Western Basin expansion reclamation area and barge unloading facility seagrass and marine plants survey

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Report No. 20/57

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A Report for Gladstone Ports Corporation

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Information should be cited as:
Smith TM, Reason CL, and Rasheed MA. 2020. Western Basin expansion reclamation area and barge unloading facility seagrass and marine plants survey. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 20/57, James Cook University, Cairns, 29 pp.

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This publication has been compiled by the Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University.

Acknowledgments:
This project was funded by the Gladstone Ports Corporation Ltd. We wish to thank the many TropWATER staff for their valuable assistance in the field, lab, and data processing.

KEY FINDINGS

1. Seagrasses in the Western Basin Expansion (WBE) and Barge Unloading Facility (BUF) at Fishermans Landing were surveyed between the 13th–17th of November 2020 in conjunction with the annual long term seagrass monitoring program for the greater Port of Gladstone (Port Curtis) area.

2. Within the area of interest, seagrass covered a total area of 207 ha across two meadows in 2020. Meadows consisted of *Zostera muelleri*, *Halophila ovalis* and *H. decipiens*.

3. Total seagrass extent as a composite combining distributions for all years between 2011-2020 was 307.45 ± 8.15 ha

4. Biomass across the meadows was low with an average of 1.76 ± 0.32 g DW m^{-2} in 2020 consistent with small ephemeral species found in the meadow.

5. Both area and biomass of the seagrass meadows had decreased since the previous survey in 2019 but remained greater than the long-term average.

6. The proposed Southern Reclamation Cell (SRC) intersects with the largest seagrass meadow in the survey area and encompasses 41.77 ha of seagrass in 2020 and ~76 ha of seagrass as a composite of all years between 2011 and 2020.

7. In addition to the mapped seagrass area within the SRC in 2020 there was a small area of low cover ephemeral filamentous algae covering an area of 0.64 ha giving a total area of marine plants (seagrass and algae combined) within the SRC footprint of 42.41ha

8. Seagrass within the southern reclamation area consisted of low biomass (1.34 ± 0.53 g DW m^{-2}) *H. ovalis* and *H. decipiens* that formed isolated patches in 2020.

IN BRIEF

Seagrass monitoring in Port Curtis and Rodds Bay commenced in 2002, and has been conducted annually since 2004. Seagrass within and adjacent to the proposed Western Basin Expansion (WBE) and barge unloading facility (BUF) at Fishermans Landing includes a monitoring meadow that is part of the annual program (meadow 8) as well as smaller meadows adjacent to the Western Basin Reclamation area (Figure 2). The annual monitoring meadow has increased in seagrass biomass but has decreased in area since the initial Western Basin Dredging and Disposal Project (WBDDP) established a reclamation over part of the meadow in 2011 (Figure 1). In 2020, meadow biomass decreased to the lowest level in 5 years but was still greater than pre reclamation levels. Meadow area on the other hand decreased slightly since 2019 but was higher than any other time since 2010.

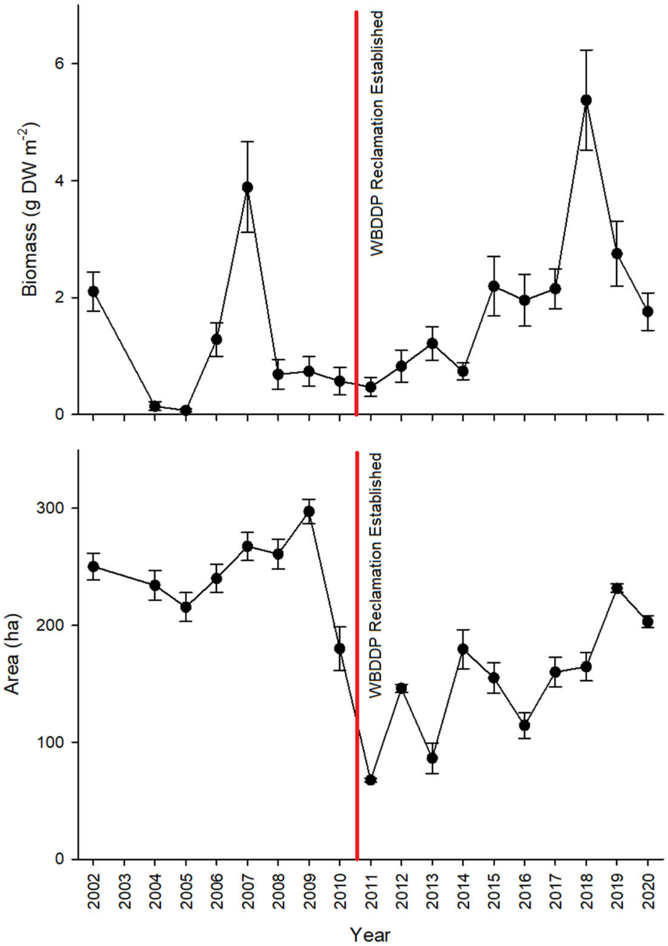


Figure 1. Annual variation in seagrass biomass and area for the annual monitoring meadow (meadow 8) within the proposed WBE and BUF areas. Red line indicates the construction of the WBDDP reclamation area in 2011.

Meadows in the WBE and BUF area of interest comprised of *Zostera muelleri, Halophila ovalis* and *H. decipiens* consistent with previous surveys. Total meadow area in the WBE/BUF footprint across all surveys between 2011 (post reclamation) and 2020 was 307.45 ± 3.45 ha and the maximum meadow biomass was 5.37 ± 0.86 g DW m^{-2} in 2018.

In 2020 a total of 41.77 ± 1.28 ha of seagrass was within the proposed Southern Reclamation Cell (SRC) consisting of low biomass *H. ovalis* and *H. decipiens*. Seagrass area and biomass within the reclamation area varies temporally with the highest seagrass area in 2019 and 2020. The composite meadow area in the SRC footprint across all surveys between 2011 (post reclamation) and 2020 was 76.18 ± 2.17 ha.

Seagrass meadows more broadly in Port Curtis and Rodds Bay area follow consistent trends in meadow biomass, area and species composition that are determined by environmental conditions. Below average rainfall, river outflow and tidal exposure over the previous 4 years has led to improved seagrass conditions throughout Port Curtis. Overall seagrass condition in 2019 was the best recorded for the past decade and one of the best recorded in the 18 years of seagrass monitoring. Environmental conditions were again favorable for seagrass in 2020 (Figure 3) and although the results from the greater Port Curtis area surveys are still being analysed, initial observations indicate seagrasses have remained in good condition.

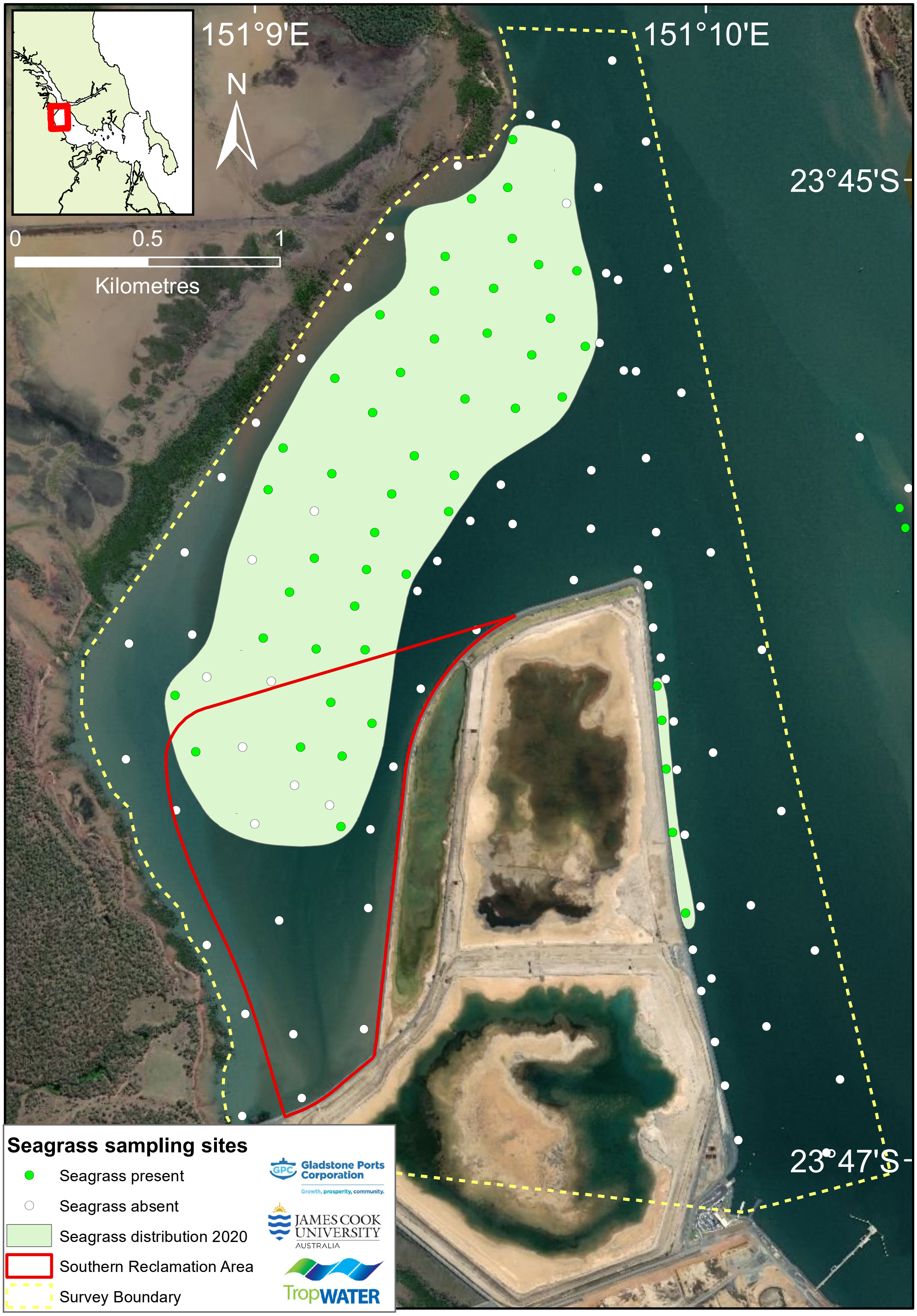


Figure 2. Seagrass meadow area and sampling sites within WBE reclamation and BUF monitoring footprint in November 2020.

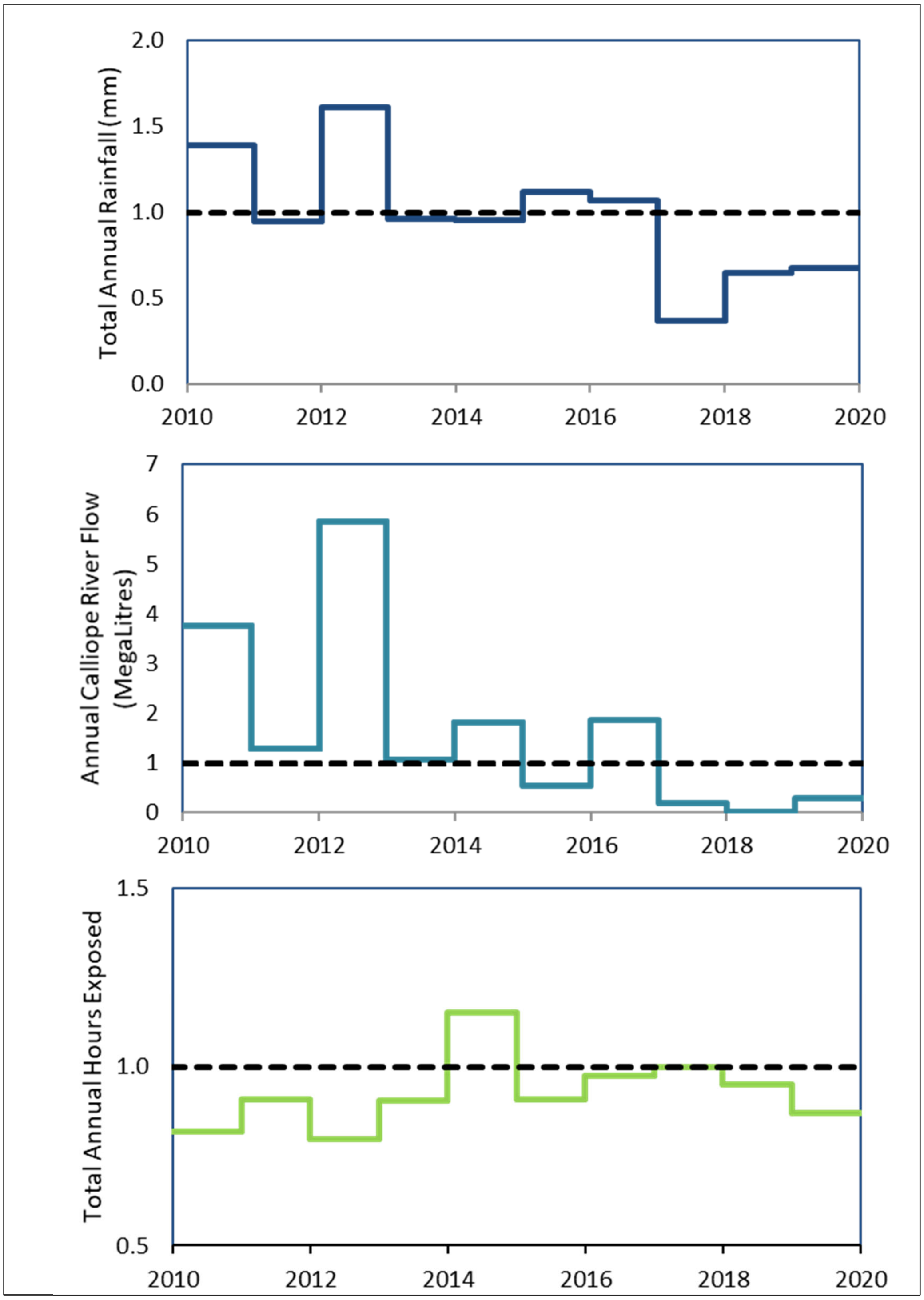


Figure 3. Climate trends in Port Curtis, 2009 to 2020. Annual average (solid coloured line) expressed as a relative change where 1.0 equals the long-term average (dashed line). Long-term averages calculated for rainfall (1958-2020), river flow (1974-2020) and hours daytime tidal exposure (2002-2020). See Section 5.3 for detailed climate data.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

dbMSL	Depth below Mean Sea Level
DFT	Dugong Feeding Trail
DPA	Dugong Protection Area
DW	Dry Weight
EBSDS	Eastern Bank Sea Disposal Site
GIS	Geographic Information System
GPC	Gladstone Ports Corporation
GPS	Global Positioning System
IDW	Inverse Distance Weighted
JCU	James Cook University
MSQ	Maritime Safety Queensland
PCIMP	Port Curtis Integrated Monitoring Program
TropWATER	Centre for Tropical Water & Aquatic Ecosystem Research
WBDDP	Western Basin Dredging and Disposal Project

1 INTRODUCTION

Seagrasses provide a range of critically important and economically valuable ecosystem services including coastal protection, support of fisheries production, nutrient cycling, and particle trapping (Costanza et al. 2014; Hemminga and Duarte 2000). Seagrass meadows show measurable responses to changes in water quality, making them ideal indicators to monitor the health of marine environments (Orth et al. 2006; Abal and Dennison 1996; Dennison et al. 1993).

Diverse and productive seagrass meadows and benthic macro- and mega-fauna flourish in Port Curtis and Rodds Bay (Smith et al. 2020, McKenna et al. 2014; Lee Long et al. 1992). Gladstone Ports Corporation (GPC) first commissioned a baseline survey of seagrass resources in Port Curtis, Rodds Bay, and the adjacent offshore area in the Great Barrier Reef Marine Park in 2002 (Rasheed et al. 2003). Over 7000 ha of coastal seagrass was mapped, including an extensive area within the port limits. The majority of Port Curtis and Rodds Bay lies within a Dugong Protection Area (DPA; declared in 1996). Port Curtis seagrasses also contribute to the Outstanding Universal Values of the Great Barrier Reef World Heritage Area rated as providing a moderate contribution locally (GPC 2019).

Annual seagrass monitoring for GPC commenced in Port Curtis and Rodds Bay in 2004 incorporating ten meadows representative of the range of seagrass communities within Port Curtis and three monitoring meadows in Rodds Bay as reference sites. In the subsequent 16 years, the program has evolved to meet GPC's obligations pertaining to the Long Term Maintenance Dredging Monitoring Plan and the development of major infrastructure projects including the Western Basin Dredging and Disposal Project (WBDDP). The program now includes annual mapping and monitoring of the 14 coastal seagrass monitoring meadows and five yearly whole port surveys. Additional research and monitoring programs have complemented annual monitoring. These include biannual surveys of Port Curtis and Rodds Bay monitoring areas from 2010-2014, the establishment of sensitive receptor sites where information on seagrass change was collected monthly to quarterly and linked to water quality monitoring, and the establishment of seagrass light requirements and investigations of sub-lethal indicators of seagrass stress (Schliep et al. 2015; Chartrand et al. 2012; 2016).

GPC's Channel Duplication (CD) project includes construction of reclamation areas at the Western Basin Expansion (WBE) and barge unloading facility (BUF) at Fisherman's Landing where seagrass meadows have been mapped as part of the annual monitoring program. The bund wall for the Southern Reclamation Cell (SRC) intersects with the southern section of the meadow that will ultimately reduce the meadow size. As part of the approval process, a survey of seagrass and macroalgae within and adjoining the WBE and BUF footprints is required to inform the Receiving Environmental Management and other applications required by Regulatory Agencies. This includes the area of meadow potentially lost to the SRC. The aim of this report is to

- survey the location, extent and condition of seagrass and marine plants within and adjacent to the WBE and BUF,
- determine the area and biomass of seagrass and marine plants within the SRC,
- provide historical context to seagrass communities within and adjacent to the WBE and BUF,
- report on environmental conditions over the past 12 months in relation to previous years.

2 METHODS

2.1 Field surveys

Survey and monitoring methods followed the established techniques for TropWATER's Queensland-wide seagrass monitoring programs (Appendix 1). Detailed methods used in Gladstone are in previous annual reports (Smith et al. 2020, Rasheed et al. 2005). Seagrass was surveyed 13th – 17th November 2020 during the peak seagrass growth period. Gladstone seagrass has two broad seasons; the growing season (July – January) when meadows typically increase in biomass and area in response to favourable conditions for growth; and the senescent season (February – June) when meadows typically retract and rely on carbohydrate stores or seeds to persist following wet season conditions such as flooding, poor water quality, and light reductions (Chartrand et al. 2016). Seagrass biomass and area is at its lowest around June, and peaks between October and November (Chartrand et al. 2017). Standardising surveys to every October-December allows for appropriate comparisons of seagrass condition among years.

This survey involved mapping and assessing:

- Seagrass and macroalgae in the WBE and BUF reclamation footprint and adjacent areas (includes meadow 8 of the annual monitoring program) (Figure 2).

Intertidal areas were surveyed at low tide using a helicopter. GPS was used to map the position of meadow boundaries and sites were scattered haphazardly within each meadow. Sites were surveyed as the helicopter hovered within one metre above the substrate (Figure 4a). Shallow subtidal meadows were sampled by boat using camera drops and 0.03 m^2 van Veen grab (Figure 4b, c). The appropriate number of sites required to detect seagrass change for each monitoring meadow was informed by power analysis (Rasheed et al. 2003). The details recorded at each site are listed in Section 2.3.1.

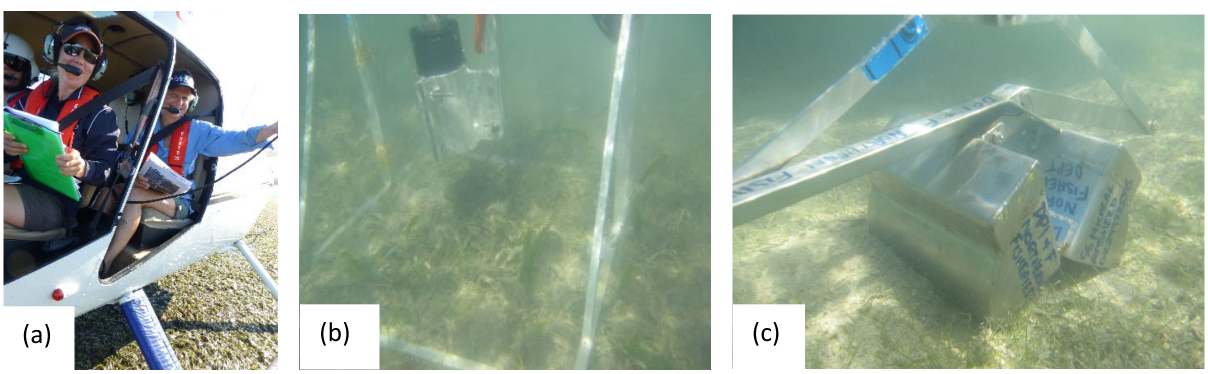


Figure 4. Seagrass monitoring methods in 2019. (a) helicopter survey of intertidal seagrass, (b, c) boat-based camera drops and van Veen grab for subtidal seagrass.

2.2 Seagrass biomass

Seagrass above-ground biomass was determined using a "visual estimates of biomass" technique (Mellors 1991; Kirkman 1978). At each coastal site, a 0.25 m^2 quadrat was placed randomly three times. 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. Two separate ranges were used - low biomass and high biomass. 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 replicate quadrats at a site. Site biomass, and the biomass of each species, is the mean of the replicates.

2.3 Geographic Information System

All survey data were entered into a Geographic Information System 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 (IDW) 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 density and community type (Tables 2, 3), meadow landscape category (Figure 8).
- Sampling method and any relevant comments.

Meadow boundaries were constructed using GPS marked meadow boundaries where possible, seagrass presence/absence site data, field notes, colour satellite imagery of the survey region (Source: Landsat 2019, courtesy ESRI), 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). The mapping precision estimate for all the WBE/BUF meadows was 5 m and 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. Methods used to determine mapping precision estimates for each seagrass meadow.

Mapping precision	Mapping method
<10 m	Meadow boundaries mapped by GPS from helicopter, Intertidal meadows completely exposed or visible at low tide, Relatively high density of mapping and survey sites, Recent aerial photography aided in mapping.
10-20 m	Meadow boundaries determined from helicopter and boat surveys, Intertidal boundaries interpreted from helicopter mapping and survey sites, Recent aerial photography aided in mapping, Subtidal boundaries interpreted from survey sites, Moderately high density of mapping and survey sites.
20-50 m	Meadow boundaries determined from helicopter and boat surveys, Intertidal boundaries interpreted from helicopter mapping and survey sites, Subtidal boundaries interpreted from boat survey sites, Lower density of survey sites for some sections of boundary.
50–200 m	Meadow boundaries determined from boat surveys, Subtidal meadows interpreted from survey sites, Lower density of survey sites for meadow boundary.

Table 2. Nomenclature for seagrass community types.

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. Seagrass meadow density categories based on mean above-ground biomass ranges for the dominant species.

Density	**Mean above-ground biomass (g DW m^{-2})**	
	Halophila ovalis; Halophila decipiens	*Zostera muelleri*
Light	<1	<20
Moderate	1-5	20–60
Dense	>5	>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 5. Seagrass meadow landscape categories: (a) Isolated seagrass patches, (b) aggregated seagrass patches, (c) continuous seagrass cover.

2.4 Environmental data

Environmental data were collated for the 12 months preceding the survey. Tidal data was provided by Maritime Safety Queensland (© The State of Queensland (Department of Transport and Main Roads) 2020, Tidal Data) for Gladstone at Auckland Point (MSQ station #052027A; www.msq.qld.gov.au). Total daily rainfall (mm) was obtained for the nearest weather station from the Australian Bureau of Meteorology (Gladstone Airport station #039123; http://www.bom.gov.au/climate/data/). Calliope River water flow data (total monthly megalitres) was obtained from the Department of Natural Resources and Mines (station #132001A; https://water-monitoring.information.qld.gov.au/).

3 RESULTS

3.1 Seagrasses in and adjacent to the WBE and BUF

A total of 127 sites were surveyed in the WBE and BUF monitoring survey area in November 2020 (Figure 2). Seagrass occurred in 49 of the sampled sites comprising three species, *Zostera muelleri*, *Halophila ovalis* and *H. decipiens*, forming two meadows (Figure 6, 7). The combined area of the two meadows was 206.35 ± 4.3 ha. The largest of these meadows at Fisherman's Landing has been surveyed and monitored annually since 2002 by the TropWATER seagrass ecology group as part of the Gladstone Ports Corporation's annual seagrass monitoring program (Meadow 8). Seagrass area in this meadow in 2020 was 203 ± 3.4 ha, slightly lower than in 2019 but greater than all other years since 2009. The composite area of this meadow incorporating everywhere seagrass has occurred between 2011 (when the WBDPP reclamation area was established) and 2020 was 307.45 ± 8.77 ha. Average biomass of the meadow in 2020 was 1.76 ± 0.3 g DW m^{-2} with the highest biomass occurring in the north of the meadow and large areas of very patchy seagrass in the southern section (Figure 8). Meadow biomass was lower than the previous two years but remained higher than years sampled prior to 2014. Species composition was roughly equal between *Z. muelleri* and *H. ovalis* with some *H. decipiens,* similar to 2019. These species have been consistently present in this meadow since 2002 (Appendix 3). The only other species found previously in the meadow is *H. spinulosa* but it has not been present since 2008. *Zostera muelleri* and *H. ovalis* formed aggregated patches of seagrass in pools in the northern section of the meadow where the highest biomass was found whereas the southern half of the meadow consisted of isolated *H. ovalis* and continuous *H. decipiens* cover was present on the seaward edge of the meadow.

Approximately 41.77 ± 1.28 ha of meadow 8 lies within the proposed Southern Reclamation Cell (SRC) bund wall. Isolated patches of *H. ovalis* and *H. decipiens* were present within the SRC in contrast to larger aggregated patches in the northern part of the meadow. Biomass in the SRC was 1.34 ± 0.53 g DW m^{-2}, lower than the overall meadow biomass and there were large areas within the boundaries of the meadow without seagrass coverage. Meadow area in the SRC fluctuates annually but has shown an increasing trend over time (Figure 9). In 2019 and 2020 the meadow extended significantly into the proposed SRC however prior to 2018 the only other time when there was a large area of seagrass within the SRC was 2012. The composite distribution of everywhere seagrass has occurred within the SRC between 2011 and 2020 was 76.18 ± 2.17 ha.

The second meadow within the survey area of interest is a thin strip of *H. decipiens* adjacent to the existing bund wall at 1.5 – 2 m depth adjacent to the shipping channel. The meadow stretches approximately 1 km along the wall and extends 40 m toward the channel covering 4.07 ± 0.99 ha. Overall biomass in this meadow was low with a mean of 0.76 ± 0.76 g DW m^{-2} ranging from 0.10 – 2.03 g DW m^{-2}. This meadow was present in 2019 and 2018 but this was the first survey to include a high density of sampling sites that allows accurate mapping as it lies outside of the normal annual monitoring meadow survey extent.

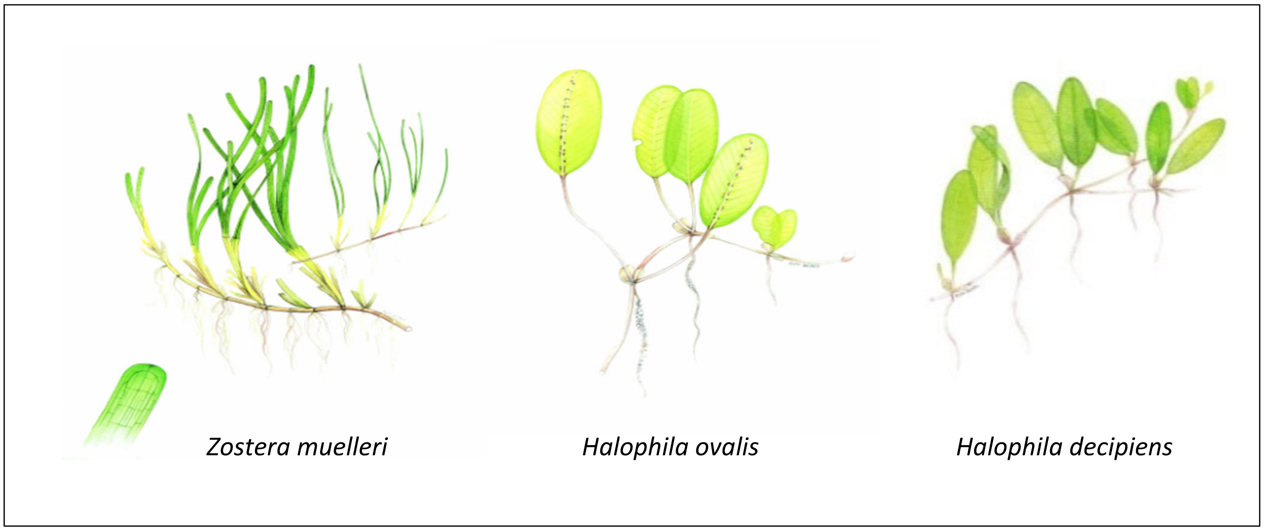


Figure 6. Seagrass species present in WBE and BUF in 2020.

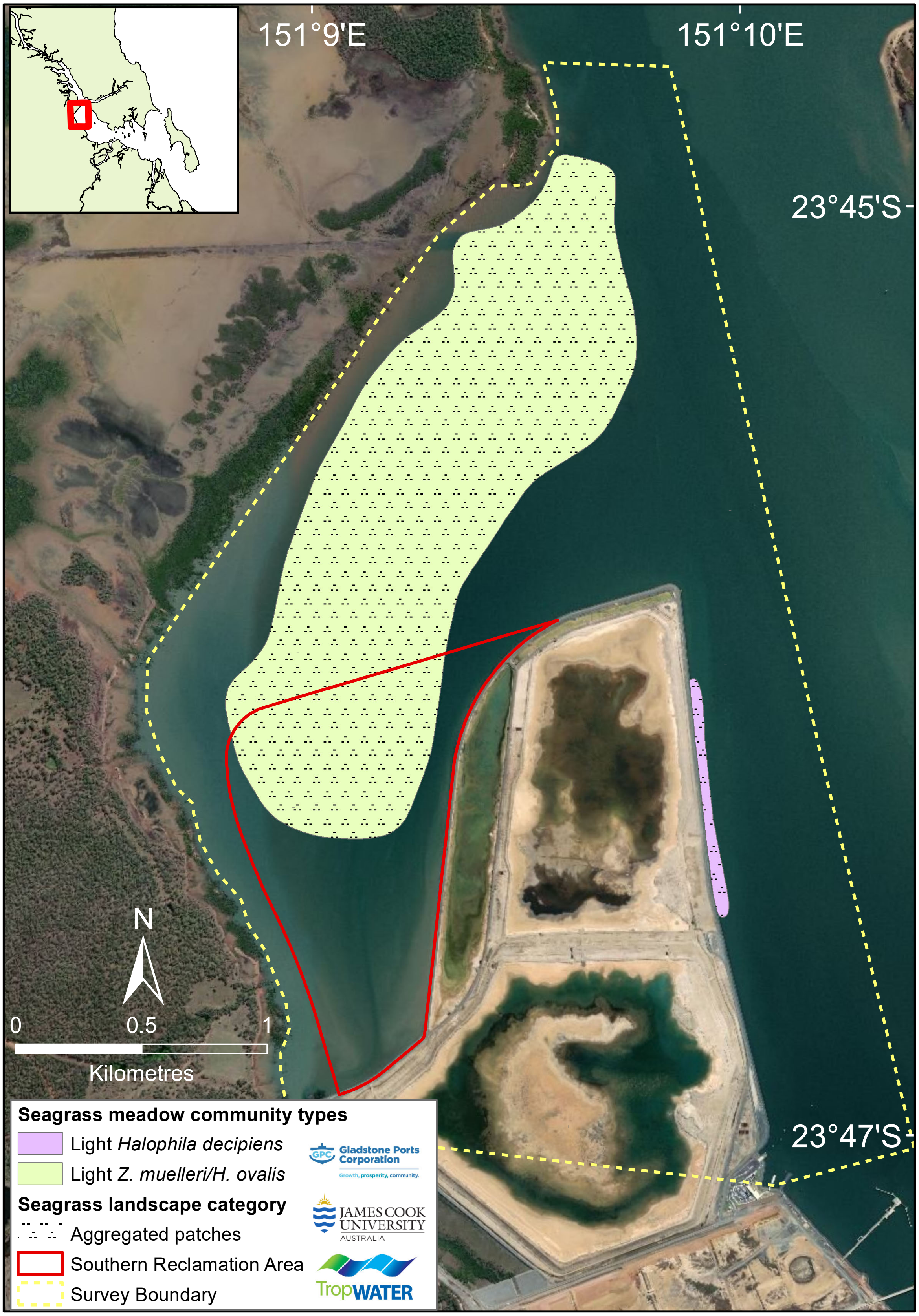


Figure 7. Seagrass boundary and community types in the WBE and BUF monitoring footprint in 2020.

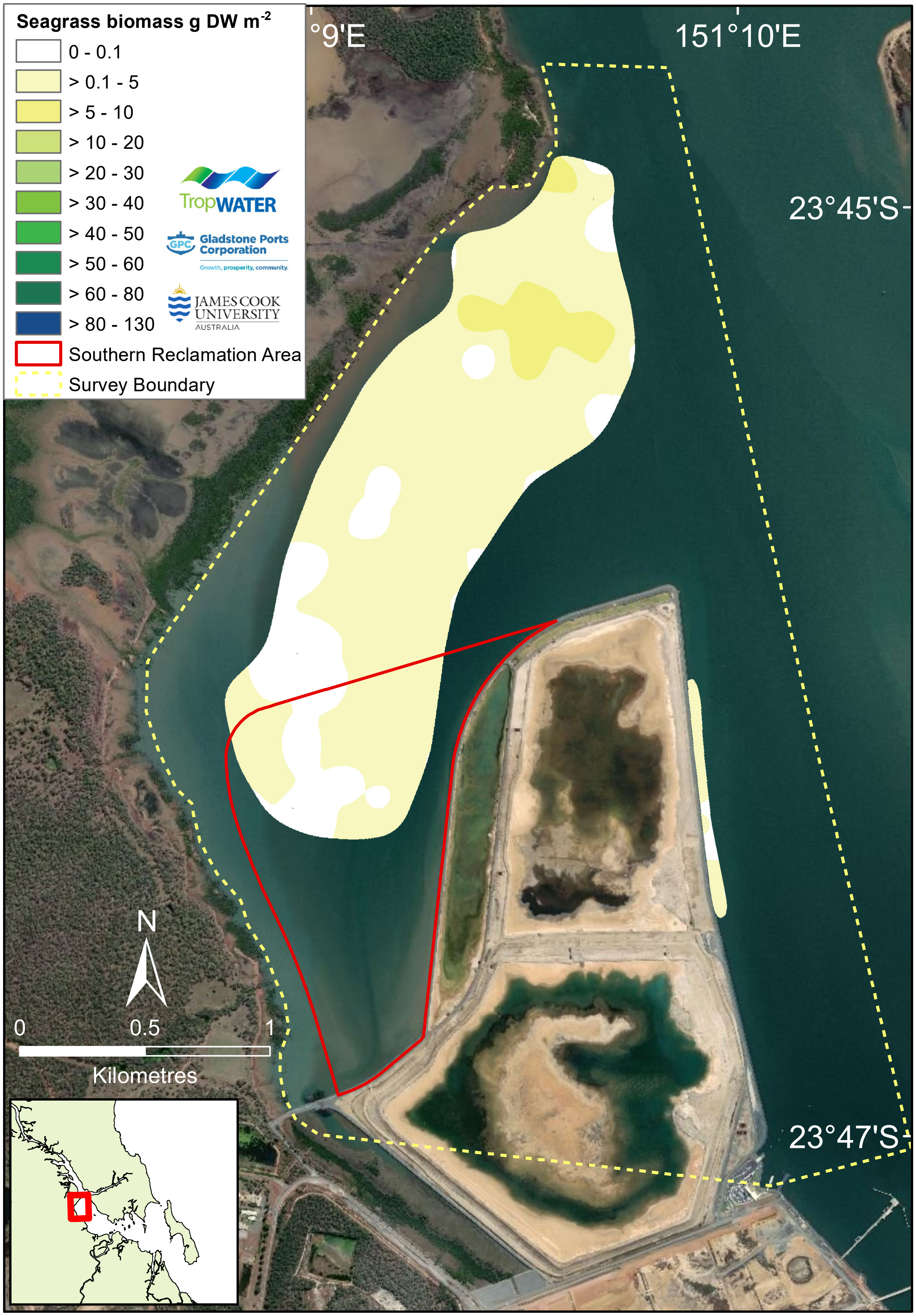


Figure 8. Seagrass meadow area and biomass distribution across meadows in WBE and BUF monitoring footprint in 2020.

Figure 9. Seagrass meadow area and community composition of meadows within the WBE and BUF monitoring footprint between 2011 - 2020.

3.2 Algae in and adjacent to the WBE and BUF

Few sites sampled within or adjacent to the WBE and BUF contained algae and where it occurred the majority of sites had low (<15%) algal cover (Figure 10). A total of 19 sites (15%) supported any algae and only 5 of those sites had more than 10% cover. Erect macroalgae was the most prevalent algae type and was common along the seaward edge of the seagrass meadow but cover was always low (<10%). Erect calcareous marcoalgae occurred at two sites with low cover while ephemeral turfing mat algae and filamentous algae had higher percentage cover where they occurred (10-80%) but were only found at 7 sites (Figure 10). One site in the SRC had low (3%) macroalgae cover and another low filamentous algae cover (5%). The only algae within the SRC outside of the mapped seagrass extent was low cover ephemeral filamentous algae found at one site and covering an additional 0.64 ha outside of the seagrass extent.

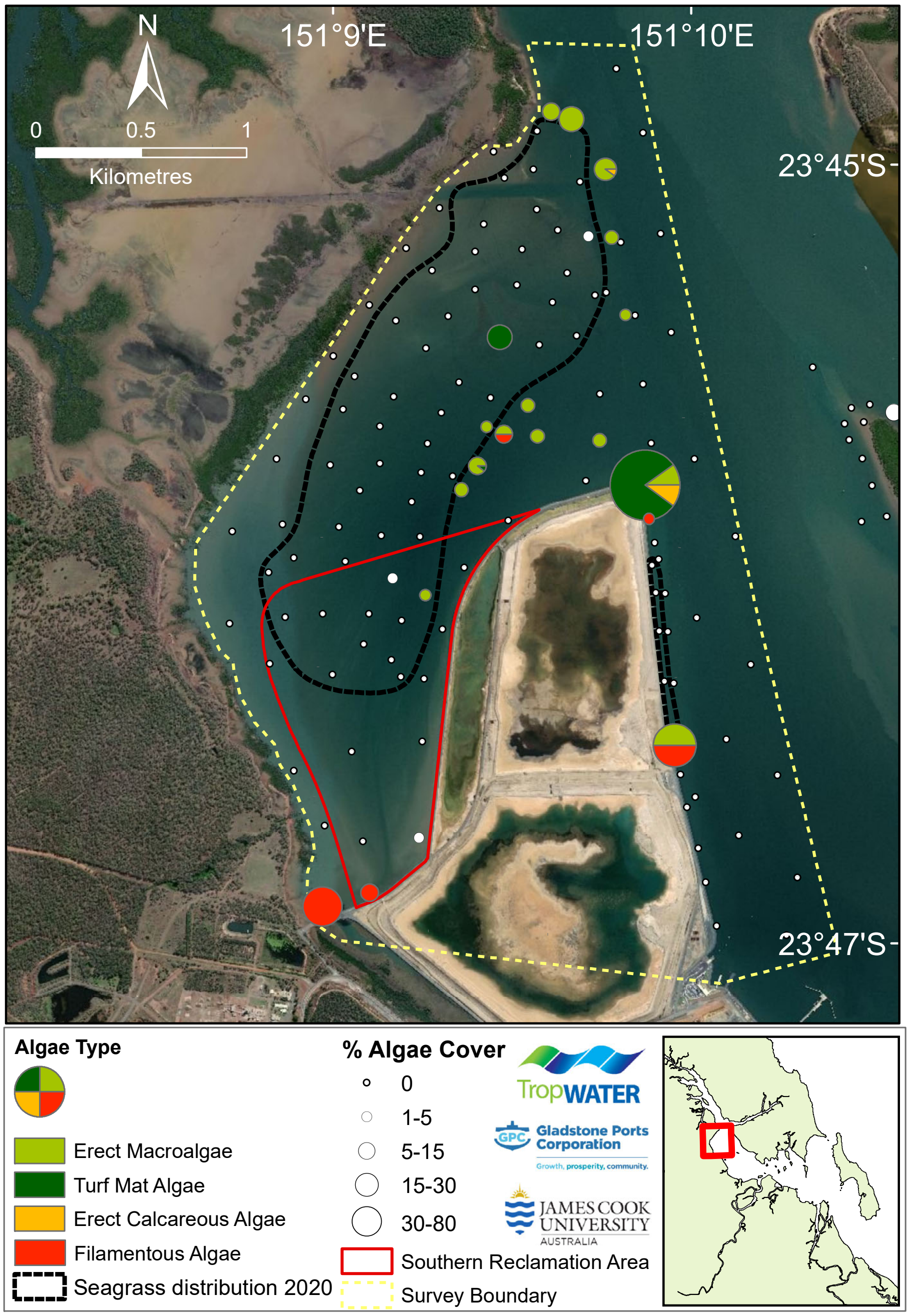
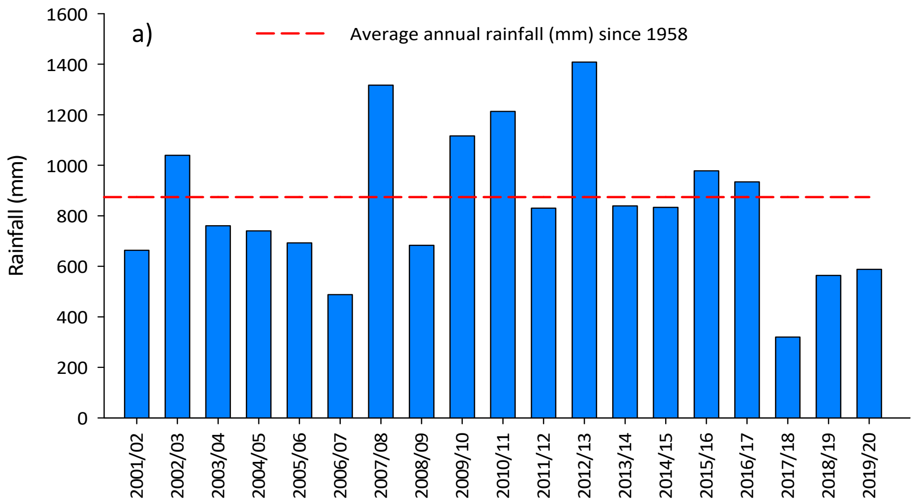


Figure 10. Percentage algae cover and the proportion of algal types at each site in the WBE and BUF monitoring footprint in 2020.

3.3 Gladstone environmental conditions

Total annual rainfall in the 12 months preceding the November 2020 survey was well below average for the third consequtive year and the fourth lowest since seagrass monitoring began in 2002 (Figure 11a). Rainfall was highest in January and March 2020 consistent with wet season conditions but there was little rain in February (Figure 11b). There was however above average rainfall during the later part of they year (August – October) during the seagrass growing period (Figure 11b). River flow from the Calliope River reached its highest volume since October 2017 in Feburuary after rainfall in January but was very low throughout the remaining year (Figure 12). Tidal exposure of intertidal meadows in Gladstone was below average for the fourth consecutive year and the lowest since 2012 (Figure 13).



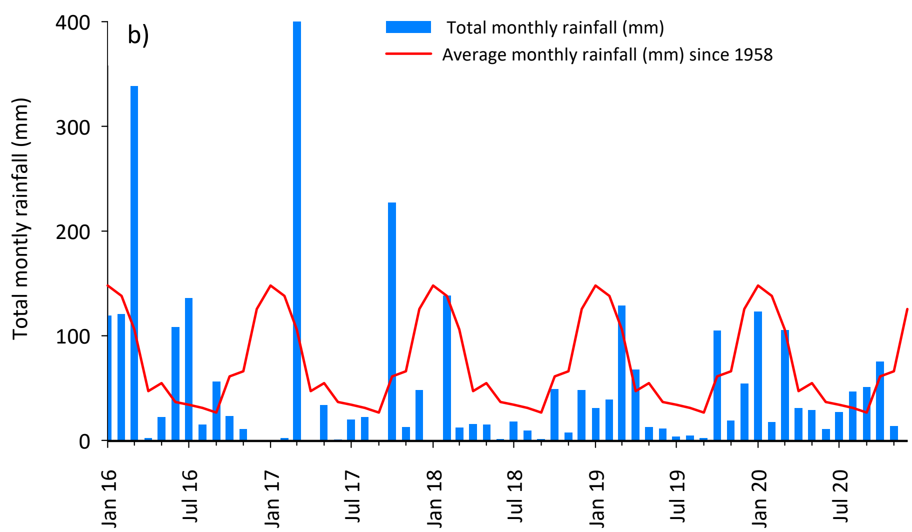


Figure 11. a) Gladstone annual rainfall (mm) and b) monthly rainfall (mm) totals; January 2016–November 2020.

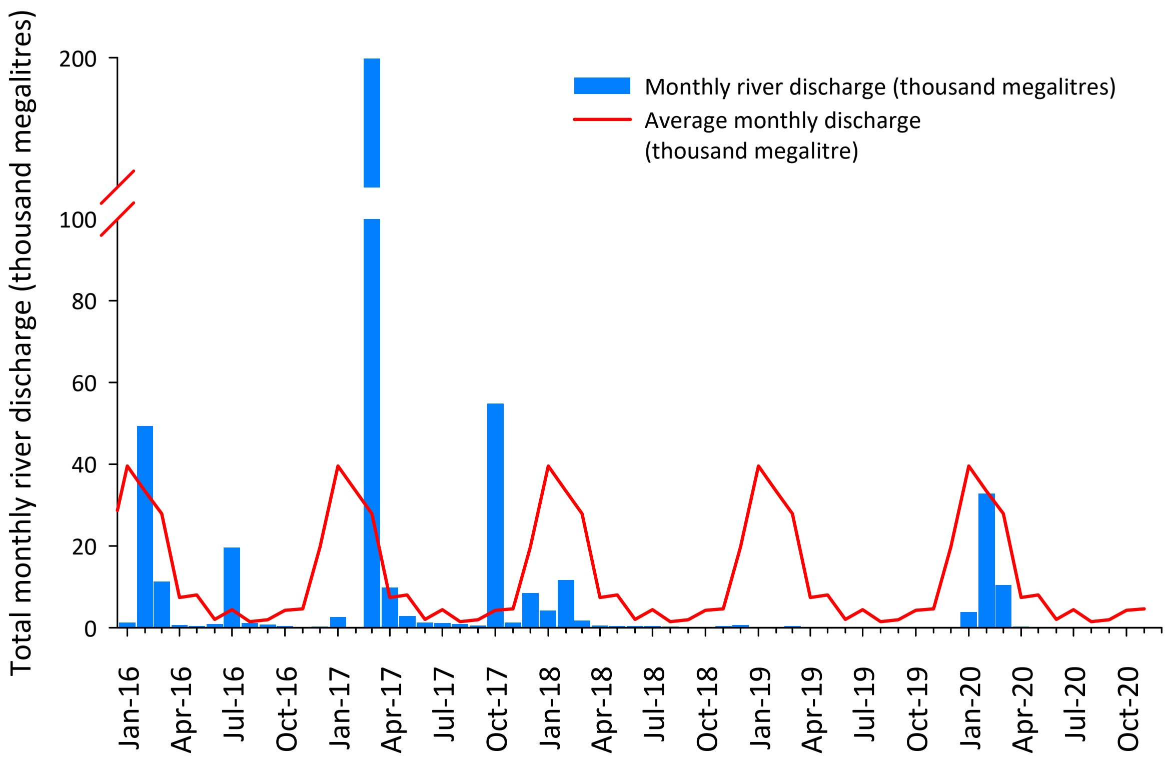


Figure 12. Monthly total river flow for the Calliope River (thousand megalitres); January 2015–November 2020.

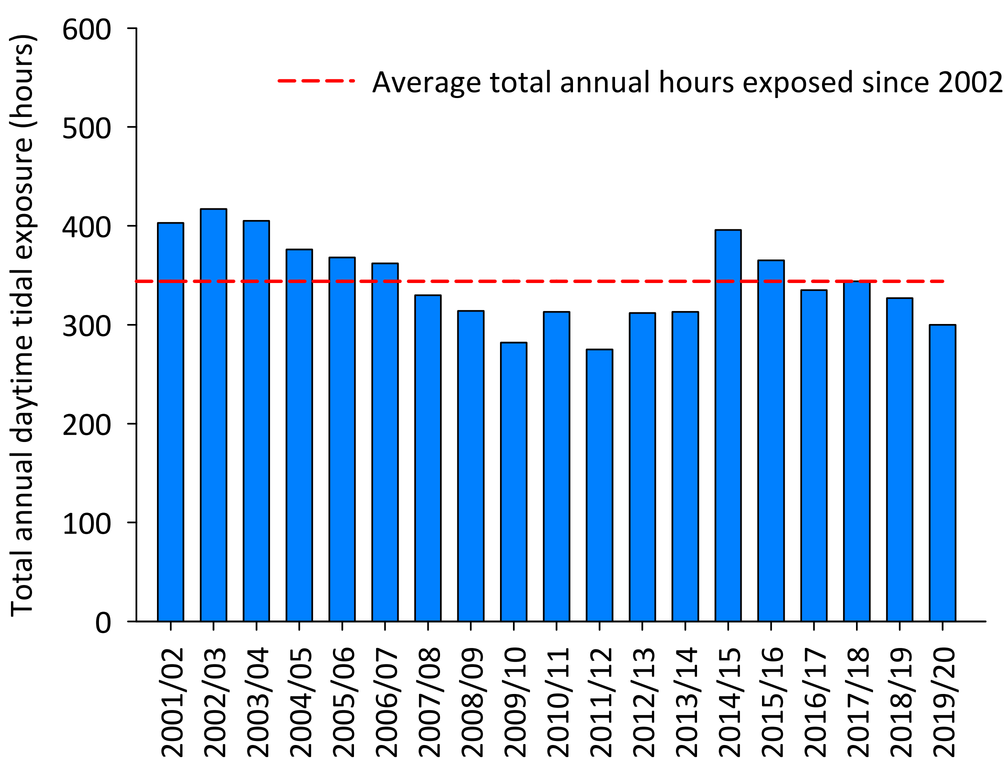


Figure 13. Total annual daytime hours exposed 2002- 2020 (06:00-18:00; <1.0 m below mean sea level)

4 DISCUSSION

In 2020 seagrass within and adjacent to the WBE and BUF investigation area formed a large, low biomass meadow covering 207 ha. This meadow has shown large flucuations in area since monitoring began in 2002. In 2020 both area and biomass were high relative to previous surveys since the establishment of the WBDPP Reclamation Area in 2011 that effectively reduced the historical footprint over which the meadow occurred, and remained in similar condition to 2019 when meadow area and biomass peaked (Smith et al. 2020). Relatively high seagrass biomass and area at Fishermans Landing between 2019-2020 is indicitive of seagrass condition across the broader Port Curtis and Rodds Bay area associated with favorable weather conditions over the last few years (Smith et al. 2020, Chartrand et al. 2019). Seagrass directly in the footprint of the SRC covered an area of 41.8 ha in 2020 and a composite area from all surveys between 2011-2020 of 91.4 ha.

Seagrass condition across Port Curtis and Rodds Bay declined dramatically in 2009-2011 following consecutive high rainfall events and flow from the Calliope River (Chartrand et al. 2019, York et al. 2016). During this period seagrass meadows recorded record low area and biomass and seagrass was absent from several meadows (Bryant et al. 2014). This period also coincided with the construction of the WBDPP Reclamation Area at Fishermans Landing (Bryant et al. 2014). Prior to the construction of the WBDPP Reclamation Area, a large (60 ha) *H. decipens* meadow was present in subtidal areas near Fishermeans Landing and an adjacent large intertidal meadow dominated by *Z. muelleri* (300 ha) also occurred (Thomas et al. 2010). Since that time seagrasses in Gladstone have been recovering and over the previous three years, meadow biomass at Fishermans Landing has reached the highest levels since 2011 (Smith et al. 2020). Meadow area is the highest since 2011 when construction of the WBDPP Reclamation Area effectively reduced the maximum extent the seagrass meadow could achieve, compared with pre 2011 surveys.

A second smaller meadow consisting of low biomass *H. decipiens* was located adjacent to the WBDPP reclamation wall in 1.5 – 2 m water depth. Prior to the construction of the reclamation area *H. decipiens* formed a large deep water meadow north of Fishermans Landing (Thomas et al. 2010). The meadow surveyed in 2020 may be a remenant of this meadow or a new meadow that has colonised suitable shallow habitat created by the wall. *Halophila decipiens* is a small ephemeral segrass species whose distribution is largely dependant on light conditions and can fluctuate markedly over small temporal scales (Chartrand et al. 2017). The narrow strip where this meadow occurred likely represents habitat where sufficient light reaches seagrass allowing it to grow before there is insuffiecent light further into the channel.

There was very little habitat forming macroalgae within or adjacent to the proposed WBE and BUF. Erect macros and calcareous macroaglae were found along the deep edge of the seagrass meadow but never represented more than 10% cover and the majority of sites were less than 3% cover. Higher algae cover was observed at 3 sites (30-80%) but these consisted of highly ephemeral and unstructured filamentous and turf algae. Filamentous and turf algae are able to quickly colonise disturbed habitats and nutrient blooms but their persitence and habitat value is poor realtive to larger habitat forming macroaglae (Wernberg and Connell 2008).

Approximately 41.77 ha of seagrass from meadow 8 occurred within the proposed bund wall for the SRC in 2020 with an additional area of 0.64 ha of filamentous algae outside of the seagrass footprint. In the 10 years since construction of the WBDPP seagrass area within the SRC has fluctuated substantially. In 2016 and 2017 there was virtually no seagrass within the SRC footprint but there has been a significant increase over the last two years to reach the current area. The area of potential seagrass habitat within the SRC when all years distributions between 2011 and 2020 are considered collectively was 91.37 ha. The seagrass in the SRC area currently has low biomass (<5 g DW m^{-2}) with large areas of bare substrate between patches of seagrass. Biomass was similar within the SRC in 2019, but included some areas of higher biomass (5-10 g DW m^{-2}) in surveys since the construction of the WBDPP (Chartrand et al. 2019, Chartrand et al 2018).

Improvement in seagrass condition over the past three years in the greater Port Curtis region can be attributed to favorable environmental conditions that promote seagrass growth. Analysis of the long-term patterns of seagrass condition from the 18 years of annual monitoring reveal a strong relationship with river flow and to rainfall in the region (Smith et al. 2020, Chartrand et al. 2019). Rainfall and flow from the Calliope River over the last three years has been the lowest since 2010 and below average each year. These conditions coincide with seagrass recovery and record biomass and the establishment of the most persistent seagrass species in the area, *Z. muelleri* at some meadows where historic lows were recorded between 2010 and 2017. The relationship between seagrass growth and river output and rainfall is the result of increases in benthic light associated with fewer significant rainfall and flood events. Below average number of tidal exposure hours for intertidal seagrasses in 2019 and 2020 may also have protected seagrasses from desiccation and thermal stress (Unsworth et al. 2012). Trends in seagrass recovery reinforce that mild environmental conditions over the previous three years have been the biggest driver in determining seagrass recovery and condition. If drier conditions continue, we would expect seagrass area and biomass to remain stable or increase into the future.

The seagrass meadows within the WBE/BUF area of interest and the SRC are highly variable between years but have always been of comparatively low biomass. While this means they are likely to have lower value in terms of ecosystem services compared to the higher biomass and more stable meadows elsewhere within Port Curtis they would still be providing some services. Recent studies indicate that even these low biomass seagrass meadows contribute to carbon storage, sediment stabilisation, fisheries habitat and food for megaherbivores (Fonseca 1989, Hays et al. 2020; Jinks et al. 2019; Scott et al. 2020; Ricart et al. 2020).

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Appendix 1. Queensland ports seagrass monitoring program

A long-term seagrass monitoring and assessment program is established in the majority of Queensland's commercial ports. The program was developed by the Seagrass Ecology Group at James Cook University's (JCU) Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) in partnership with the various Queensland port authorities. A common method and rationale provides a network of seagrass monitoring locations comparable across the State (Figure A1).

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

Figure A1. Location of Queensland ports where seagrass monitoring occurs. Red dots: long-term monitoring; blue dots: baseline mapping only.

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

Appendix 2. Meadow area and above-ground biomass

Meadow ID	Biomass ± SE (g dw m^{-2})	Area ± R (ha)	Community Type	Landscape Category	Species Present	Sites Sampled
8	1.76 ± 0.32	202.99 ± 3.45	Light *Z. muelleri/H. ovalis*	Aggregated patches	*Z. muelleri, H. ovalis, H. decipiens*	53
8 (inside Southern Reclamation)	1.34 ± 0.53	41.77 ± 1.28	Light *H. decipiens/H. ovalis*	Isolated patches	*H. decipiens, H. ovalis*	10
1	0.76 ± 0.76	4.08 ± 0.99	Light *H. decipiens*	Aggregated patches	*H. decipiens*	5

Appendix 3. Detailed species composition, Meadow 8, 2002-2020