions in the area. Consecutive years of healthy seagrass condition means that they likely maintained high levels of resilience to natural and anthropogenic pressures in 2023.

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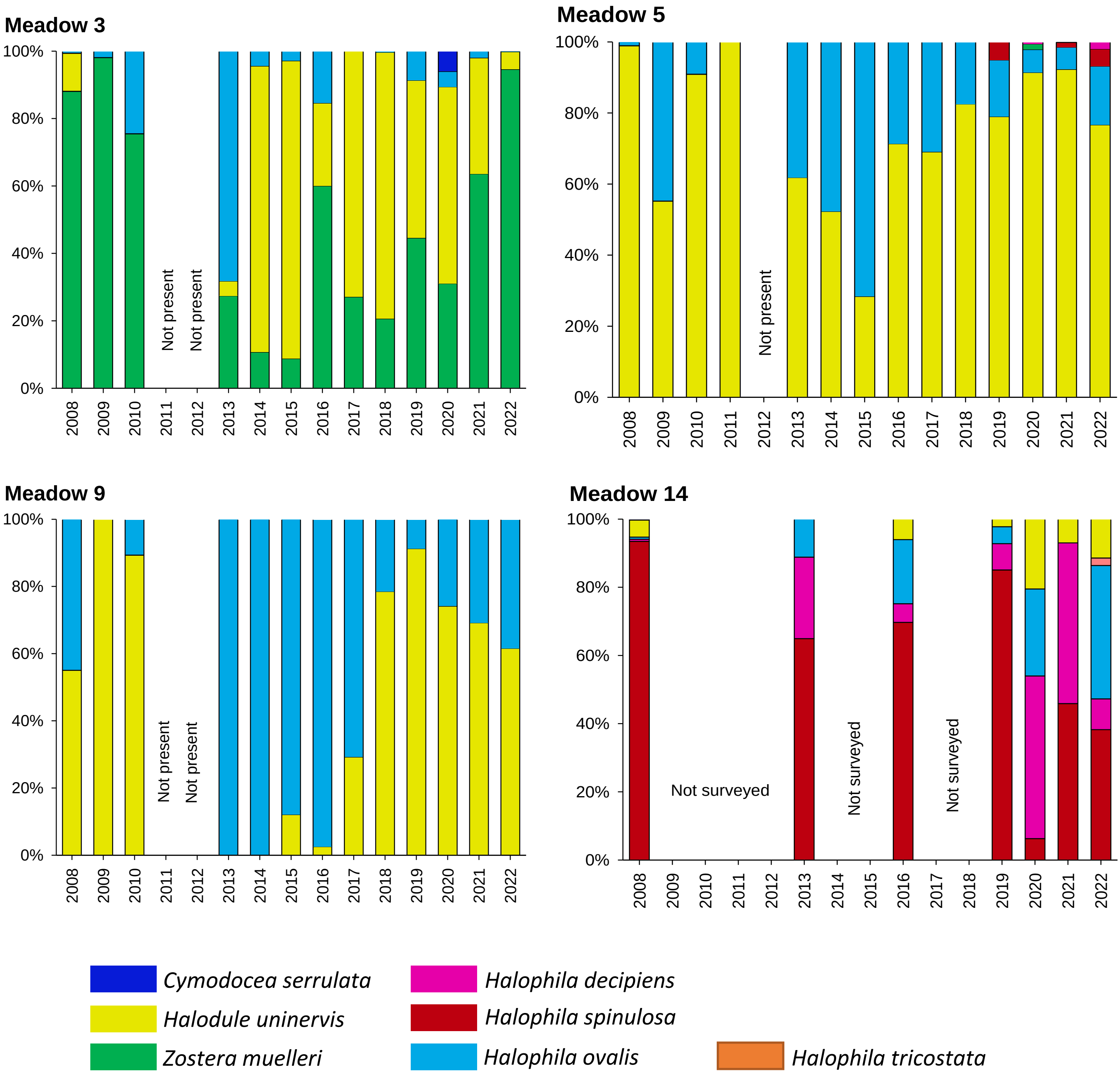
8 APPENDICES

8.1 Species composition of inshore and offshore monitoring meadows



8.2 Biomass and area of annual monitoring meadows

8.2.1 Mean biomass of monitoring meadows in the Abbot Point region

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)

NP – No seagrass present in meadow; NS – Seagrass meadow not surveyed (offshore meadows have only been surveyed in whole-of-port surveys: 2008, 2013, 2016, 2019, 2020, 2022. Offshore meadow 14 has was added to the long-term monitoring program in 2020.)

8.2.2 Area (ha) of monitoring meadows in the Abbot Point region

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