Seagrass Habitat of Mourilyan Harbour: Annual Monitoring Report 2022

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Annual Monitoring Report 2022

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KEY FINDINGS

Seagrass Condition 2022

Very Poor

1. In 2022 the overall seagrass condition in Mourilyan Harbour remained very poor, although there was an increase in seagrass presence compared with 2021.
2. Seagrass was present in four of the five long term monitoring meadows, and condition within these meadows was classified as poor and very poor compared with the long term baseline.
3. Four meadows had an improvement in biomass and two meadows improved in area, however across all meadows either the biomass and extent were still well below the long-term average.
4. Biomass improved to a good condition grade in three of the monitoring meadows Channel (5), Seaforth Edge (4) and Bradshaw (5).
5. Restoration trials in Bradshaw (5) meadow over the past three years has seen a return of small patches of the foundation species *Zostera muelleri* and is a promising sign that restoration methods were successful and ready to be scaled up for a full restoration program for Mourilyan Harbour.
6. Conditions were reasonably favourable for seagrass growth in 2022 but high temperatures and above average river flow and solar radiation in the months leading up to the survey may have limited seagrass growth and recovery.
7. 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 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 (see section 2.4 of this report for further details).

Overall seagrass condition remained very poor in 2022 although there was some improvement from 2021. Seagrass was present at four of the five monitoring meadows, however, it had either a low areal extent or biomass and wasn't enough to improve overall condition grades compared with the baseline conditions for these meadows. Due to the restoration of small patches of seagrass, *Zostera muelleri* in the Bradshaw (1) meadow increased in biomass condition and its ability to persist over the past two years is an encouraging sign for the potential return of this foundation species in Mourilyan Harbour. Seaforth Bank (3) improved in biomass and maintained a very good grade for the species shift back to *Halophila ovalis*. Seaforth Edge (4) also improved in biomass and area however, remained dominated by *H. decipiens*, leaving it in a very poor condition overall. The Channel (5) meadow returned after being absent for a year and had a good condition for biomass in 2022. Lily (2) meadow remains absent for the third year in a row. This meadow has been dominated by colonising *Halophila spp*. in the past decade, which are highly variable in abundance and distribution. While the overall meadow condition of seagrasses in Mourilyan Harbour is heavily influenced by the presence/absence of *Zostera muelleri* in Bradshaw (1) and Lily (2) meadows, the persistence of this species in 2022 following transplant trials is a positive sign of improvement for future growing seasons.

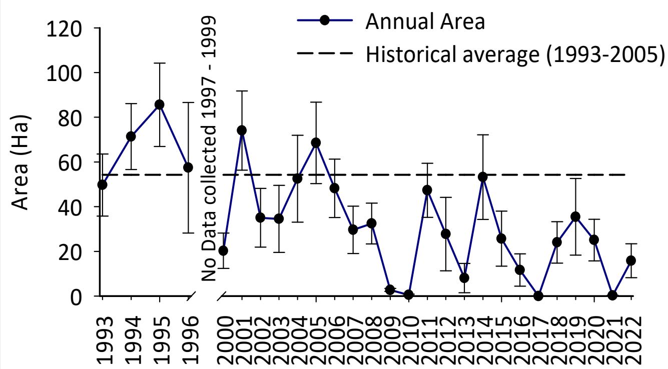

FIGURE 1: MOURILYAN HARBOUR SEAGRASS MONITORING MEADOW TOTAL AREA (HA) FROM 1993 TO 2022.

While the distribution of seagrass in the broader harbour has declined from previous years, a narrow strip of intertidal *Halodule uninervis* that has persisted in the same location over the past few years. The Seaforth Bank meadow also has a couple of small isolated patches of *Enhalus acoroides* persisting in the same location year after year.

Environmental conditions during 2022 such as annual rainfall and amount of daytime tidal exposure of intertidal meadows were generally favourable for seagrass growth and may explain some of the improvements between 2021 and 2022 as well as the continued survival and spread of the transplant plots. However some conditions in the lead up to the monitoring survey may have limited the amount of seagrass recovery. These include above average river flow in the five months leading up to the survey, and the warmest annual temperatures recorded since seagrass monitoring began. River flows had the potential to lower water quality and light availability prior to the survey and would have particularly strong impacts on smaller *Halophila* species.

A partnership with JCU/TropWATER, and OzFish Unlimited in 2020, have implemented a small and successful pilot restoration study using vegetative fragments of *Z. muelleri.* This partnership grew with the inclusion of Mandubarra and Gimuy Rangers in 2021-22 and two more pilot studies to refine planting methods. These studies have provided the framework for a large-scale restoration project to return the seagrass to its previous healthy condition and re-establish the vital ecological functions that it can provide. The return of the foundation species *Z. muelleri* should lead to the start of a return of important ecosystem functions within the estuary such as nursery habitat for juvenile fish and prawns, storage of carbon in sediments and sediment stabilisation and particle trapping that improve water quality. Plans are underway between JCU and their partners to scale up the restoration efforts for *Z. muelleri* at the over the next four years.

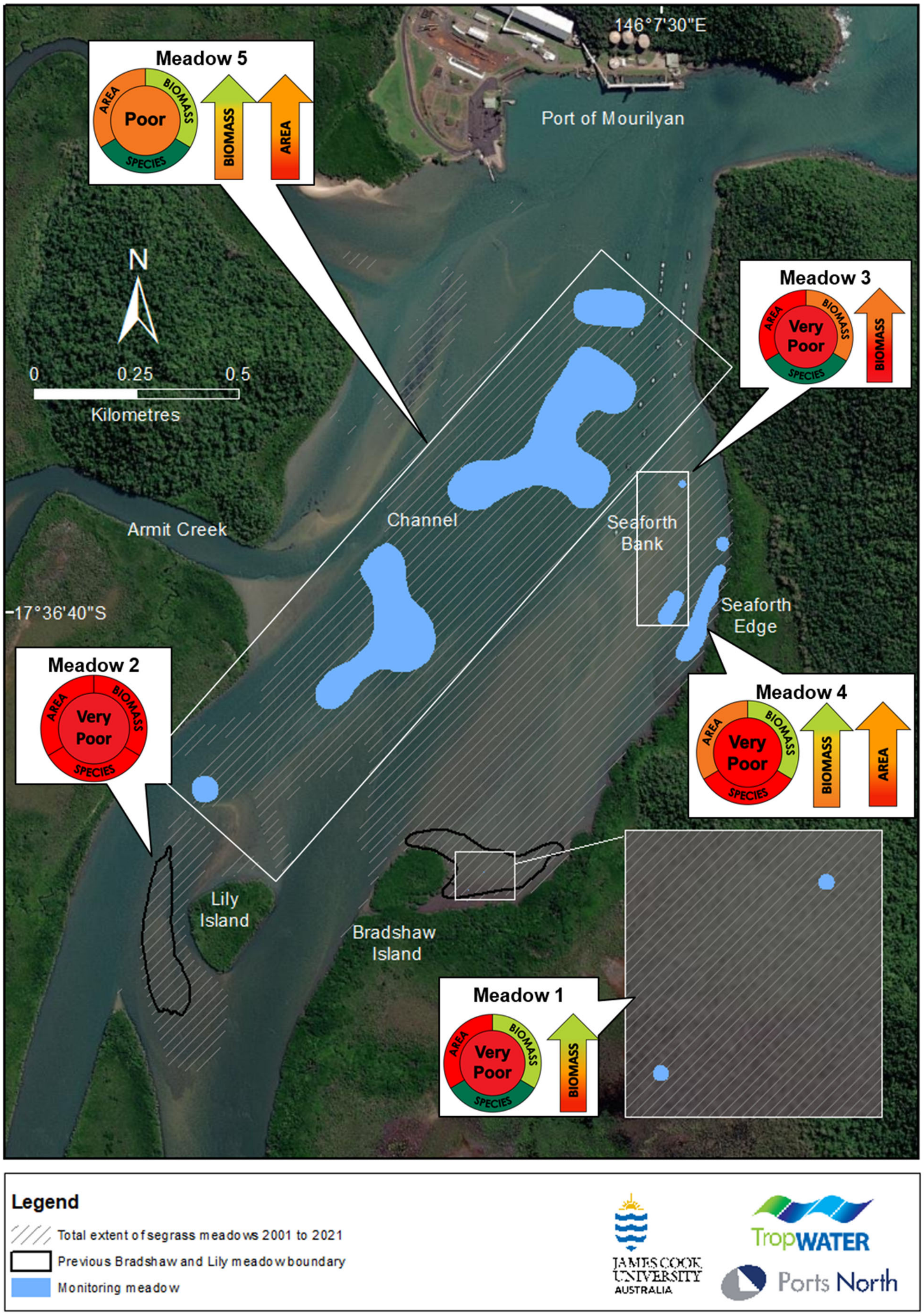

FIGURE 2. SEAGRASS CONDITION FOR MOURILYAN HARBOUR SEAGRASS MEADOWS IN 2022

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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).

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.

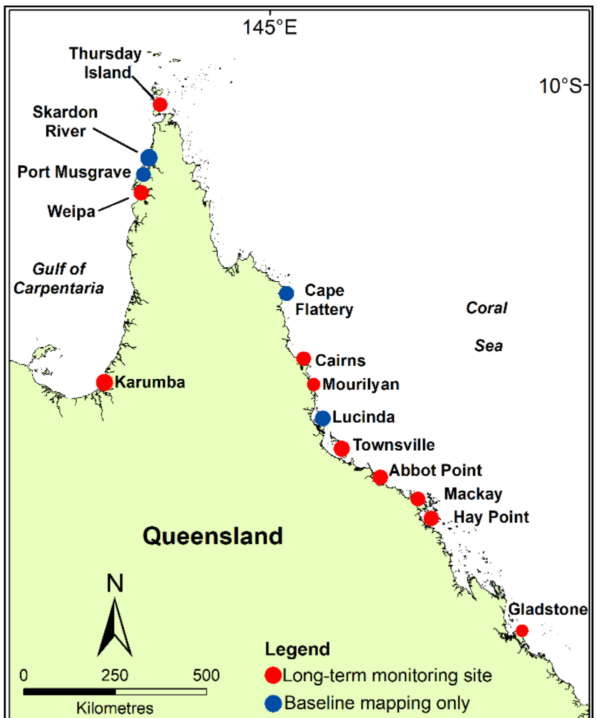


FIGURE 3. LOCATION OF QUEENSLAND PORTS SEAGRASS MONITORING LOCATIONS.

For more information on the program and reports from other monitoring locations, see https://www.tropwater.com/project/management-of-ports-and-coastal-facilities/

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.

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 2022 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;
- 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.

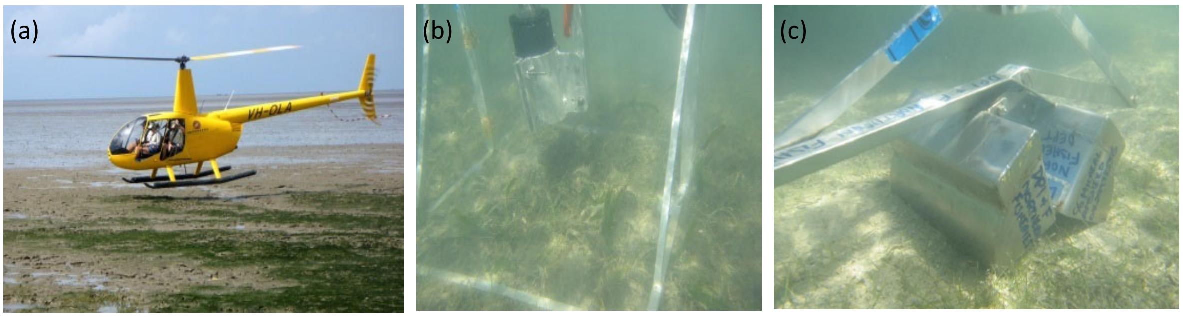
2 METHODS

2.1 FIELD SURVEYS

The survey involved mapping and assessing the five annual monitoring meadows in Mourilyan Harbour during the seasonal peak of seagrass growth. Aerial surveys were conducted on 8th October and boat based surveys on 15th November 2022. 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 ESTIMATES

Seagrass above-ground biomass was determined using a “visual estimates of biomass” technique (Mellors 1991; Kirkman 1978). At each site a 0.25 m^2 quadrat was placed randomly 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.

2.3 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.

2.3.1 *Site layer*

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

- Site number
- Temporal details – Survey date and time.
- Spatial details – Latitude, 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.

2.3.2 *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.

2.3.3 *Meadow layer*

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

- Meadow ID number – A unique number assigned to each meadow to allow comparisons among surveys.
- Temporal details – Survey date.
- Habitat information – Mean meadow biomass ± standard error (SE), meadow area (hectares) ± reliability estimate (R) (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 m	Intertidal meadows completely exposed or visible at low tide; High resolution drone photogrammetry aided in mapping; Meadow boundaries determined by orthomosaic imagery;
± 1 - 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;
± 10 - 30 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.

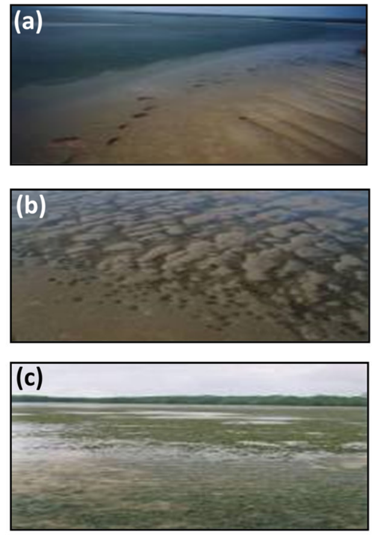


FIGURE 5. SEAGRASS MEADOW LANDSCAPE CATEGORIES: (A) ISOLATED SEAGRASS PATCHES, (B) AGGREGATED SEAGRASS PATCHES, (C) CONTINUOUS SEAGRASS COVER.

2.4 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).

2.5 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) 2021, 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 2022). 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, 2000 – 2021), which flows to the north of Mourilyan Harbour, is presented instead. South Johnstone River flow data (gigalitres; GL) was obtained from the Department of Natural Resources and Mines (station #112101B; https://water-monitoring.information.qld.gov.au/).

3 RESULTS

3.1 SEAGRASSEES IN MOURILYAN HARBOUR

In 2022, seagrass was present at 10% of the 231 sites surveyed (Figure 6). The annual monitoring meadows had a total area of 15 ± 7 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 *Enhalus acoroides* and *Halodule uninervis* were observed outside of the monitoring meadows (Figures 7 and 8).

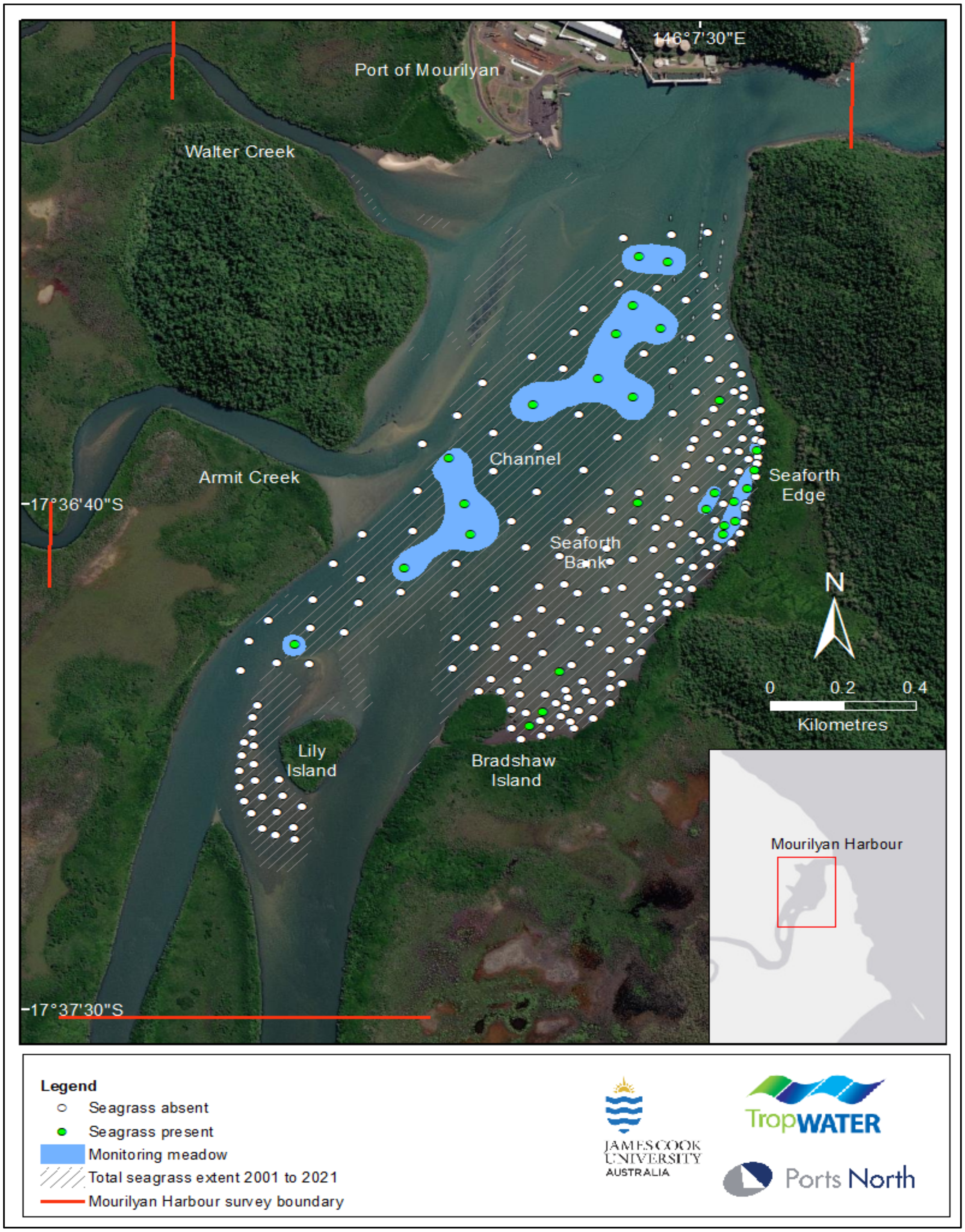


FIGURE 6. SEAGRASS PRESENCE/ABSENCE AT SURVEY SITES, 2022.

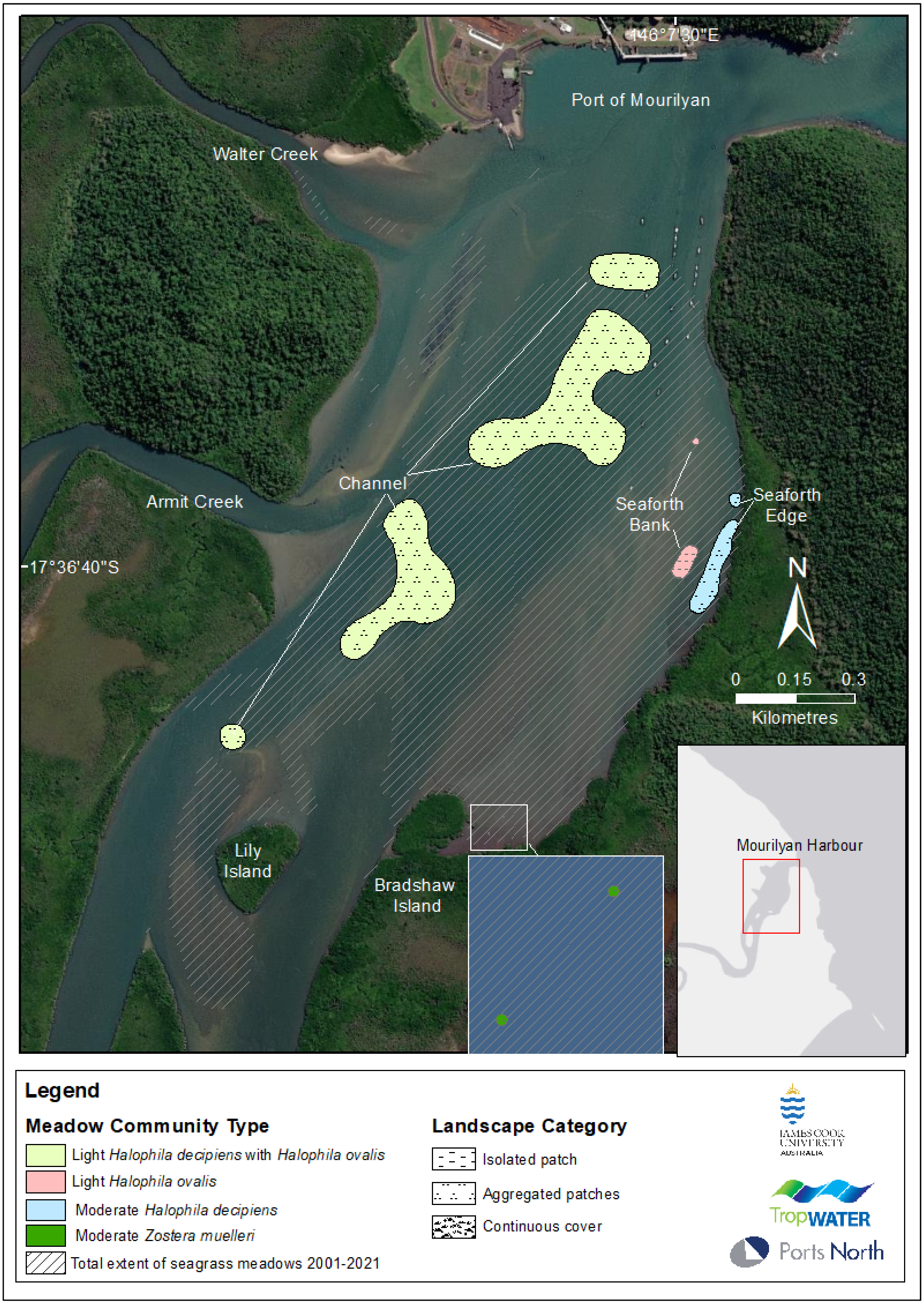


FIGURE 7. MOURILYAN HARBOUR SEAGRASS DISTRIBUTION AND COMMUNITY TYPE FOR ALL MAPPED MEADOWS, 2022.

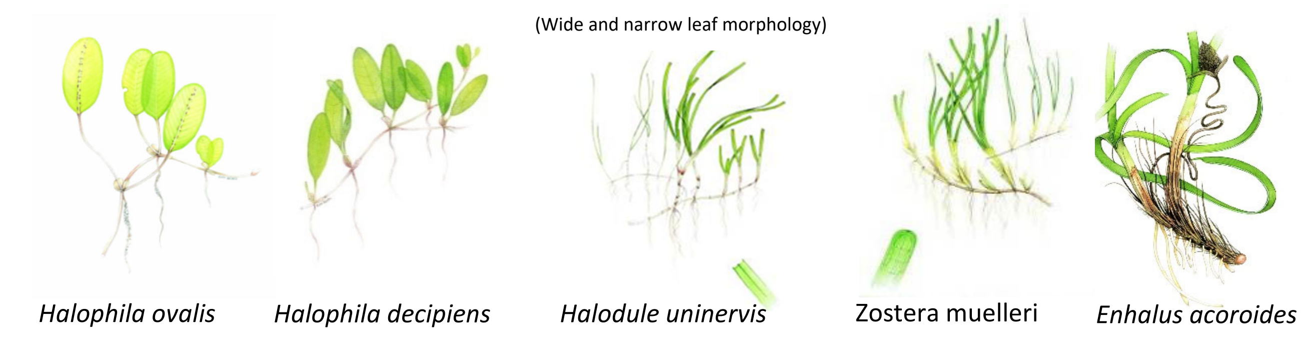


Figure 8. Seagrass species present in Mourilyan Harbour, 2022.

3.2 SEAGRASS CONDITION FOR ANNUAL MONITORING MEADOWS

Seagrass condition overall was in a very poor condition in Mourilyan Harbour in 2022. Four of the five monitoring meadows were present with Lily (2) being absent again in 2022. The extent and biomass of seagrass in the meadows that were present remain below baseline conditions, however did show some small improvements compared with the previous year. The condition of Bradshaw (1), Lily (2), Seaforth Bank (3) and Seaforth Edge (4) all remained very poor while Channel (5) slightly improved in condition from very poor to poor (Table 4).

Table 4. Grades and scores for condition indicators (biomass, area and species composition) for Mourilyan Harbour monitoring meadows, 2022.

Meadow	Biomass Score	Area Score	Species Composition Score	Overall Meadow Score
1 - Bradshaw	0.68	0.000319	1	0.000319
2 - Lily	0	0	0	0
3 - Seaforth Bank	0.37	0.03	1	0.03
4 - Seaforth Edge	0.69	0.43	0	0.22
5 - Channel	0.66	0.46	1	0.46
Mourilyan Harbour Overall Score				0.14

In 2022 biomass improved in the Bradshaw Island meadow (1) to a good condition with *Z. muelleri* recorded in two isolated patches (Figure 9). This is the second year in a row it has been detected, and is a result of the spread and growth from the restoration plots. The condition grade of species composition also remains very good, however due to the footprint of the small isolated patches the area remains in a very poor condition, and so does the overall condition grade for this meadow (Table 4; Figure 10; Appendix 6.2, 6.3). This meadow was once dominated by *Z. muelleri* up until climate events in 2009 – 2010 resulted in complete meadow loss. Since 2020 efforts were put into a pilot seagrass restoration project to trial seagrass restoration methods in Mourilyan Harbour. The success of the restoration trail is evident in the continued presence of a small area of healthy and spreading *Z. muelleri*.

The Lily Island meadow (2) remained absent in 2022 and therefore in a very poor condition. This is the third 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 2022 there were no signs of this colonising species (Table 4; Figure 11). This intertidal meadow was once dominated by *Z. muelleri* and this foundation species has been absent since 2009 (Figure 11; Appendix 6.2, 6.3).

The Seaforth Bank Meadow (3) improved in biomass to poor with an increase in the species *H. ovalis* in 2022 (Table 4; Figure 12). Species composition continued to be dominated by *H. ovalis*, the condition indicator species and resulting in a very good grade for that condition (Figure 12). The overall condition of this meadow remained in a very poor condition in 2022 due to the footprint remaining well below baseline levels (Figure 12). Several isolated patches of *Enhalus acoroides* remains 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) had improvements in biomass and area in 2022. Even though the species condition remained very poor with less stable *H. decipiens* being recorded, biomass improved to good and not far off reaching baseline records (Table 4; Figure 13). The footprint of this meadow did improve from very poor to a poor condition, and is still below long term levels (Table 4; Figure 13). 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 13, Appendix 6.2, 6.3).

The Channel meadow (5) improved from being absent in 2021 to being present and in an overall poor condition in 2022 (Table 4; Figure 14). Biomass was in a good condition and species composition was in a very good condition with the return of the condition grade species *H. decipiens* (Table 4; Figure 14). The footprint of this meadow remains below the long term average in a poor condition, and is spread out within the Harbour in aggregated patches (Figure 14). 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. HEALTHY ISOLATED PATCH FROM RESTORATION OF ZOSTERA MUELLERI IN BRADSHAW ISLAND MEADOW (1).

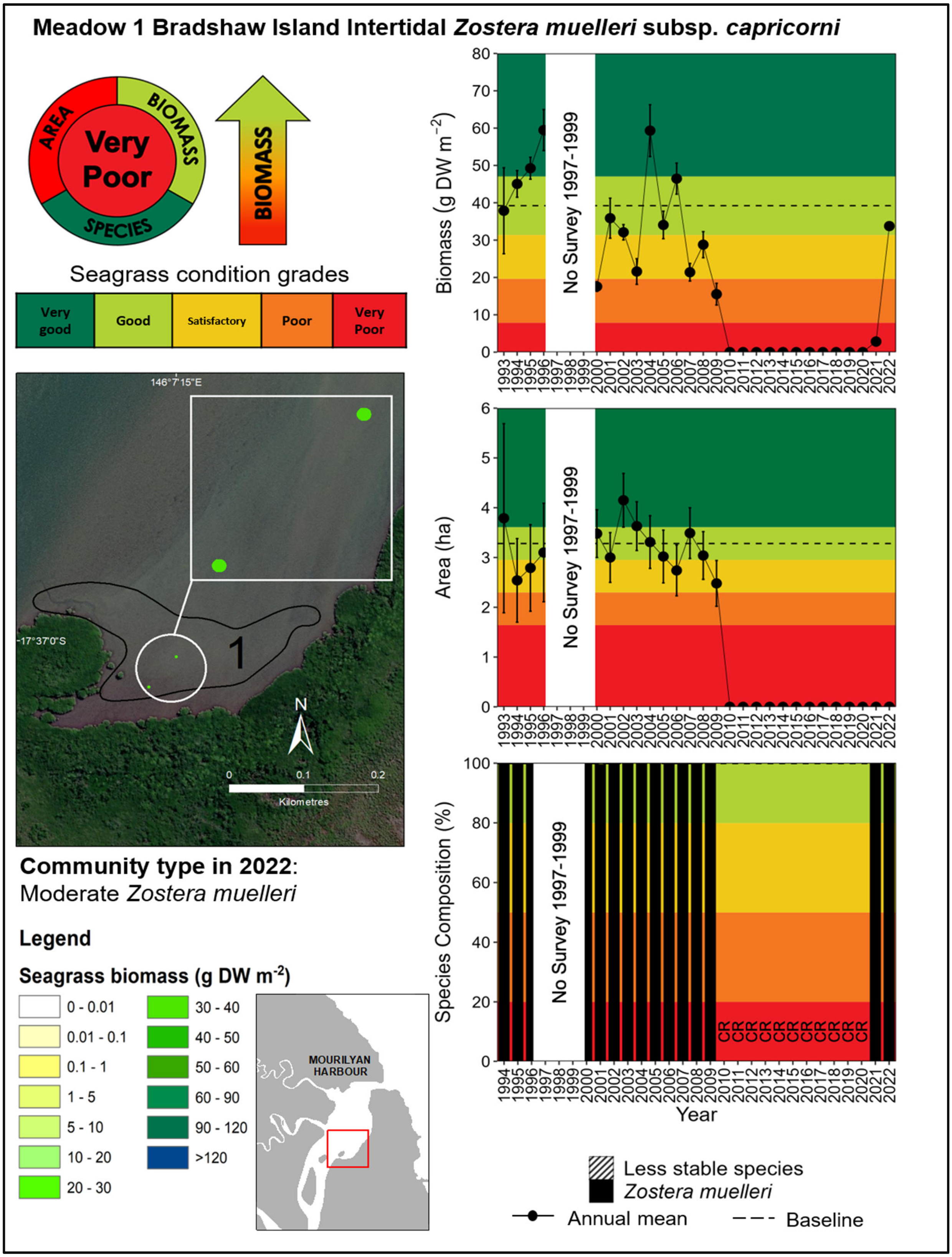


FIGURE 10. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE BRADSHAW ISLAND MEADOW FROM 1993 – 2022 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

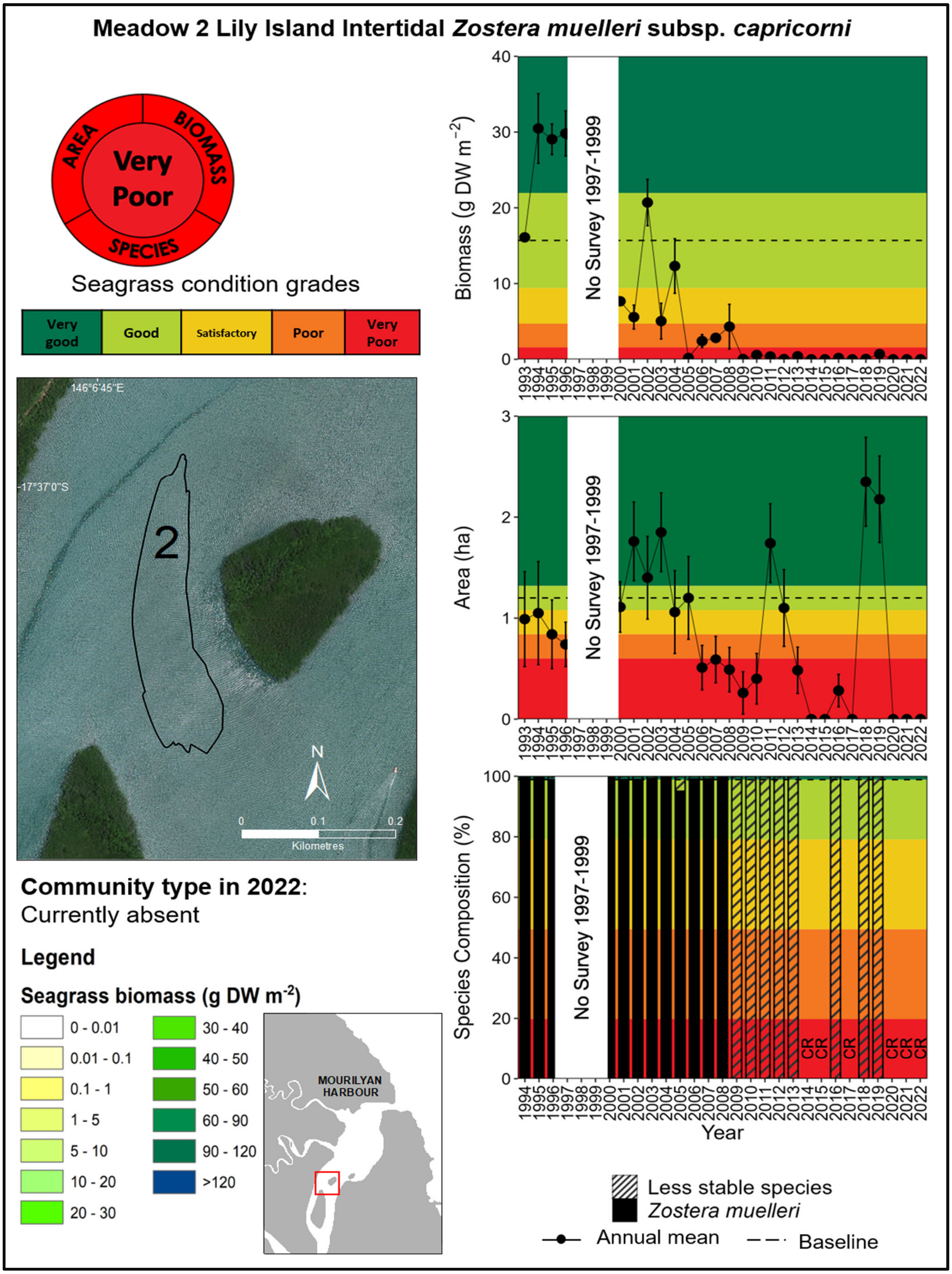


FIGURE 11. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE LILY ISLAND MEADOWS FROM 1993 – 2022 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

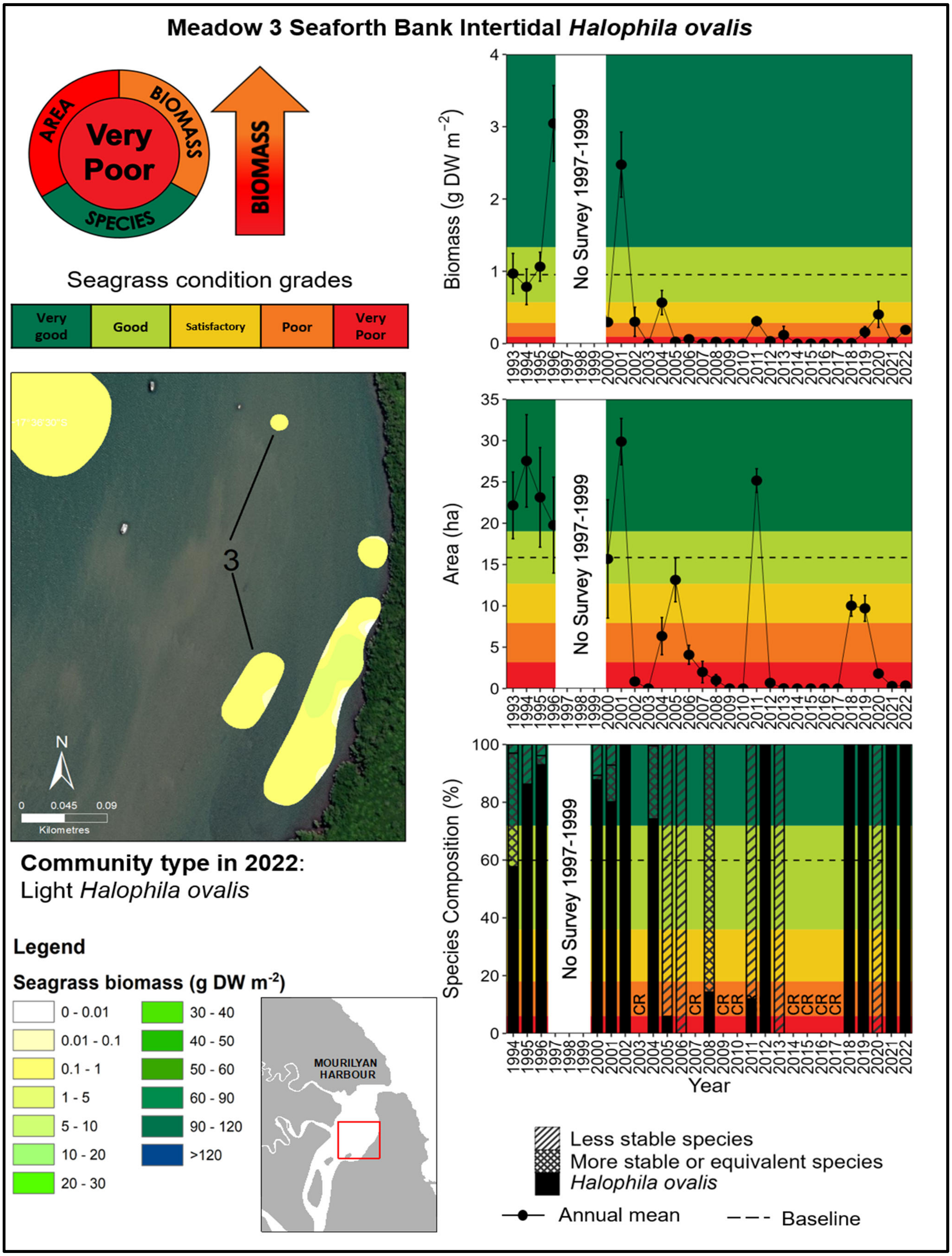


FIGURE 12. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR SEAFORTH BANK MEADOW FROM 1993 – 2022 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

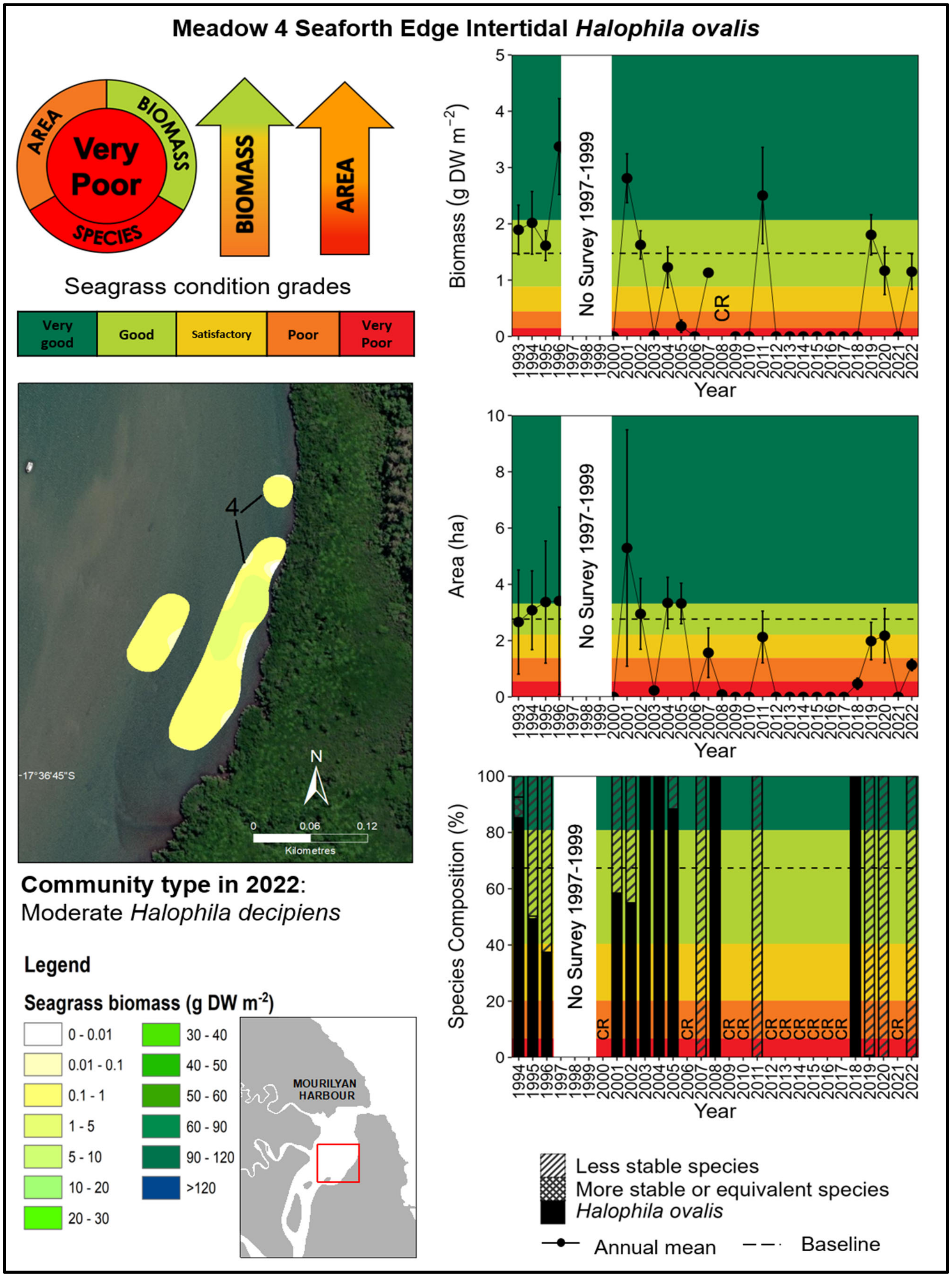


FIGURE 13. CHANGES IN BIOMASS, AREA AND SPECIES COMPOSITION FOR THE SEAFORTH EDGE MEADOW FROM 1993 – 2022 (BIOMASS ERROR BARS = SE; AREA ERROR BARS = "R" RELIABILITY ESTIMATE). THE COMMUNITY TYPE IN BOLD AT TOP REPRESENTS THE BASELINE COMMUNITY TYPE. CR = CALCULATION RESTRICTION DUE TO SEAGRASS ABSENCE.

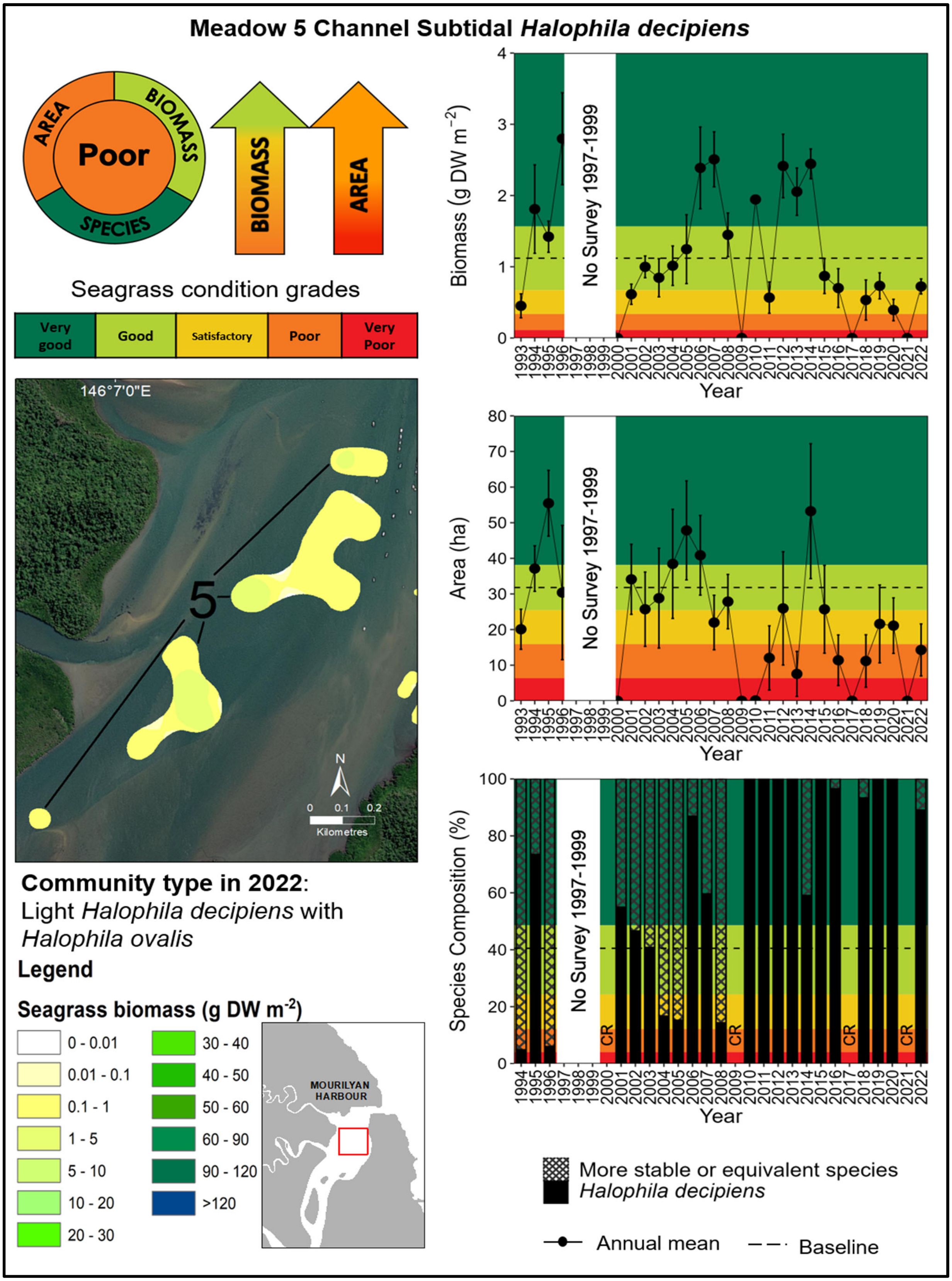


Figure 14. Changes in biomass, area and species composition for the Channel meadow from 1993 – 2022 (biomass error bars = SE; area error bars = "R" reliability estimate). The community type in bold at top represents the baseline community type. CR = calculation restriction due to seagrass absence.

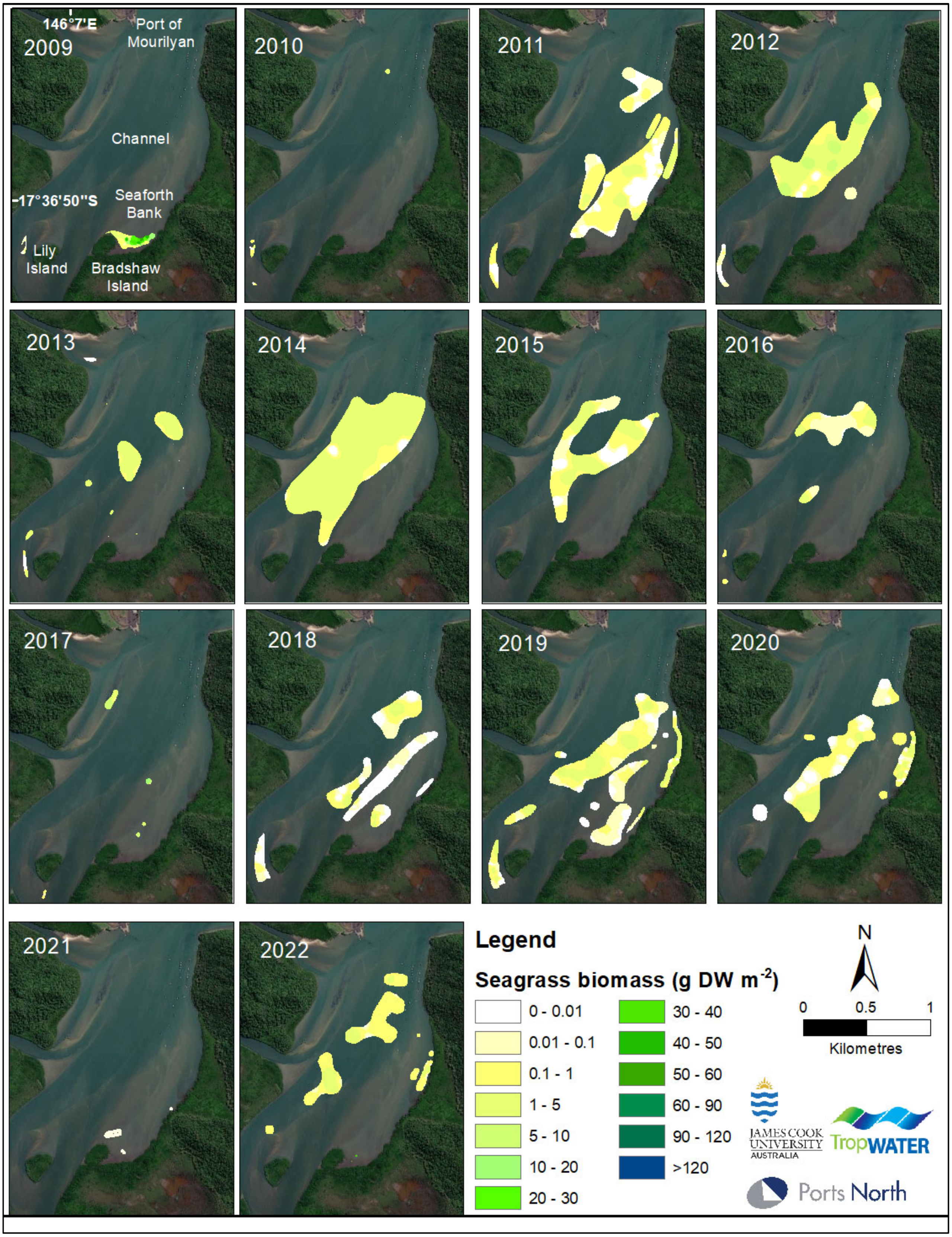


FIGURE 15. CHANGE IN SEAGRASS DISTRIBUTION OVER TIME (2009-2022) IN MOURILYAN HARBOUR.

3.3 MOURILYAN ENVIRONMENTAL DATA

3.3.1 RAINFALL

In 2022 rainfall (3206 mm) in Mourilyan Harbour was below the long term average (3547 mm) in the twelve months prior to the survey (Figure 16). Above average rainfall occurred in the months of May and July 2022, with below average rainfall occurring in the two months leading up to the survey that was in October (Figure 17).

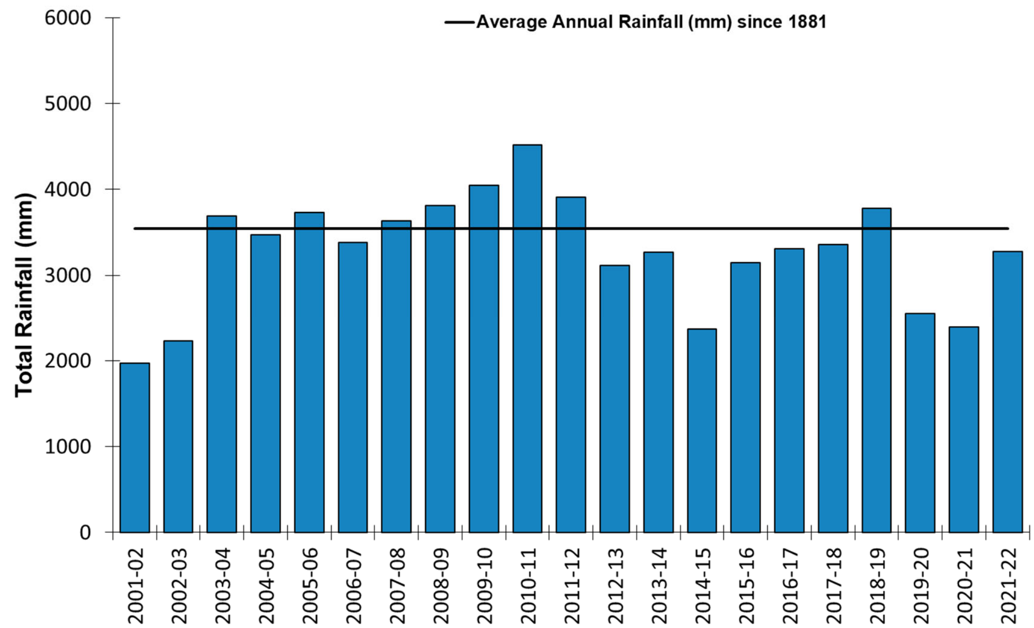


FIGURE 16. TOTAL ANNUAL RAINFALL (MM) RECORDED IN THE TWELVE MONTHS PRIOR TO SURVEY, AT INNISFAIL, 2001 – 2022. SOURCE: BUREAU OF METEOROLOGY, STATION 032025, 32197 AVAILABLE AT: WWW.BOM.GOV.AU.

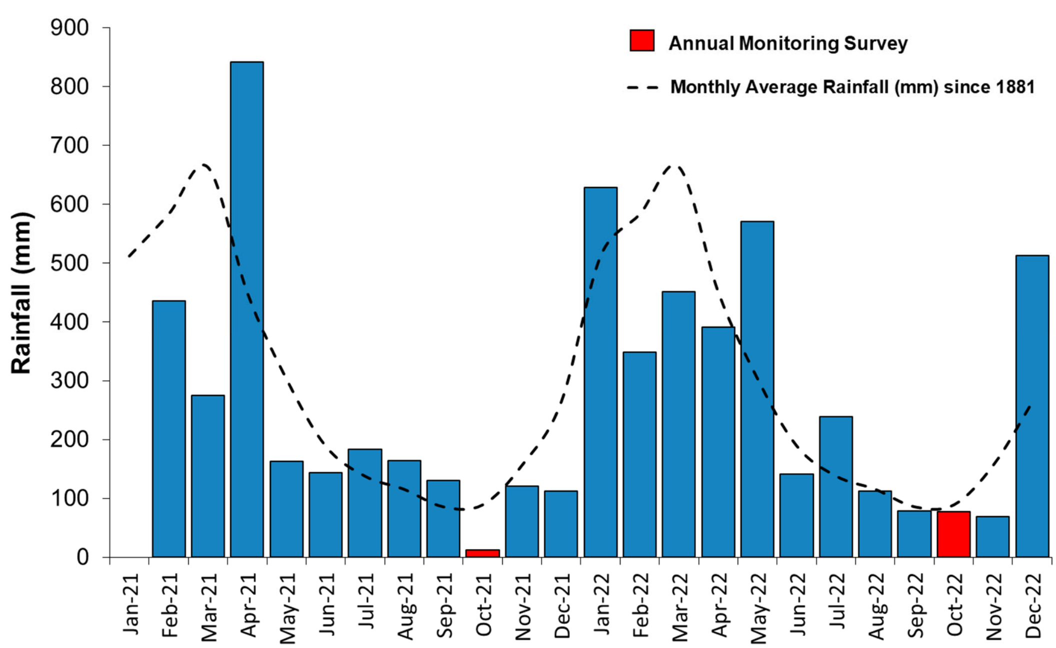


FIGURE 17. TOTAL MONTHLY RAINFALL (MM) RECORDED AT INNISFAIL, JANUARY 2020 – DECEMBER 2022. SOURCE: BUREAU OF METEOROLOGY, STATION 032025, 32197 AVAILABLE AT: WWW.BOM.GOV.AU.

3.3.2 River Flow

South Johnstone River total annual flow increased in 2022 to 1287 GL, which is also above the long-term mean of 814 GL (Figure 18). Half of the year experienced above average total monthly river flow with five of the nine months in the lead up to the survey having higher flows (Figure 19).

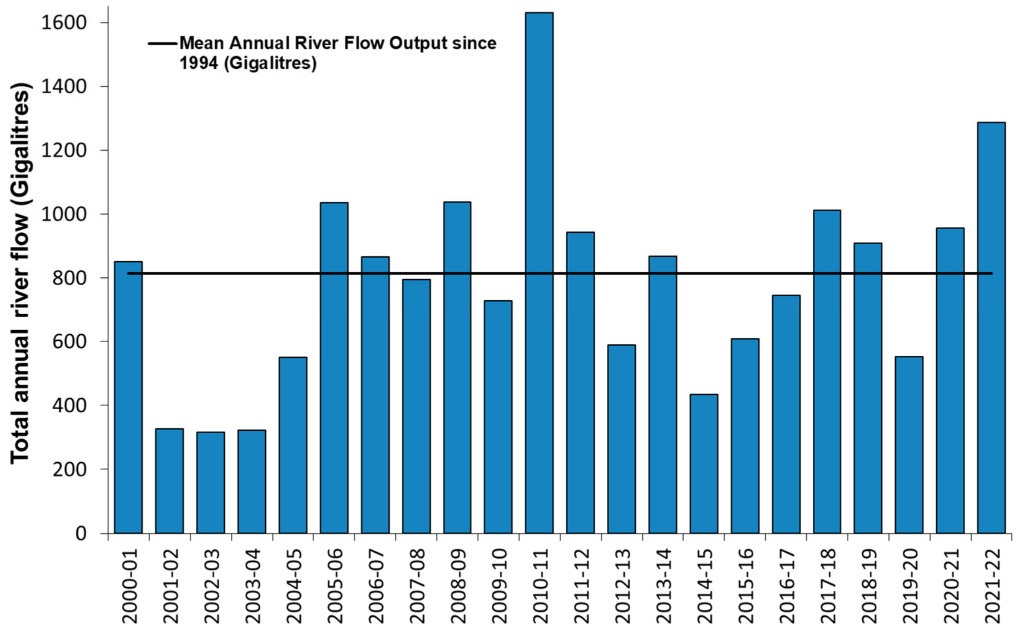


Figure 18. Annual river flow (gigalitres, GL) for the South Johnstone River. Source: Queensland Department of Environment and Resource Management, Station 112101B, available at: http://watermonitoring.derm.qld.gov.au/host.htm

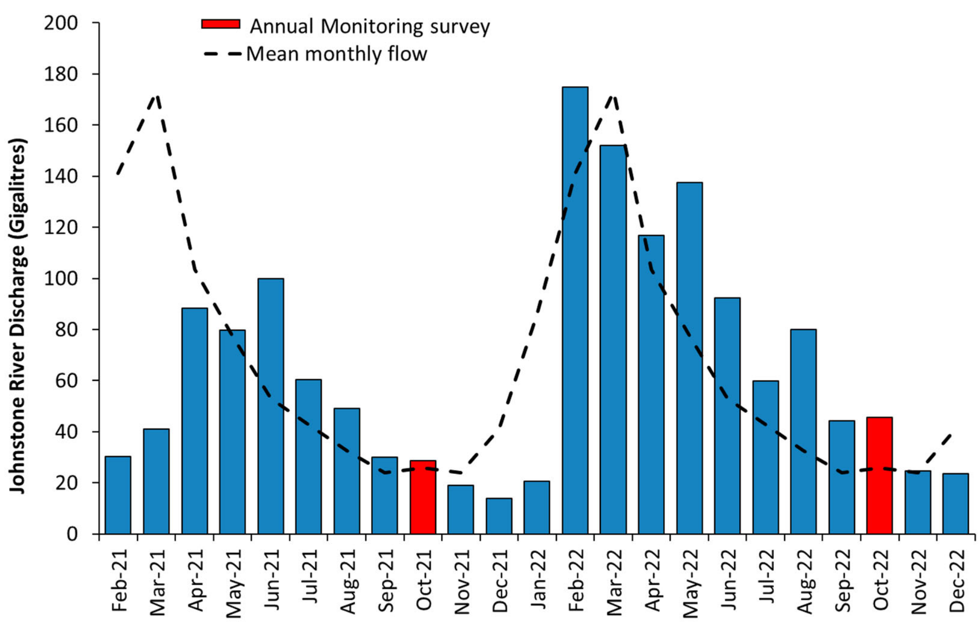


Figure 19. Monthly river flow (gigalitres) for the South Johnstone River, December 2018 – December 2022. Source: Queensland Department of Environment and Resource Management, Station 112101B, available at: http://watermonitoring.derm.qld.gov.au/host.htm

3.3.3 Air Temperature and Daily Global Solar Exposure

The warmest mean annual maximum daily air temperature of 29.2°C was recorded at Innisfail in 2022 and was just over 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 only slightly above average (19.7 MJ m^{-2}) at 19.78 MJ m^{-2} (Figure 21).

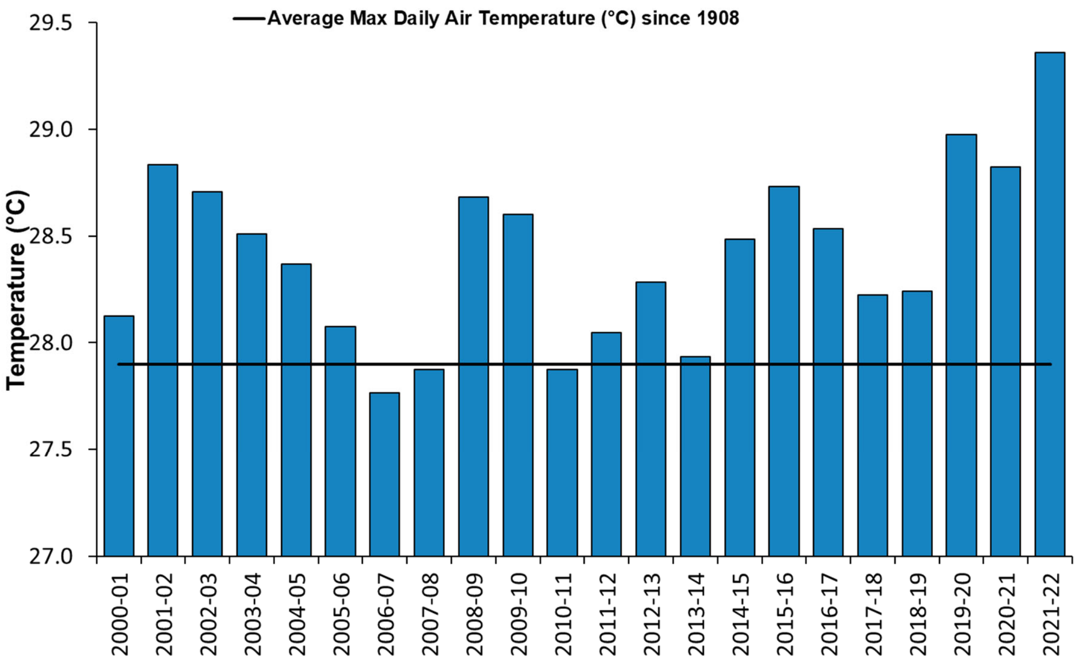


Figure 20. Mean annual maximum daily air temperature (°C) recorded at Innisfail in the twelve months prior to survey, 2000 – 2022. Source: Bureau of Meteorology, Station 032025, 32197, available at: www.bom.gov.au.

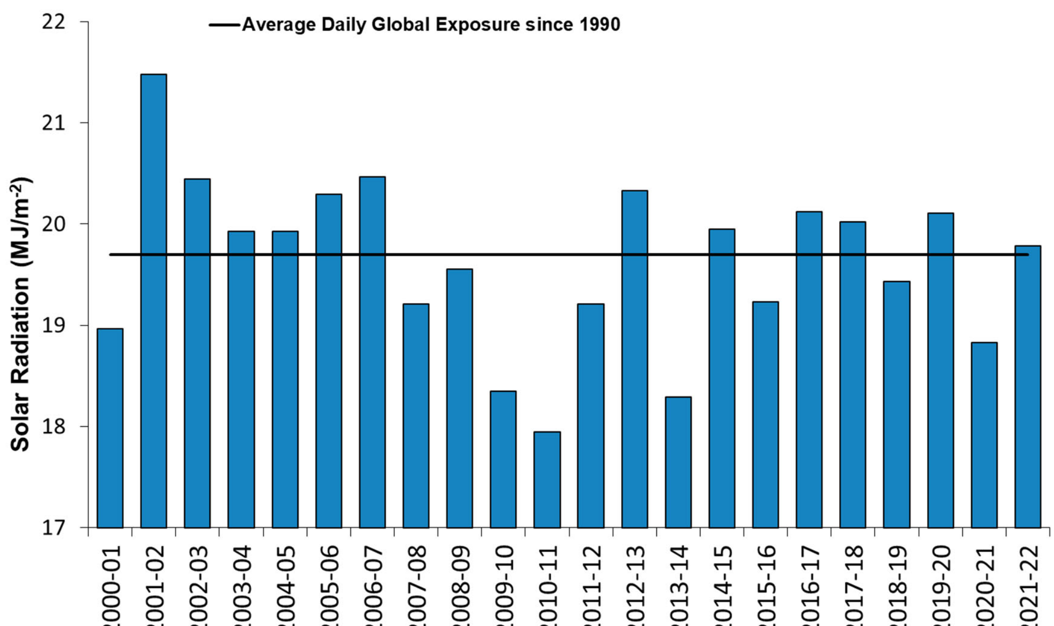


Figure 21. Mean annual daily global solar exposure (MJ m^{-2}) recorded at Innisfail in the twelve months prior to survey, 2000 – 2022. Source: Bureau of Meteorology, Station 032025, available at: www.bom.gov.au.

3.3.4 Tidal Exposure of Seagrass Meadows

Total annual daytime exposure of Mourilyan Harbour's intertidal seagrass meadows in 2022 (136 hours) was well below the long-term annual average (173 hours) (Figure 22). In 2022 all months had below average exposure with October 2021 the previous year being the last above average exposure month (Figure 23).

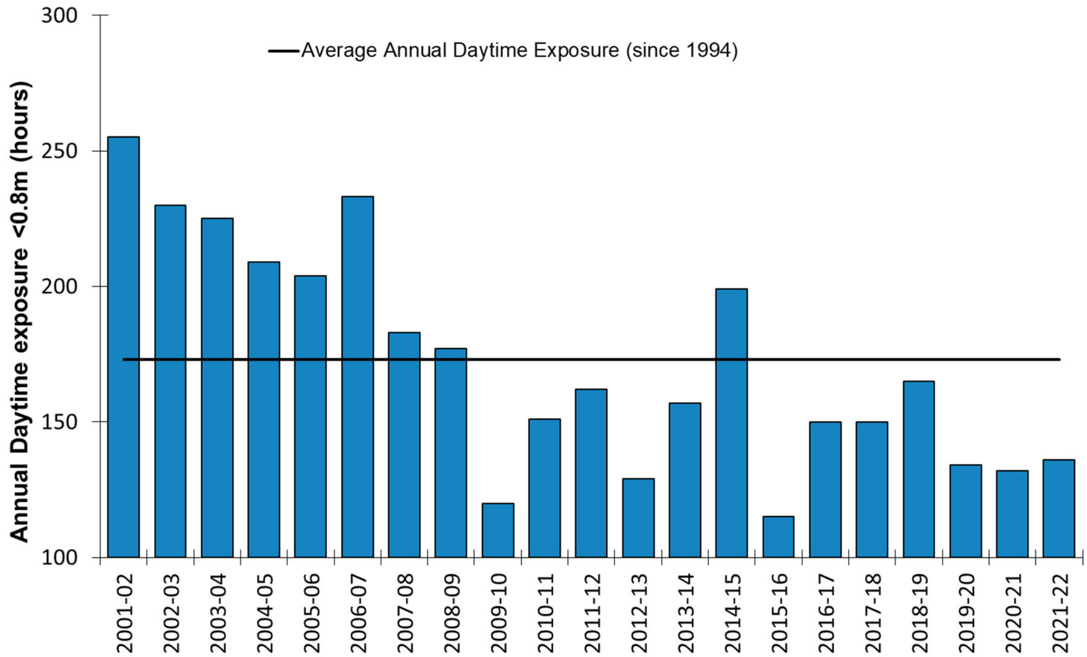


Figure 22. Annual daytime tidal exposure (total hours) of seagrass meadows in Mourilyan Harbour in the twelve months prior to survey; 2001 - 2022. Source: Maritime Safety Queensland, 2022.

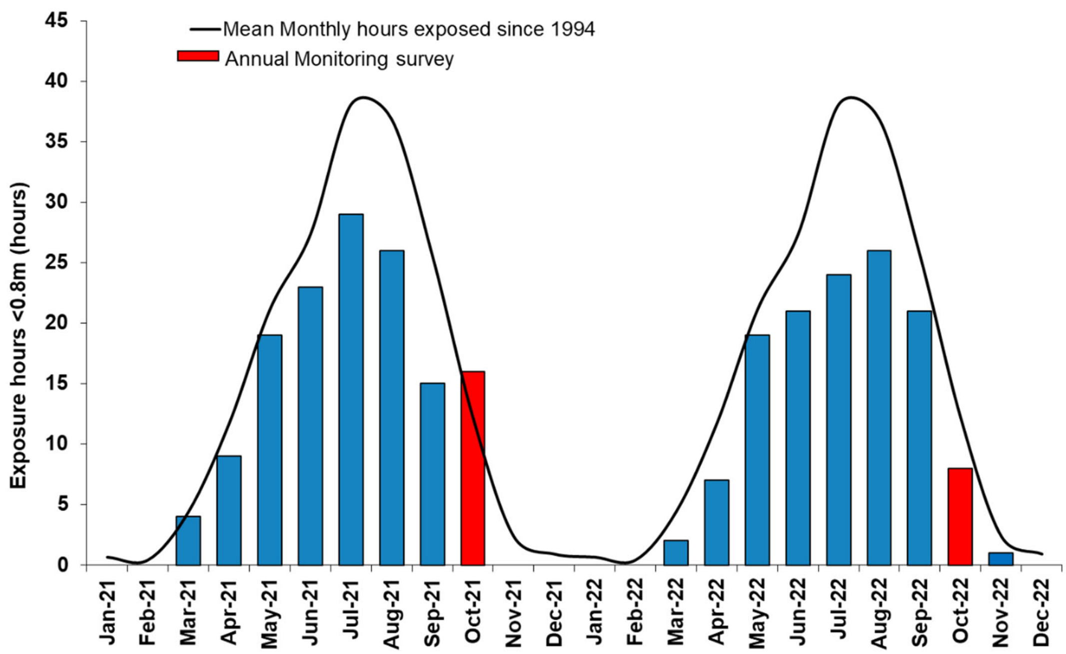


Figure 23. Total monthly daytime tidal exposure (total hours) in Mourilyan Harbour; January 2021 – December 2022. Source: Maritime Safety Queensland, 2022.

4 DISCUSSION

In 2022 seagrass improved slightly from the previous year being found in four of the five monitoring meadows but remained in a very poor condition overall. Seagrass extent in the five monitoring meadows is very low compared to baseline conditions and is the main contributor to the very poor condition grades that have been evident in Mourilyan Harbour over the past few years.

Improvements in biomass in four of the monitoring meadows is a promising sign. The return of foundation species *Zostera muelleri* in small isolated patches in the Bradshaw (1) meadow from restoration pilot work, and continued healthy growth for a second year is a positive result of the restoration efforts at the site. Over the past three years the pilot seagrass restoration program conducted by JCU TropWATER researchers in collaboration with OzFish and the Mandubarra and Goondoi Rangers trialled transplanting seagrass fragments collected from a donor meadow in Cairns Harbour. While the overall condition of this meadow remained very poor, the reestablishment of the foundation species is an encouraging sign for further recovery of this meadow. Lily (1), the other intertidal *Zostera* meadow, was completely absent for the third year in a row with no colonising species in or around the perimeter as has been found in previous years.

Regardless of improvements in biomass and area the overall meadow condition of Seaforth Bank (3) and Seaforth Edge (4) remained in a very poor condition. This is largely due to the footprint of both meadows remaining well below baseline levels. The Seaforth Edge (4) meadow had less stable species *H. decipiens* dominate the meadow which reduced the condition grade to very poor. The Channel (5) meadow returned in 2022 with aggregated patches of *Halophila spp*., however the small area was well below the expected baseline levels. The Seaforth Bank (3), Seaforth Edge (4) and Channel (5) meadows are usually dominated by colonising *Halophila spp*. which are highly variable in abundance and distribution (Kilminster et al. 2015) and can rapidly decline in response to low light conditions. They are also the first to return and quick to colonise once conditions improve (Kenworthy 2000).

Overall environmental conditions were somewhat favorable for seagrass growth during 2022 with annual rainfall and amount of daytime tidal exposure of intertidal meadows below average, which may have contributed to the improvements in seagrass between 2021 and 2022 and the continued survival and expansion of the restoration pilot plots observed over the year. However, some conditions in the 5 months prior to the survey were less favorable, with high river flows in the nearby Johnstone River and the highest mean temperatures recorded in the monitoring program since it began in 1994. These conditions may have limited the amount of recovery and potentially impacted deeper *Halophila* meadows in the months prior to the survey. If river flows in the Moresby were similarly increased to that of the neighbouring Johnstone they had the potential to lower water quality and light availability and would have particularly strong impacts on smaller *Halophila* species that are susceptible to relatively short periods of low light conditions.

The observed changes in the seagrass monitoring meadows in Mourilyan Harbour have been linked with major climate and weather events resulting in the loss of foundation seagrass species and the periodic impact to colonising species within the harbour. There is no evidence that port activities or operations have led to the recent declines in seagrasses. No major changes to activities or development activity for the port have occurred during the periods of seagrass decline over recent years.

Seagrass condition in the broader Queensland monitoring network generally all showed signs of improvement. The closest monitored meadows are in Cairns Harbour which continued their decade long recovery with increases in the dominance of larger growing foundation species such as *Zostera muelleri*, and overall good condition of the coastal meadows (Reason et al. 2023). Improvements in biomass in the meadows upstream in the Trinity Inlet estuary that consist of the same small highly ephemeral *Halophila* species that occur throughout Mourilyan Harbour and were in a satisfactory condition (Reason et al. 2023).

The next closest monitored meadows in Townsville to the south remained in a good condition due to stable climate conditions over the past two years (McKenna et al. 2023). Further afield 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).

Seagrasses are an ecologically important structural component within coastal ecosystems (Coles et al. 2015). The loss of the foundation species in Mourilyan Harbour reduces important ecosystem functions within the estuary. The Mourilyan Harbour seagrasses have been in poor to very poor condition since severe weather events from 2009-11 resulted in the loss of the foundation species *Z. muelleri* from the estuary in 2010. The loss of the foundation species reduces important ecosystem functions within the estuary. In North Queensland *Zostera muelleri* has been identified as an important habitat for juvenile fish and prawns from studies in Trinity Inlet, Cairns (Coles et al. 1993; Watson et al. 1993) with species of commercial and recreational importance also found in the seagrass meadows in Mourilyan Harbour (McKenzie et al. 1996). In depositional environments like the Bradshaw Island meadow, *Z. muelleri* beds can also store high amounts of Blue Carbon in their muddy sediments (Ricart et al. 2020). Regaining these meadows and their functions back to their state prior to 2009 would provide significant benefits.

Over the past 3 years, JCU/TropWATER, in partnership with OzFish Unlimited and Mandubarra and Goondoi Rangers have implemented a small scale pilot studies in Bradshaw meadow using vegetative fragments of *Z. muelleri*. Transplants were tied to either steel frames, biodegradable mesh frames of two sizes or individually weighted shoots and placed within the meadow footprint. The trials from 2020 and 2021 resulted in several persistent seagrass patches from the steel frames (2020) and individual shoots (2021) that have survived the wet season and were still expanding up to two and a half years after planting. These patches were surveyed and included in this report. The 2022 pilot study saw good preliminary results for individually weighted shoots in the months after planting and will be reassessed in 2023 following the wet season to determine success. The results of these three trials are so far very promising and provide a pathway to a large-scale restoration project that can return the seagrass to its previous healthy condition and to re-establish the vital ecological functions that it provides.

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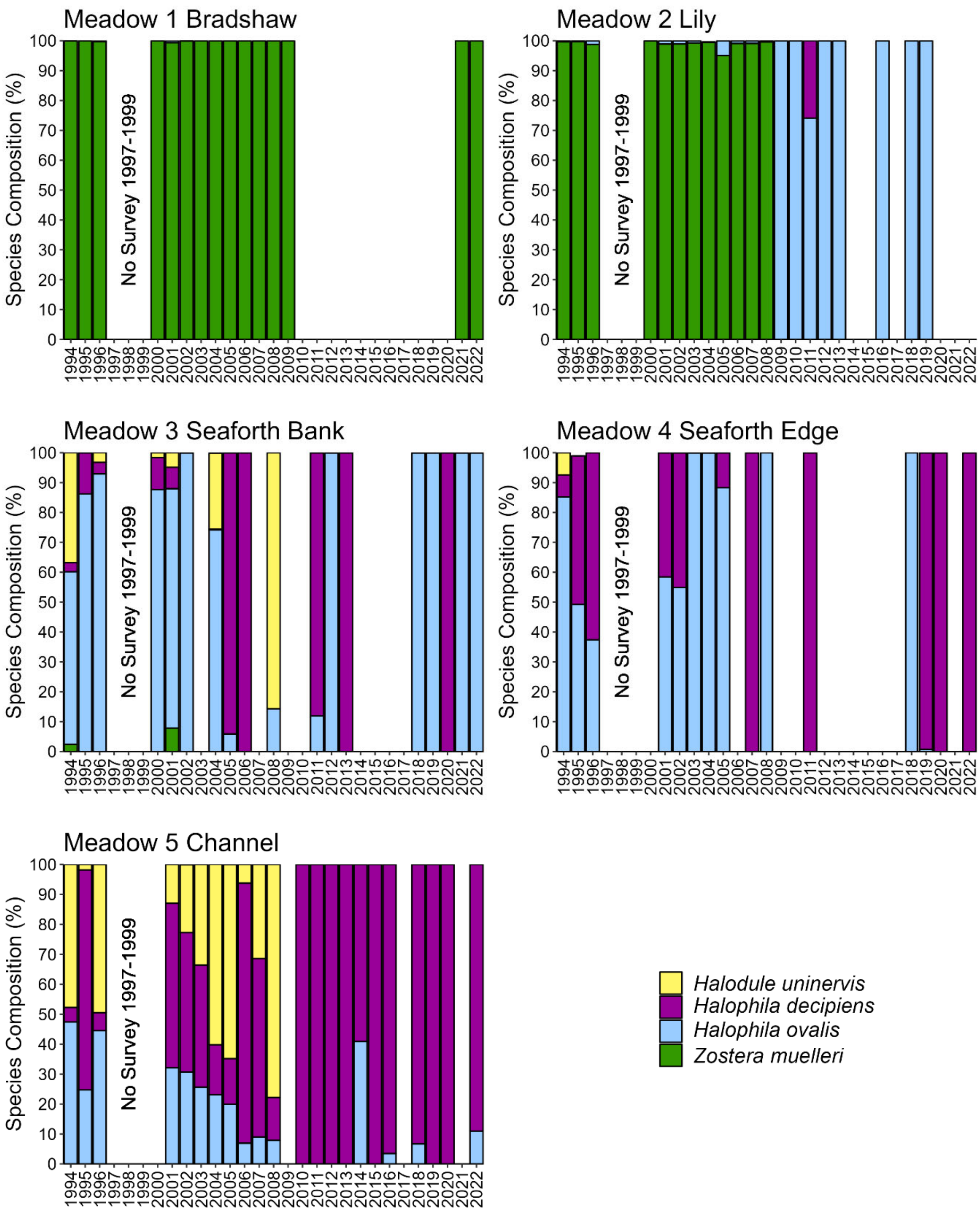
6 APPENDICES

6.1 SPECIES COMPOSITION OF MONITORING MEADOWS

SPECIES COMPOSITION OF MONITORING MEADOWS IN THE PORT OF MOURILYAN, 1994 – 2022.



6.2 AREA CHANGES: 1993 – 2022

SEAGRASS MONITORING MEADOW AREA (HA) IN MOURILYAN HARBOUR, 1993-2022 (±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

6.3 ABOVE-GROUND BIOMASS CHANGES: 1993 – 2022

MEAN ABOVE-GROUND BIOMASS (G DW M¯2) OF SEAGRASS FOR MONITORING MEADOWS IN MOURILYAN HARBOUR, 1993-2022. 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