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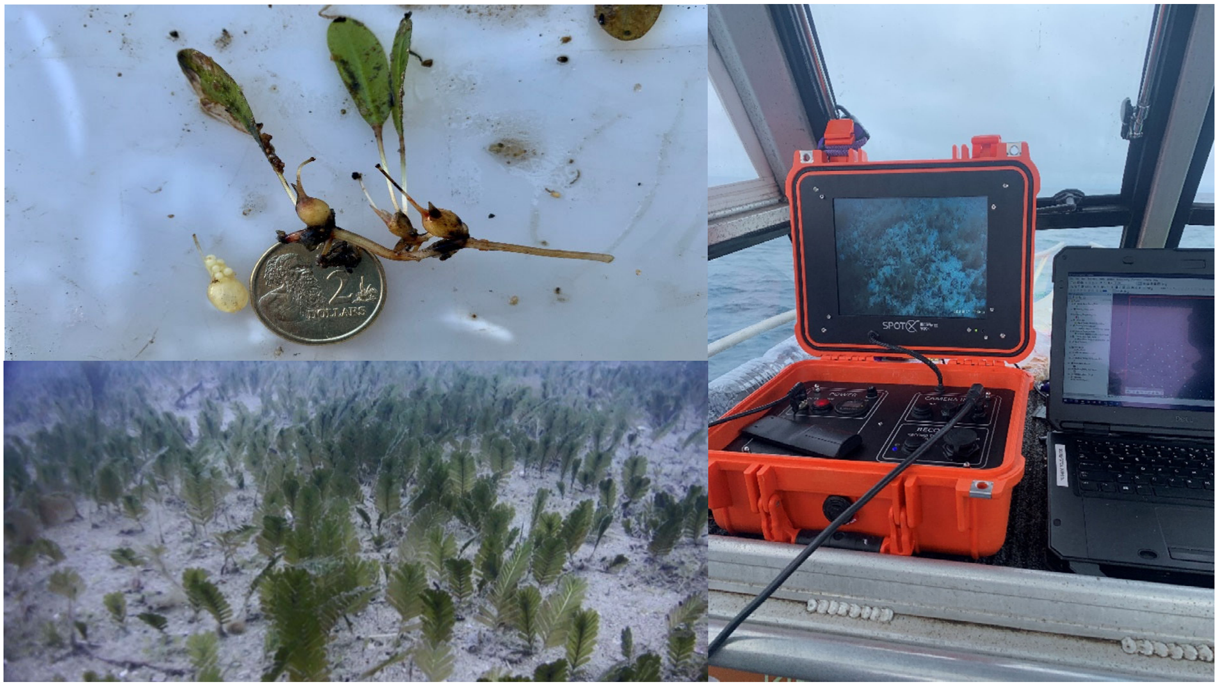

Port of Bundaberg Seagrass and Benthic Monitoring Survey 2020

Smith TM & Rasheed MA

Report No. 21/07
March 2021

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A Report for Gladstone Ports Corporation

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Information should be cited as:
Smith TM. and Rasheed MA. 2020. Port of Bundaberg Seagrass Baseline Survey 2020. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 21/07, James Cook University, Cairns, 21 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. A baseline survey of seagrasses and associated benthic communities was conducted in the Port of Bundaberg from the 27th – 30th October 2020.

2. Seagrass formed large deep-water meadows of *Halophila decipiens*, *H. ovalis* and *H. spinulosa* in offshore areas of the Port of Bundaberg but was absent from shallower coastal and estuarine areas of the port.

3. Deep-water seagrass meadows covered 5,788 ± 975 ha or 35% of the port limits area. Seagrass was mapped to the port limits boundary but was likely that the meadows extended much further outside the port limits.

4. Average biomass of deep-water seagrass across all meadows was 1.08 ± 0.16 g DW m^{-2} ranging from 0.06 to 3.69 g DW m^{-2} for individual meadows. Seagrass biomass in the Port of Bundaberg was similar to seagrass meadows in other deep-water areas in North Queensland.

5. Macroalgae occurred throughout the port but at very low cover. Filamentous algae was common seaward of the spoil grounds often as epiphytes on seagrass and erect macrophytes were more common in the coastal zone with turf algae in the estuary and shipping channel.

6. Seagrass meadows and their associated epiphytes in the Port of Bundaberg likely provide a foraging area for dugongs and turtles and habitat for a range of fauna.

7. It is likely that these deep-water meadows found in the Port of Bundaberg are highly variable seasonally and between years. This survey can form a baseline from which a regular monitoring program for seagrasses and macro-algae could be developed if required.

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ACRONYMS AND ABBREVIATIONS

dbMSL	Depth below Mean Sea Level
DFT	Dugong Feeding Trail
DW	Dry Weight
GIS	Geographic Information System
GPC	Gladstone Ports Corporation
GPS	Global Positioning System
IDW	Inverse Distance Weighted
JCU	James Cook University
LTMMP	Long-Term Management and Monitoring Program
MSQ	Maritime Safety Queensland
PCIMP	Port Curtis Integrated Monitoring Program
PoB	Port of Bundaberg
TropWATER	Centre for Tropical Water & Aquatic Ecosystem Research

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).

The Port of Bundaberg (PoB) is located at the mouth of the Burnett River approximately 14 km from the city of Bundaberg and is managed by Gladstone Ports Corporation (GPC). Previously seagrass and benthic habitats in the PoB limits have received relatively infrequent assessment compared to other ports in North Queensland, and generally targeted small areas within the port limits. Seagrasses have been recorded from the Burnett River in the early 90's (Lee Long et al. 1993) and intermittently during benthic spoil ground surveys focussed on an area immediately adjacent to the offshore disposal ground (Worley Parsons 2011, Spooner & Cohen. 2015). However a comprehensive survey of seagrass, macro algae and other benthic habitat throughout the port limits has not previously been conducted. Seagrass in Bundaberg is thought to be a critical food source of endangered dugongs (Marsh et al. 1992) and may support key turtle populations at nearby Mon Repos, the largest concentration on nesting turtles on the east Australian mainland. Despite their importance seagrasses in Queensland are threatened by both natural (cyclones, flooding) and anthropogenic (coastal development, agricultural runoff) disturbances that can result in large-scale seagrass decline (McKenna et al. 2015).

This report was commissioned by GPC to provide a baseline survey of seagrass and other benthic habitats in the PoB. The report provides key inputs into the PoB sustainable sediment management project and may also help inform the Maintenance Dredging Strategy and Long-Term Maintenance Dredging Management Plan. It also identifies critical habitats that support dugong and turtle within the port. The survey provides a baseline for comparison with any future seagrass surveys in the area and a basis for designing an ongoing monitoring program if required.

1.1 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 1).

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 environmental thresholds for the protection and management of seagrass, and an understanding of the reasons for seagrass change.

Figure 1. 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/

2 METHODS

2.1 Field surveys

Survey and monitoring methods followed the established techniques for TropWATER's Queensland-wide seagrass monitoring programs (Rasheed et al. 2005; Rasheed et al. 2003). Seagrass and macro-algae were surveyed 27th - 30th October 2020 during the seasonal peak in seagrass abundance. Conducting surveys between October and December allows the greatest likelihood of sampling seagrass and for appropriate comparisons to seagrass in other ports across north Queensland. This survey involved mapping and assessing:

- Shallow subtidal seagrasses and macro-algae within the Port of Bundaberg including the Burnett River, shipping channel and spoil ground
- Deep-water areas within the Port of Bundaberg port limits

Shallow subtidal meadows were sampled by boat using camera drops and 0.03 m^2 van Veen grab (Figure 7a, b). Subtidal sites were positioned at ~50 - 500 m intervals running perpendicular from the shoreline, or where major changes in bottom topography occurred, and extended offshore beyond the edge of any seagrass meadows. Where underwater visibility was poor additional sites were sampled using the van Veen grab were used to assist in determining the presence of seagrass for mapping meadow boundaries. The details recorded at each site are listed in Section 2.3.1.

At each deep-water offshore sampling site an underwater camera system (Figure 2c) was towed for approximately 100 m while footage was observed on a monitor and recorded. Benthos on the seafloor was captured in the net and used to confirm seagrass species observed on the monitor. The technique ensures that a large area of seafloor was sampled at each site so that patchily distributed seagrass typically found in deep-water habitats was detected. Seagrass species composition was measured from the sled net sample and from the video screen and species identified according to Waycott et al. (2014). Seagrass biomass estimates were made from video images using a calibrated visual estimates technique (see below).

Figure 2. Seagrass monitoring methods used in the Port of Bundaberg in 2020. Boat-based camera drops (a) and van Veen grab (b) for subtidal seagrass and video sled (c) used to sample deep-water seagrass.

2.2 Seagrass biomass

Seagrass above-ground biomass was determined using a "visual estimates of biomass" technique (Mellors 1991; Kirkman 1978). At each shallow subtidal site, a 0.25 m^2 quadrat was placed randomly three times. For deep-water video transect analysis 10 randomly assigned 0.25 m^2 quadrats were assessed for each 100 m transect. 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 have previously been harvested for each species 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 meter (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). 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. Mapping precision ranged from ± 50 to 200 m for subtidal meadows with boundaries mapped by distance between sites with and without seagrass. The mapping precision estimate was used to calculate a buffer around each meadow representing error; the area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Meadows were described using a standard nomenclature system developed for Queensland's seagrass meadows. Seagrass community type was determined using the dominant and other species' percent contribution to mean meadow biomass (for all sites within a meadow) (Table 1). Community density was based on mean biomass of the dominant species within the meadow (Table 2) and landscape categories based on biomass and observations in the field (Figure 3).

Table 1. 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 2. 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*
Light	<1
Moderate	1-5
Dense	>5

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

3 RESULTS

3.1 Seagrasses in Port of Bundaberg

A total of 141 coastal sites and 46 deep-water transects were surveyed in the Port of Bundaberg survey area in 2020 (Figure 4). A seagrass area of 5,788 ha exclusively in deep-water habitats (> 12 m) was mapped across two meadows consisting of the seagrass *Halophila ovalis*, *H. decipiens* and *H. spinulosa* (Figure 4, 5). Seagrass was recorded at the maximum depth sampled (22 m) and extended beyond the port boundaries, but mapping was restricted to the port limits boundary. No seagrass was found in any of the shallow coastal sites including the Burnett River estuary and the shipping channel despite a high sampling effort.

The largest seagrass meadow covered approximately 5,564.3 ± 851 ha, over 35% of the port limit area and consisted of all three *Halophila* species forming isolated patches (Figure 6, Appendix 1). Biomass in this meadow ranged from 0.06 to 3.69 g DW m^2. The highest biomass was recorded in the north of the meadow toward the port boundary and to the north east of the spoil ground (Figure 7). The lowest biomass was in the southern section of the spoil ground and western edge of the meadow (Figure 7). A single site within the spoil ground recorded no seagrass but there was seagrass at all other spoil ground sites (see concurrent benthic survey of the spoil ground Smith and Rasheed 2021). Reproductive structures were commonly observed in *H. ovalis* sampled from the sled containing both fruits and seeds (Figure 8). The small, shallower meadow covered 223.2 ± 124 ha and consisted of low biomass *H. decipiens* in isolated patches (Figure 6, 7).

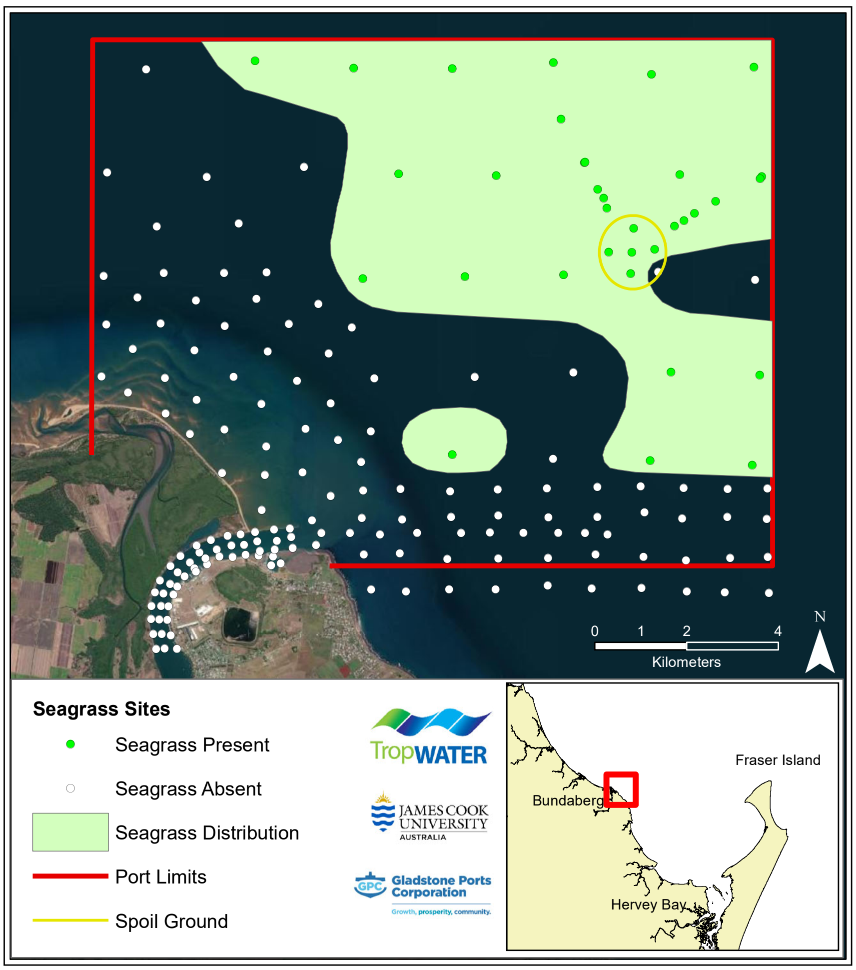

Figure 4. Seagrass presence/absence at sites surveyed and seagrass distribution within Port of Bundaberg in 2020.

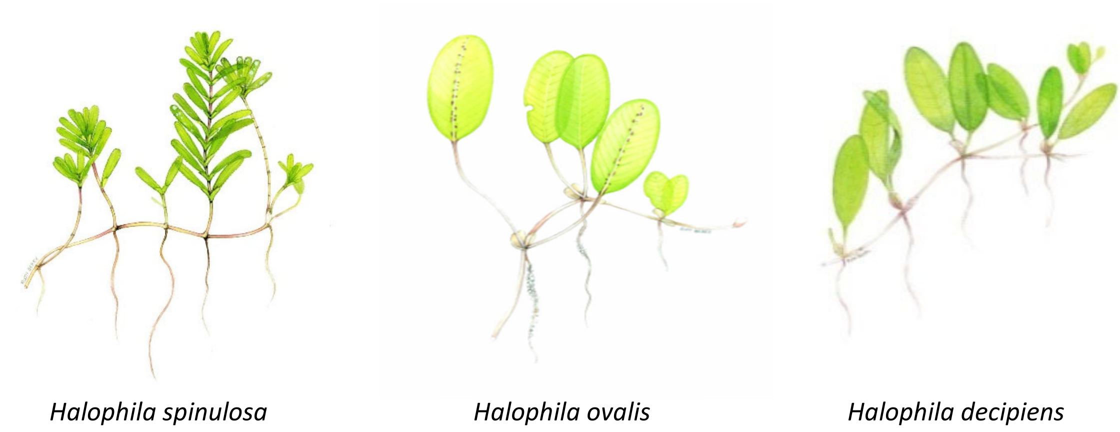

Figure 5. Seagrass species present in Port of Bundaberg seagrass survey in 2020.

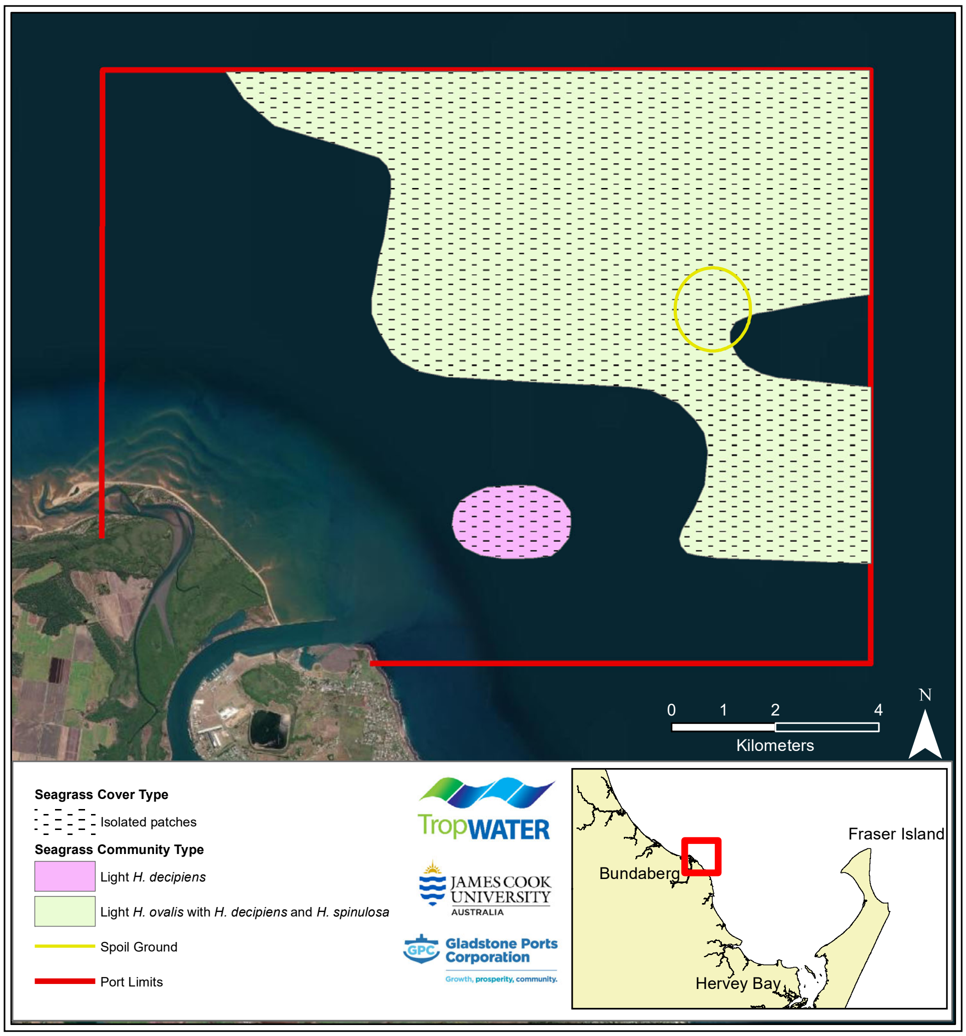

Figure 6. Seagrass community types and cover in the Port of Bundaberg 2020.

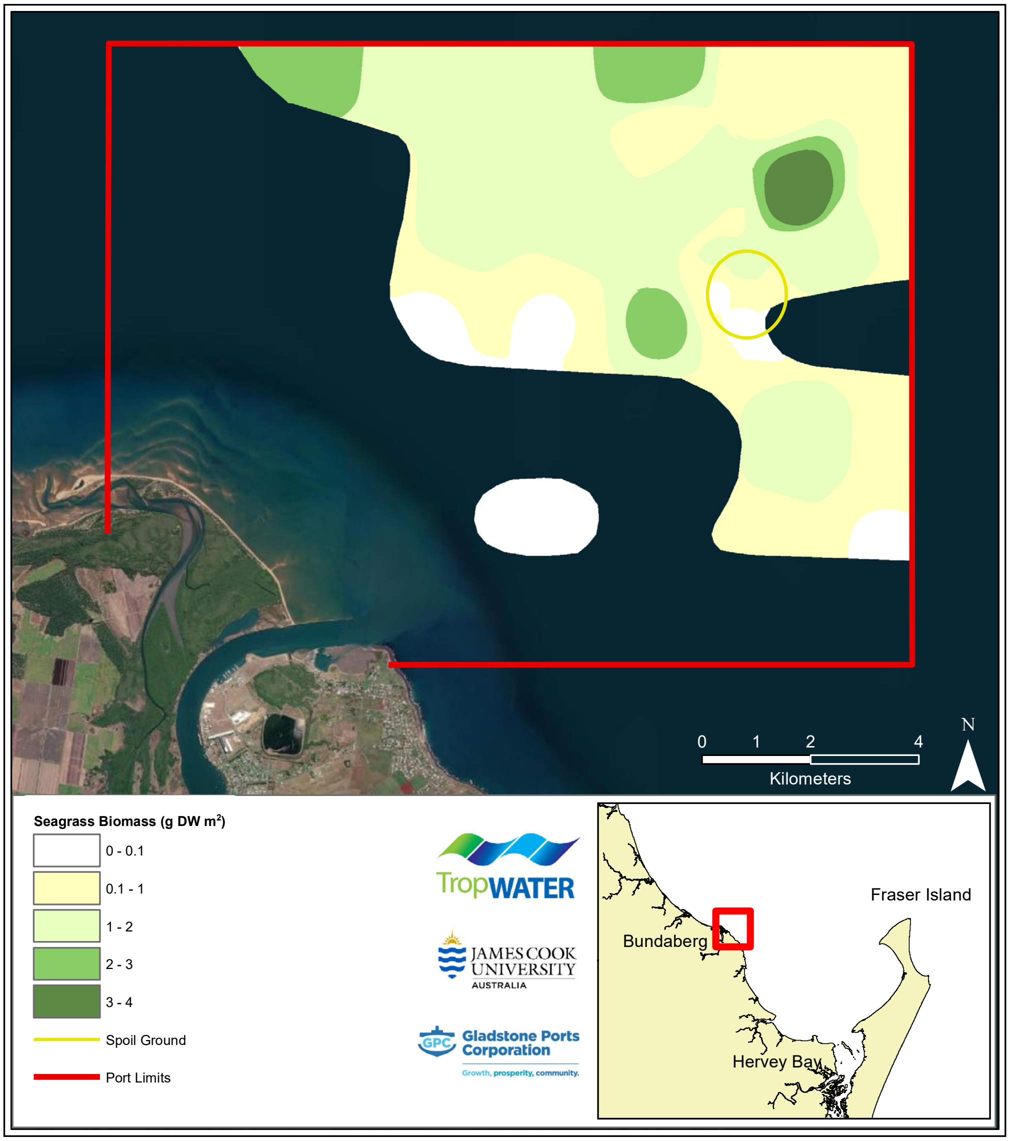

Figure 7. Seagrass biomass in deep water meadows in the Port of Bundaberg 2020.

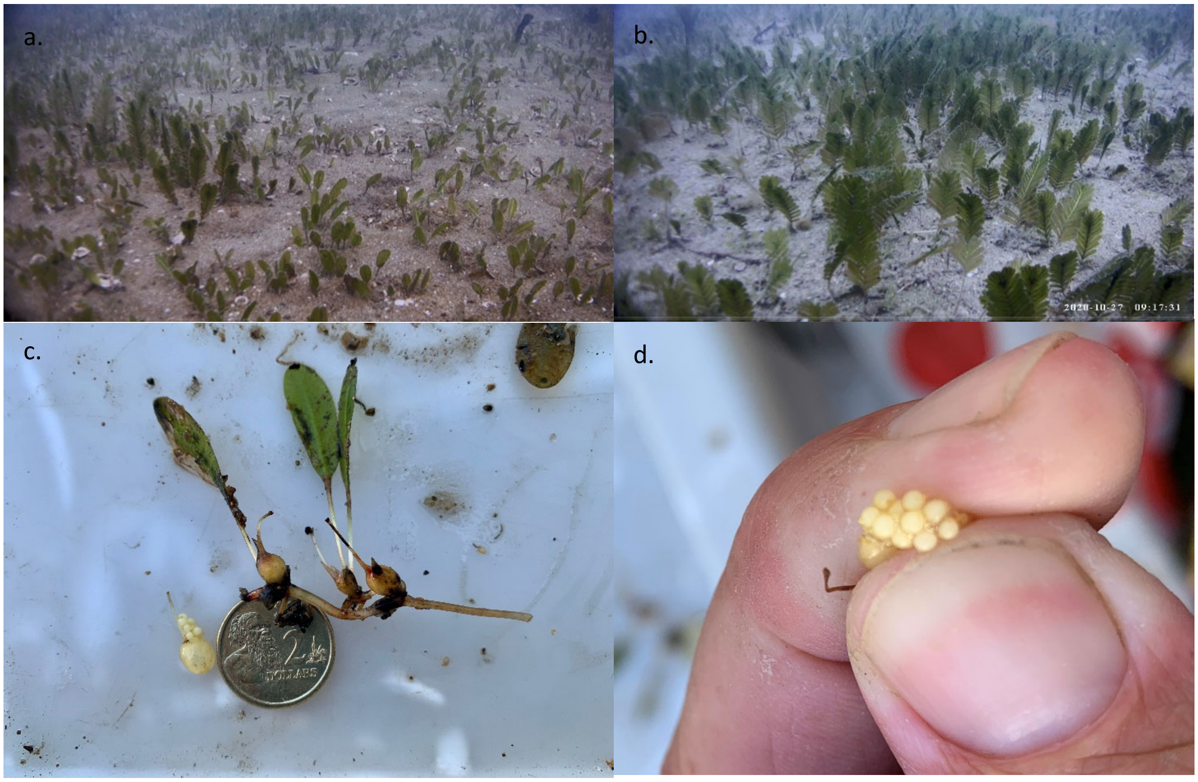

Figure 8. Deep-water *H. ovalis* (a) and *H. spinulosa* (b) meadows from the Port of Bundaberg and *H. ovalis* with fruit (c) and *H. ovalis* seeds (d).

3.2 Macroalgae and benthic macroinvertebrates

Macroalgae was common throughout the PoB but had low coverage where it occurred (< 30%) and was dominated by filamentous and erect macroalgae (Figure 9). Filamentous algae was found almost exclusively in the north east of the PoB, offshore of the spoil ground. Erect macro-algae, often *Caulerpa* spp. was widespread within the port with highest cover in the shallower coastal sites north of the Burnett River mouth. Erect calcareous algae included *Halimeda* sp and *Udotea* sp. (Figure 12) and were restricted to deep habitats while turf algae occurred almost exclusively in the estuary and shipping channel.

Habitat forming benthic macro invertebrates were observed in the PoB but were not common and were generally isolated individuals rather than high density continuous habitats. Habitat forming benthic macroinvertebrates included commonly recorded included Porifera (sponges), soft corals, bryozoans and isolated hard corals (Figure 12) but were generally restricted to one or two sites in low densities at the north east of the port.

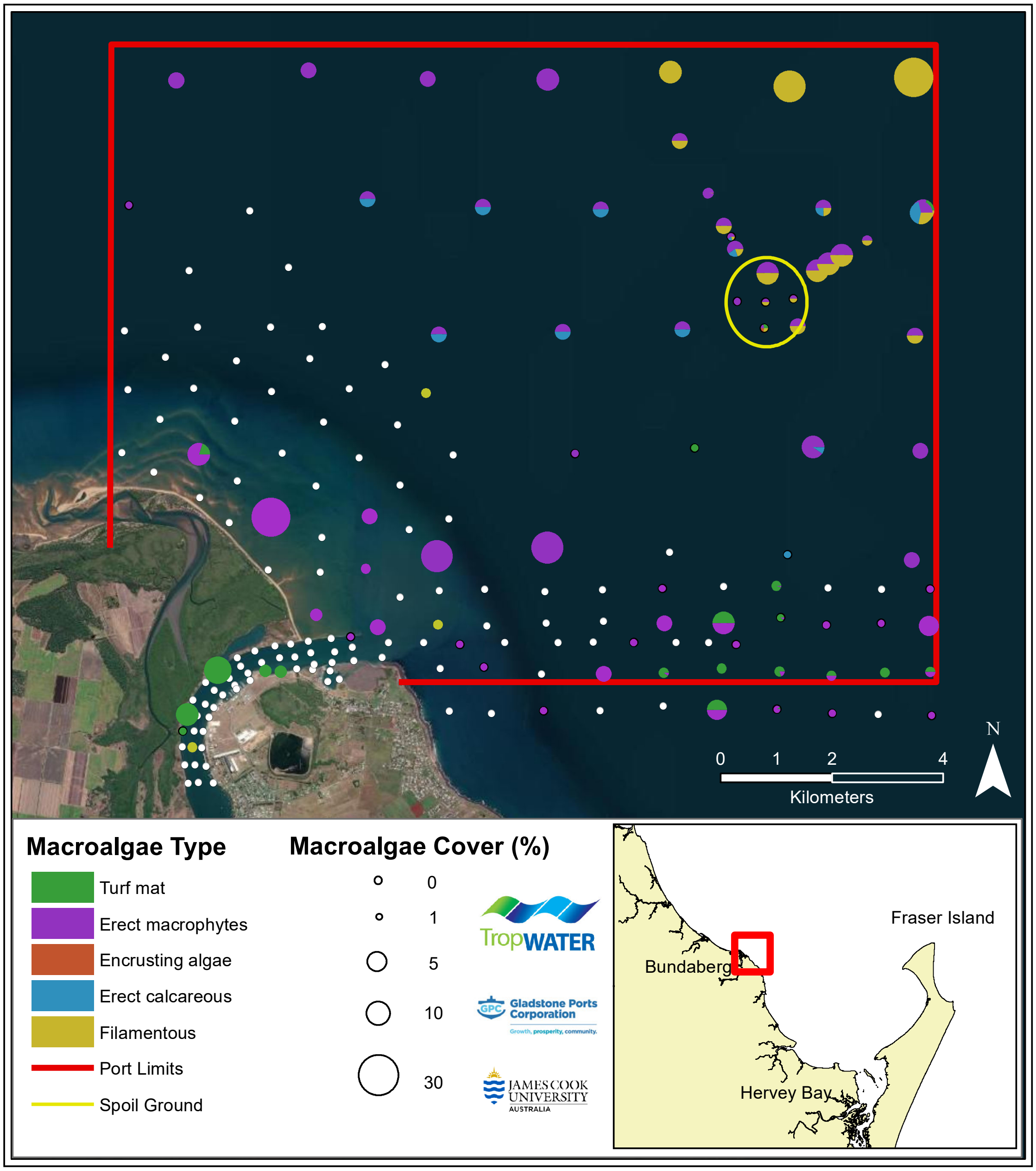

Figure 9. Macroalgae distribution, type and percent cover at sites surveyed in the Port of Bundaberg.

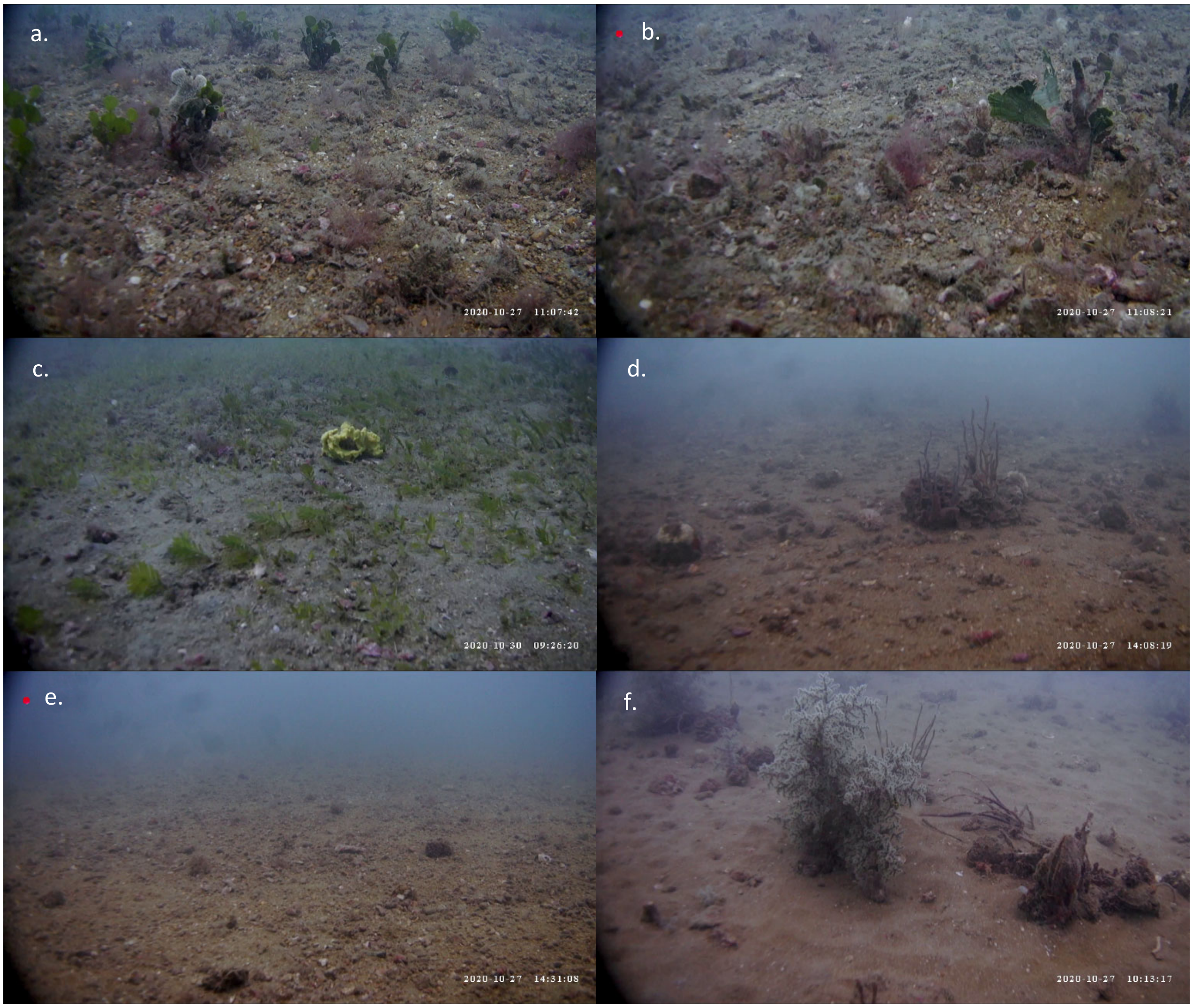

Figure 10. Erect macrophytes and habitat forming benthic macro invertebrates observed in the PoB. Erect calcareous algae *Halimeda* sp. (a) and *Udotea* sp. (b) and habitat forming Porifera (sponges) in seagrass (c) and in rubble (d), rubble with unidentified macro invertebrates (e) and soft coral (f).

4 DISCUSSION

The PoB supports a large area of deep-water seagrass that stretches beyond the port limits. This is the first whole of port limits seagrass survey at the PoB and meadow size, biomass and diversity describe an offshore seagrass area that was substantial compared with similar deep-water seagrass areas along the Queensland coast. The offshore meadows also covered much of the spoil ground. In contrast, no seagrass was found in the shallow subtidal, estuary or shipping channel with seagrass only found at depths greater than 9 m.

Halophila ovalis, *H. decipiens* and *H. spinulosa* are low biomass, ephemeral species common in deep-water habitats throughout north Queensland. Deep-water seagrass at PoB was similar to, or in better condition than, other ports in north Queensland sampled in 2019 or 2020 where similar deep-water seagrasses occur. Seagrass biomass in PoB ranged from 0.06 to 2.97 g DW m^2, greater than deep-water meadows sampled in Gladstone, Townsville and Hay Point in 2019 and similar to those at Abbot Point (Smith et al. 2020, Van De Wetering et al. 2020, York and Rasheed 2020). High biomass relative to other seagrass meadows in similar habitats suggest PoB seagrass is in good health, however the biomass was much lower than *H. spinulosa* peaks which can reach up to 25 g DW m^2 under favorable conditions at similar depths (> 10m, York and Rasheed 2020).

The distribution of deep-water *Halophila* seagrass fluctuates rapidly in response to variations in light conditions and water quality (York et al. 2015). *Halophila* spp. are highly susceptible to low light conditions, even over short time periods but can colonise habitats quickly, often from the seed bank, when conditions improve (Chartrand et al. 2018, Hammerstorm et al. 2006, York et al, 2015). High rainfall and flooding releases sediment loads into coastal deep-water seagrass habitat that leads to reduced light and significant seagrass losses throughout north Queensland, including nearby Gladstone and Hervey Bay (Preen et al. 1995, Smith et al. 2020). Large seagrass meadow area, and comparatively high biomass combined with the abundance of fruits observed, suggest PoB seagrass would be able to recover rapidly from episodic high rainfall events and normal seasonal cycles of loss. However, repeated high rainfall and flooding without sufficient time to recover can cause major declines in seagrass (McKenna et al. 2015).

Previous surveys of seagrass in the PoB have occurred infrequently at much smaller spatial scales. Benthic surveys within and adjacent to the spoil ground have occurred at roughly five yearly intervals since 2006 (2006, 2008, 2011, 2015) and found comparable seagrass to this study within the common areas of the surveys. Transects to the north and east of the spoil grounds have moderate to dense *H. ovalis* and *H. decipiens* cover in previous surveys similar to the locations of high biomass in this survey. Previous benthic spoil ground surveys have used broad categories of seagrass cover (sparse, moderate, dense) making direct comparisons to more accurate biomass estimates used in 2020 difficult. Estimates of seagrass cover over multiple projects by multiple observers can lead to observer biases and therefore direct comparison of seagrass cover across years may not reflect actual variation. Biomass assessments used in this survey are standardised across observers and will allow for accurate comparisons across survey times and locations in the future.

Seagrass communities in Queensland are highly seasonal, where biomass and growth peak between October to December and goes into senecence during the wet season under stressful light conditions (Chartrand et al. 2018). Monitoring during the growing period is important to capture seagrass distribution and abundance at their annual peak and enable direct comparisons to other seagrass monitoring programs. Variation in the timing of seagrass monitoring may affect seagrass distribution. For example, the 2011 PoB spoil ground survey was undertaken in early Autumn directly after the wet season when seagrass is in senescence and is the likely explanation why no seagrass was recorded in that survey.

Seagrass was recorded at all sites in the PoB spoil ground specified for monitoring in the PoB LTMMP. Seagrass in the spoil ground suggests dredge spoil deposition is not preventing seagrass recruitment into the area. Previous surveys have however found little or no seagrass within the spoil grounds that was attributed to smoothing from spoil (WorleyParsons 2011, Spooner & Cohen. 2015). *Halophila* spp. are rapid colonisers that are able to establish meadows quickly after a disturbance (Kilminster et al. 2015). Temporal variation in *Halophila* spp. presence in the spoil ground over time may be related to the timing of monitoring relative to dredging regimes, growing seasons or natural disturbance and the general ephemeral nature of deepwater seagrass. In deeper water areas of Queensland *Halophila decipiens* is generally annual in occurance existing only as a seed bank for much of the year (York et al 2015; Chartrand et al 2018) and while other *Halophila* species may retain some above ground biomass throughout the year they generally undergo substantial seasonal declines.

There was no seagrass found at any of the shallower coastal habitats or in the Burnett River in the PoB. In the early 1990s *H. ovalis* and *H. decipiens* formed a small meadow (2 km^2) in the Burnett River estuary but the meadow was not present in this survey (Lee Long et al 1993). The absence of seagrass in the coastal and estuarine zone can be explained by a number of factors. The coastal zone in the PoB is typified by high-energy beaches and coarse sediment and rubble potentially preventing seagrass colonisation, until deeper locations (>9 m) where there is generally a much lower energy environment, and little resuspension from wave action allowing seagrass establishment. The presence of the small, *Halophila* meadow in the Burnett River estuary in the past reflect the typical ephemeral nature of these sub-tidal *Halophila* meadows along the Queensland coast where meadows may occur under favorable environmental conditions but their presence likely fluctuates over time. Seagrass is known to occur in nearby less developed estuaries (Baffle Creek, Kauri Creek and Snapper Creek) (BMRG 2009) and may also be present in protected shallow backwaters of the Burnett estuary surrounding Burubbra Island but were outside the scope of this survey.

Macroalgae was present throughout the PoB but generally covered only small areas of the benthos where it was present. Erect macrophytes, generally *Caulerpa* sp. and *Udota* spp., and erect calcareous algae *Halimeda* were associated with deeper habitats where there was little wave energy and in areas with rubble or rocky sediment to provide attachment points to the benthos. Filamentous algae was generally epiphytic and associated with seagrass while turf mat algae was restricted to the estuary and channel. The low cover of algae and low three dimensional structure of the species observed suggest that they may have limited habitat value compared with more substantive algae communities. Habitat forming benthic macroinvertebrates including sponges, soft corals and bryozoans were restricted to only a few deep water sites and were in small isolated patches rather than continuous high density habitat.

The low-density benthic habitats and deep-water seagrass and macroalgae communities in the PoB may still play a role supporting fish and invertebrates despite their sparse and low-biomass nature. Both sponges and soft corals can support highly diverse fish and invertebrate communities at small scales, providing both food and shelter to a range of species (Poulos et al. 2013). The presence of habitat forming macroinvertebrates in the PoB may support a range of species but little is known about the deep-water function of these kinds of communities. Low biomass deep-water seagrass meadows have generally been assumed to have only a minor role as fish habitat but recent work in tropical Queensland has shown that they can play an important role for a range of nekton including species of recreational and commercial importance and a foraging habitat both directly and indirectly through trophic transfer (Hayes et al 2020).

Large deep-water seagrass meadows in the PoB are likely to provide a food sources for both turtles and dugongs in the area. Dugongs near Bundaberg have been reported to eat *Halophila* spp. and the loss of large seagrass meadows from flooding in Hervey Bay in the early 1990s caused the death and displacement of large numbers of dugongs (Marsh et al. 1982, Preen et al. 1995, Preen and Marsh 1995). Seagrass, particularly *Halophila* spp. is also an important food source for green turtles and foraging habitat for loggerhead turtles (Scott et al. 2021, Shimada et al. 2019). Mon Repos beach just outside the PoB boundary has the highest concentration of nesting loggerhead turtles in eastern Australia and also supports green turtle populations. It is likely the deep-water seagrass meadows within in the PoB provide a seasonally available foraging habitat for both dugongs and turtles.

The PoB has large seagrass meadows in deep-water habitat but seagrass was absent for nearshore locations in the port. While coastal modification in the past may have contributed to the lack of nearshore seagrass, current port operations (maintenance dredging, shipping, etc) are unlikely to substantially impact on its current abundance or distribution, given the relatively small scale of these operations and experience of seagrass resilience to similar short-term maintenance dredging programs elsewhere in Queensland. Local factors such as flooding events, wave energy and sediment conditions as well as herbivory and seasonal conditions are likely to play a greater role in determining seagrass distribution. The large deep-water seagrass meadows with their associated epiphytic communities are likely to provide a seasonally available food source for local marine megafauna and fish populations and are therefore worthy of consideration when managing activities with the potential to impact on their health. Due to their likely substantial intra and inter-annual variability in presence, large spatial scale sampling across the port such as conducted in this survey, will be most suited to understand their dynamics. Regular monitoring of deep-water seagrass in the PoB could be designed using the results of this baseline as required.

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Appendix 1. Seagrass meadow area and above-ground biomass

Meadow ID	Type	Cover	Species	Sites	Biomass	Area	Methods
1	Light *H. ovalis* with *H. decipiens* and *H. spinulosa*	Isolated patches	*H. decipiens, H. spinulosa, H. ovalis*	33	1.11 ± 0.16	5 564.26 ± 851	Camera Tow
2	Light *H. decipiens*	Isolated patches	*H. decipiens*	1	0.09	223.21 ±124	Camera Tow