Seagrass Habitat of Mourilyan Harbour: Annual Monitoring Report 2024

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Annual Monitoring Report 2024

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KEY FINDINGS

Seagrass Condition 2024

Very Poor

1. In 2024, the overall seagrass condition in Mourilyan Harbour remained very poor, continuing the poor health of these important ecosystems since major climate related losses from 2007-2010.
2. Seagrass was present in three of the five long-term monitoring meadows, however, condition within all these meadows was classified as very poor when benchmarked against the long-term baselines.
3. There was a slight improvement in biomass in *Z. muelleri* dominated Bradshaw Meadow (1) due to seagrass restoration efforts, however, meadow extent was still well below the long-term average and had declined over the last year due to the loss of some restored patches following strong wet-season conditions.
4. Restoration of *Z. muelleri* is scheduled to continue in the Bradshaw and Lily meadows in 2025 as part of a four-year program led by JCU and including local Traditional Owner and community groups.
5. Seagrasses in the region were likely impacted by turbid flood plumes reducing light for photosynthesis and freshwater intrusions due to high rainfall following Tropical Cyclone Jasper in December 2023 and further flooding in March 2024.
6. Current seagrass condition was unlikely to be related to port operations with the major losses and declines associated with previous La Niña climate events and more recent wet weather and river flows.

IN BRIEF

Seagrasses in Mourilyan Harbour have been monitored annually since 2000, following initial assessments conducted between 1993 and 1996. Five seagrass meadows are monitored annually, and the entire port limits area is surveyed every three years. These meadows represent the range of different seagrass community types found in Mourilyan Harbour and are assessed for changes in biomass, area, and species composition. These indicators are used to develop a seagrass condition index.

Overall seagrass condition in Mourilyan Harbour remained very poor in 2024, with further declines from 2023. Seagrass was present in only three of the five annual monitoring meadows and continued to be in very low abundance. The number of small, restored patches of *Zostera muelleri* in Bradshaw (1) meadow declined, with only one dense patch remaining, compared to five patches observed the previous year. Seaforth Bank (3) and Lily (2) meadows were both entirely absent. While Seaforth Edge (4) retained a good biomass score, it had a substantially reduced footprint and was dominated by *Halophila decipiens*. Channel (5) meadow persisted in scattered patches with poor overall condition due to limited area.

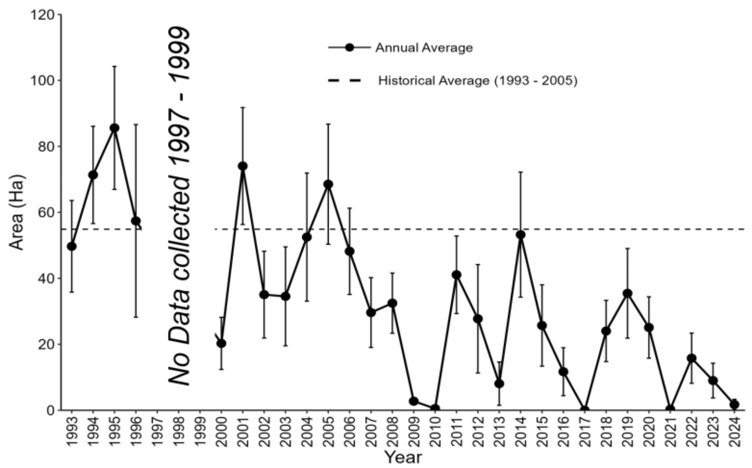

FIGURE 1: MOURILYAN HARBOUR SEAGRASS MONITORING MEADOW TOTAL AREA (HA) FROM 1993 TO 2024.

Environmental conditions leading into the 2024 survey were challenging for seagrass growth, with above-average rainfall, elevated river flow, and warm annual temperatures. These factors likely contributed to increased turbidity, reduced light availability, stress from desiccation when intertidal meadows were exposed to low tides and freshwater intrusions. While long-term seagrass condition has remained poor, narrow bands of *Halodule uninervis, Halophila decipiens* and isolated *Enhalus acoroides* patches outside the core monitoring areas continue to persist and may play a role in future recovery.

In the Bradshaw meadow, restoration efforts have led to the presence of Z. *muelleri* for four consecutive years, although distribution declined for the first time over the last year. A large-scale, multi-year restoration program launched in August 2023 aims to expand this recovery effort into the Lily Island and Bradshaw meadows. Further planting was conducted in August- September 2024 just prior to this monitoring survey. However, the program faced setbacks in the past two years due to the impacts of ex-Tropical Cyclone Jasper and prolonged high rainfall conditions continuing through the 2024-25 wet season.

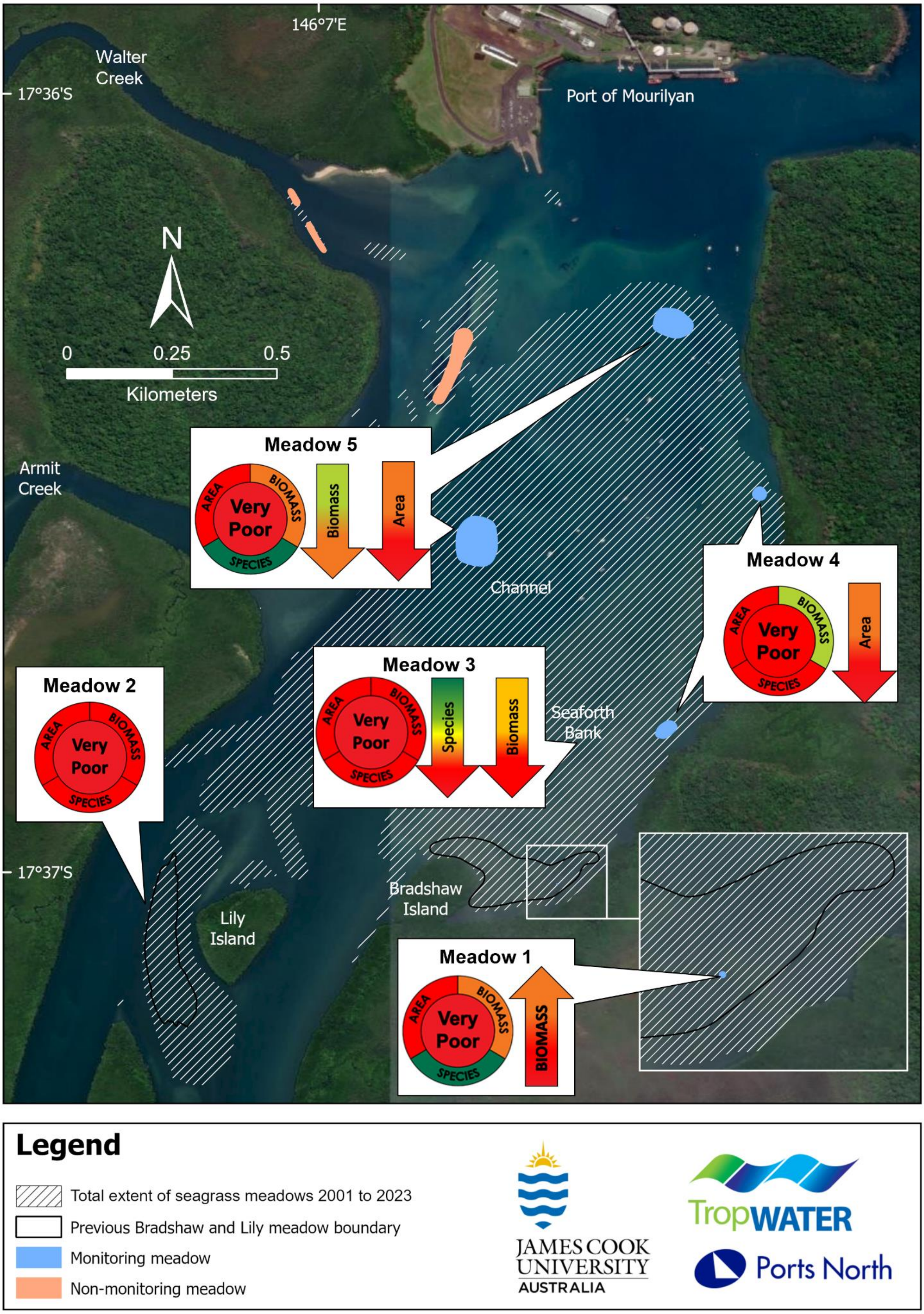

FIGURE 2. SEAGRASS CONDITION FOR MOURILYAN HARBOUR SEAGRASS MEADOWS IN 2024

TABLE OF CONTENTS

1 INTRODUCTION

Seagrasses are one of the most productive marine habitats on earth and provide a variety of important ecosystem services worth substantial economic value (Costanza et al. 2014). These services include the provision of nursery habitat for economically important fish and crustaceans (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; Scott et al. 2020). 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), 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 (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 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).

1.1 QUEENSLAND PORTS SEAGRASS MONITORING PROGRAM

The majority of Queensland's commercial ports have a long-term seagrass monitoring program. The program was developed by the Seagrass Ecology Group at James Cook University's (JCU) Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) in partnership with the various Queensland port authorities. A common program, methods and rationale provides a network of seagrass monitoring locations comparable across the state (Figure 3).

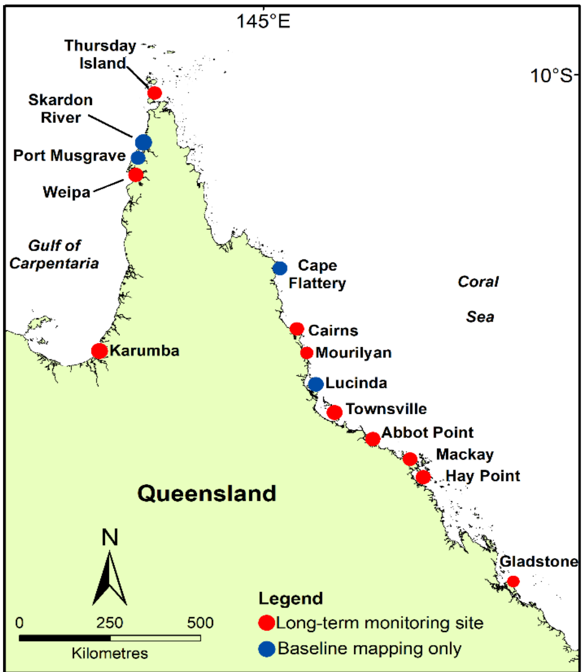

Figure 3. Location of Queensland ports seagrass monitoring locations.

A strategic long-term assessment and monitoring program for seagrass provides port managers and regulators with key information to ensure effective management of seagrass habitat. This information is often central to planning and implementing port development and maintenance programs that ensure minimal impact on seagrass.

The program provides an ongoing assessment of many of the most vulnerable seagrass communities in Queensland, and feeds into regional assessments of the status of seagrass. The program also has provided significant advances in the science and knowledge of tropical seagrass ecology. This includes the development of tools, indicators, and thresholds for the protection and management of seagrass, and an understanding of the drivers of seagrass change.

For more information on the program and reports from other monitoring locations, see https://www.tropwater.com/themes/seagrass-habitats

1.2 MOURILYAN HARBOUR MONITORING PROGRAM

Initial seagrass surveys were conducted between 1993 and 1996, then an annual monitoring program was established in 2000. Five meadows were selected for annual monitoring that represented the range of seagrass species and habitat types (intertidal and subtidal) identified within the port limits. This monitoring program has provided critical information on variation in seagrass communities and the links between seagrass change and climate.

Seagrass monitoring is conducted between October and December each year and provides an assessment of seagrass condition and resilience that informs port management. Expanded seagrass surveys occur periodically to assess the state of seagrass across the whole harbour; these were most recently conducted in 2015, 2018 and 2021. The current 2024 survey was also a whole of harbour survey.

Results of the program also contribute an important information feed on estuarine seagrass condition for the Wet Tropics Healthy Waterways annual report card.

This report presents findings from the 2024 monitoring survey, including:

- Maps of seagrass distribution, abundance, and species composition within the annual monitoring meadows;
- Assessments and comparison of seagrass condition in the monitoring meadows within the context of historical seagrass conditions, and discussion of the observed changes in a regional and state-wide context;
- Comparison with previous whole of harbour surveys of the extent and composition of seagrass meadows not included in annual monitoring meadows;
- Overview of environmental conditions that are likely to impact seagrass condition;
- Discussion of the implications of monitoring results in relation to the overall health of the marine environment in the harbour, and advice for management.

2 METHODS

2.1 FIELD SURVEYS

The survey involved mapping and assessing the five annual monitoring meadows and other non-monitoring meadows in Mourilyan Harbour during the seasonal peak of seagrass growth. Aerial surveys were conducted on 19th September and boat-based surveys on 2nd, 21st October and 11th December 2024. Survey methods followed the established techniques for TropWATER's Queensland-wide seagrass monitoring programs.

Intertidal meadows were surveyed at low tide using a helicopter. GPS was used to map the position of meadow boundaries and survey sites. Sites were scattered haphazardly within each meadow and surveyed while the helicopter hovered less than one metre above the substrate (Figure 4a). Subtidal seagrass was sampled by boat using camera drops and van Veen grab (Figure 4b, 4c). Subtidal sites were positioned at ~50 - 100 m intervals running perpendicular from the shoreline, or where major changes in bottom topography occurred, and extended offshore beyond the edge of each meadow. Random sites also were surveyed within each meadow. The details recorded at each site are listed in Section 2.3.1.

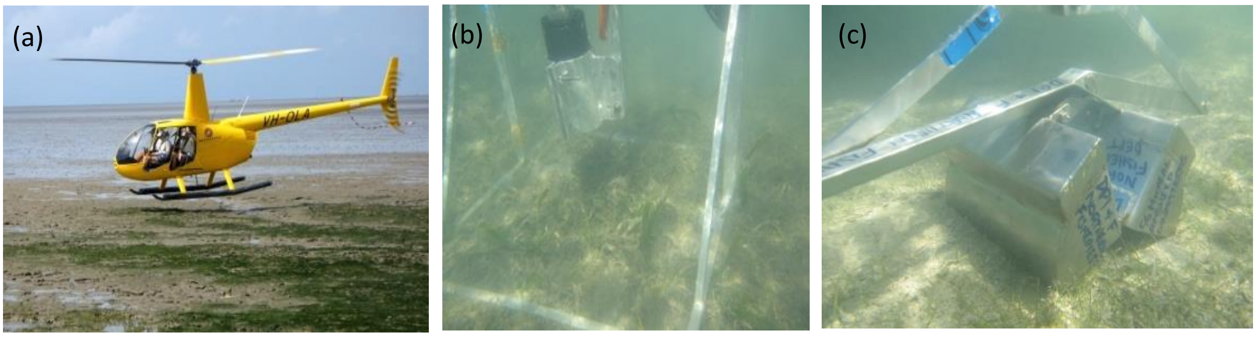

FIGURE 4: SEAGRASS MONITORING METHODS. (A) HELICOPTER SURVEY OF INTERTIDAL SEAGRASS; (B, C) BOAT-BASED CAMERA DROPS AND VAN VEEN GRAB FOR SUBTIDAL SEAGRASS.

2.2 SEAGRASS BIOMASS

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

At the survey's completion, the observer ranked a series of calibration quadrat photographs representative of the range of seagrass biomass and species composition observed during the survey. These calibration quadrats had previously been harvested and the above-ground biomass weighed in the laboratory. A separate regression of ranks and biomass from the calibration quadrats was generated for each observer and applied to the biomass ranks recorded in the field. Field biomass ranks were converted into above-ground biomass estimates in grams dry weight per square metre (g DW m^{-2}) for each of the three replicate quadrats per site. Site biomass, and the biomass of each species at the site, is the mean of the three replicates.

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, biomass interpolation layer and meadow layer.

2.2.1 SITE LAYER

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

- Site number
- Temporal details – Survey date and time.
- Spatial details – Latitude, longitude, depth below mean sea level (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.

2.2.2 Interpolation layer

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

2.2.3 Meadow layer

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

- Meadow ID number – A unique number assigned to each meadow to allow comparisons among surveys.
- Temporal details – Survey date.
- Habitat information – Mean meadow biomass ± standard error (SE), meadow area (hectares) ± reliability estimate (R) (Table 1), number of sites within the meadow, seagrass species present, meadow community type and density (Tables 2, 3), and meadow landscape category (Figure 5).
- Sampling method and any relevant comments.

Meadow boundaries were constructed using GPS marked meadow boundaries where possible, seagrass presence/absence site data, field notes, and aerial photographs taken during helicopter surveys. Meadow area was determined using the calculate geometry function in ArcGIS®. Meadows were assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow (Table 1). Mapping precision ranged from 1 m for intertidal seagrass meadows with boundaries mapped by helicopter to ± 30 m for subtidal meadows with boundaries mapped by distance between sites with and without seagrass. The mapping precision estimate was used to calculate a buffer around each meadow representing error; the area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Meadows were described using a standard nomenclature system developed for Queensland's seagrass meadows. Seagrass community type was determined using the dominant and other species' percent contribution to mean meadow biomass (for all sites within a meadow) (Table 2). Community density was based on mean biomass of the dominant species within the meadow (Table 3).

Table 1. Mapping precision and method for Mourilyan Harbour seagrass meadows.

Mapping precision	Mapping method
0.5 m	Intertidal meadows completely exposed or visible at low tide; High resolution drone photogrammetry aided in mapping; Meadow boundaries determined by orthomosaic imagery;
± 3 - 5 m	Intertidal meadows completely exposed or visible at low tide; Aerial photography aided in mapping; Meadow boundaries determined from helicopter; High density of mapping and survey sites;
± 20 m	Some intertidal meadow boundaries determined from helicopter; Most meadow boundaries determined from camera/grab surveys; Patchy cover of seagrass throughout meadow; Moderate density of survey sites; Recent aerial photography aided in mapping.

TABLE 2. NOMENCLATURE FOR SEAGRASS COMMUNITY TYPES IN MOURILYAN HARBOUR.

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

TABLE 3. DENSITY CATEGORIES AND MEAN ABOVE-GROUND BIOMASS RANGES FOR EACH SPECIES USED IN DETERMINING SEAGRASS MEADOW DENSITY IN MOURILYAN HARBOUR.

Density	Mean above-ground biomass (g DW m^{-2})				
	Halodule uninervis (narrow)	*Halophila ovalis/ Halophila decipiens*	*Halodule uninervis* (wide)	*Zostera muelleri*	*Enhalus acoroides*
Light	< 1	< 1	< 5	< 20	< 40
Moderate	1 - 4	1 - 5	5 - 25	20 - 60	40 - 100
Dense	> 4	> 5	> 25	> 60	> 100

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.

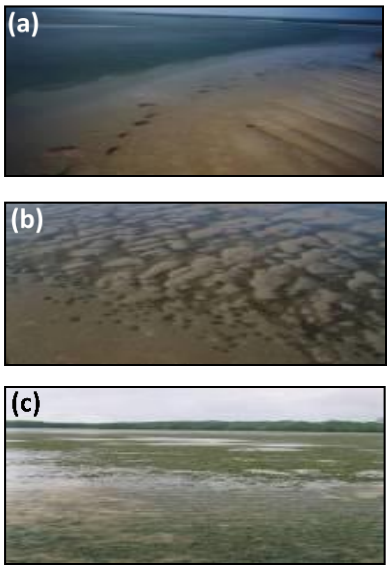

FIGURE 5. SEAGRASS MEADOW LANDSCAPE CATEGORIES: (A) ISOLATED SEAGRASS PATCHES, (B) AGGREGATED SEAGRASS PATCHES, (C) CONTINUOUS SEAGRASS COVER.

2.3 SEAGRASS 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 in Mourilyan Harbour was scored from 0 to 1 and assigned one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor). Overall meadow condition is the lowest indicator score where this is driven by biomass or area. Where species composition is the lowest score, it contributes 50% of the overall meadow score, and the next lowest indicator (area or biomass) contributes the remaining 50% (Carter et al. 2023).

2.4 ENVIRONMENTAL DATA

Temperature, river flow and tidal exposure are environmental conditions that impact seagrass biomass and distribution (Rasheed & Unsworth 2011). Increased rainfall and flooding events can cause sudden changes in water quality, in particular increased turbidity that reduces the light available for photosynthesis (Campbell & McKenzie 2004; Waycott et al. 2007; Cardoso et al. 2008; Rasheed et al. 2014; Mckenna et al. 2015). Increased direct sunlight during tidal exposure can severely reduce above ground biomass through burning seagrasses (Stapel & Manuntun 1997). When all seasonal data is combined poor correlations were found between seagrass productivity and seasonal water temperatures (Lee et al. 2007), however, numerous researchers consider temperature to play a vital role in seasonal growth and signalling stages within their life cycle (Lee et al. 2007; Lee & Dunton 1996). As part of the monitoring program we examine available data on these environmental factors, to provide insight on their potential influencing on seagrass condition.

Tidal data was provided by Maritime Safety Queensland (MSQ) (© The State of Queensland (Department of Transport and Main Roads) 2024, Tidal Data) for Mourilyan (MSQ station #063012A; www.msq.qld.gov.au). This data allows us to calculate daytime tidal exposure of intertidal meadows. Assuming intertidal banks become exposed at a tide height of 0.8m above Lowest Astronomical Tide.

Total daily rainfall (mm), temperature and solar exposure was obtained for the nearest weather station from the Australian Bureau of Meteorology (Innisfail station #32197 and #032025) (BOM 2025). Daily global solar exposure is a measure of the total amount of solar energy falling on a horizontal surface. The values are usually highest in clear, sunny conditions during the spring/summer prior to the wet season and lowest during winter. River-flow data is unavailable for the Moresby River which flows directly into Mourilyan Harbour, so flow for the nearby South Johnstone River (recorded at Upstream Central Mill, 2001 – 2024), which flows to the north of Mourilyan Harbour, is presented instead. South Johnstone River flow data (gigalitres; GL) was obtained from the Department of Regional Development, Manufacturing and Water. (Station #112101B; https://water-monitoring.information.qld.gov.au/)

3 RESULTS

3.1 SEAGRASSEES IN MOURILYAN HARBOUR

In 2024, seagrass was present at 11 of the 386 sites surveyed 2.85% (Figure 6). The annual monitoring meadows had a total area of 1.73 ± 1.57 ha, which is well below the long-term average of 54 ha (Figure 1). Seagrass species found in the monitoring meadows include *Halophila ovalis*, *Halophila decipiens* and *Zostera muelleri*, while *Halodule uninervis* was observed outside of the monitoring meadows (Figures 6 and 7).

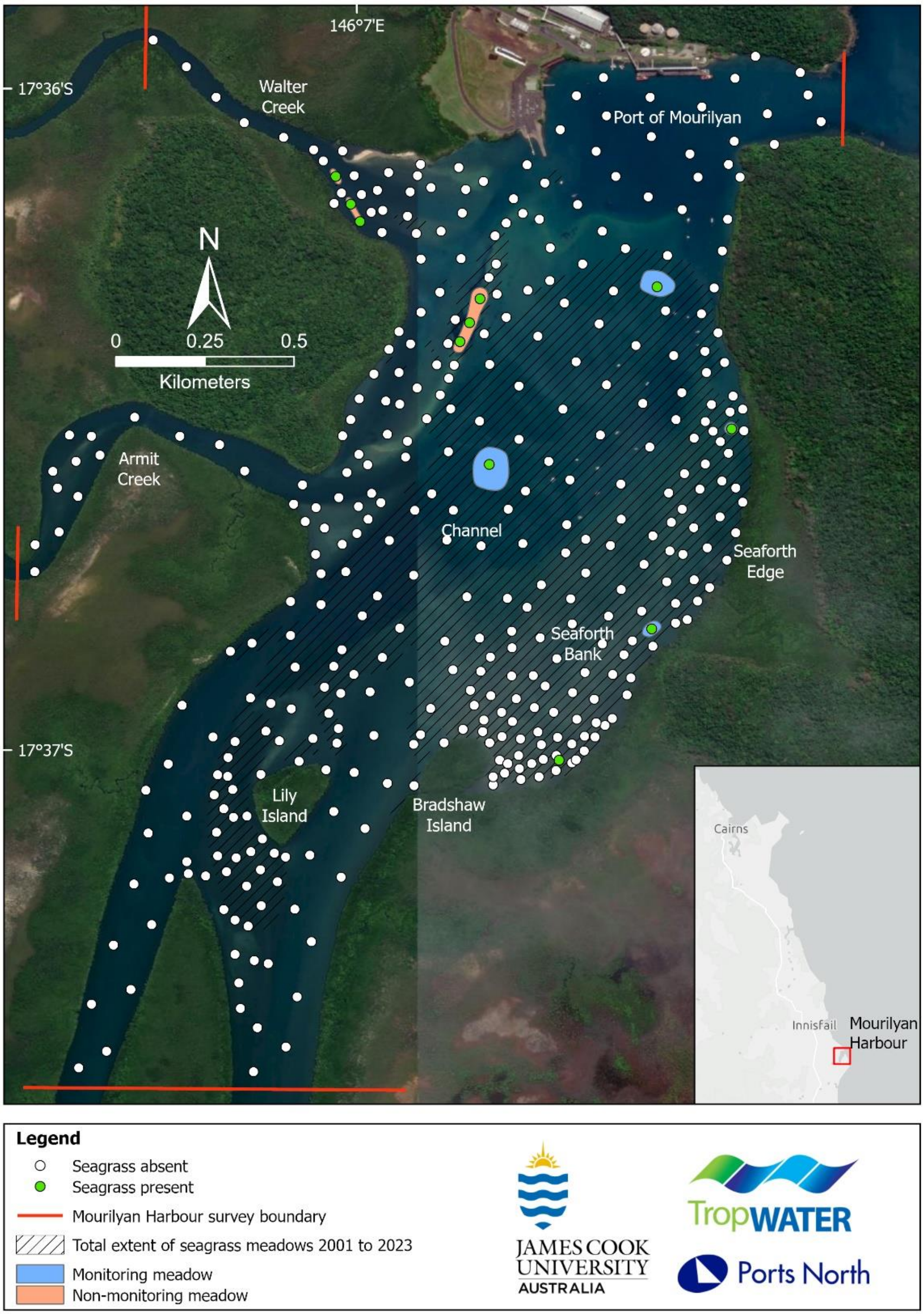

FIGURE 6. SEAGRASS PRESENCE/ABSENCE AT SURVEY SITES, 2024.

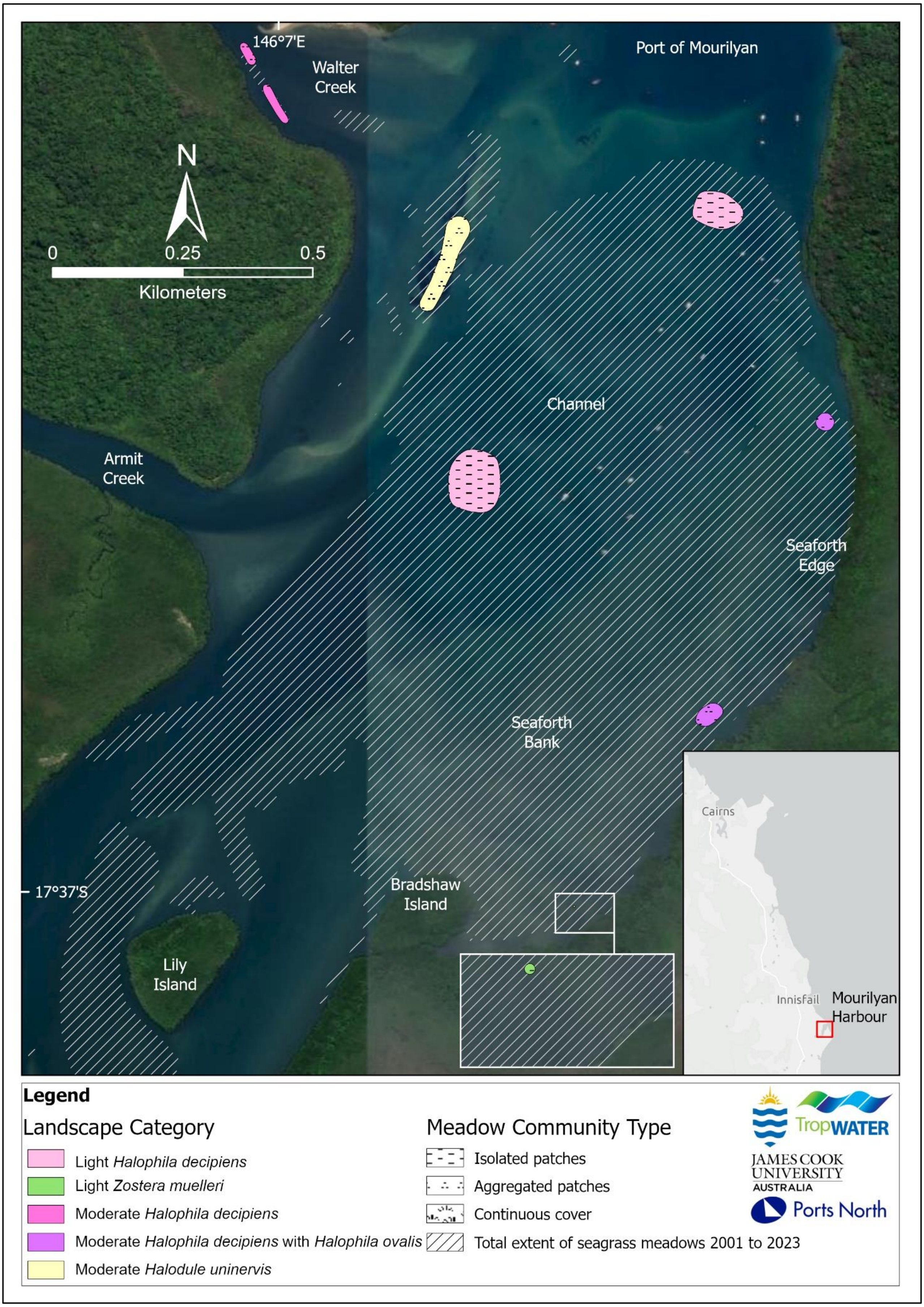

FIGURE 7. MOURILYAN HARBOUR SEAGRASS DISTRIBUTION AND COMMUNITY TYPE FOR ALL MAPPED MEADOWS, 2024.

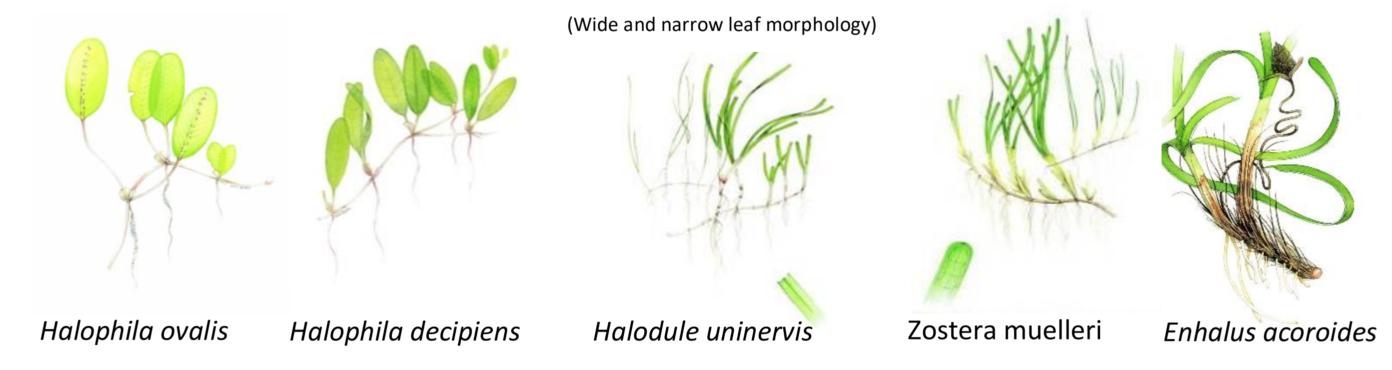

FIGURE 8. SEAGRASS SPECIES PRESENT IN MOURILYAN HARBOUR, 2024.

3.2 SEAGRASS CONDITION FOR ANNUAL MONITORING MEADOWS

Seagrass overall was in a very poor condition in Mourilyan Harbour in 2024. Three of the five monitoring meadows had seagrass presence with Lily (2) and Seaforth Bank (3) having no seagrass in 2024. The extent and biomass of seagrass in the meadows that were present remain below baseline conditions. The condition of Bradshaw (1), Lily (2), Seaforth Bank (3), Seaforth Edge (4) and Channel (5) were all very poor (Table 4).

TABLE 4. GRADES AND SCORES FOR CONDITION INDICATORS (BIOMASS, AREA AND SPECIES COMPOSITION) FOR MOURILYAN HARBOUR MONITORING MEADOWS, 2024.

Meadow	Biomass Score	Area Score	Species Composition Score	Overall Meadow Score
1 - Bradshaw	0.28	0.00	1.00	0.00
2 - Lily	0.00	0.00	0.00	0.00
3 - Seaforth Bank	0.00	0.00	0.00	0.00
4 - Seaforth Edge	0.73	0.11	0.24	0.11
5 - Channel	0.42	0.06	1.00	0.06
Mourilyan Harbour Overall Score				**0.09**

In 2024, biomass increased slightly in the Bradshaw Island meadow (1) but was still in poor condition with *Z. muelleri* recorded at 1 dense isolated patch, a decrease from 5 the previous year (Figure 2; Figure 9). This is the fourth consecutive year seagrass has been detected and is a result of the spread and growth from seagrass restoration activities. The condition grade of species composition remains very good, however, due to the small footprint of the isolated patches the area remains in a very poor condition, and so does the overall condition grade for this meadow (Table 4; Figure 9; Appendix 6.2, 6.3). This meadow was dominated by *Z. muelleri* up until climate events in 2009 – 2010 resulted in complete meadow loss with seagrass failing to return naturally for over a decade.

The Lily Island meadow (2) remained absent in 2024 and therefore in a very poor condition. This is the fourth year in a row this meadow has been completely absent. Since 2009 there have been small, isolated patches of *Halophila* species within and just outside the meadow, however, in 2024 there were no signs of this colonising species (Table 4; Figure 10). This intertidal meadow was once dominated by *Z. muelleri* and this foundation species has been absent since 2009 (Figure 10; Appendix 6.2, 6.3).

The Seaforth Bank Meadow, usually dominated by *H. ovalis*, (3) was absent in 2024 (Table 4, Figure 11). Several isolated patches of *Enhalus acoroides* remain present in the same locations that has been observed previously, however, this species is not part of the long-term monitoring condition assessment as it falls outside of the meadow stable state species classification.

The Seaforth Edge meadow (4) remained in very poor condition in 2024 (Table 4; Figure 12). The biomass condition remained in a good condition and close to the baseline level (Table 4; Figure 12). Species condition remained very poor with less stable *H. decipiens* dominant in 2024, however, this is historically a *H. ovalis* meadow. The footprint of this meadow dropped and is still well below long-term average levels resulting in a very poor condition (Table 4; Figure 7; Figure 12). Since 2000 the presence of seagrass has been intermittent with multiple years without seagrass from 2012 to 2017 and species composition has alternated between colonising species *H. ovalis* and *H. decipiens* (Figure 12, Appendix 6.2, 6.3).

The Channel meadow (5) remained in an overall poor condition in 2024 (Table 4; Figure 13). Biomass was in a poor condition and species composition was in a very good condition with *H. decipiens* traditionally dominating these meadows (Table 4; Figure 13). The footprint of this meadow remains substantially below the long-term average and spread throughout the channel in isolated patches resulting in a very poor condition score (Figure 13). This meadow has been absent in the past in 2009, 2017 and 2021 and has managed to return by the following season due to the colonising nature of the *H. decipiens* species found here.

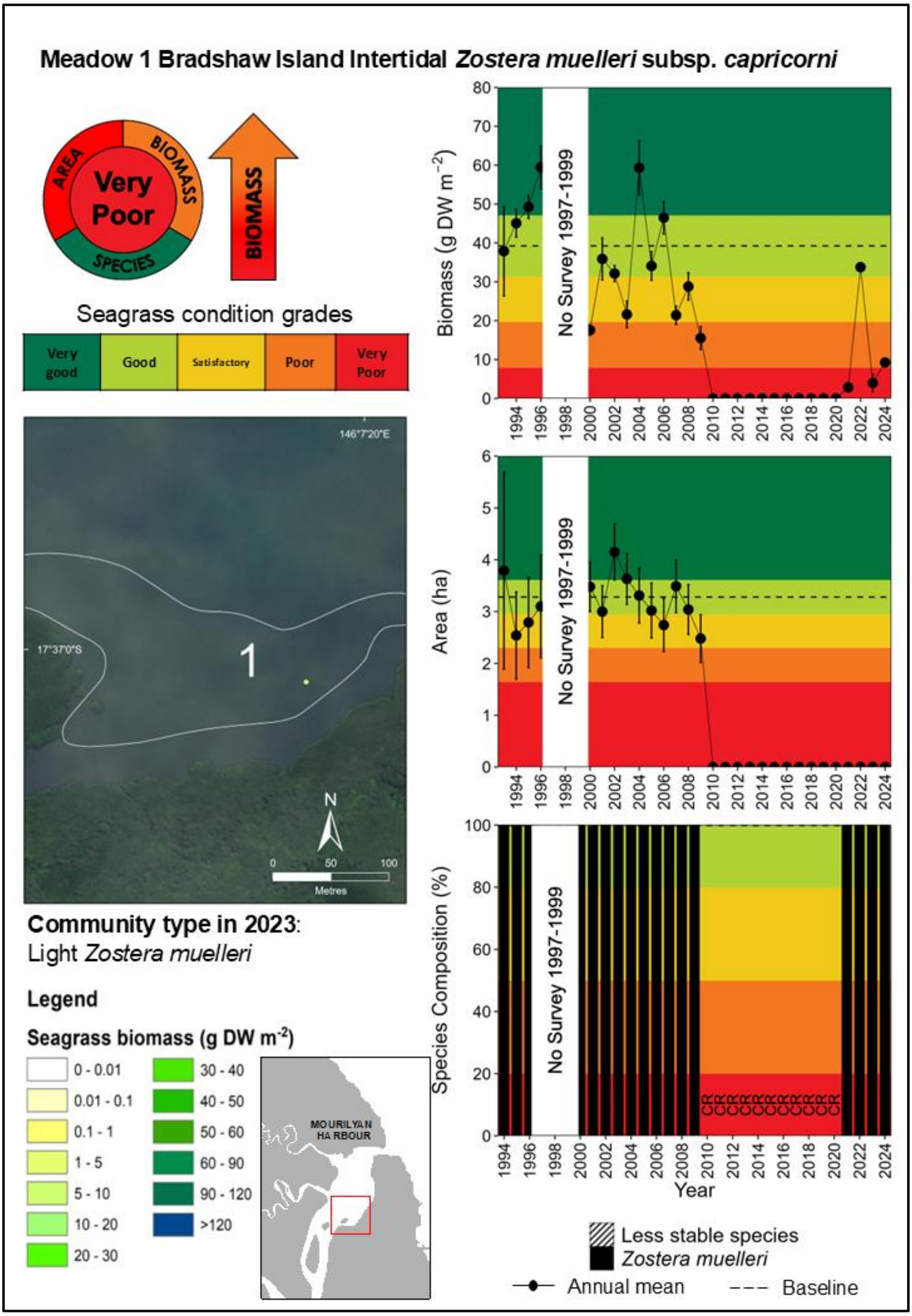

FIGURE 9. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE BRADSHAW ISLAND MEADOW FROM 1993 – 2024 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

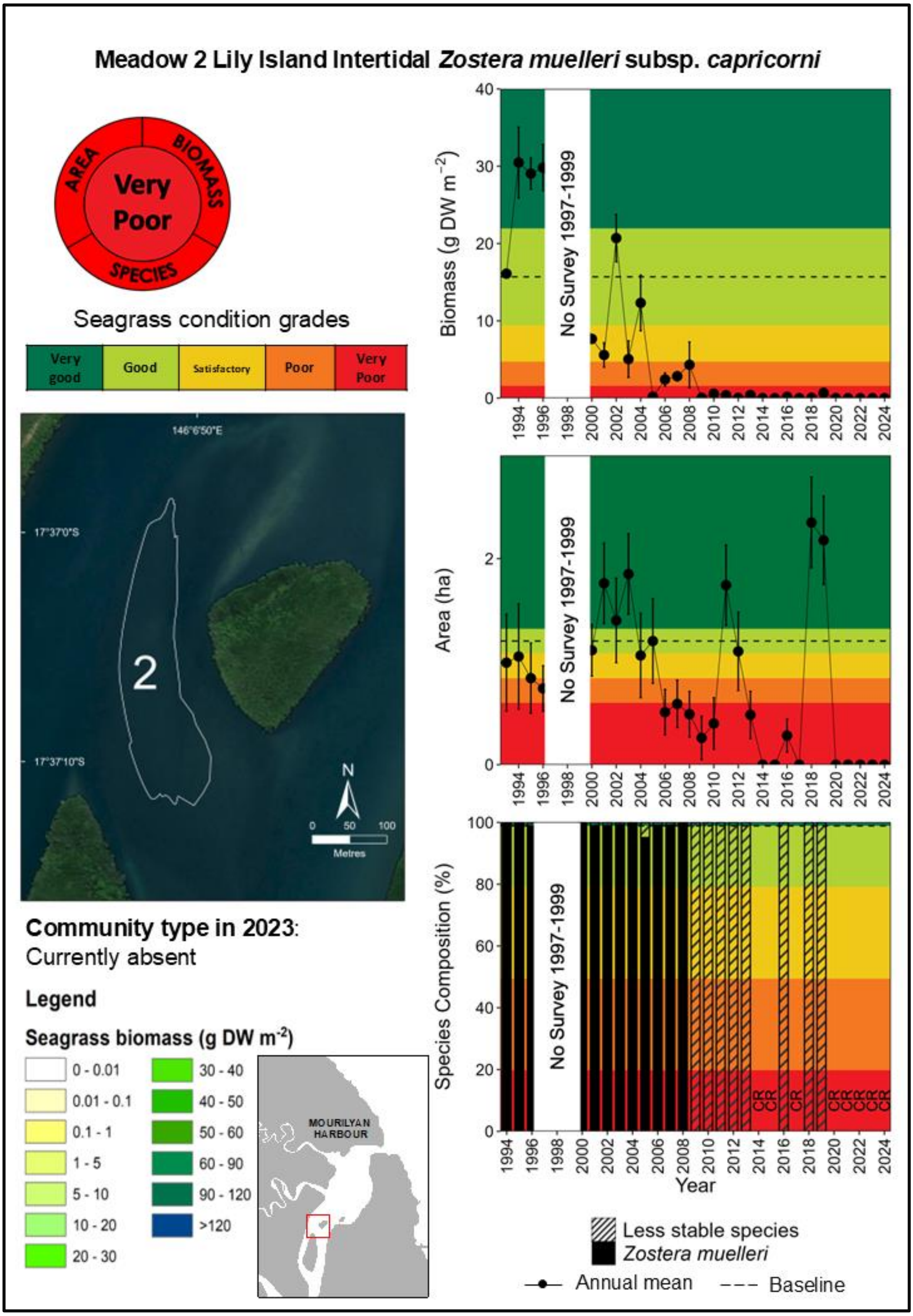

FIGURE 10. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE LILY ISLAND MEADOWS FROM 1993 – 2024 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

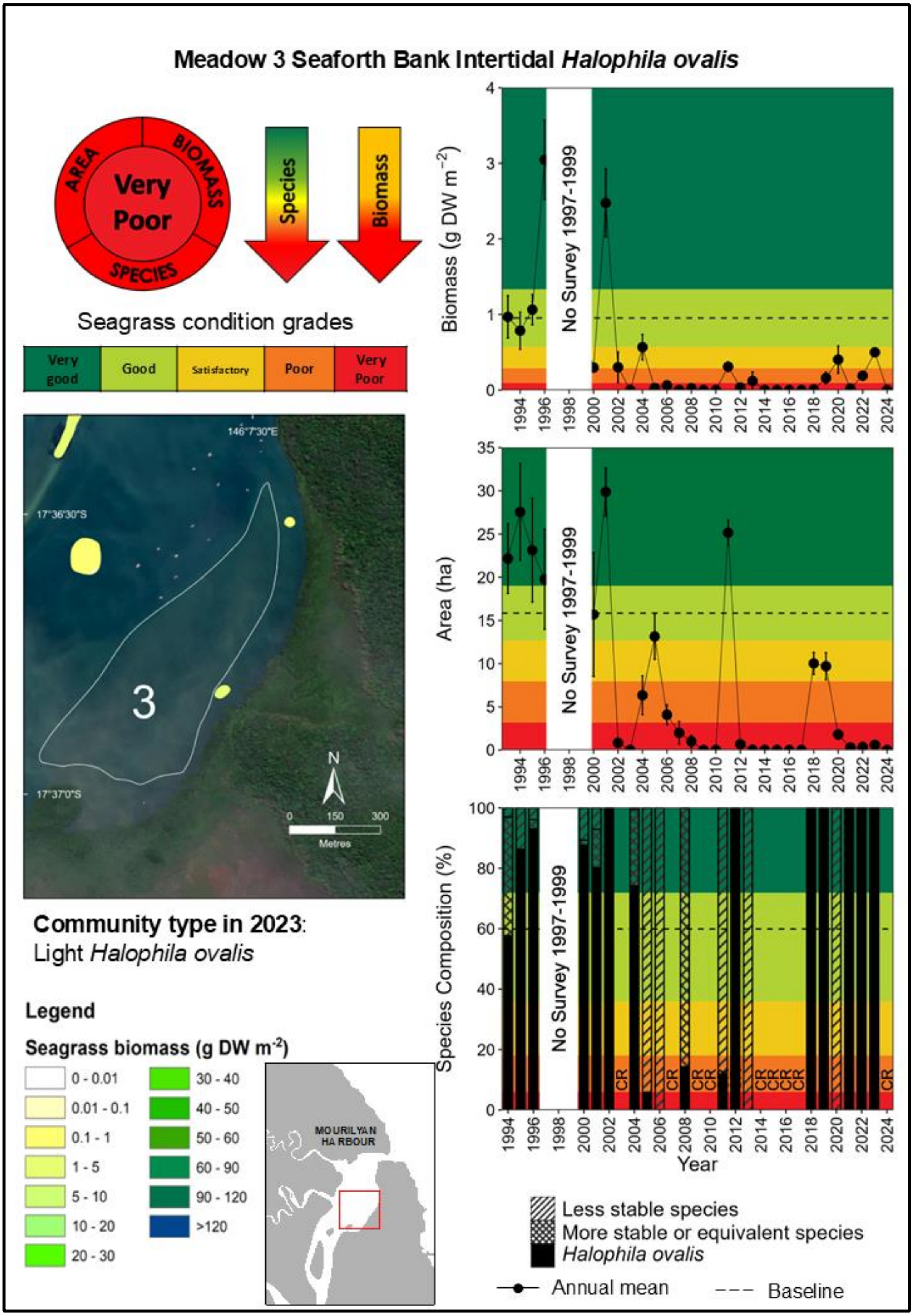

FIGURE 11. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR SEAFORTH BANK MEADOW FROM 1993 – 2024 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

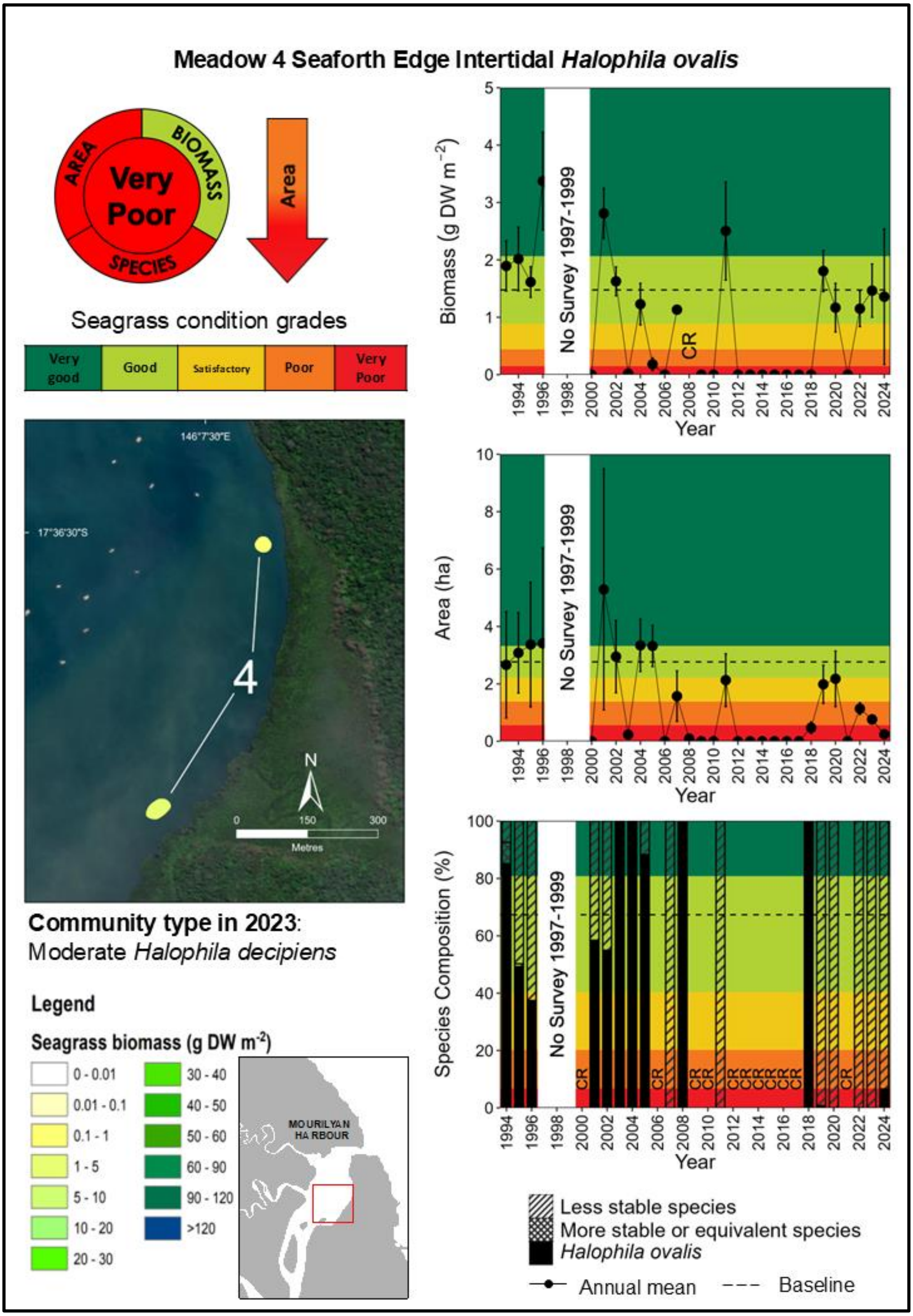

Figure 12. Changes in biomass, area and species composition for the Seaforth Edge meadow from 1993 – 2024 (biomass error bars = SE; area error bars = "R" reliability estimate). The community type in bold at top represents the baseline community type. CR = calculation restriction due to seagrass absence.

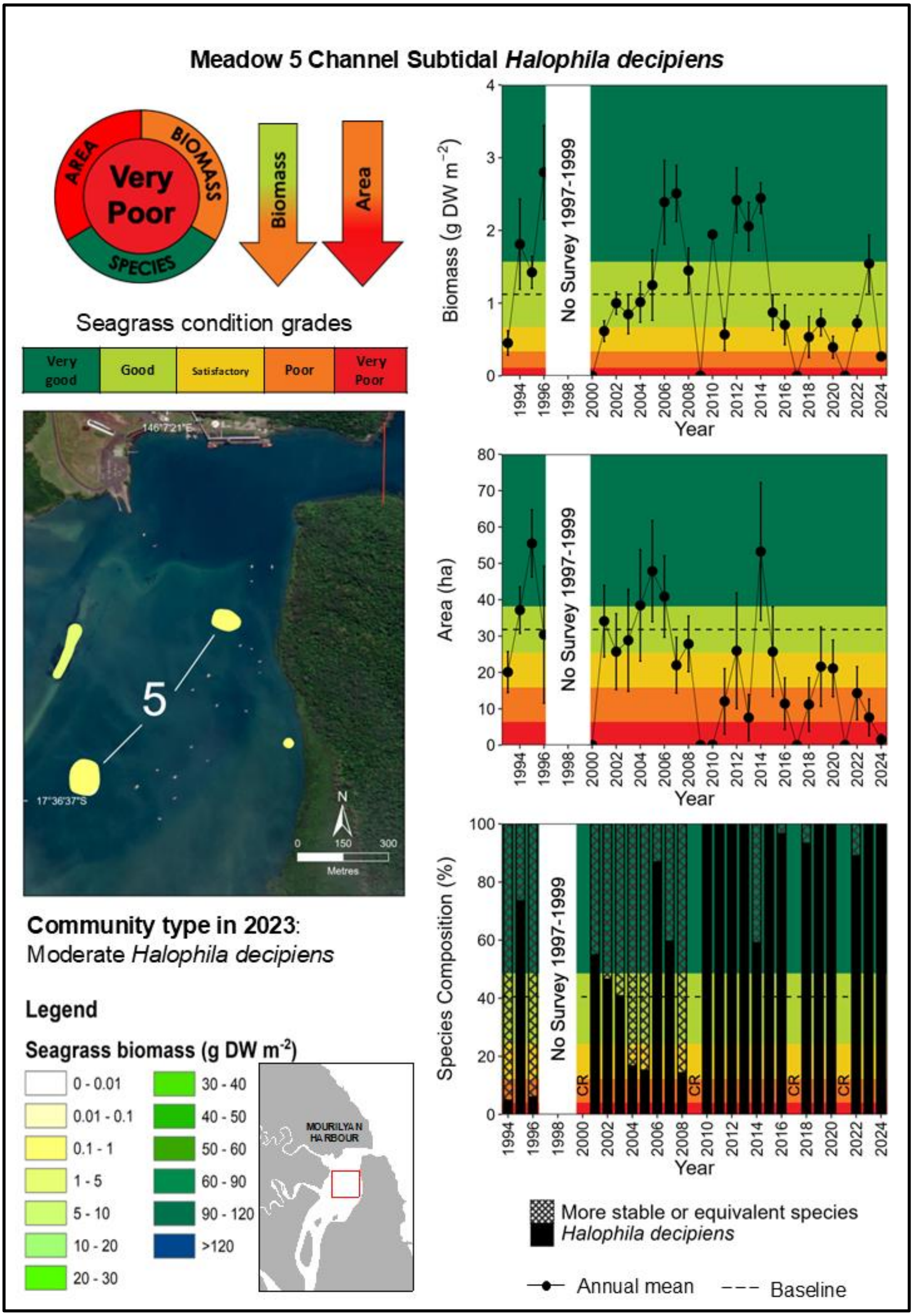

FIGURE 13. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE CHANNEL MEADOW FROM 1993 – 2024 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

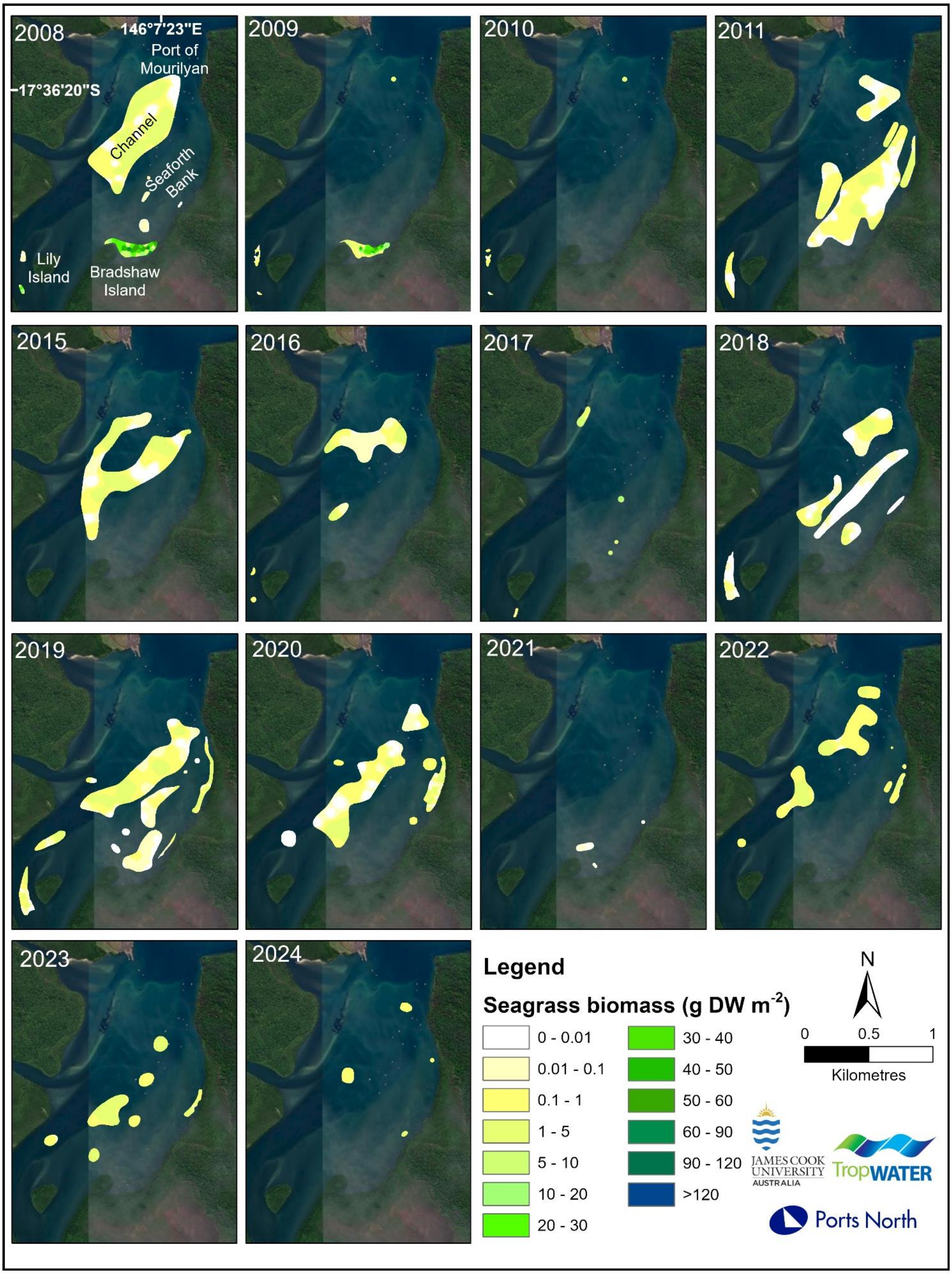

FIGURE 14. CHANGE IN SEAGRASS DISTRIBUTION OVER TIME (2008-2011, 2015-2024) IN MOURILYAN HARBOUR.

3.3 SEAGRASS IN THE WHOLE HARBOUR AREA

In addition to the five long-term monitoring meadows assessed annually (see Section 3.2), two other seagrass meadows were mapped within the whole of Mourilyan Harbour area (Figure 7). This included a narrow band of *H. decipiens* in the mouth of Walter Creek and an intertidal meadow of *H. uninervis* on the sandbanks to the west of the main channel between Walter Creek and Armit Creek (Figure 7). The persistent patches of *E. acoroides* along Seaforth Bank were not recorded in this survey, but were observed to still occur shortly afterwards during monitoring surveys for seagrass restoration. The *H. uninervis* meadow was present during many of the previous whole of harbour surveys. In 2015 it was a light meadow with biomass of 0.56 ± 0.15 g DW m^{-2}, in 2018 it was a dense meadow with biomass of 5.8 ± 1.35 g DW m^{-2}, in 2021 it was a light meadow with biomass of 0.91 ± 0.21 g DW m^{-2}, and now in 2024 it is a moderate meadow with biomass of 3.45 ± 0.47 g DWm^{-2} (Figure 7). The *H. decipiens* meadow in Walter creek was present in 2018 as a moderate patch with a biomass of 1.79 ± 0.43 g DW m^{-2}, and in 2024 it is still a moderate meadow with biomass off 1.68 ± 0.88 g DW m^{-2}.

The whole of port seagrass habitat re-mapping in Mourilyan Harbour in 2024 found a slight increase in seagrass meadow area compared with the previous whole harbour survey in 2021 (Figure 15). The increase in the whole of port footprint is primarily driven by an increase in area of monitoring meadows rather than an increase in the area of non-monitored meadows (Figure 15). Despite this slight increase, the 2024 whole-of-harbour seagrass area is just 2.91% of the 2001 peak of 87.24 hectares. The *H. uninervis* meadow has remained persistent since it was observed in 2015 and is a positive sign for the resilience of the larger species within Mourilyan Harbour and may also aid recovery within the adjacent meadows in the future. Overall, the low area footprint is consistent with the trends that have occurred in the annual monitoring meadows since 2009.

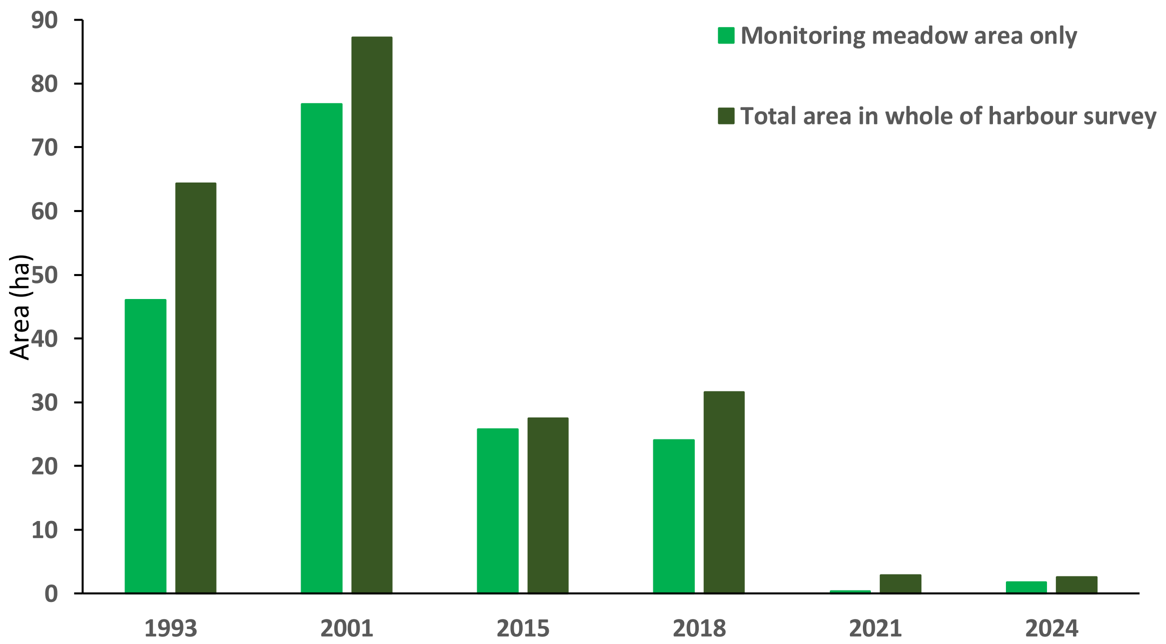

FIGURE 15. COMPARISON OF TOTAL SEAGRASS AREA (HECTARES) IN THE BROADER MOURILYAN HARBOUR REGION IN 1993, 2001, 2015 AND 2018, 2021, 2024

3.4 MOURILYAN ENVIRONMENTAL DATA

3.4.1 RAINFALL

In 2024 rainfall (3863 mm) in Mourilyan Harbour was above the long-term average (3547 mm) in the twelve months prior to the survey (Figure 16). Above average rainfall occurred in the months of December 2023, and January, February, March, July, and December 2024, with below average rainfall occurring in October and November 2023, and April, May, June, August, September, October and November 2024. (Figure 17).

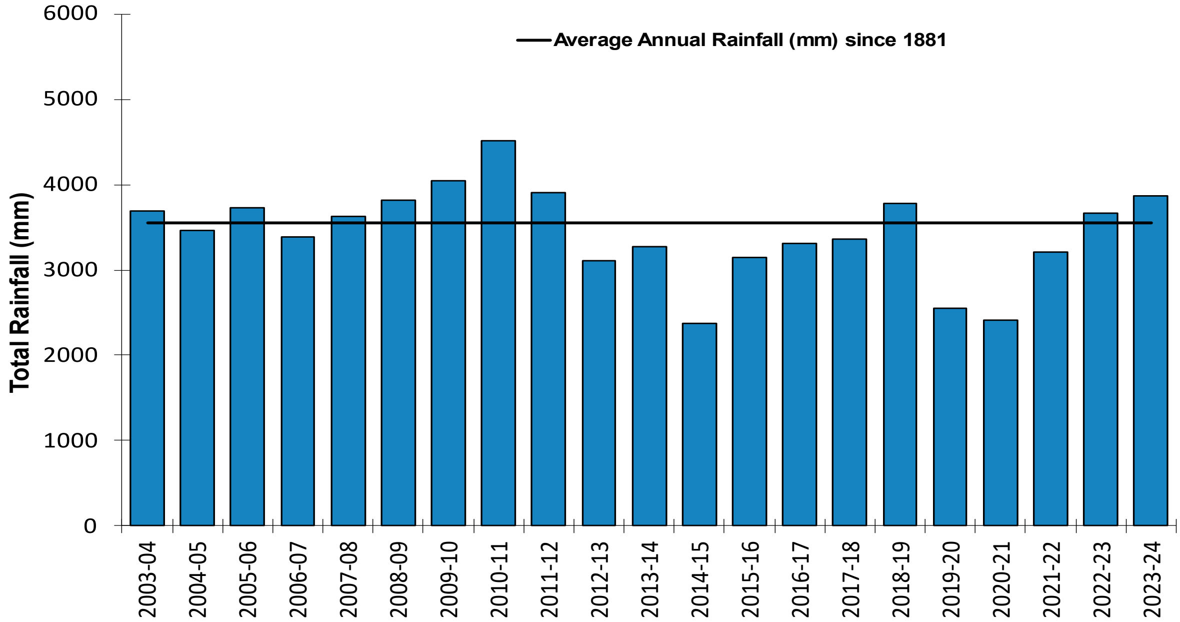

FIGURE 16. TOTAL ANNUAL RAINFALL (MM) RECORDED IN THE TWELVE MONTHS PRIOR TO SURVEY, AT INNISFAIL, 2003 – 2024. SOURCE: BUREAU OF METEOROLOGY, STATION 032025, 32197 AVAILABLE AT: WWW.BOM.GOV.AU.

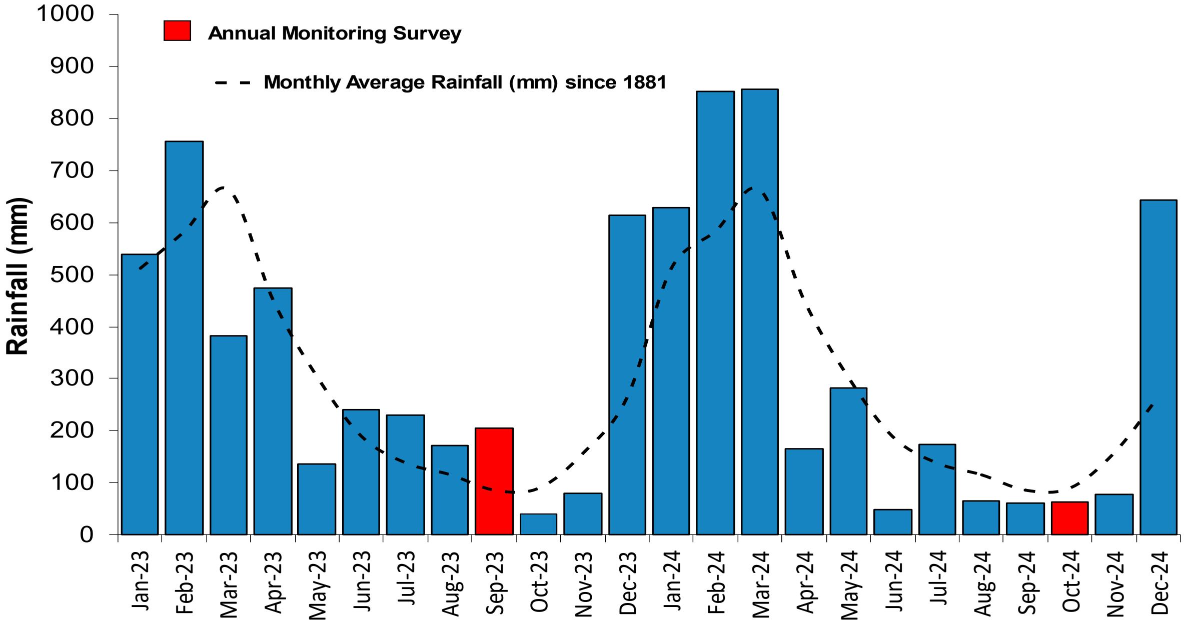

FIGURE 17. TOTAL MONTHLY RAINFALL (MM) RECORDED AT INNISFAIL, JANUARY 2023 – DECEMBER 2024. SOURCE: BUREAU OF METEOROLOGY, STATION 032025, 32197 AVAILABLE AT: WWW.BOM.GOV.AU.

3.4.2 River Flow

South Johnstone River total annual flow increased in 2024 to 1451 GL, which is also above the long-term mean of 815 GL (Figure 18). The two months in the lead up to the survey had slightly higher than average river flows (Figure 19). Extremely high river flow occurred in December 2023 associated with ex TC Jasper and again in March 2024.

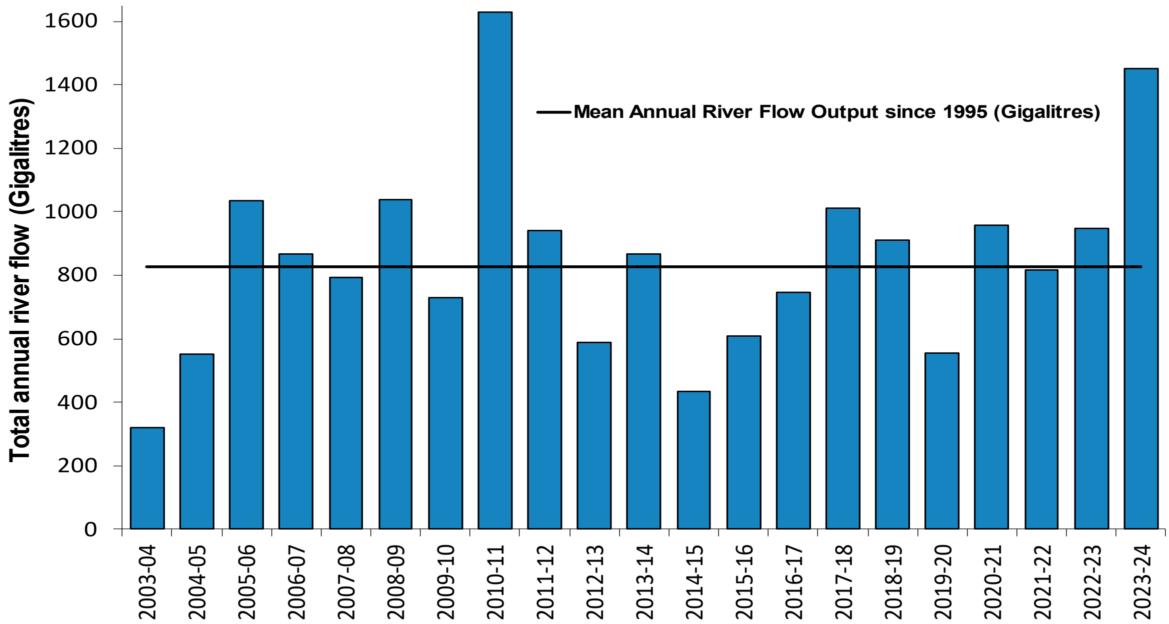

FIGURE 18. ANNUAL RIVER FLOW (GIGALITRES, GL) FOR THE SOUTH JOHNSTONE RIVER, 2003 – 2024. SOURCE: QUEENSLAND DEPARTMENT OF ENVIRONMENT AND RESOURCE MANAGEMENT, STATION 112101B, AVAILABLE AT: HTTP://WATERMONITORING.DERM.QLD.GOV.AU/HOST.HTM

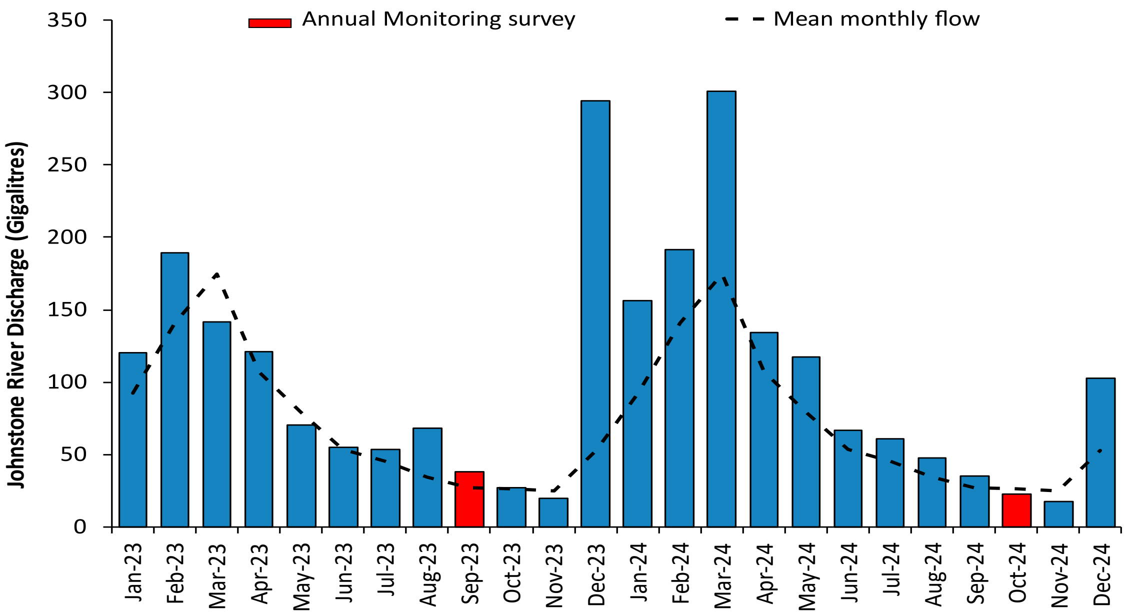

FIGURE 19. MONTHLY RIVER FLOW (GIGALITRES) FOR THE SOUTH JOHNSTONE RIVER, JANUARY 2023 – DECEMBER 2024. SOURCE: QUEENSLAND DEPARTMENT OF ENVIRONMENT AND RESOURCE MANAGEMENT, STATION 112101B, AVAILABLE AT: HTTP://WATERMONITORING.DERM.QLD.GOV.AU/HOST.HTM

3.4.3 Air Temperature and Daily Global Solar Exposure

The mean annual maximum daily air temperature of 28.83°C was recorded at Innisfail in 2024 and was less than one degree warmer than the long-term average of 27.9°C (Figure 20). Daily global solar exposure in the twelve months leading up to the survey was below average (19.7 MJ m^{-2}) at 18.95 MJ m^{-2} (Figure 21).

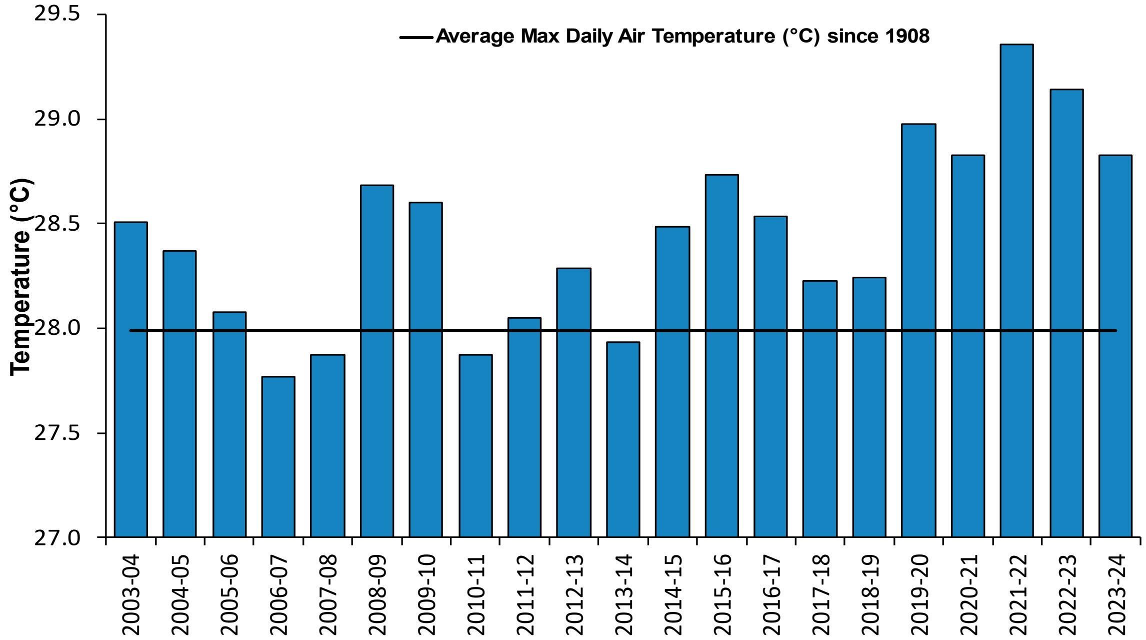

Figure 20. Mean annual maximum daily air temperature (°C) recorded at Innisfail in the twelve months prior to survey, 2003 – 2024. Source: Bureau of Meteorology, Station 032025, 32197, available at: www.bom.gov.au.

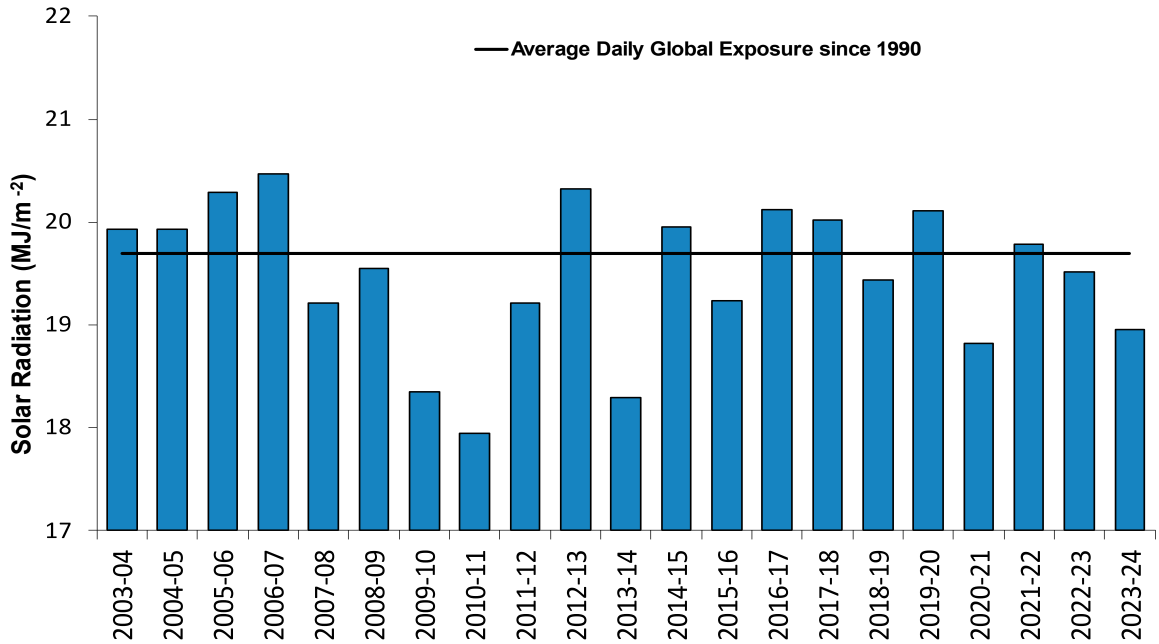

Figure 21. Mean annual daily global solar exposure (MJ m^{-2}) recorded at Innisfail in the twelve months prior to survey, 2003 – 2024. Source: Bureau of Meteorology, Station 032025, available at: www.bom.gov.au.

3.4.4 Tidal Exposure of Seagrass Meadows

Total annual daytime exposure of Mourilyan Harbour's intertidal seagrass meadows in 2024 (137 hours) was well below the long-term annual average (168 hours) (Figure 22). In 2024 all months had below average exposure except June 2024 being slightly above the mean monthly average (Figure 23).

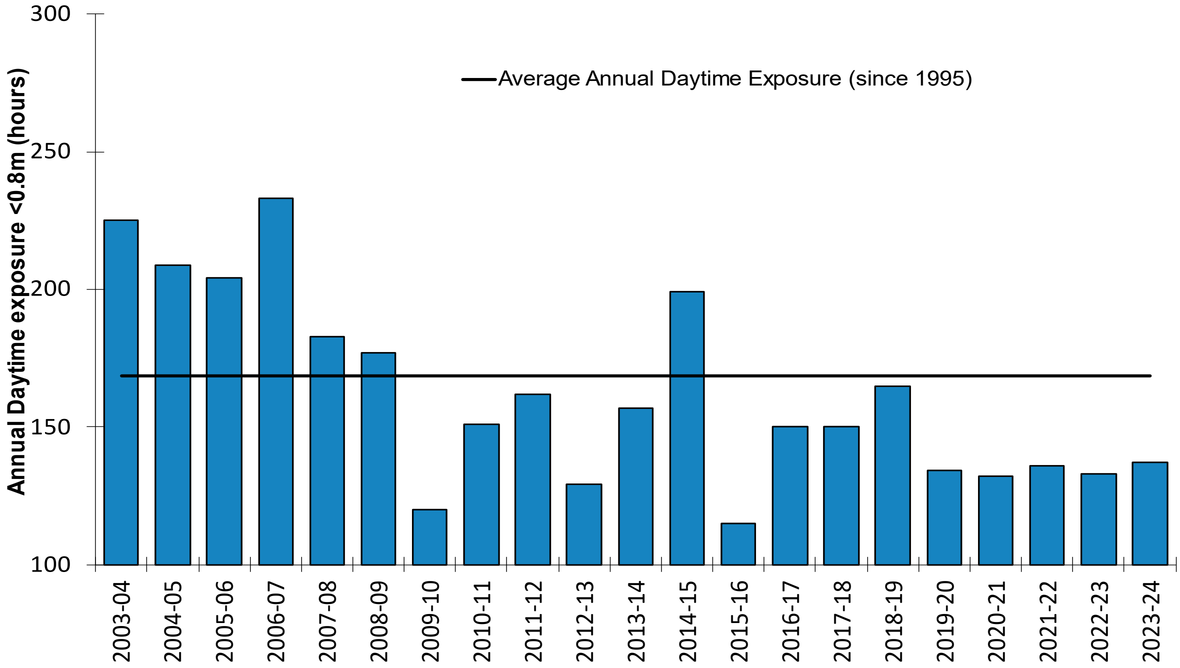

Figure 22. Annual daytime tidal exposure (total hours) of seagrass meadows in Mourilyan Harbour in the twelve months prior to survey; 2003 - 2024. Source: Maritime Safety Queensland, 2024.

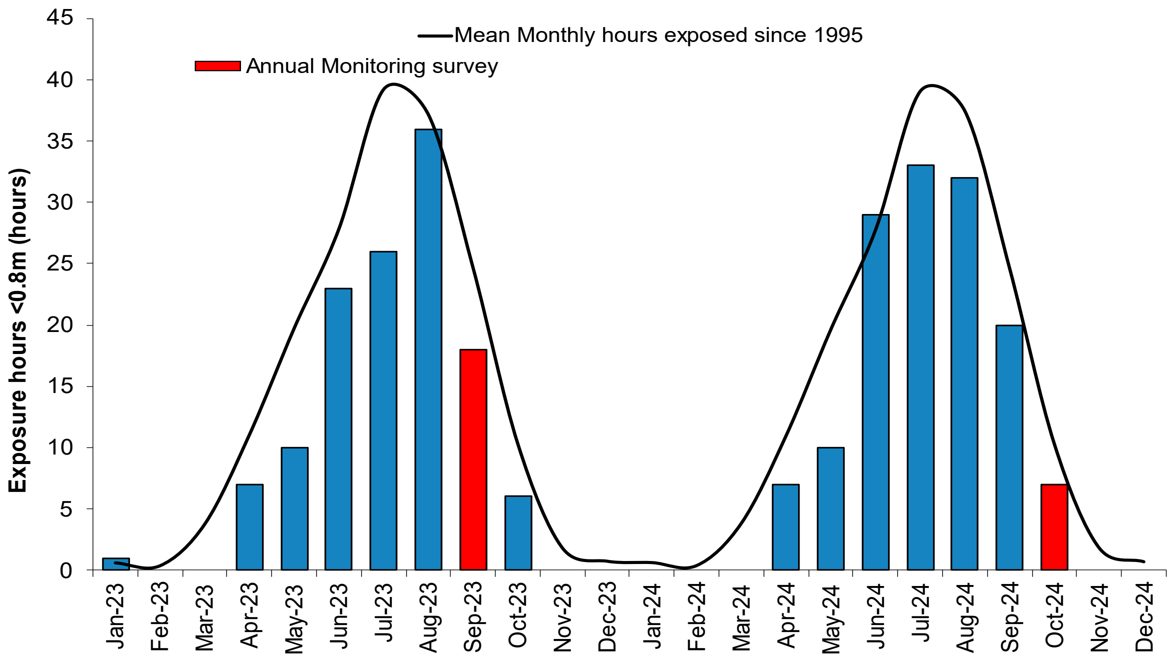

Figure 23. Total monthly daytime tidal exposure (total hours) in Mourilyan Harbour; January 2023 – December 2024. Source: Maritime Safety Queensland, 2024.

4 DISCUSSION

Mourilyan Harbour seagrass meadows remained in a very poor overall condition in 2024, with further declines compared to 2023. Seagrasses in this system have been in a degraded state since major losses occurred between 2007 and 2010 due to severe weather events including floods and cyclones. The estuary's primary foundation species, *Zostera muelleri*, has remained largely absent since that time, apart from recent reintroductions through restoration trials in the Bradshaw (1) meadow between 2020 and 2024. Meanwhile, meadows previously dominated by *Halophila* species — including Seaforth Bank (3), Seaforth Edge (4), and the Channel (5) — have exhibited high variability and limited recovery, remaining far below their historical baselines. This long-term trend highlights the low resilience of these meadows and their susceptibility to environmental pressures.

In 2024, meadow extent declined across multiple sites. Seagrass was completely absent in the Lily (2) for the fifth consecutive year and Seaforth Bank (3) which had a small amount of seagrass in 2023 also had no seagrass in 2024. The Seaforth Edge meadow (4) remained in very poor overall condition due to a decline in the area of seagrass and dominance by the more ephemeral species *H. decipiens.* The Bradshaw meadow (1) saw a decline in area with only a single patch of *Z. muelleri* persisting from restoration efforts. While *Z. muelleri* had previously established up to five expanding patches in this area, the loss of most patches between 2023 and 2024 marks a setback in recovery. Thousands of newly planted restoration shoots placed in Bradshaw and Lily meadows in August and September 2023 also likely experienced high mortality in the months following planting, with heavy rainfall and flooding occurring again through the wet season.

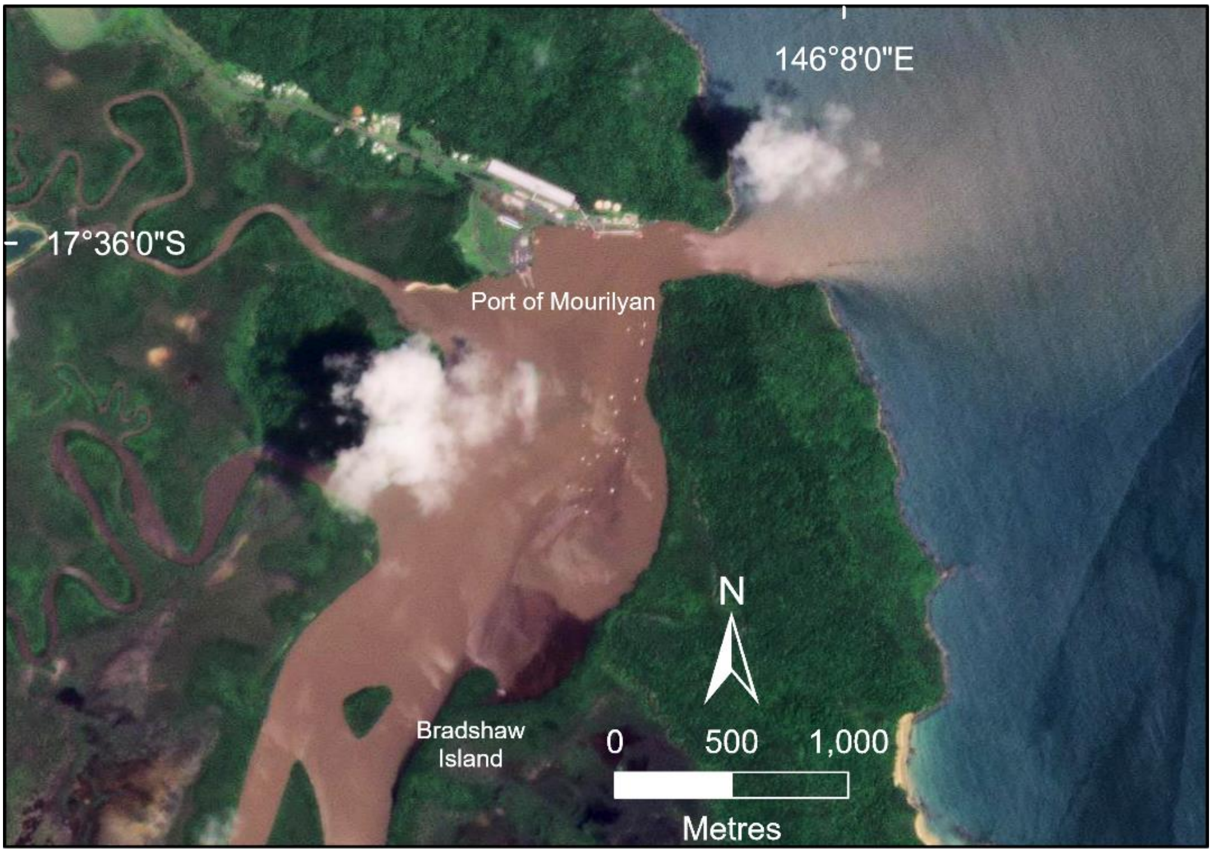

FIGURE 24. TURBID FLOOD WATERS THROUGH MOURILYAN HARBOUR 24TH DECEMBER 2024. SOURCE: IMAGE © 2024 PLANET LABS PBC.

Several environmental factors likely contributed to these losses. Rainfall and river flow were above average leading into the 2024 survey, increasing turbidity and reducing available light for seagrass photosynthesis

(Ralph et al. 2007, Chartrand et al. 2016). This included very large river flow events following Tropical Cyclone Jasper in mid-December 2023 with rainfall well above average through the entire wet season from December 2023 to March 2024. These large river flows are associated with freshwater intrusions into estuarine waters, significantly lowering salinity. Seagrasses can undergo osmotic shock that can damage plant tissue when salinity changes, however, the species growing in Mourilyan harbour have high tolerances to salinity change and can withstand long periods of hyposalinity (Collier et al. 2014). Prolonged air exposure during low tides may have caused desiccation and heat stress in intertidal areas (Boese et al. 2005), although recorded temperatures did not exceed extreme thresholds. A range of other factors can also impact seagrass condition including herbivory from green turtles which have been observed in the harbour.

Despite the challenges of 2024, the persistence of *Z. muelleri* in Bradshaw for a fourth consecutive year remains an encouraging sign. This ongoing restoration effort has now expanded into a multi-year restoration program led by JCU in collaboration with Traditional Owner groups, OzFish, local schools, and community volunteers. Although the initial plantings were impacted by flooding associated with ex-Tropical Cyclone Jasper in December 2023, the program continues, with additional monitoring and adaptive planting strategies underway. Drones and frequent surveys will be used to refine methods and support the continued reintroduction of this foundation species into both Bradshaw and Lily meadows.

Outside the five core monitoring meadows, other seagrass species and meadows were recorded in the harbour in the broader survey. A narrow intertidal band of *Halodule uninervis* along the northern bank of the main channel and patches of *Halophila ovalis* and *Enhalus acoroides* were observed in similar locations as previous years. These persistent patches are potential sources for natural recolonisation and may contribute to recovery over longer timeframes.

The long-term monitoring data from Mourilyan Harbour remains central to understanding the dynamics of local seagrass recovery and loss. When compared to previous whole-of-harbour surveys in 2021, the 2024 results indicate only a slight increase in meadow area, largely driven by isolated coloniser patches. Seagrass area remains just 2.91% of the 2001 peak extent, underscoring the importance of restoration to reverse current trends. The restoration program has also spurred community involvement and educational outreach, and additional ecosystem service assessments will quantify the benefits of restored seagrass meadows in terms of fish and prawn habitat and blue carbon storage.

Current seagrass condition was unlikely to be related to port operations with the major losses and declines associated with previous La Niña climate events and more recent wet weather and river flows and no major port developments or activities occurring over the previous year.

Seagrass condition at other monitored ports across Queensland in 2024 varied depending on local environmental conditions. The nearest seagrass monitoring locations to the north and south of Mourilyan Harbour both underwent declines in condition in 2024. Coastal meadows in Cairns Harbour to the north reduced in condition from “good” in 2023 to “satisfactory” while estuarine meadows in Trinity Inlet remained in a “poor” condition (Reason et al. 2025a). Townsville, to the south, declined for the second consecutive year from “satisfactory” in 2023 to “poor” in 2024 (McKenna et al. 2025). All of these declines are likely due to the high rainfall particularly following Tropical Cyclone Jasper in the Wet Tropics in December 2023 and Tropical Cyclone Kirrily in January 2024 around Townsville. Further north, in the Torres Straits, seagrass around Thursday Island (Scott et al. 2024) also declined in condition while to the south in Gladstone (Reason et al. 2025b) and Hervey Bay (Smith et al. 2025) showed great improvement in seagrass condition.

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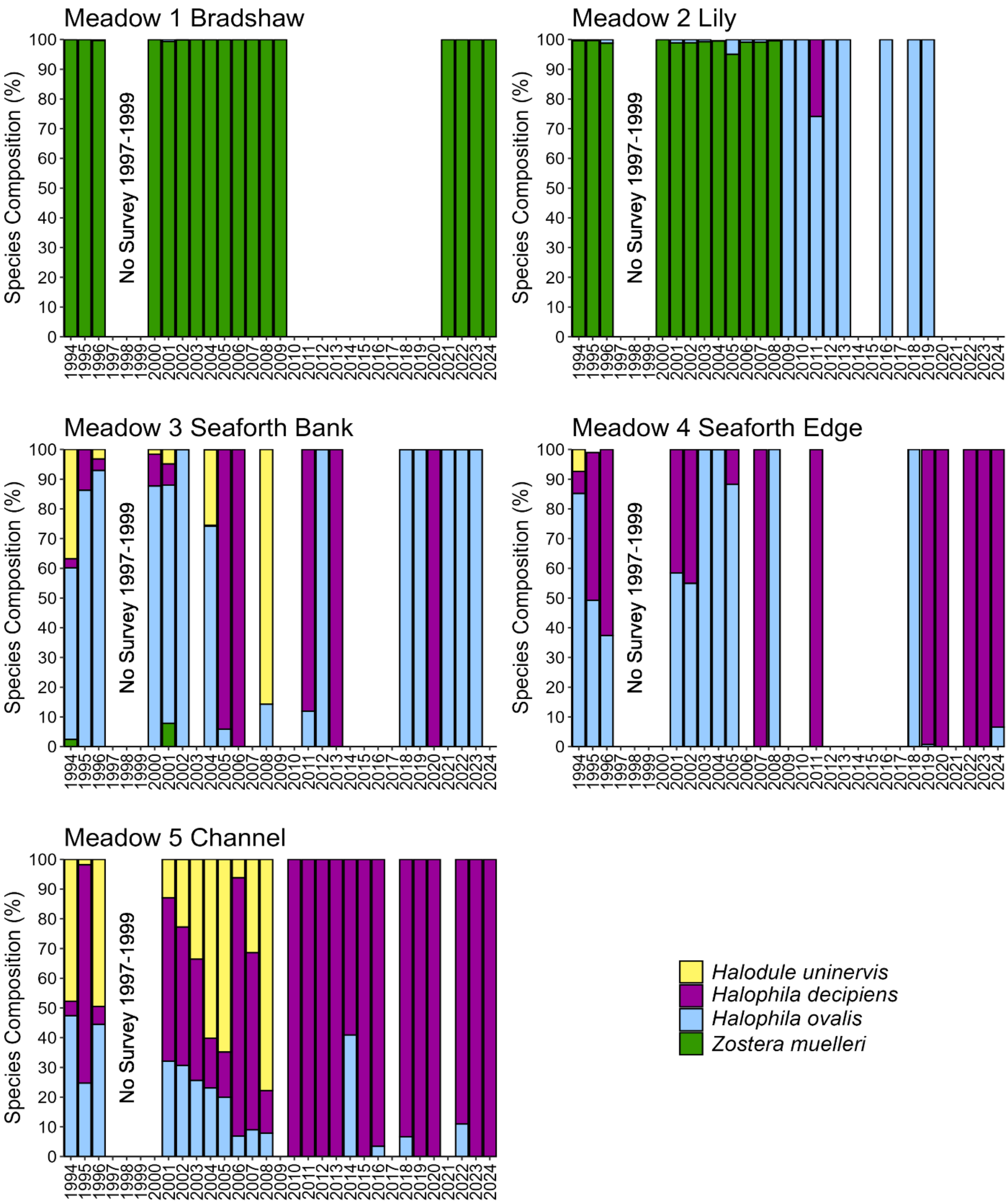
6 APPENDICES

6.1 SPECIES COMPOSITION OF MONITORING MEADOWS

SPECIES COMPOSITION OF MONITORING MEADOWS IN THE PORT OF MOURILYAN, 1994 – 2024.



6.2 AREA CHANGES: 1993 – 2024

SEAGRASS MONITORING MEADOW AREA (HA) IN MOURILYAN HARBOUR, 1993-2024 (±R = RELIABILITY ESTIMATE).

NP - SEAGRASS NOT PRESENT. NOTE: NO DATA COLLECTED IN 1997, 1998 AND 1999

Area (ha) (± R)						
	Bradshaw (1)	**Lily (2)**	**Seaforth Bank (3)**	**Seaforth Edge (4)**	**Channel (5)**	**Total (ha) combined**
Jan 1993	3.7 ± 1.9	0.9 ± 0.4	22.1 ± 4.0	2.6 ± 1.8	20.0 ± 5.63	49.6 ± 13.8
Dec 1994	2.5 ± 0.8	1.0 ± 0.5	27.5 ± 5.5	3.0 ± 1.4	37.1 ± 6.4	71.3 ± 14.7
Jan 1995	2.7 ± 0.8	0.8 ± 0.3	23.1 ± 6.0	3.3 ± 2.1	55.4 ± 9.2	71.3 ± 14.7
Dec 1996	3.1 ± 0.9	0.7 ± 0.2	19.7 ± 5.8	3.4 ± 3.3	30.3 ± 18.8	57.4 ± 29.1
Dec 2000	3.4 ± 0.4	1.1 ± 0.2	15.6 ± 7.1	NP	NP	20.2 ± 7.8
Dec 2001	3.0 ± 0.5	1.7 ± 0.3	29.8 ± 2.8	5.2 ± 4.2	34.1 ± 9.8	74.0 ± 17.7
Nov 2002	4.1 ± 0.5	1.4 ± 0.4	0.8 ± 0.5	2.9 ± 1.2	25.7 ± 10.4	35.0 ± 13.1
Dec 2003	3.6 ± 0.4	1.8 ± 0.3	NP	0.2 ± 0.1	28.8 ± 14.1	34.5 ± 14.9
Dec 2004	3.3 ± 0.5	1.0 ± 0.4	6.3 ± 2.2	3.3 ± 0.9	38.4 ± 15.3	52.4 ± 19.4
Nov 2005	3.0 ± 0.5	1.2 ± 0.4	13.1 ± 2.6	3.3 ± 0.7	47.8 ± 13.9	68.5 ± 18.2
Nov 2006	2.7 ± 0.5	0.5 ± 0.2	4.0 ± 1.1	NP	40.8 ± 11.1	48.1 ± 13.0
Oct - Dec 2007	3.4 ± 0.5	0.5 ± 0.2	1.9 ± 1.3	1.5 ± 0.8	21.9 ± 7.6	29.6 ± 10.5
Oct - Dec 2008	3.0 ± 0.4	0.4 ± 0.2	0.9 ± 0.7	0.1 ± 0	27.8 ± 7.6	32.4 ± 9.1
Oct - Nov 2009	2.4 ± 0.4	0.2 ± 0.2	NP	NP	NP	2.7 ± 0.6
Oct - Nov 2010	NP	0.4 ± 0.2	NP	NP	0.11 ± 0	0.51 ± 0.3
Sept – Nov 2011	NP	1.74 ± 0.3	25.1 ± 1.4	2.1 ± 0.9	12.0 ± 9.0	47.3 ± 12.0
Oct 2012	NP	1.1 ± 0.3	0.6 ± 0.1	NP	25.9 ± 15.9	27.7 ± 16.4
Oct - Nov 2013	NP	0.4 ± 0.2	0.02 ± 0.01	NP	7.5 ± 6.3	8.0 ± 6.5
Dec 2014	NP	NP	NP	NP	53.2 ± 18.9	53.2 ± 18.9
Sept – Nov 2015	NP	NP	NP	NP	25.7 ± 12.33	25.7 ± 12.33
Oct - Nov 2016	NP	0.283 ± 0.16	NP	NP	11.39 ± 7.1	11.67 ± 7.26
Oct - Nov 2017	NP	NP	NP	NP	NP	NP
Oct - Dec 2018	NP	2.35 ± 0.44	10.02 ± 1.27	0.47 ± 0.20	11.18 ± 7.37	24.02 ± 9.28
Oct - Dec 2019	NP	2.18 ± 0.43	9.70 ± 1.57	1.98 ± 0.66	21.59 ± 10.93	35.45 ± 17.16
Oct 2020	NP	NP	1.80 ± 0.54	2.18 ± 0.87	21.11 ± 7.79	25.09 ± 9.3
Oct 2021	0.00042 ± 0.0	NP	0.29 ± 0.07	0.0014 ± 0.0007	NP	0.30 ± 0.079
Oct 2022	0.002 ± 0.001	NP	0.36 ± 0.09	1.14 ± 0.20	14.28 ± 7.30	15.79 ± 7.6
Sept – Nov 2023	0.0027 ± 0.0022	NP	0.60 ± 0.09	0.76 ± 0.16	7.62 ± 5.00	8.99 ± 5.26
Sept – Dec 2024	0.0013 ± 0.007	NP	NP	0.24 ± 0.08	1.49 ± 1.48	1.73 ± 1.57

6.3 ABOVE-GROUND BIOMASS CHANGES: 1993 – 2024

MEAN ABOVE-GROUND BIOMASS (G DW M¯2) OF SEAGRASS FOR MONITORING MEADOWS IN MOURILYAN HARBOUR, 1993-2024. NR (NOT RECORDED) SEAGRASS PRESENT BUT TOO SPARSE TO RECORD BIOMASS, NP SEAGRASS NOT PRESENT, COLLECTED IN 1997, 1998 AND 1999.

Mean Biomass ± SE (g DW m^{-2})					
	Bradshaw (1) meadow	**Lily (2) meadow**	**Seaforth Bank (3) meadow**	**Seaforth Edge (4)**	**Channel (5)**
Jan 1993	37.8 ± 11.5	16.1 ± 0	0.9 ± 0.2	1.8 ± 0.4	0.4 ± 0.1
Dec 1994	45.1 ± 3.5	30.4 ± 4.5	0.7 ± 0.2	2.0 ± 0.5	1.8 ± 0.6
Jan 1995	49.2 ± 2.9	29.4 ± 2.0	1.1 ± 0.2	1.6 ± 0.2	1.4 ± 0.2
Dec 1996	59.4 ± 5.4	29.8 ± 2.9	3.0 ± 0.5	3.3 ± 0.8	2.7 ± 0.6
Dec 2000	17.5 ± 1.3	7.6 ± 0.5	0.2 ± 0.05	NP	NP
Dec 2001	35.8 ± 5.3	5.5 ± 1.5	2.4 ± 0.4	2.1 ± 0.4	0.6 ± 0.1
Nov 2002	32.1 ± 2.0	20.6 ± 3.0	0.3 ± 0.2	1.6 ± 0.2	1.0 ± 0.1
Dec 2003	21.5 ± 3.4	5.0 ± 2.3	NP	0.02 ± 0.02	0.8 ± 0.2
Dec 2004	59.3 ± 6.9	12.3 ± 3.6	0.5 ± 0.1	1.2 ± 0.3	1.0 ± 0.2
Nov 2005	34.1 ± 3.6	0.1 ± 0.1	0.02 ± 0.005	0.1 ± 0.1	1.2 ± 0.4
Nov 2006	46.5 ± 4.1	2.4 ± 0.8	0.06 ± 0.02	NP	2.3 ± 0.5
Oct - Dec 2007	21.4 ± 2.3	2.8 ± 0.6	NR	1.1 ± 0.03	2.5 ± 0.3
Oct - Dec 2008	28.7 ± 3.5	4.3 ± 2.9	0.02 ± 0.006	NR	1.5 ± 0.3
Oct - Nov 2009	15.5 ± 2.9	0.03 ± 0.01	NP	NP	NP
Oct - Nov 2010	NP	0.57 ± 0.19	NP	NP	1.94 ± 0
Sept – Nov 2011	NP	0.37 ± 0.13	0.3 ± 0.06	2.5 ± 0.8	0.56 ± 0.21
Oct 2012	NP	0.03 ± 0.01	0.03 ± 0	NP	2.41 ± 0.45
Oct - Nov 2013	NP	0.4 ± 0.2	0.1 ± 0.1	NP	2.1 ± 0.3
Dec 2014	NP	NP	NP	NP	2.4 ± 0.2
Sept – Nov 2015	NP	NP	NP	NP	0.87 ± 0.24
Oct - Nov 2016	NP	0.17 ± 0.004	NP	NP	0.70 ± 0.27
Oct - Nov 2017	NP	NP	NP	NP	NP
Oct - Dec 2018	NP	0.04 ± 0.04	0.007 ± 0.003	NR	0.53 ± 0.28
Oct - Dec 2019	NP	0.69 ± 0.19	0.16 ± 0.08	1.80 ± 0.36	0.73 ± 0.18
Oct 2020	NP	NP	0.40 ± 0.18	1.17 ± 0.42	0.39 ± 0.15
Oct 2021	2.82 ± 1.21	NP	0.018 ± 0.018	NR	NP
Oct 2022	33.76	NP	0.19 ± 0.05	1.15 ± 0.31	0.72 ± 0.10
Sept – Nov 2023	3.95 ± 2.19	NP	0.49 ± 0.00	1.46 ± 0.46	1.54 ± 0.39
Sept – Dec 2024	9.22	NP	NP	1.35 ± 1.18	0.26