Annual Seagrass Monitoring in the Mackay – Hay Point Region-2022

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CONTENTS

1 KEY FINDINGS

Seagrass Condition 2022

SATISFACTORY

This report compiles findings of the annual Hay Point-Mackay long-term seagrass monitoring conducted in September-October 2022.

- Overall seagrass in 2022 was in a satisfactory condition in the Hay Point-Mackay region, a downgrade from good in 2021.

- Seagrass condition was variable among different seagrass habitats and locations.
    - The seagrass in the Hay Point offshore deep-water meadow (8) was in its very good condition with the highest biomass recorded since 2004.
    - The Mackay offshore deep-water meadow (5) was in a good condition with seagrass present at every survey site, recording the largest area since sampling began there in 2017.
    - Coastal meadows at Dudgeon Point declined from good to poor condition in 2022 due to a decrease in meadow area.
    - Meadows at offshore Islands, Keswick (14) and St Bees (10) both declined in area but increased in biomass resulting in overall conditions of poor (Keswick) and satisfactory (St Bees).

- The were no major weather or climatic events in the 12 months before the survey and changes in area, biomass and species composition are in line with short-term natural variation experienced by these habitats.

Ongoing monitoring of the Dudgeon, Keswick and St Bees Island meadows will identify if the downward trends observed in this survey continue and any requirement for further investigation of causes.

2 IN BRIEF

A long-term seagrass monitoring program and strategy was developed for the Mackay-Hay Point region following a broad-scale extended survey of the region in 2014. The annual monitoring strategy now assesses two deep offshore monitoring areas at Mackay and Hay Point, a coastal intertidal area between Dudgeon Point and Hay Point, and two subtidal meadows at the Keswick Island group. Seagrass meadows in these areas represent the range of different seagrass community types found in the Mackay-Hay Point region.

The overall seagrass condition throughout the region was satisfactory in 2022, down from good in 2021. Seagrass condition and trends in indicators varied among monitoring locations. The Hay Point offshore meadow recorded the largest biomass since 2004 and was in very good condition while deep-water seagrass offshore from Mackay recorded the largest area for the monitoring area since sampling commenced in 2017 and was in a good condition despite a decline in mean biomass (Figure 1). The six month period leading up to the survey was characterised by below average significant wave height and this would likely have reduced resuspension of particles in the water column and resulted in a good light environment for seagrass growth in these offshore areas. This is supported by the increase in benthic PAR at Round Top Island compared to the previous two years.

The shallower coastal meadow at Dudgeon Point and the meadows at Keswick Island and St Bees Island all underwent reductions in meadow area in 2022 leading to the downgrading of the condition of Dudgeon Point and Keswick Island to poor condition (Figure 1). The seagrass assemblages at all of these meadows consist of colonising (e.g. *Halophila*) or opportunistic (e.g. *Halodule*) species that fluctuate in their distribution and abundance both annually and over shorter periods of weeks to months depending on environmental conditions. As the mean biomass at these meadows either increased or remained stable there are currently no great concerns for these meadows unless these declining trends in meadow size continue during future monitoring surveys.

The seagrass habitats in the Hay Point-Mackay region are known to be highly variable and assemblages are dominated by species that are adapted to surviving in low light conditions and dynamic benthic conditions that can be disturbed by storms and floods. When conditions for seagrass growth are unfavourable these colonising and opportunistic species have been shown to have much lower resistance to light deprivation than other seagrass species with mortality occurring in days to weeks rather than months for other larger seagrass species. These species are also known to recover quickly following disturbance. Critical to this recovery is their ability to produce a seed bank that allows for seagrass recruitment each growing season.

The climate conditions for seagrass growth were favourable for much of the year prior to the survey with below-average river flows and wave height, and rainfall and sea surface temperature only slightly above average (Figure 2). At the time of the 2022 survey, the region had experienced a five-year period of no major flooding or cyclones with meadow condition during this period ranging from good to satisfactory. The prolonged period of relatively stable environmental and climate conditions suggests that the seagrass habitats around the Mackay-Hay Point region have been able to build resilience and are well placed to continue to prosper as long as the growing conditions remain favourable. The good condition of seagrass in locations to the north (Abbot Point and Townsville) and satisfactory conditions to the south (Gladstone) indicate that regional scale factors were also good for seagrass growth and survival in 2022.

The monitoring program at Mackay-Hay Point is reaching maturity and is a valuable tool for assessing the ecological health of the marine environment in the region. A long-term (10-year) baseline of monitoring data was established at the Hay Point offshore meadow in 2021 and the annual survey in 2023 will see a full 10 year baseline established at Dudgeon Point and Keswick and St Bees Islands monitoring areas. The Mackay offshore baseline will be finalised in 2026. This will ensure long-term data will be in place for benchmarking of seagrass meadow condition indicators into the future.

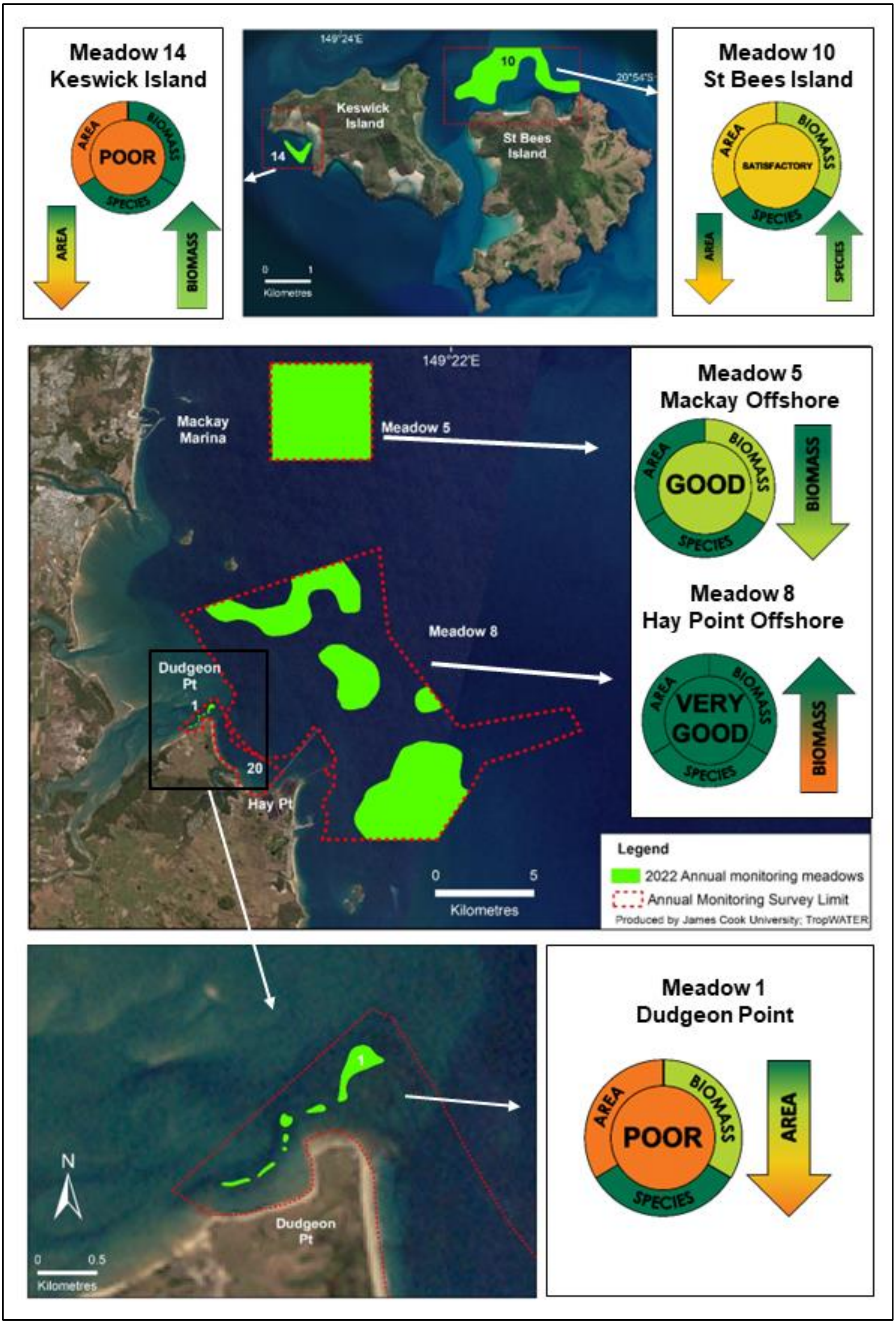

Figure 1. Seagrass meadow condition for the ports of Mackay, Hay Point, Keswick and St Bees Island 2022.

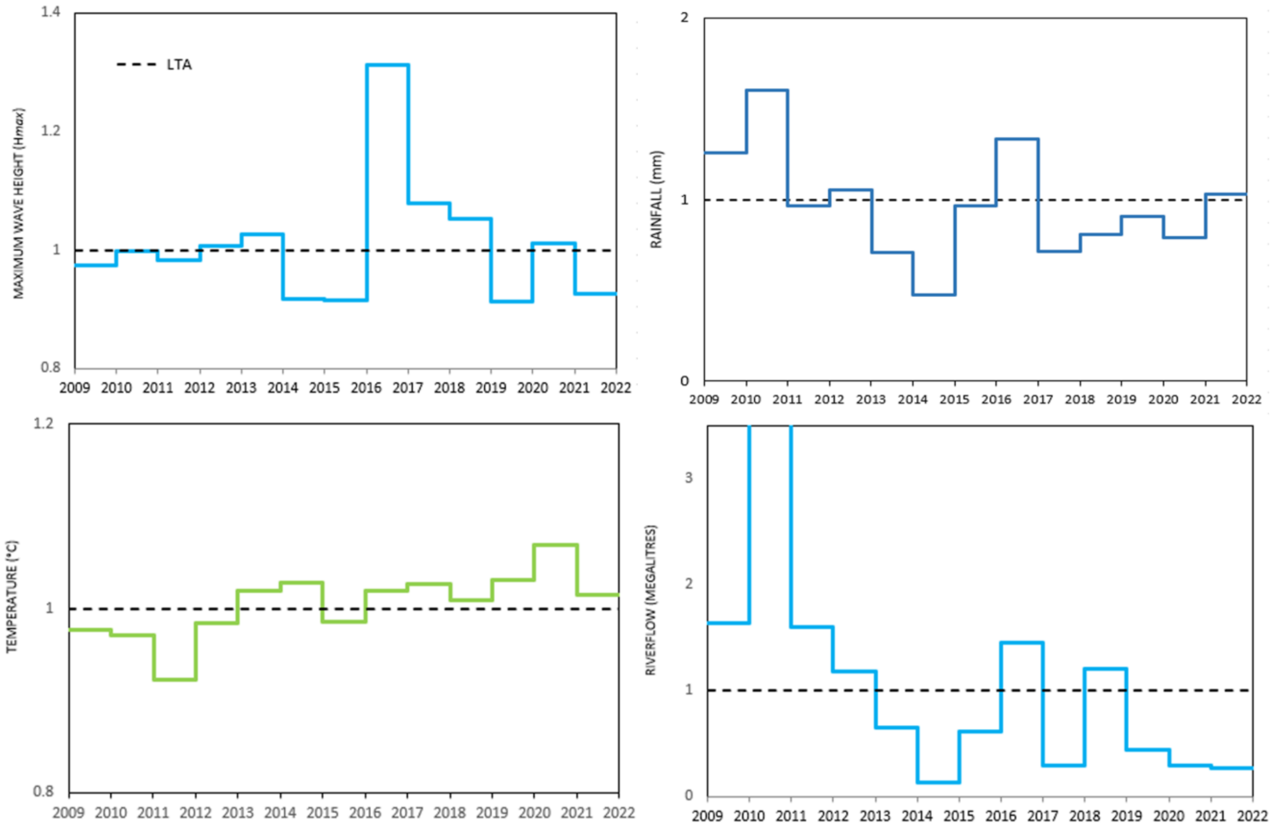

Figure 2. Recent climate trends in the Hay Point Area: change in climate variables as a proportion of the long-term average over the last 13 years (2009 – 2022). Black dotted line represents the long-term average. (See section 6.2 for detailed climate data).

3 INTRODUCTION

Seagrasses are one of the most productive marine habitats on earth and provide a variety of important ecosystem services worth substantial economic value (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. 2021). Seagrasses also play a major role in the cycling of nutrients (McMahon and Walker 1998), sequestration of carbon (Fourqurean et al. 2012; Lavery et al. 2013; York et al. 2018, Rasheed et al. 2019), stabilisation of sediments (James et al. 2019), and the improvement of water quality (McGlathery et al. 2007).

Globally, seagrasses have been declining due to natural and anthropogenic causes (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).

3.1 Queensland ports seagrass monitoring program

A long-term seagrass monitoring and assessment program has been established in the majority of Queensland commercial ports. The program was developed by the Seagrass Ecology Group at James Cook University's Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) in partnership with Queensland port authorities. A common methodology and rationale is used to provide a network of seagrass monitoring locations throughout the state (Figure 3).

A strategic long-term assessment and monitoring program for seagrasses provides port managers and regulators with the key information to ensure effective management of seagrass resources. It is useful information for planning and implementing port development and maintenance programs so they have a minimal impact on seagrasses. The program provides an ongoing assessment of many of the most threatened seagrass communities in the state.

The program delivers key information for the management of port activities to minimise impacts on seagrass habitat and has resulted in significant advances in the science and knowledge of tropical seagrass ecology. It has been instrumental in developing tools, indicators and thresholds for the protection and management of seagrasses, and an understanding of the causes of tropical seagrass change. It provides local information for individual ports as well as feeding into regional assessments of the status of seagrasses.

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

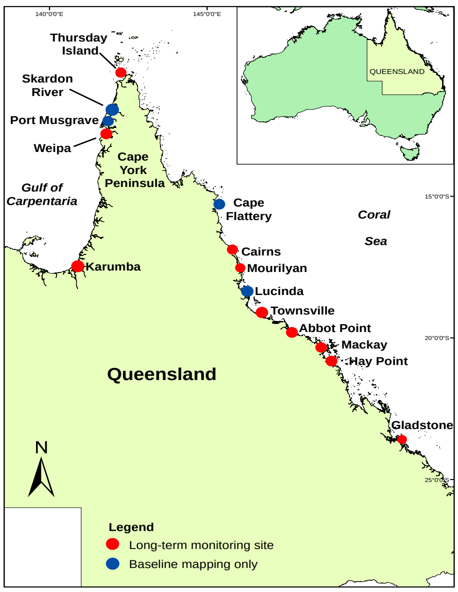

Figure 3. Location of Queensland Port Seagrass assessment sites.

3.2 Mackay and Hay Point seagrass monitoring program

The Port of Hay Point (approximately 38 km south of Mackay) is one of the world's largest coal exporting ports and comprises two coal export terminals; Dalrymple Bay Coal Terminal and the Hay Point Coal Terminal. The Port of Mackay is a multi-commodity port mainly exporting sugar and grain; located 5km from the city of Mackay. The Port comprises four wharves and a harbour formed by rock breakwaters. North Queensland Bulk Ports (NQBP) is the port authority for the Port of Hay Point and the Port of Mackay.

TropWATER's Seagrass Ecology Group first mapped significant areas of seagrass within the Port of Hay Point in a benthic survey conducted in July 2004 (Rasheed et al. 2004) and in Mackay in 2001 (Rasheed et al. 2001). The broad-scale habitat surveys that have since occurred at Hay Point (2005, 2010, 2011, 2014, 2016, 2017 and 2020), as well as the seagrass monitoring program that ran between 2005 and 2012, has established that the majority of seagrass in the area is of low density and cover (< 1 gdw m^{-2} and < 5% cover). The program has also shown that the natural spatial extent of deep water seagrasses around Hay Point is extremely variable with an annual cycle of absence and occurrence; deep water seagrass being present within the period from July to December each year (York et al. 2015). The broad scale surveys and current monitoring program also show that inshore seagrass meadows at Hay Point are highly variable in distribution and species composition. A collection of small meadows at Dudgeon Point are intermittent through time and also shift in species composition between domination by more persistent species (*Halodule uninervis* and *Zostera muelleri*) and the colonising *Halophila ovalis* and *H. decipiens* species.

The monitoring program between 2004 and 2012 found that Hay Point deep-water seagrass meadows were susceptible to impacts associated with large-scale capital dredging operations but re-established quickly once dredging was completed (York et al. 2015). Monitoring has also found that deep-water seagrasses at Hay Point, despite considerable inter annual variability, had a regular annual pattern of occurrence, low resistance to reduced water quality but a capacity for rapid colonisation on the cessation of impacts. Extensive and persistent turbid plumes from a large-scale and extended dredging program (in 2006) over an eight-month period resulted in a failure of the seagrasses to establish in 2006, however, recruitment occurred the following year and the regular annual cycle was re-established (York et al. 2015).

NQBP recognise that seagrasses form a key ecological habitat in the Mackay-Hay Point region and commissioned TropWATER to re-establish and expand on the long-term seagrass monitoring program that had been conducted between 2004 and 2012. The broad-scale survey in 2014 was used as a platform to re-establish the program, with added monitoring in the Keswick and St Bees Islands (southern Whitsunday Islands) and Mackay areas. There was also a change in approach to annual monitoring of the highly variable offshore seagrasses at Hay Point, from focusing on the fixed blocks to a more expansive meadow scale assessment based on the 2004 survey limit to incorporate change in seagrass area to the assessment (Figure 4). The long-term monitoring program coupled with regular broad-scale surveys and other research programs conducted in the Hay Point region by TropWATER enhance our understanding of water quality, seagrass and benthic habitat community dynamics, and enable more effective management of valuable marine habitats and port marine environments. Information collected in these programs aims to assist in planning and managing future developments in coastal areas. The monitoring program also forms part of Queensland's network of long-term monitoring sites of important fish habitats in high risk areas. It provides a key input into the condition and trend of seagrasses in the Mackay-Whitsundays NRM region, an area which otherwise has a poor spatial coverage for seagrass assessment and condition.

This report presents the findings of the annual seagrass habitat monitoring survey conducted in September/October 2022 in the Hay Point-Mackay region. The objectives of these studies were to:

- Map seagrass distribution and determine seagrass density and community type at all the monitoring areas in the Hay Point-Mackay region;
- Compare with results of previous monitoring surveys and assess any changes in seagrass area and abundance in relation to natural events or human induced port and catchment activities;

- Incorporate the results into the Geographic Information System (GIS) database for the Mackay-Hay Point region;
- Incorporate findings for the Mackay/Hay Point region into a report card system for seagrass condition developed across ports inshore of the GBR;
- Discuss the implications of monitoring results for overall health of the Mackay-Hay Point marine environment and provide advice to relevant management agencies.

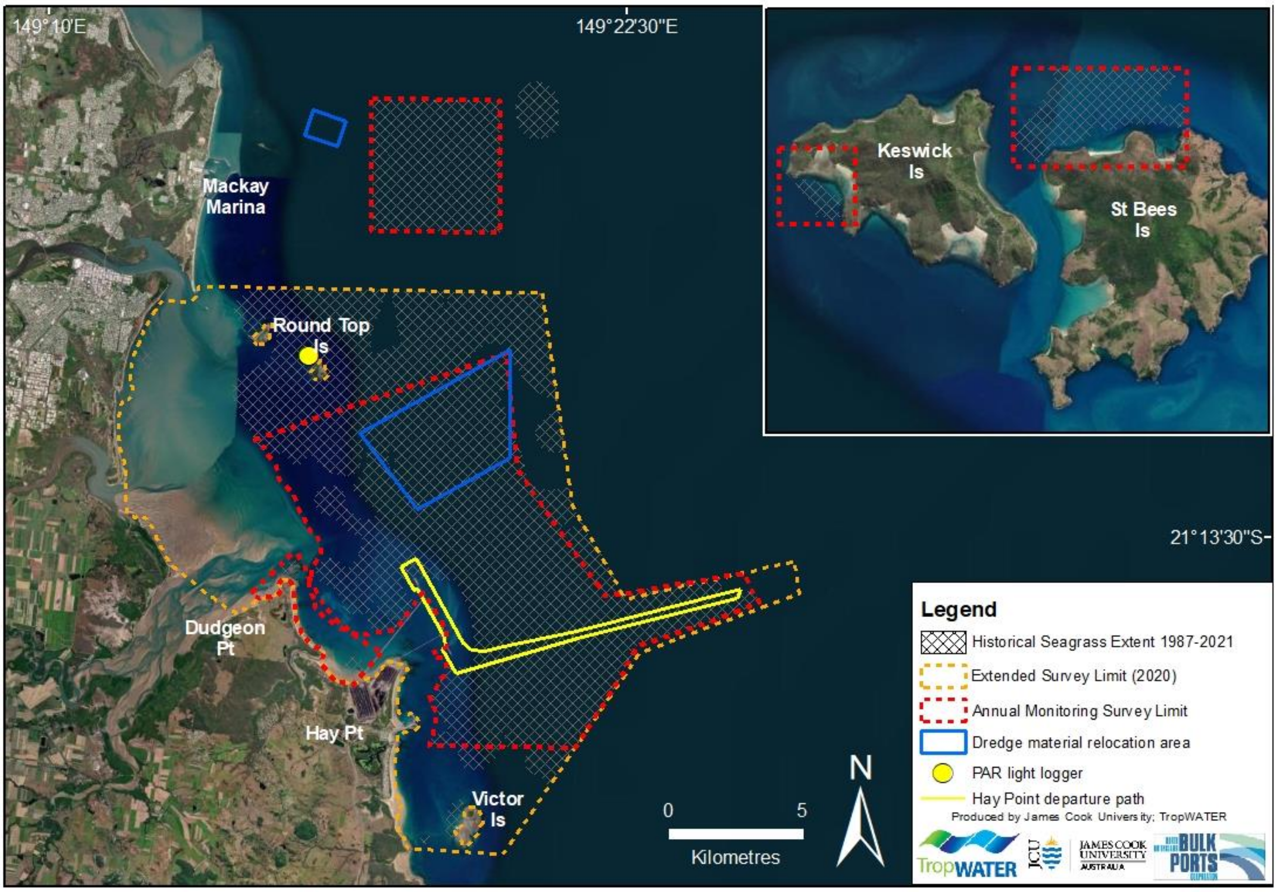

Figure 4. Location of survey limits of annual and extended seagrass monitoring areas around Mackay, Hay Point and the Keswick Island group in 2022.

4 METHODS

4.1 Sampling Approach

The approach of annual monitoring of representative meadows with a broader survey every three years has been adopted as part of NQBP's long-term seagrass programs in the Ports of Weipa, Hay Point, Mackay and Abbot Point, and elsewhere in other Queensland ports. Monitoring meadows were selected for detailed assessment because they were representative of the range of seagrass meadow communities identified in initial surveys and because they were located in areas likely to be vulnerable to impacts from port operations and developments or act as reference sites. Surveys are conducted between September and December to capture seagrasses at their likely seasonal peak in distribution and abundance, and to facilitate comparisons with the previous surveys conducted in the area. The annual monitoring of seagrass communities within the Hay Point-Mackay region (including Keswick and St Bees Islands) were conducted in September and October 2022 (Figure 4).

Methods followed previous surveys and employed standard and extensively reviewed techniques applied for baseline assessments and monitoring of seagrasses and benthic communities in Queensland. These surveys include; Gladstone, Cairns, Mourilyan, Karumba, Abbot Point, Weipa, Torres Strait and Townsville. Techniques in offshore areas ensure that a large area of seafloor is included at each site to take into account the low density, spatial variability and patchiness common for many tropical benthic habitats. Techniques also take into account logistical issues associated with naturally high water turbidity and the presence of dangerous marine animals. These standard methods were used to ensure that new information collected would be directly comparable with past programs.

4.2 Seagrass monitoring, habitat mapping and Geographic Information System

Sampling methods were based on existing knowledge of benthic habitats and physical characteristics of the location such as depth, visibility and logistical and safety constraints. Three sampling techniques were used:

1. Intertidal areas: Walking at low tide;
2. Subtidal inshore areas <8m below MSL: Boat based underwater digital camera mounted on a drop frame
3. Offshore subtidal areas >8m below MSL: Boat based digital camera sled tows with sled net attached.

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

At sites where seagrass was present, seagrass above-ground biomass was measured using a "visual estimates of biomass" technique (Kirkman 1978; Mellors 1991). At camera drop sites this technique involved an observer ranking seagrass biomass within three randomly placed 0.25m^2 quadrats at each site (Figure 5A-B). At digital camera sled tow sites this technique involved an observer ranking seagrass at 10 random time frames allocated within the 100m of footage for each site (Figure 5C-D). The video was paused at each of the ten time frames then advanced to the nearest point on the tape where the bottom was visible and sled was stable on the bottom. From this frame an observer ranked seagrass biomass and species composition. A 0.25m^2 quadrat, scaled to the video camera lens used in the field, was superimposed on the screen to standardise biomass estimates.

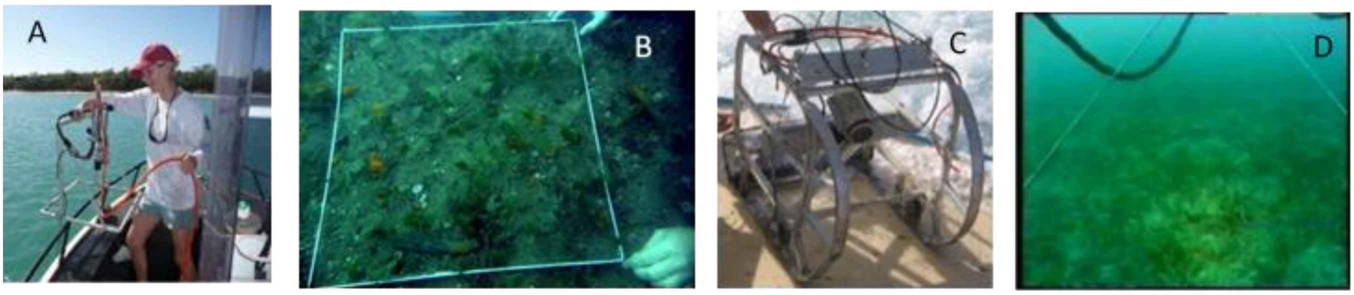

Figure 5. (A) Shallow subtidal mapping of seagrass meadows using digital camera mounted on a 0.25m^2 drop frame, (B) visual observation by free diver and (C-D) offshore underwater sled tows with digital camera

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, meadow layer and biomass interpolation layer.

- *Site Layer:* The site (point) layer contains data collected at each site, including:
    - Site number
    - Temporal details – Survey date and time.
    - Spatial details – Latitude, longitude, depth below mean sea level (dbMSL; metres) for subtidal sites.
    - Habitat information – Sediment type; seagrass information including presence/absence, above-ground biomass (total and for each species) and biomass standard error (SE); dugong feeding trail (DFT) presence/absence.
    - Sampling method and any relevant comments.

- *Meadow layer:* The meadow (polygon) layer provides summary information for all sites within each meadow, including:
    - Meadow ID number – A unique number assigned to each meadow to allow comparisons among surveys
    - Temporal details – Survey date.
    - Habitat information – Mean meadow biomass ± standard error (SE), meadow area (hectares) ± reliability estimate (R) (Table 3), number of sites within the meadow, seagrass species present, meadow density and community type (Tables 1 & 2), meadow landscape category (Figure 6).
    - Sampling method and any relevant comments.

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

Table 1. Nomenclature for Queensland seagrass community types.

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

Table 2. Density categories and mean above-ground biomass ranges for each species used in determining seagrass community density in the Hay Point-Mackay region.

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

Isolated seagrass patches

The majority of area within the meadow consists of unvegetated sediment interspersed with isolated patches of seagrass.

Aggregated seagrass patches

The meadow consists of numerous seagrass patches but still features substantial gaps of unvegetated sediment within the boundary.

Continuous seagrass cover

The majority of meadow area consists of continuous seagrass cover with a few gaps of unvegetated sediment.

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

Seagrass meadow boundaries were determined from a combination of techniques. Exposed inshore boundaries were guided by recent satellite imagery of the region (Source: ESRI; Google Earth). Subtidal boundaries were interpreted from a combination of subtidal survey sites and the distance between sites, field notes, depth contours and recent satellite imagery.

Meadow area was measured using the calculate geometry function in ArcGIS®. Meadows were assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow (Table 3). Mapping precision ranged from ≤10 m for intertidal seagrass meadows with boundaries mapped by walking to 100 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.

Table 3. Mapping precision and methodology for boundary mapping in the Port of Hay Point and Keswick Island group.

Mapping precision	Mapping methodology
10 m	Subtidal meadow boundaries determined from walking in meadows at low tide; Relatively high density of survey sites; Recent aerial photography aided in mapping.
20-50 m	Subtidal meadow boundaries determined from underwater CCTV camera drops; Moderate to high density of survey sites.
100 m	Larger subtidal meadows with boundaries determined from underwater CCTV and sled tows; All meadows subtidal; Relatively low density of survey sites.

4.3 Seagrass meadow condition index

A condition index was developed for seagrass monitoring meadows based on changes in mean above-ground biomass, total meadow area and species composition relative to a baseline (see Carter et al. 2023 for full details). Seagrass condition for each indicator in Hay Point-Mackay was scored from 0 to 1 and assigned one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor). Overall meadow condition is the lowest indicator score where this is driven by biomass or area. Where species composition is the lowest score, it contributes 50% of the overall meadow score, and the next lowest indicator (area or biomass) contributes the remaining 50% (Carter et al. 2023).

4.4 Environmental data

Environmental data was collated for the 12 months preceding the survey. River flow was provided by the Queensland Government Water Monitoring Information Portal (Station 125016A – Pioneer River at Dumbleton Weir). Total daily rainfall, temperature and global solar exposure was obtained for the nearest weather station from the Australian Bureau of Meteorology (Mackay Aero station #033045; http://www.bom.gov.au/climate/data/). Wave data and sea surface temperature was provided by Queensland Government coastal data system – (Hay Point).

Irradiance measured as photosynthetically active radiation (PAR - mol photons m^{-2} day^{-1}) was collected at Round Top Island nearby to the offshore seagrass meadows as part of the Ambient Water Quality monitoring Program at the Ports of Mackay and Hay Point. Data was collected from a PAR Sensor positioned on the horizontal surface of a multiparameter water quality logging instrument, which takes a PAR measurement at ten (10) minute intervals for a one second period (Waltham et al. 2021). Data is presented as a 7-day rolling average of total daily PAR to allow for comparison with modelled thresholds for light requirements of deep-water seagrass in the region (McKenna et al. 2015).

5 RESULTS

5.1 Seagrass in the Hay Point, Mackay and Keswick Island areas

In 2022 the annual monitoring survey in the Hay Point, Mackay and Keswick Island area surveyed a total of 303 sites (Figure 9). The survey was conducted during September and October and seagrass was present at 34 % of all the coastal and offshores survey sites. The coastal areas of Keswick Island, St Bees Island and Dudgeon Point had seagrass present at 28% of the sites. The offshore survey area, which includes the Mackay offshore annual monitoring area (Meadow 5) and the Hay Point offshore annual monitoring area (Meadow 8) had seagrass present at 50 % of sites (Figure 9).

Five seagrass species were observed in 2022, and the species were typical of those found in coastal and offshore areas in Hay Point/ Mackay and more broadly in central Queensland (Figure 8; Figure A1). The inshore meadows at Dudgeon Point were dominated by *Halodule uninervis* (both wide and narrow forms) with a smaller amount of *Halophila ovalis* (Figure 8; Figure 10; Figure A1). The small amount of *Zostera muelleri* that was observed in 2021 was not present at survey sites in 2022. The two meadows at Keswick and St Bees Islands were dominated by *Halophila tricostata* and *Halophila spinulosa* with smaller amounts of *Halophila decipiens, H. ovalis* and *H. uninervis* also occurring (Figure 8; Figure 10; Table A1). Deepwater seagrass assemblages offshore from Hay Point and Mackay were dominated by *H. decipiens* and *H. spinulosa* (Figure 8; Figure 10; Figure A1).

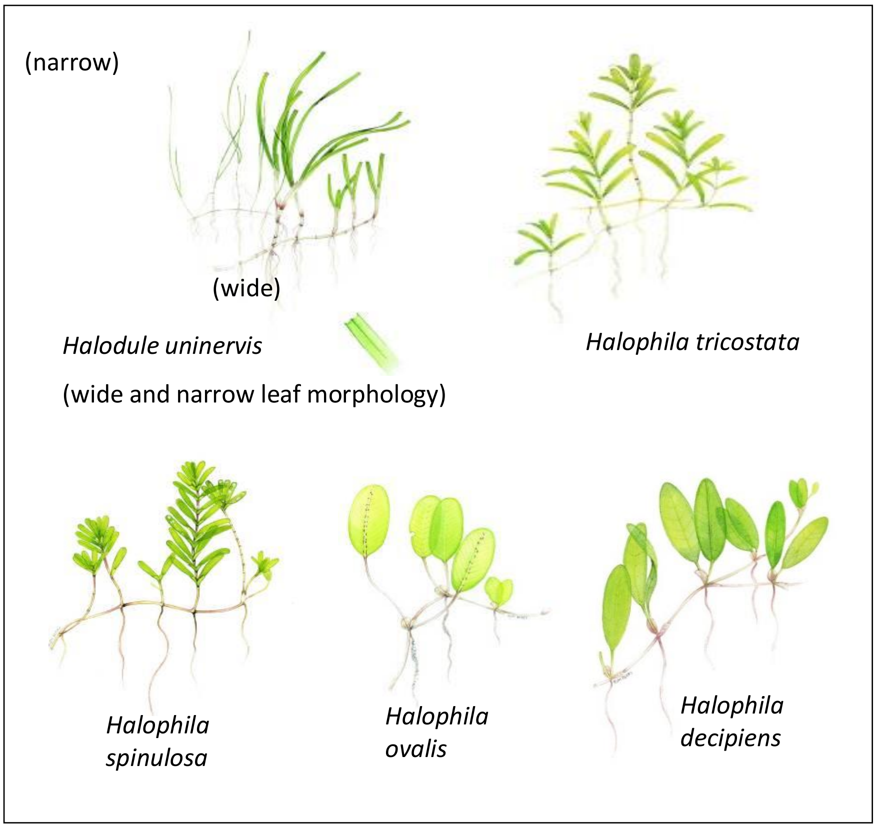

Figure 8. Seagrass species identified in the Hay Point-Mackay annual monitoring program in 2022. Leaf size varies widely within species and diagrams are not to scale.

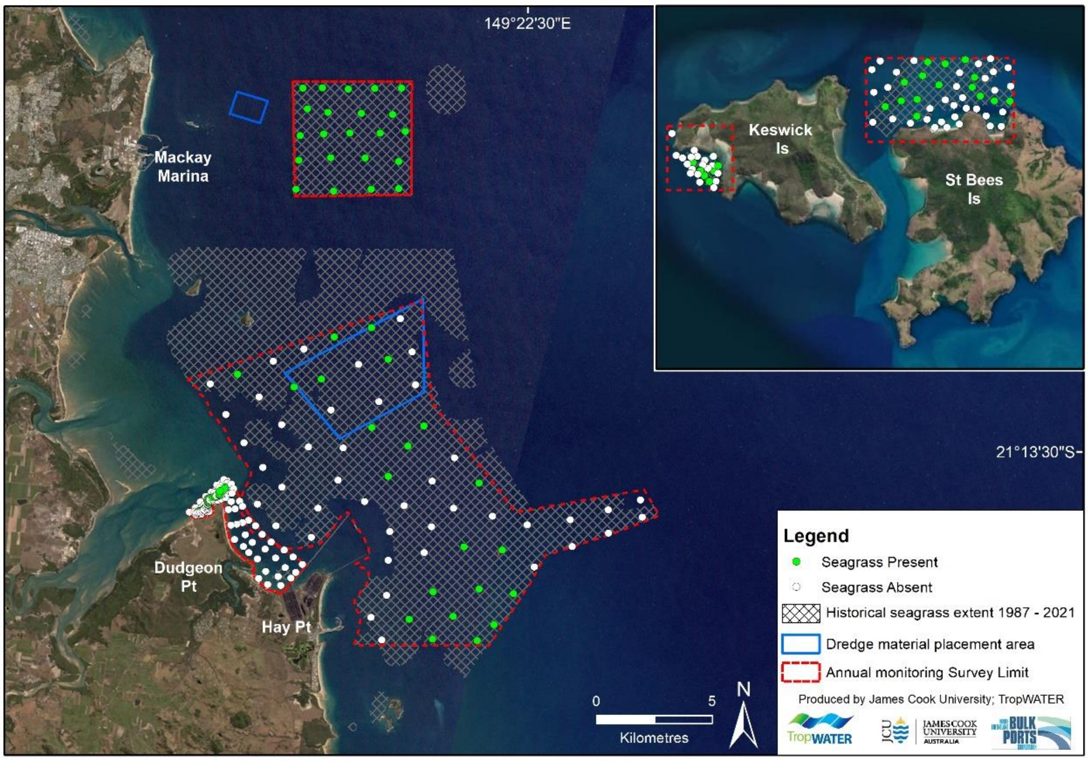

Figure 9. Location of 2022 annual and extended seagrass monitoring survey sites in the Hay Point-Mackay region.

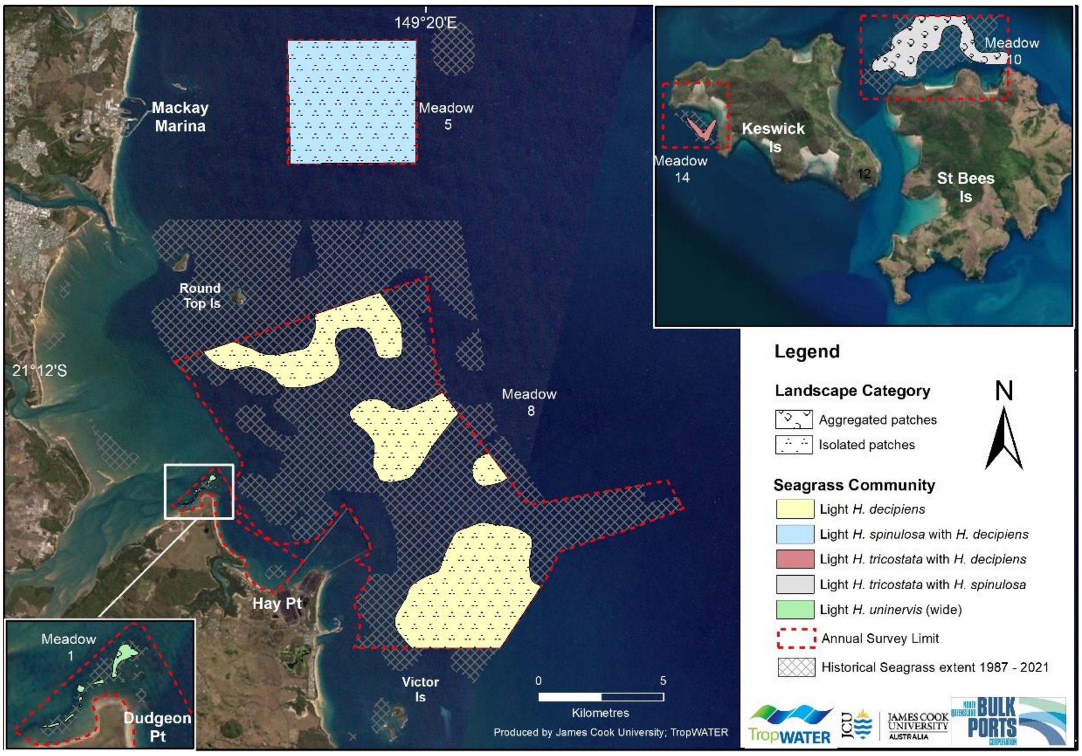

Figure 10. Location of 2021 seagrass meadows in the Hay Point region showing seagrass communities and landscape categories.

5.2 Seagrass condition in the Hay Point - Mackay region

5.2.1 Offshore seagrass at Hay Point and Mackay

The Offshore Hay Point monitoring area (M8) overall condition of seagrasses was very good in 2022 (Table 4; Figure 11). This is an improvement on the poor condition grade from 2021, and is driven by an almost doubling of mean biomass in 2022 (Table 4; Figure 11; Table A1). All condition grades of biomass, area and species composition were in a very good condition in 2022, and this is the first time it has reached such a state since it was first assessed in 2004 (Figure 11; Table A1). The area of this meadow reduced from 5,216.6 ± 618.2 ha in 2021, to 3,853.2 ± 559.6 ha in 2022, but remains within the same very good condition grade (Figure 11). This meadow is dominated by the pioneering *H. decipiens*, which has been the main species in this area throughout the program's history, along with small amounts of *Halophila spinulosa* (Figure11; Figure A1).

The Offshore Mackay meadow (5) declined in overall condition in 2022 from very good to a good condition (Table 4; Figure 12). After six years of continuous data collection, this is the second year that a condition score has been calculated for this meadow. Biomass declined from 0.203 ± 0.080 g DW m^2 in 2021 to 0.09 ± 0.02 g DW m^2 in 2022 (Figure 12; Table A1). Seagrass was present at every survey site and area (2326.3 ± 196.0 ha) increased slightly to be the highest recorded since monitoring began in 2017 (Figure 12; Table A1). The species composition in this meadow is a mix of *H. decipiens* and *H. spinulosa,* with a shift in 2022 to *H. spinulosa* becoming more dominant (Table A1; Figure A1).

5.2.2 Inshore seagrass at Dudgeon Point

The Dudgeon Point (1) coastal intertidal monitoring meadow declined in condition grade from good to poor in 2022, returning to 2020 levels (Table 4; Table A2). The main driver behind the decline was due to a 43 % reduction in area (Figure 13; Table A2). This meadow is made up of multiple small isolated patches of seagrass dominated by *H. uninervis* (both wide and narrow leaf forms) with a small amount of *H. ovalis*. The species composition of this meadow remained in a very good condition for the seventh year in a row, however the *Z. muelleri* that was present last year was not observed in 2022 (Figure 13; Figure A1). Biomass remained in a good condition for the fourth year in a row with little change, most likely due to the persistence of the *H. uninervis* in this area (Figure 13).

5.2.3 Keswick and St Bees Islands

The St Bees Island (10) seagrass monitoring meadow remained in a satisfactory condition for the third consecutive year (Table 4; Figure 14). While the biomass of this meadow improved from a satisfactory to a good condition, with a 44% increase since 2021 (Figure 14; Table A3), however, a 31 % decrease in the area of this meadow saw this indicator downgrade in 2022 from very good to satisfactory (Figure 14; Table A3). The species composition of this meadow improved to a very good condition with increasing dominance of *H. tricostata* and *H. spinulosa* with a small amount of *H. decipiens* also occurring (Figure 14; Figure A1). The Keswick Island (14) subtidal monitoring meadow declined to a poor condition in 2022 (Table 4; Figure 15). The footprint of this meadow declined by 54 % to 10.3 ± 3.9 ha, changing from a very good to a poor condition (Table 4; Figure 15). However, there was a concurrent 53 % increase in biomass (2.86 ± 1.08 g DW m^2) in the meadow which improved this indicator grade from good to very good (Figure 15, Table A3). The species composition of the meadow remained in a very good condition with an increase in the dominance of the *Halophila tricostata*, the indicator species for this meadow (Figure 15; Figure A1).

Table 4. Grades and scores for seagrass indicators (biomass, area and species composition) for the Hay Point-Mackay monitoring meadow in 2022.

Meadow	Location	Biomass	Area	Species Composition	Overall Meadow Score
1	Dudgeon Point	0.845	0.48	0.93	0.48
5	Mackay - Offshore	0.74	0.98	1.00	0.74
8	Hay Point - Offshore	0.90	0.90	1.00	0.90
10	St Bees Island	0.77	0.58	0.99	0.58
14	Keswick Island	0.85	0.45	0.94	0.45
Overall Score for the Hay Point-Mackay region					0.63

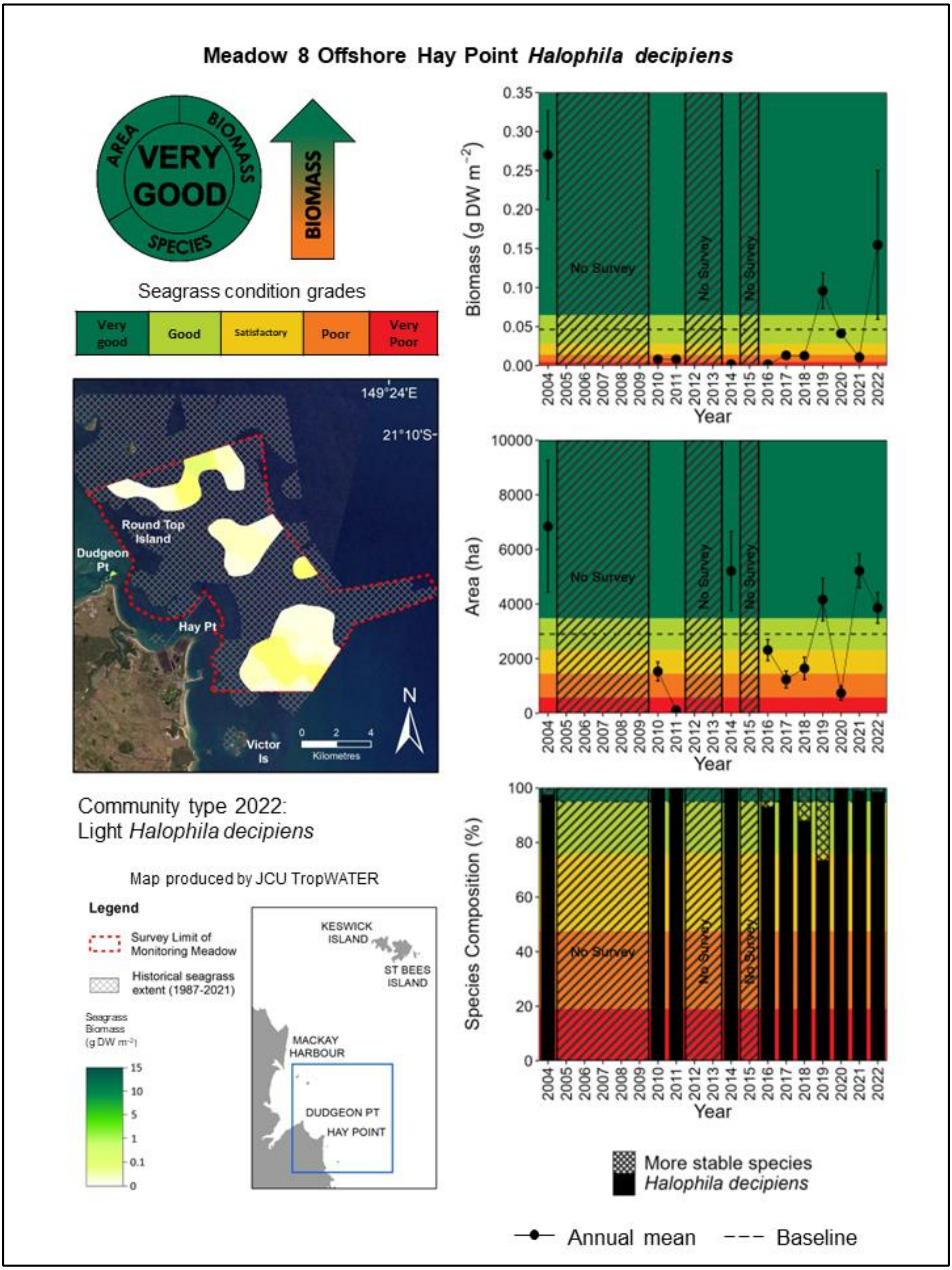

Figure 11. Changes in meadow biomass, area and species composition for seagrass in the Hay Point offshore area (Meadow 8), 2004 – 2022 (biomass error bars = SE).

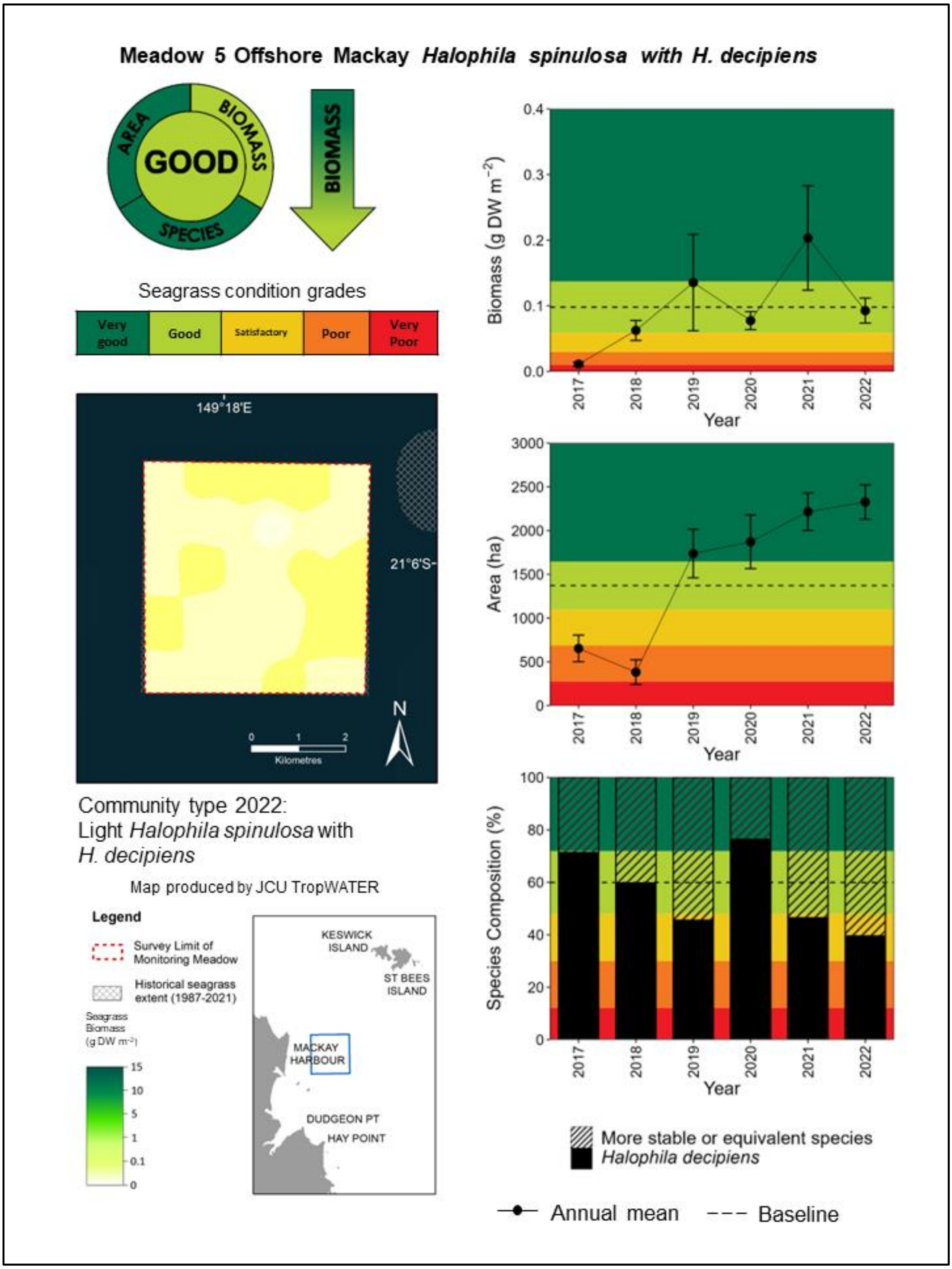

Figure 12. Changes in meadow biomass, area and species composition for seagrass in the Mackay offshore area (Meadow 5), 2017 – 2022 (biomass error bars = SE).

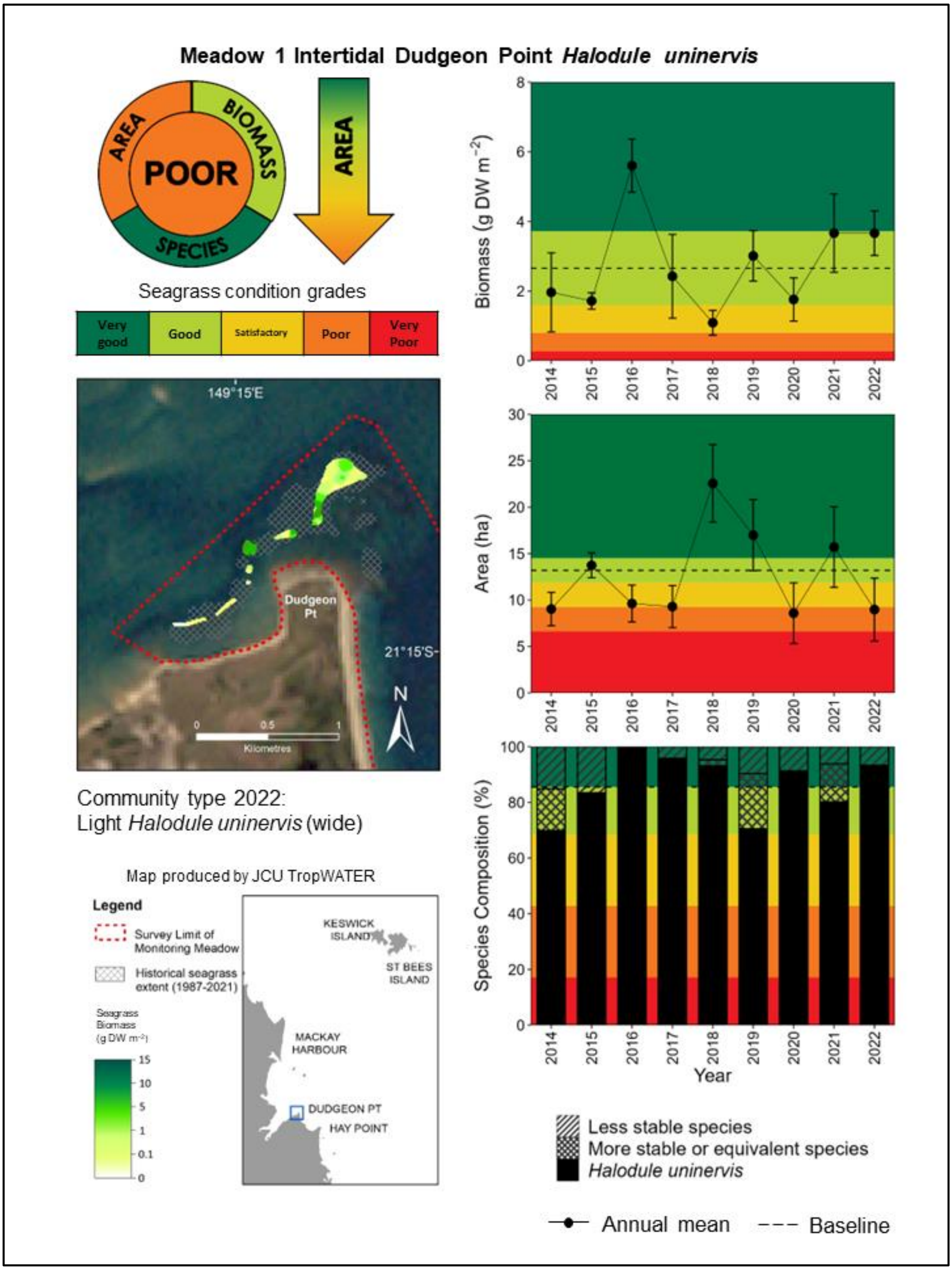

Figure 13. Changes in meadow biomass, area and species composition for seagrass in the Dudgeon Point coastal area (Meadow 1), 2014 – 2022 (biomass error bars = SE).

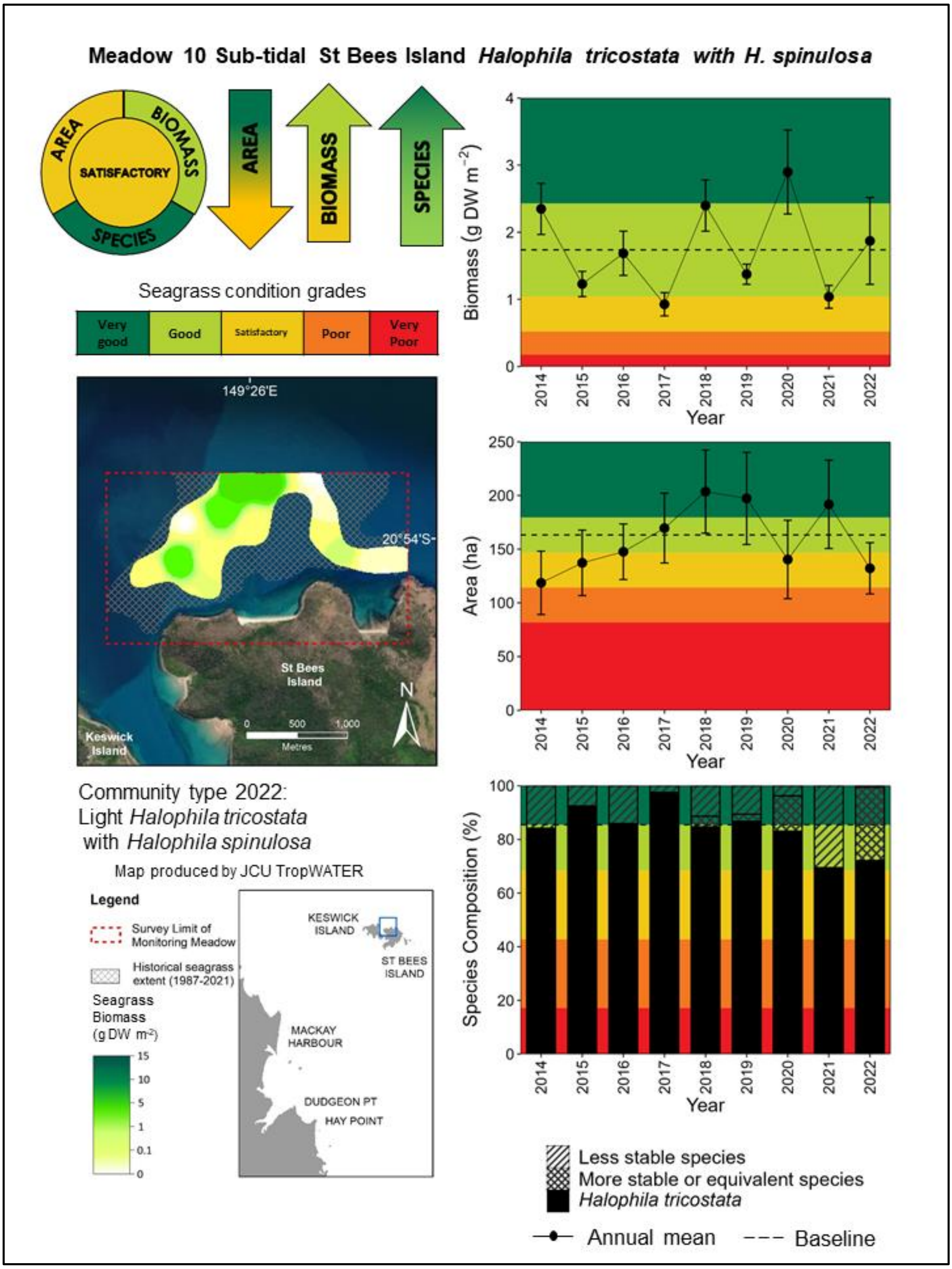

Figure 14. Changes in meadow biomass, area and species composition for seagrass in the St Bees Island coastal area (Meadow 10), 2014 – 2022 (biomass error bars = SE).

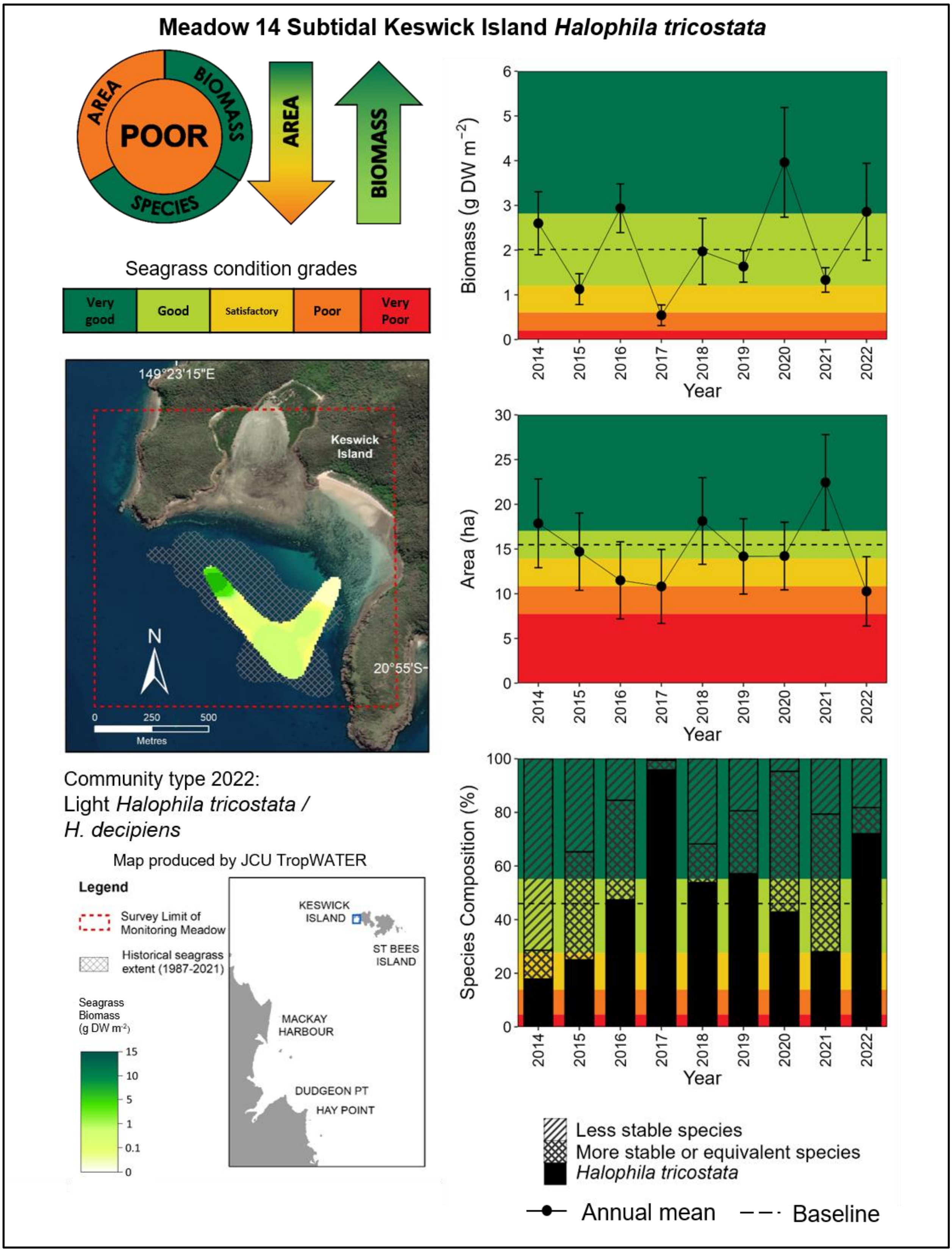

Figure 15. Changes in meadow biomass, area and species composition for seagrass in the Keswick Island coastal area (Meadow 14), 2014 – 2022 (biomass error bars = SE).

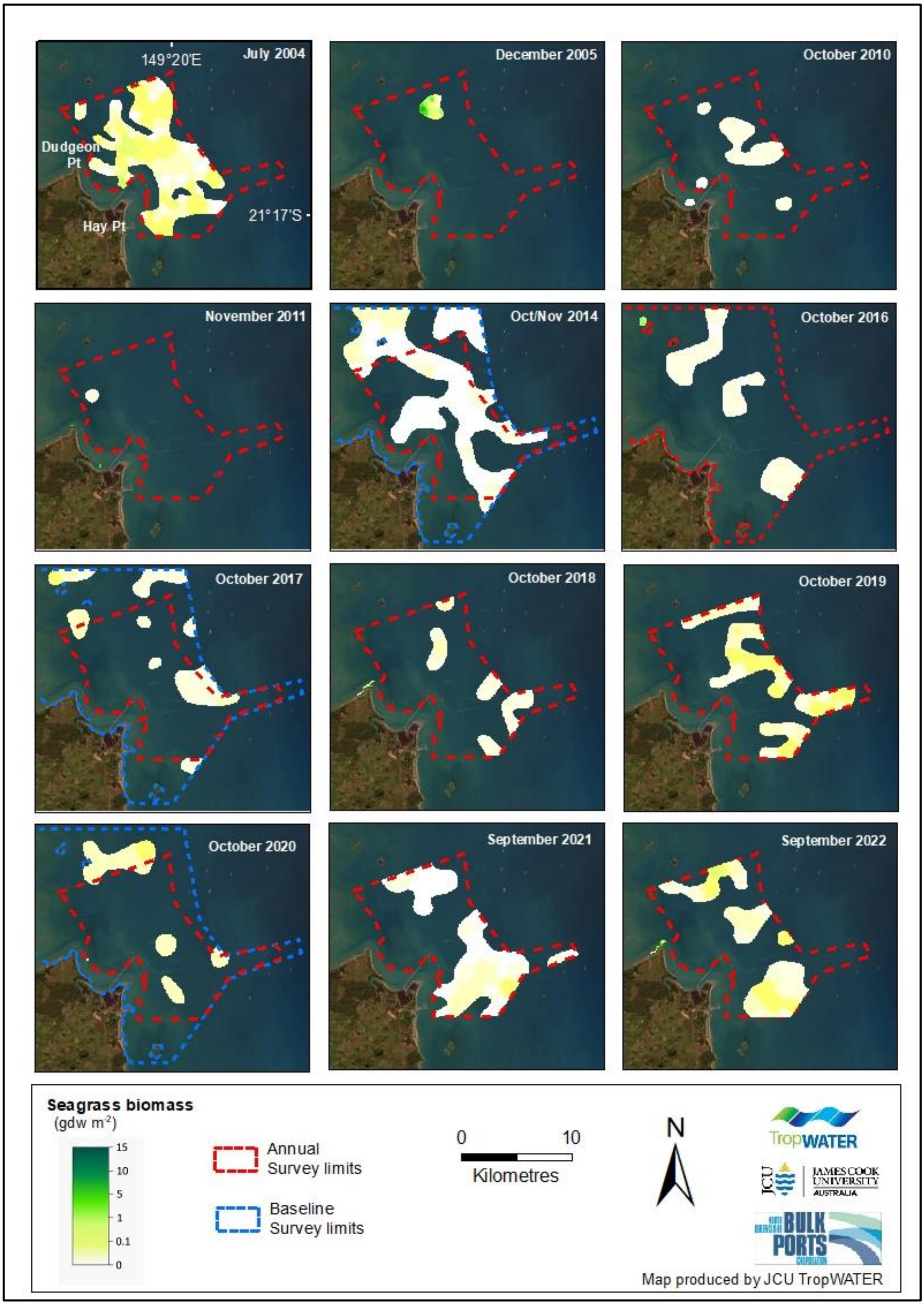

Figure 16. Seagrass biomass distribution in the Hay Point offshore monitoring area when surveys were conducted between 2004-2022.

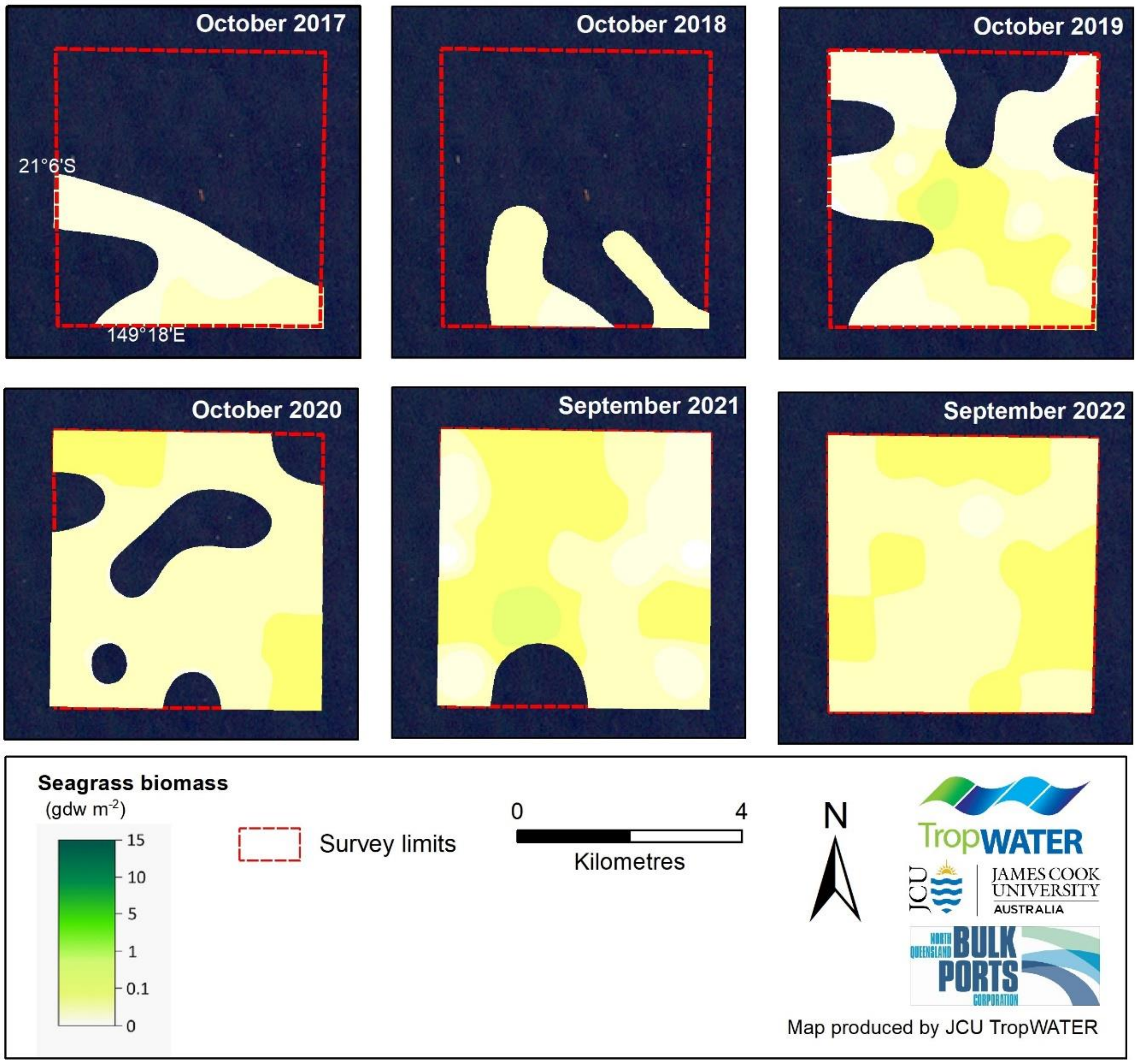

Figure 17. Seagrass biomass distribution in the Mackay offshore monitoring area when surveys were conducted between 2017-2022.

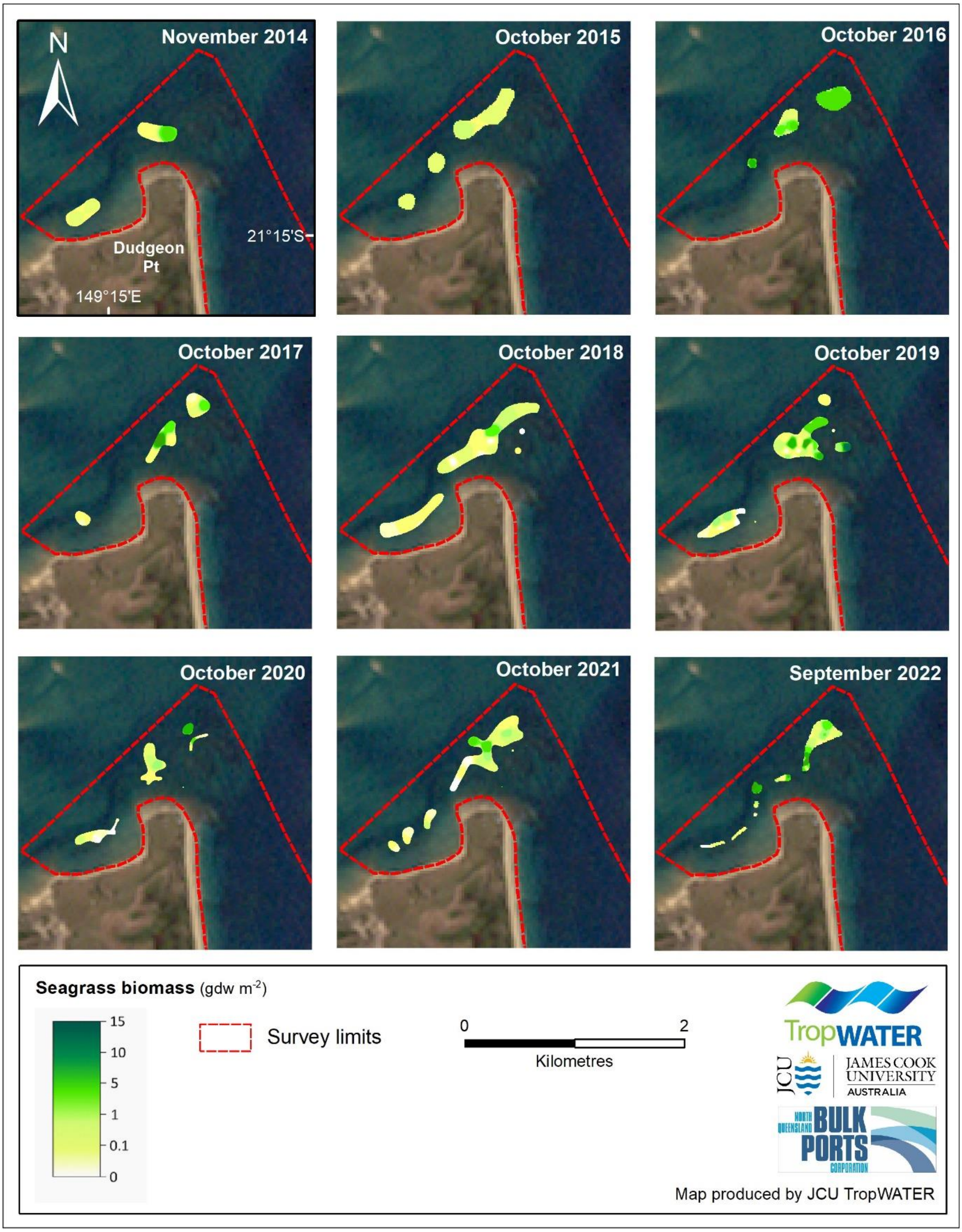

Figure 18. Seagrass biomass distribution in the Dudgeon Point to Hay Point annual monitoring area, 2014 -2022.

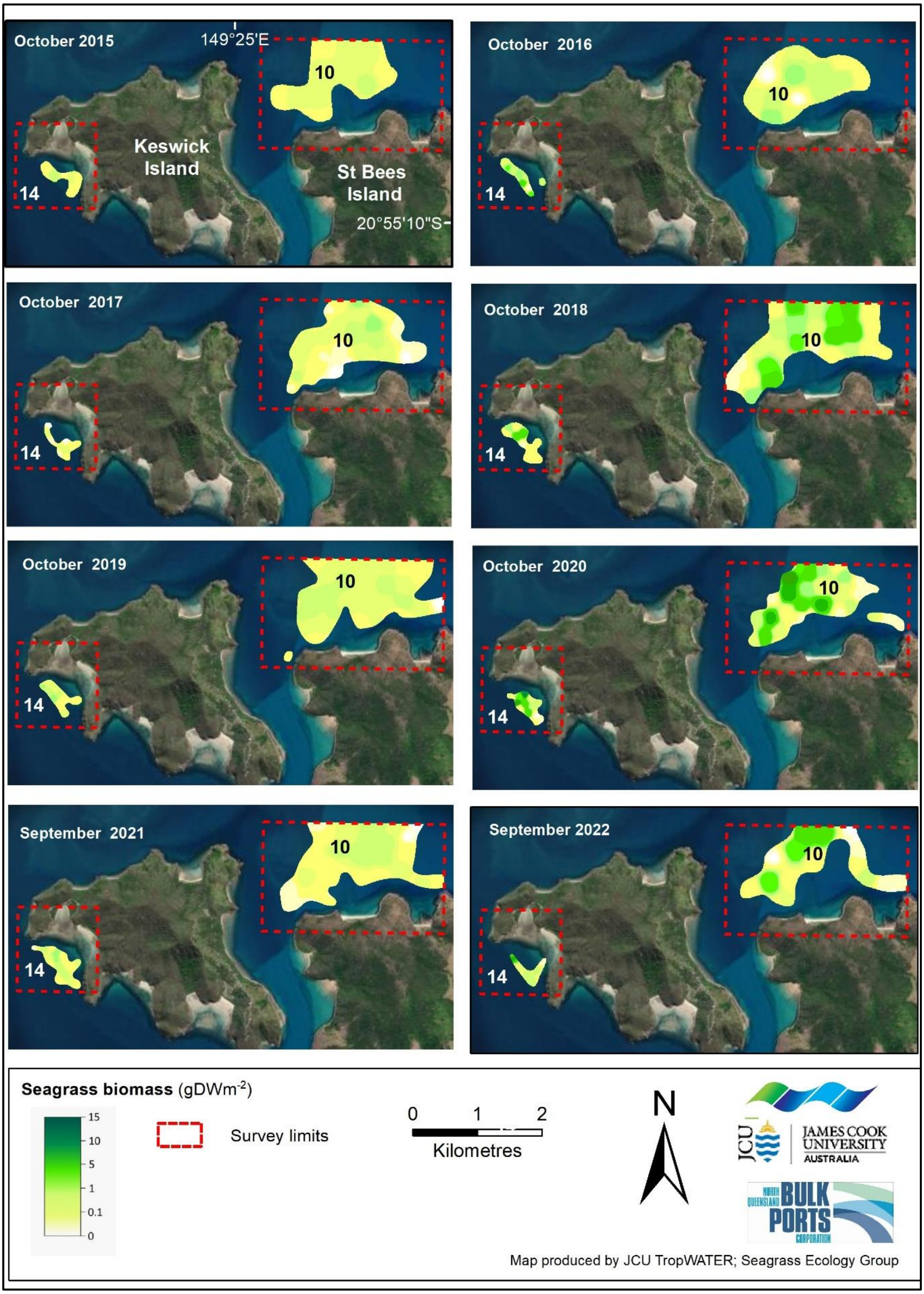

Figure 19. Seagrass biomass distribution in the annual monitoring meadows at Keswick and St Bees Islands 2015 – 2022.

5.3 Environmental data

5.3.1 Rainfall

In 2022 annual rainfall in the region was (1624 mm), just above the long term average (1594 mm) for the first time in four years (Figure 20a). Throughout the year the majority of rain fell between November 2021 and May 2022, with rainfall in April, May and July being above the monthly long-term averages. (Figure 20b). Rainfall was well above average the during the month of the survey and substantially above average in July (Figure 20b).

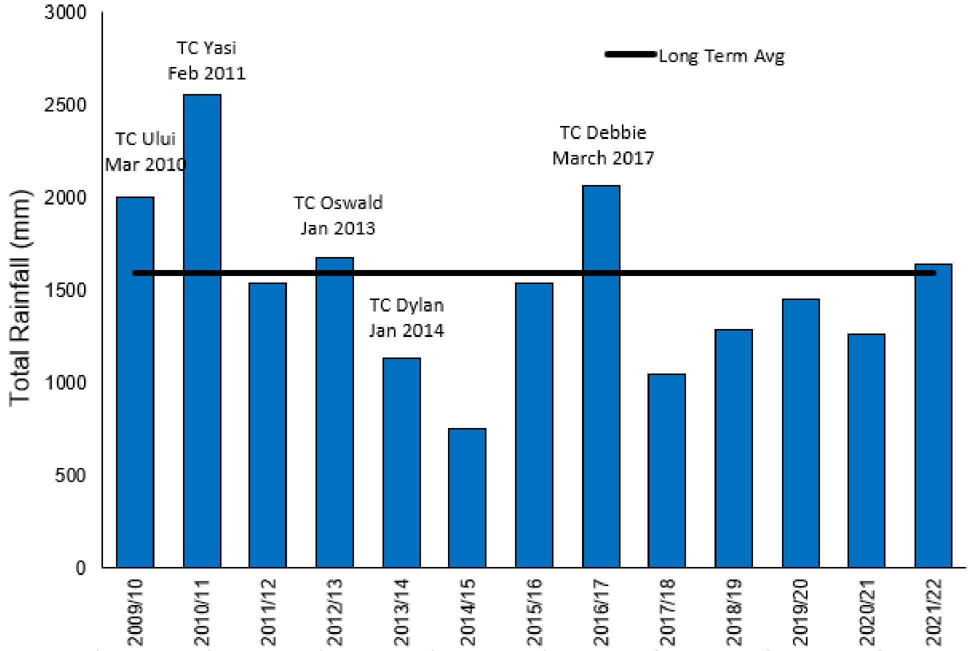

Figure 20a. Total annual rainfall (mm) recorded at Mackay Aero, 2009/10-2020/21. Twelve months prior to the survey. Source: Bureau of Meteorology (BOM), Station number 033045.

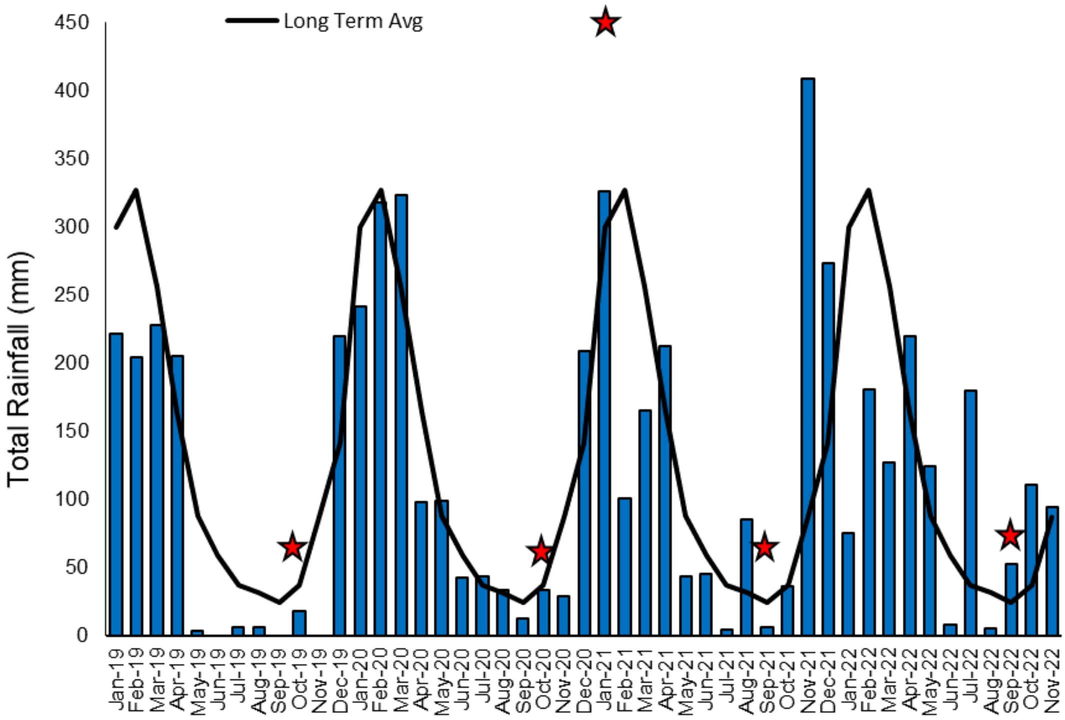

Figure 20b. Total monthly rainfall (mm) recorded at Mackay Aero, January 2019 – November 2022. Source: BOM, Station number 033045.

5.3.2 River flow

For the third year in a row annual river flow of the Pioneer River was considerably below the long-term average (Figure 21a). Monthly flow levels peaked in May and July of 2022 then were below the long term average for the rest of the year (Figure 21b).

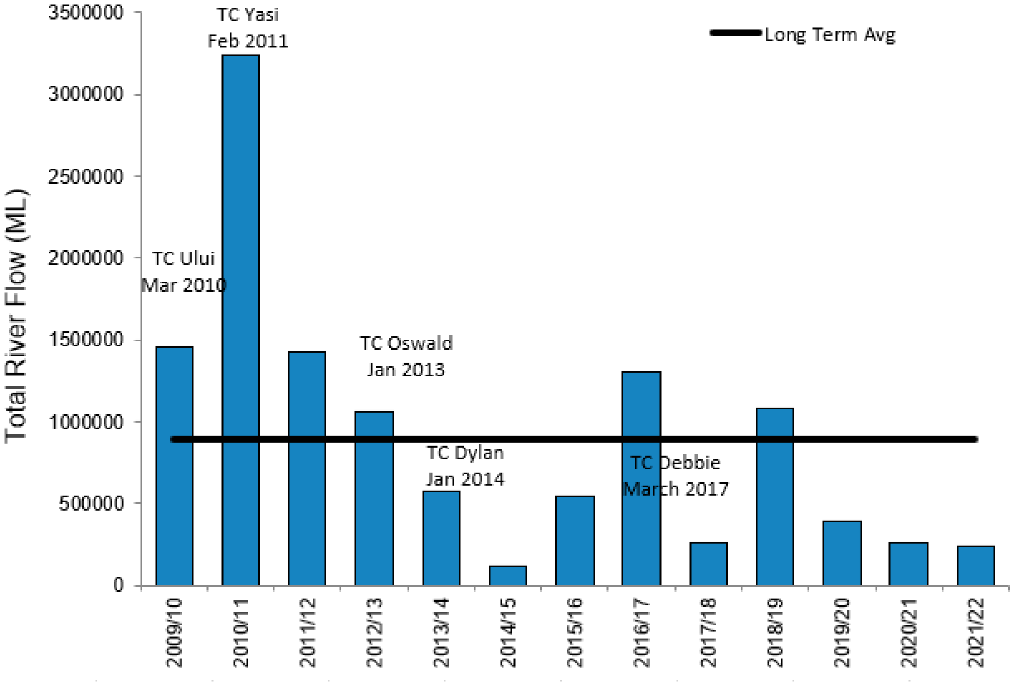

Figure 21a. Annual river flow (Mega litres) for the Pioneer River, 2009/10-2021/22. Source: Queensland Department of Natural Resources, Mines and Energy, Station number 125016A.

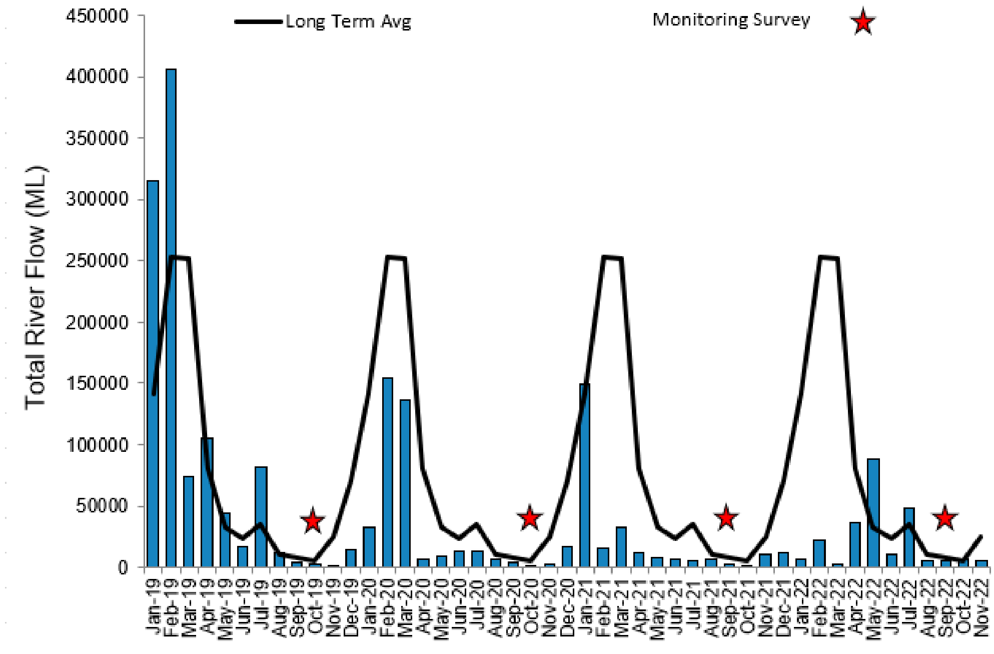

Figure 21b. Monthly river flow (Mega litres) for the Pioneer River January 2019-November 2022. Source: Queensland Department of Natural Resources, Mines and Energy, Station number 125016A.

5.3.3 Sea surface temperature

In 2021-22 the mean annual maximum daily SST (25.30°C) was above the long-term average (24.93°C) for this location (Figure 22a). Monthly data shows that sea surface temperature was above the long-term monthly average in April and May of 2022 but was below the monthly average in the three months leading up to the survey from June to August 2022 (Figure 22b).

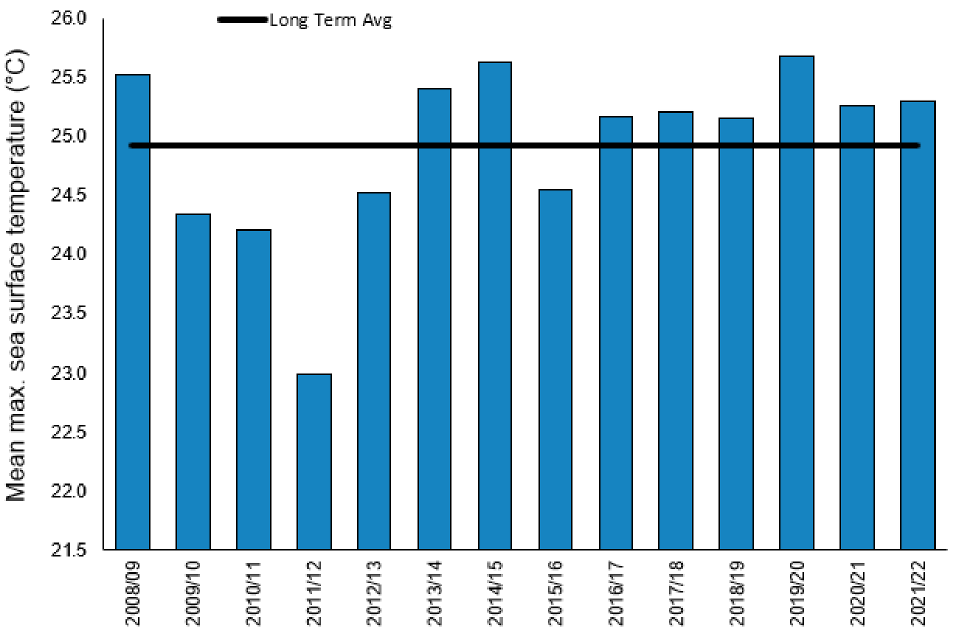

Figure 22a. Mean annual maximum sea surface temperature (°C) recorded at Hay Point 2008/09-2021/22. Source: QLD Department of Environment and Science.

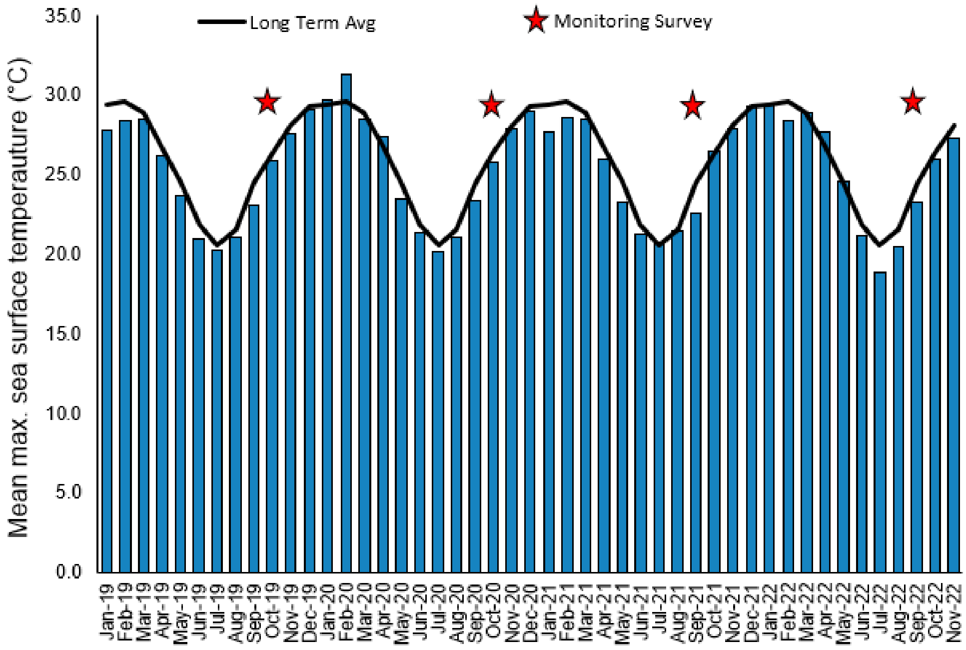

Figure 22b. Monthly maximum sea surface temperature (°C) recorded at Hay Point; January 2019 to November 2022. Source: QLD Department of Environment and Science.

5.3.4 Daily solar radiation

Solar exposure in the Hay Point area in the twelve months leading up to the 2021/22 survey (20.86 MJ m^{-2}) was above the regional long-term average (20.70 MJ m^{-2}) (Figure 23a). Exposure was below average in the two months July and August leading up to the survey in September 2022 (Figure 23b.) In the months from December 2021 to March 2022 and June monthly exposure was above the long-term average (Figure 23b).

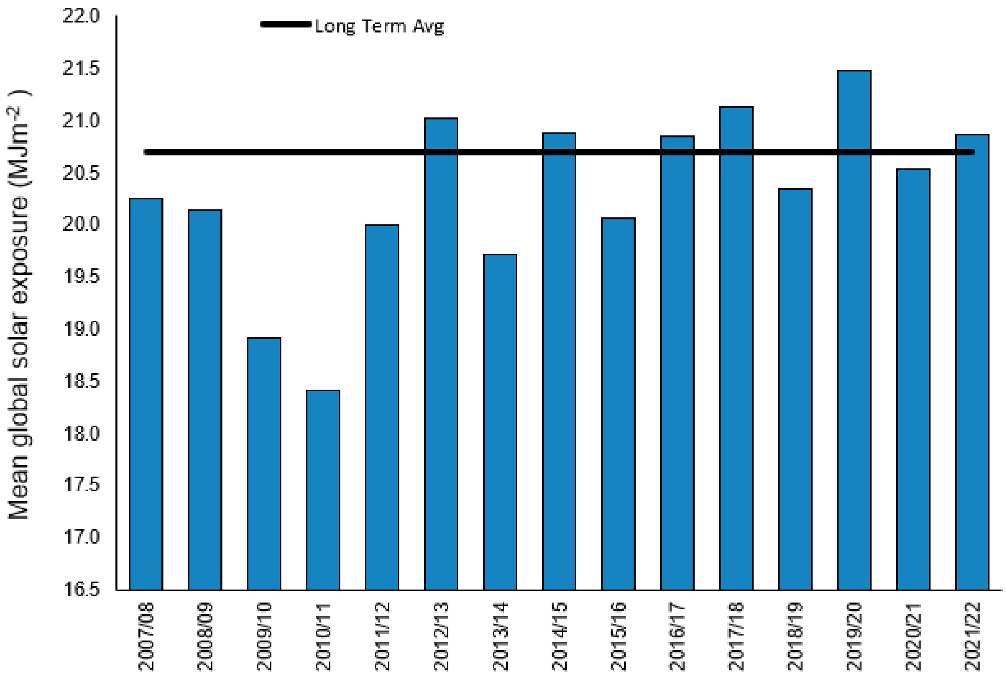

Figure 23a. Mean annual solar radiation (MJm-2) recorded Mackay Aero (Station 033045) 2007/08 – 2021/22. Source: BOM.

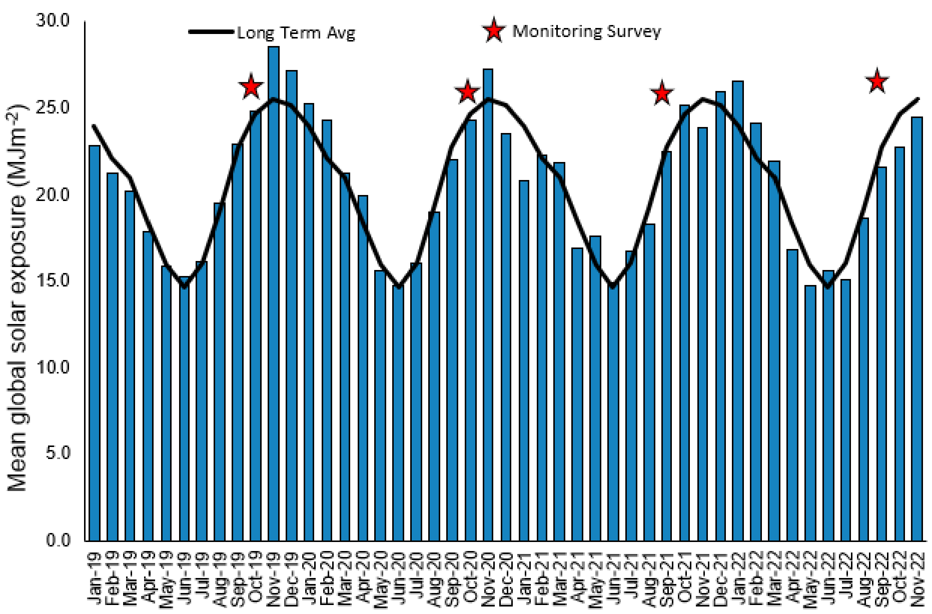

Figure 23b. Mean monthly daily global solar exposure (MJ m-2) recorded at Mackay Aero (Station 033045) January 2019-November 2022. Source: BOM.

5.3.5 Significant wave height

The general trend of recorded wave height prior to the annual survey was well below the long-term monthly averages for the area (Figure 24). In 2022, April had the highest mean maximum monthly wave height of 1.23 m, with the lowest of 0.56 recorded in September (Figure 24).

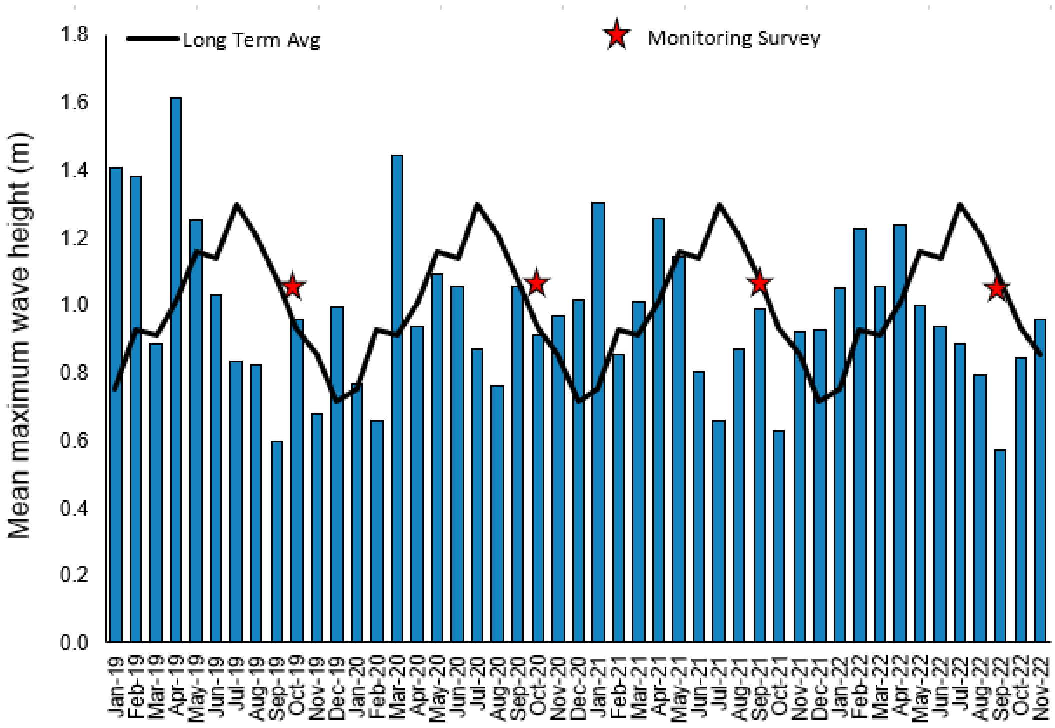

Figure 24. Mean monthly maximum wave height (m) recorded at Hay Point, January 2019-November 2022. Source: QLD Department of Environment and Science.

5.3.6 Benthic daily light (Photosynthetically active radiation - PAR)

Total daily light measured as photosynthetically active radiation (PAR) is monitored as part of the Ambient Marine Water Quality Monitoring Program for the ports of Mackay and Hay Point. PAR was collected near and at the same depth as offshore seagrass meadows at Round Top Island (PAR light loggers - Figure 5). During the period since the previous survey light levels are generally above the threshold for healthy growing conditions for *Halophila* species in the region (Figure 25) (McKenna et al. 2015). Benthic light levels were generally higher than in the previous two years (Figure 25) and only fell below the threshold for these species in the wet season (Jan-February 2022 and May-June 2022) coinciding with the period where deep-water seagrass is usually in its senescent period at Hay Point (York et al. 2015).

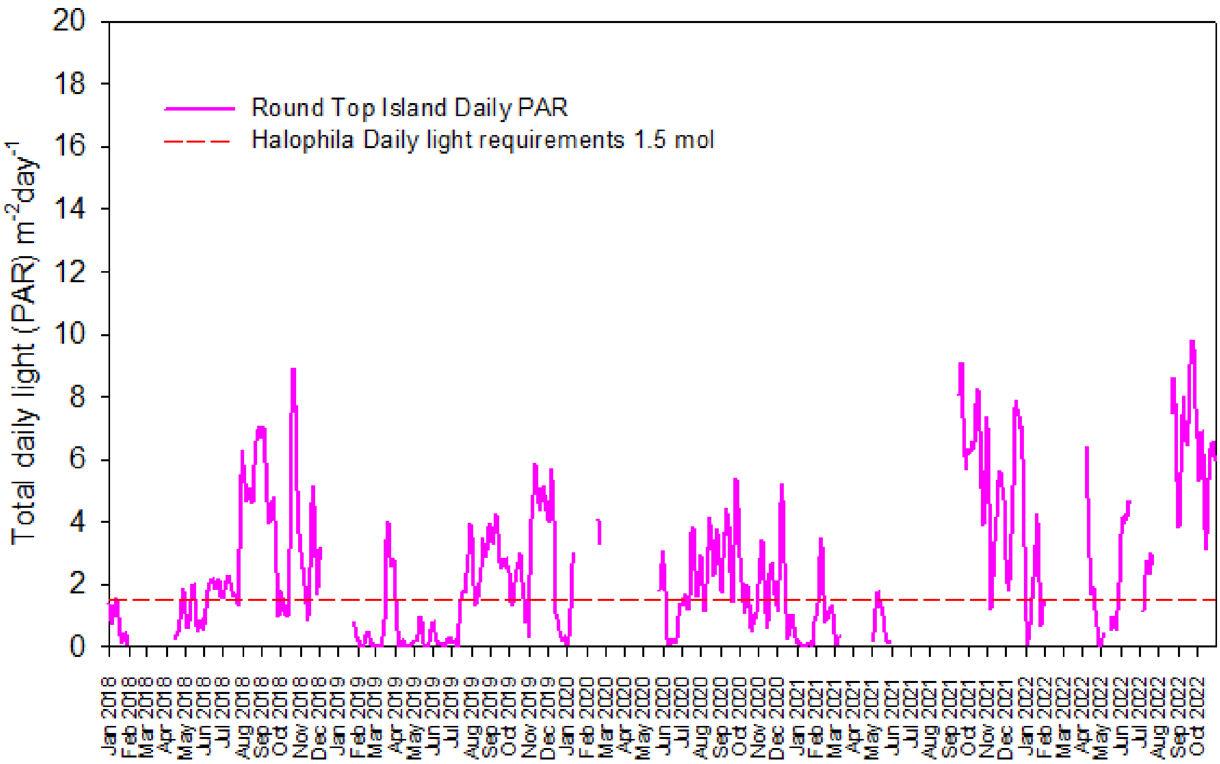

Figure 25. Daily photosynthetically active radiation (PAR; mol photons m^{-2} day^{-1} over a 7 day rolling average) at Round Top Island. Data presented from January 2018 to July 2022. Source: Port of Mackay and Hay Point Ambient Marine Water Quality Monitoring Program (Waltham et al. 2022).

6 DISCUSSION

The overall condition of seagrass meadows in the Hay Point-Mackay region in 2022 was classified as satisfactory which represents a downgrading from good in 2021. Seagrass condition and trends in indicators varied among monitoring locations. The deep-water seagrass offshore from Hay Point and Mackay were in the best condition of all the meadows in the region. The Hay Point offshore meadow recorded the largest biomass since 2004 and was in very good condition. Seagrass offshore from Mackay was present at every sampling site, recording the largest area for the monitoring program since sampling commenced in 2017, however a decrease in mean biomass to around the long-term average at this location resulted in a condition of good. The six month period leading up to the survey were characterised by below average significant wave height and this would likely have reduced resuspension of particles in the water column resulted in a good light environment for seagrass growth in these deeper offshore areas. This is supported by the increase in benthic PAR at Round Top Island compared to the previous two years.

The shallower coastal meadow at Dudgeon Point and the meadows at Keswick Island and St Bees Island all underwent reductions in meadow area in 2022 leading to the downgrading of the condition of Dudgeon Point and Keswick Island to poor condition. Despite this, area of these meadows remained in the range of previously recorded values and such changes are within expectations for these highly variable meadows. The seagrass assemblages at all of these meadows consist of colonising (e.g. *Halophila*) or opportunistic (e.g. *Halodule*) species (Kilminster et al. 2015) and fluctuate in their distribution and abundance interannually, seasonally and over shorter periods of weeks to months depending on environmental conditions. As the mean biomass at these meadows either increased or remained stable there are no great concerns for these meadows unless these declining trends in meadow size continue over several years of monitoring. There were no major weather or environmental events that can be attributed to these declines with climatic indicators throughout the period characterised by average rainfall, low river discharge, below average wave height and sea surface temperature and solar radiation only slightly above long term means. All of these conditions are seen as generally favourable to the long-term growth and survival of seagrass. There was, however, rainfall at the start of the growing season in July 2022 that was substantially above average that may have delayed or reduced growth and expansion of meadows following the wet season.

The seagrass habitats in the Hay Point-Mackay region are known to be highly variable and assemblages are dominated by species that are adapted to surviving in low light conditions (Josselyn et al. 1986, McKenna et al. 2015, Chartrand et al. 2017). When conditions for seagrass growth are unfavourable these colonising and opportunistic species, consisting of mainly *H. decipiens, H. tricostata, H. spinulosa,* and *Halodule uninervis* have been shown to have much lower resistance to light deprivation than other seagrass species with mortality occurring in days to weeks rather than months for other larger seagrass species (Collier et al. 2016). These species also exhibit faster recovery following disturbances and loss of habitat. Critical to this recovery is the ability of offshore seagrasses to produce a seed bank that allows for seagrass recruitment each growing season, especially for the annual *H. decipiens* in offshore areas (Kenworthy 2000). The prolonged period of relatively stable environmental and climate conditions over the last 5 years and the good to satisfactory condition of meadows during this period suggests that the seagrass habitats around the Mackay-Hay Point region have been able to build resilience and are well placed to continue to prosper as long as the growing conditions remain favourable.

The Mackay-Hay Point long-term monitoring program is incorporated into the broader Queensland Ports seagrass monitoring program using the consistent state-wide monitoring methodology. This enables direct comparisons with regional and state-wide trends to put local changes into context. It also provides a key input into the condition and trend of seagrasses in the Mackay Whitsunday Issac NRM regional report card, an area which otherwise has a poor coverage for seagrass assessment and condition. Monitoring at other sites has shown a range of results during 2022. Coastal areas to the north of the Hay Point-Mackay region had seagrass in good condition (e.g., Abbot Point – Reason et al. 2023a; Cairns Harbour - Reason et al. 2023b; and Townsville – McKenna et al. 2023). Coastal areas to the south had seagrass in a satisfactory condition such as Gladstone Harbour (Smith et al. 2023). 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).

6.1 Ongoing development of seagrass condition indices

This is the sixth year of the monitoring program and reporting of seagrass condition established in 2017 for Hay Point, Mackay and the Southern Whitsundays. As the program continues to develop and mature it will align with reporting of seagrass at most of the major ports in north Queensland (e.g. Gladstone, Abbot Point, Townsville, Mourilyan, Cairns, Karumba, Weipa and Thursday Island) and the information will continue to be incorporated into the Mackay Whitsunday Isaac Healthy Rivers to Reef Partnership report card.

For the Hay Point offshore seagrass the long-term averages for meadow indicator conditions have now established a permanent baseline with 10 years of data available in 2021. The Dudgeon Point and Keswick and St Bees Islands monitoring areas have now established an interim 9-year long-term average with the permanent baseline (10 years) being locked in following the 2023 survey for these meadows. The Mackay offshore seagrasses were monitored for the sixth time in 2022 and an interim score for this area was assigned for the second consecutive year. The interim baseline conditions will continue to change for this meadow until a 10-year baseline is settled upon in 2026.

6.2 Conclusion

Seagrasses in the Hay Point – Mackay – Keswick Island region are in a satisfactory condition in 2022. This extends the period of seagrass health ranging from satisfactory to good over the last five years following the impacts of TC Debbie in 2017 which saw the seagrasses of the region in a poor condition. There were variable conditions of different habitats across the region with deep-water offshore meadows at Mackay and Hay Point in good and very good condition respectively while coastal meadows at Dudgeon Point and Keswick Island reduced in condition over the last year to poor due to declines in the areas of meadows at these locations. The overall weather and climate conditions in the Mackay-Hay Point region appeared to be generally favourable for seagrass growth during the year with no major storms or floods. The good condition of seagrass in locations to the north (Abbot Point and Townsville) and satisfactory conditions to the south (Gladstone) indicate that regional scale factors were also good for seagrass growth and survival in 2022.

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8 APPENDICES

Table A1. Seagrass community types, mean above-ground biomass and meadow area in the Hay Point (Meadow 8) and Mackay (Meadow 5) offshore areas.

Hay Point and Mackay Offshore survey area				
Meadow ID	**Meadow location**	**Community type**	**Mean meadow biomass (gDWm^{-2} ± SE)**	**Area ± R (ha)**
July 2004				
5	Offshore	Not surveyed	na	na
8	Offshore	Light *H. decipiens*	0.270 ± 0.057	6837.6 ± 2415.3
Total				**6837.6 ± 2415.3**
December 2005				
5	Offshore	Not surveyed	na	na
8	Offshore	Light *H. spinulosa*	2.186 ± 0.764	332.9 ± 152.9
Total				**332.9 ± 152.9**
October 2010				
5	Offshore	Not surveyed	na	na
8	Offshore	Light *H. decipiens*	0.008 ± 0.003	1528.6 ± 346.6
Total				**1528.6 ± 346.6**
November 2011				
5	Offshore	Not surveyed	na	na
8	Offshore	Light *H. decipiens*	0.008	105.1 ± 39.8
Total				**105.1 ± 39.8**
October/November 2014				
5	Offshore	Light *H. spinulosa* with *H. decipiens*	0.244 ± 0.108	Not mapped
8	Offshore	Light *H. decipiens*	0.002 ± 0.001	5204.7 ± 1448.1
Total				**5204.7 ± 1448.1**
October/November 2016				
5	Offshore	Light *H. spinulosa*	0.108 ± 0.078	Not mapped
8	Offshore	Light *H. decipiens*	0.002 ± 0.0001	2311.0 ± 387.0
Total				**2311.0 ± 387.0**
October 2017				
5	Offshore	Light H. *decipiens* with *H. spinulosa*	0.011 ± 0.003	652.8 ± 151.9
8	Offshore	Light *H. decipiens*	0.046 ± 0.032	1234.1 ± 309.9
Total				**1886.9 ± 461.8**
October 2018				
5	Offshore	Light *H. decipiens* with *H. spinulosa*	0.062 ± 0.015	381.6 ± 141.2
8	Offshore	Light *H. decipiens*	0.013 ± 0.004	1642.7 ± 406.2
Total				**2024.3 ± 547.4**
October 2019				
5	Offshore	Light *H. spinulosa* with *H. decipiens*	0.135 ± 0.073	1737.3 ± 277.4
8	Offshore	Light *H. decipiens* with *H. spinulosa*	0.096 ± 0.023	4160.8 ± 777.8
Total				**5898.1 ± 1055.2**
October 2020				
5	Offshore	Light *H. decipiens* with *H. spinulosa*	0.077 ± 0.0137	1871.6 ± 306.6
8	Offshore	Light *H. decipiens*	0.041 ± 0.004	736.9 ± 258.2
Total				**2608.5 ± 564.8**
September 2021				
5	Offshore	Light *H. spinulosa* with *H. decipiens*	0.203 ± 0.080	2215.7 ± 213.0
8	Offshore	Light *H. decipiens*	0.011 ± 0.006	5216.6 ± 618.2
Total				**7432.3 ± 831.2**
September 2022				
5	Offshore	Light *H. spinulosa* with *H. decipiens*	0.09 ± 0.02	2326.3 ± 196.0
8	Offshore	Light *H. decipiens*	0.15 ± 0.1	3853.2 ± 559.65
Total				**6163.2 ± 729.6**

Table A2. Seagrass community type, mean above-ground biomass and meadow area in the Dudgeon Point - Hay Point annual survey areas, 2010 – 2022.

Hay Point – Dudgeon Point inshore survey area				
Meadow ID	**Meadow location**	**Seagrass meadow community type**	**Meadow biomass (mean g dw m-2 ± SE)**	**Area ± R (ha)**
October 2010				
1	Inshore	Light *Halodule uninervis* with *H. ovalis*	Not assessed	12.2 ± 4.9
20	Inshore	Light *Halodule uninervis*	Not assessed	36.5 ± 12.2
Total				**48.7 ± 17.1**
November 2011				
1	Inshore	Light *Halodule uninervis*	Not assessed	4.3 ± 1.9
20	Inshore	Light *Halodule uninervis*	Not assessed	6.3 ± 1.9
Total				**10.6 ± 3.8**
October/November 2014				
1	Inshore	Light *H. uninervis* with *Z. muelleri* & *H. ovalis*	1.96 ± 1.14	9.0 ± 1.8
20	Inshore	Not present	-	-
Total				**9.0 ± 1.8**
October 2015				
1	Inshore	Light *Halodule uninervis* (wide) with *H. decipiens*	1.72 ± 0.23	13.7 ± 1.3
20	Inshore	Not present	-	-
Total				**13.7 ± 1.3**
October/November 2016				
1	Inshore	Moderate *Halodule uninervis* (wide)	5.60 ± 0.76	9.6 ± 2.0
20	Inshore	Not present	-	-
Total				**9.6 ± 2.0**
October 2017				
1	Inshore	Light *Halodule uninervis* (wide)	2.42 ± 1.20	9.3 ± 2.3
20	Inshore	Not present	-	-
Total				**9.3 ± 2.3**
October 2018				
1	Inshore	Light *H. uninervis* (wide) with *H. ovalis*	1.09 ± 0.35	22.6 ± 4.2
20	Inshore	Not present	-	-
Total				**22.6 ± 4.2**
October 2019				
1	Inshore	Light *H. uninervis* with *Z. muelleri* /*H. decipiens*	3.01 ± 0.72	17.0 ± 3.8
20	Inshore	Light *Halodule uninervis*	0.72 ± 0.72	1.7 ± 1.1
Total				**18.7 ± 4.9**
October 2020				
1	Inshore	Light *Halodule uninervis* with *H. uninervis*	1.76 ± 0.62	8.6 ± 3.3
20	Inshore	Not present	-	-
Total				**8.6 ± 3.3**
September 2021				
1	Inshore	Light *Halodule uninervis*	3.66 ± 1.12	15.7 ± 4.3
20	Inshore	Not present	-	-
Total				**15.7 ± 4.3**
September 2022				
1	Inshore	Light *Halodule uninervis*	3.66 ± 0.64	8.97 ± 3.4
20	Inshore	Not present	-	-
Total				**8.97 ± 3.4**

Table A3. Seagrass community type, mean above-ground biomass and meadow area in the Keswick Island and St Bees Island annual survey areas, 2014 – 2022.

Keswick/St Bees Islands inshore survey areas				
Meadow ID	**Meadow location**	**Seagrass meadow community type**	**Meadow biomass (mean g dw m^{-2} ± SE)**	**Area ± R (ha)**
October/November 2014				
10	Inshore	Light *H. tricostata* with *H. decipiens*	2.34 ± 0.38	118.6 ± 29.5
14	Inshore	Moderate *H. decipiens* with mixed species	2.6 ± 0.71	17.9 ± 5.0
Total				**136.5 ± 34.5**
October 2015				
10	Inshore	Light *Halophila tricostata*	1.23 ± 0.19	137.2 ± 30.5
14	Inshore	Light *H. spinulosa* with mixed species	1.13 ± 0.35	14.7 ± 4.3
Total				**151.9 ± 34.8**
October/November 2016				
10	Inshore	Light *Halophila tricostata*	1.69 ± 0.33	147.6 ± 25.9
14	Inshore	Light *H. spinulosa* with mixed species	2.94 ± 0.54	11.5 ± 4.3
Total				**159.1 ± 30.2**
October 2017				
10	Inshore	Light *Halophila tricostata*	1.09 ± 0.23	169.6 ± 32.5
14	Inshore	Light *Halophila tricostata*	0.54 ± 0.23	10.8 ± 4.1
Total				**180.4 ± 36.6**
October 2018				
10	Inshore	Light *H. tricostata* with H. *decipiens*	2.40 ± 0.38	203.6 ± 38.7
14	Inshore	Light *Halophila tricostata*	1.97 ± 0.74	18.1 ± 4.8
Total				**221.7 ± 43.5**
October 2019				
10	Inshore	Light H. *tricostata* with *H. decipiens*	1.37 ± 0.15	197.3 ± 42.9
14	Inshore	Light *H. tricostata* with *H. spiniulosa / H. decipiens*	1.63 ± 0.35	14.2 ± 4.2
Total				**211.5 ± 47.1**
October 2020				
10	Inshore	Light *Halophila tricostata* with *H. spinulosa*	2.90 ± 0.63	140.4 ± 36.5
14	Inshore	Light *Halophila spinulosa / H. tricostata*	3.96 ± 1.23	14.2 ± 3.8
Total				**154.6 ± 40.3**
September 2021				
10	Inshore	Light *H.tricostata* with H. *decipiens*	1.04 ± 0.17	191.8 ± 41.1
14	Inshore	Light *Halophila spinulosa / H. tricostata*	1.33 ± 0.27	22.5 ± 5.4
Total				**206.0 ± 46.5**
September 2022				
10	Inshore	Light *H.tricostata* with *H. spinulosa*	1.87 ± 0.65	132.2 ± 23.8
14	Inshore	Light *H. tricostata* with *H. decipiens*	2.86 ± 1.10	10.3 ± 3.9
Total				**142.5 ± 27.7**

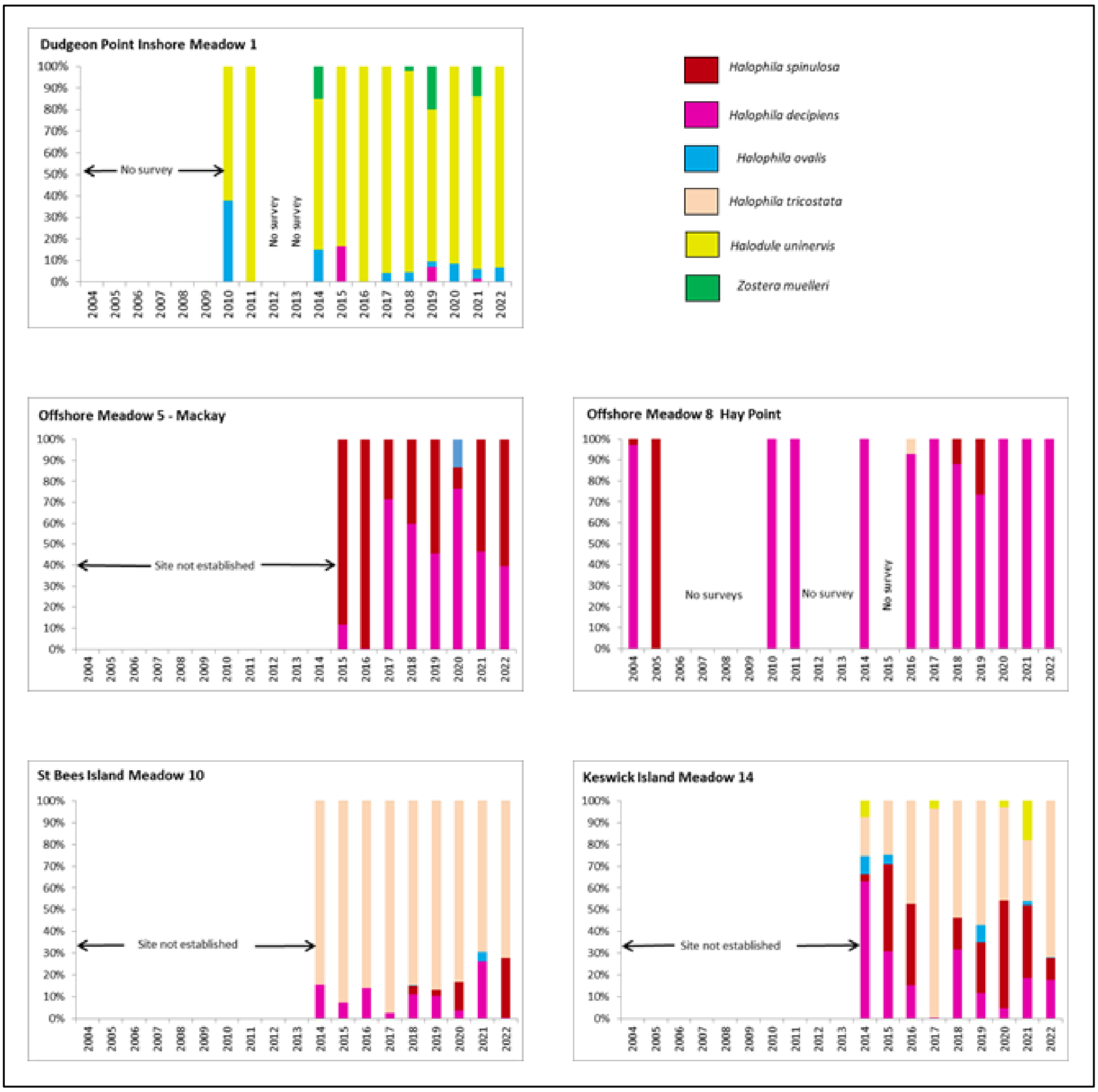

Figure A1. Species composition of monitoring meadows in the Hay Point-Mackay region, and the Keswick Island group.