Port of Brisbane Seagrass Monitoring Program 2018 - Final Report

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Synopsis: Findings of the 2018 seagrass monitoring program at Port of Brisbane, Queensland		

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Executive Summary

Background

Seabed areas east of Fisherman Island support some of the most extensive seagrass meadows in western Moreton Bay. Port of Brisbane Pty Ltd (PBPL) undertakes annual monitoring of seagrass meadows adjacent to Fisherman Island, and control locations at Manly and Cleveland. The seagrass monitoring program (SMP) commenced in 2002 and provides a semi-continuous record of seagrass meadow extent and condition over time. The SMP aims to provide port management with information on the condition and status of seagrass meadows, and to identify potential impacts of port operations on seagrass meadows.

Study Findings

The key findings of the 2018 SMP survey were as follows:

- The eelgrass *Zostera muelleri* formed dense meadows in the intertidal and shallow subtidal waters at all three locations. Intertidal meadows were comprised largely of dense mono-specific *Z. muelleri* meadows with occasional patches of the paddle grass *Halophila ovalis*. The paddle grasses *Halophila ovalis, H. spinulosa, H. decipiens* and/or the narrowleaf seagrass *Halodule uninervis* formed sparse mono-specific and mixed meadows in subtidal waters. This pattern in assemblage structure is consistent with previous surveys in the SMP, and is a typical pattern observed in Moreton Bay and other subtropical Queensland estuaries.
- *Zostera muelleri* meadows within the intertidal and shallow subtidal habitats of Fisherman Island have historically been the most stable seagrass meadows, while subtidal seagrass meadows show greater shift in community composition.
- The SMP and historical mapping shows that there has been a long-term trend of seagrass meadow expansion at Fisherman Island. The expansion in seagrass meadows at Fisherman Island is consistent with the findings of the Future Port Expansion Impact Assessment Study, which predicted that the reclamation would enhance seagrass local growing conditions.
- The long-term findings show there is year to year variability within seagrass meadows. There was a period of seagrass meadow expansion during the Millennium drought, and retractions between 2011 and 2013 following major flood events.
- Seagrass depth range (SDR) is a function of water quality and availability of suitable substrates. In 2018, Z. *muelleri* SDR was higher (i.e. in better condition) or equal than the average of control in all years surveyed. Consistent with previous surveys, *Zostera* SDR at Transect H had recovered to pre-2013 levels, however, levels were slightly lower than the 2017 survey. Likewise, *Zostera* SDR at Transect F was lower in 2018 than in 2017 and continue to be below pre-2013 levels.
- *Environmental Protection Policy (Water*) sets out water quality objectives (WQO) for the protection of environmental values. WQOs encompass physio-chemical and biological indicators, including *Zostera muelleri* SDR. The *Zostera muelleri* SDR WQO (Waterloo Bay) was used as a benchmark to assess seagrass condition. Fisherman Islands Transect H and Manly Transect J met the WQO in 2018, whereas all other transects did not meet the WQO.

- Filamentous algae were the most abundant algae group at all locations. Filamentous algae cover was highest cover at Fisherman Islands, possibly in response to nutrient enrichment by the Brisbane River.
- *Caulerpa taxifolia* was a dominant component of the benthic community throughout the study area during the 2000’s when El Niño (dry weather) conditions prevailed. However, the distribution and density of *C. taxifolia* declined post-2010, and in 2018 was only observed at <3% of all surveyed sites. *C. taxifolia* was only recorded at Manly and Fisherman Island.
- The SMP demonstrates that despite a long history of water quality degradation and habitat modification, seagrass meadows at Fisherman Island are in good condition and continue to represent a critical ecosystem component in western Moreton Bay.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

The Fisherman Islands area contains one of the largest seagrass meadows in western Moreton Bay (Dennison and Abal 1999). These seagrass meadows have high biodiversity and fisheries habitat values, and are also located within an internationally significant wetland (Moreton Bay Ramsar site) and Moreton Bay Marine Park (Figure 1-1).

The Port of Brisbane is located directly adjacent to the Fisherman Islands seagrass meadows. In recognition of the values of local seagrass meadows, the Port of Brisbane Pty Ltd (PBPL) undertakes routine monitoring of seagrass meadows adjacent to the port and more broadly at Manly and Cleveland. This Seagrass Monitoring Program (SMP) is intended to provide port management with information on the condition and status of seagrass meadows. It also is serves to identify whether there is any evidence that port operations are having an impact on these seagrass meadows so that management measures can be reviewed and adapted to further minimise impacts.

Seagrass distribution and extent has been identified as a useful bio-indicator of water quality degradation because it can “integrate changes in aquatic light climate caused by various factors, and because seagrasses themselves are important and highly-valued elements of marine and estuarine environments.” (ANZECC/ARMCANZ 2000, p A3-79). The maximum depth at which seagrass grows is thought to mainly be a function of the availability of certain wavelengths of light[1] (Abal and Dennison, 1996). A reduction in light availability below the requirements of a particular seagrass species can reduce seagrass energy production (through the process of photosynthesis), typically resulting in the death of that seagrass. A reduction in light availability and associated loss of seagrass can therefore be manifested as a reduction in the vertical, and associated horizontal, distribution of seagrass.

Different species of seagrass vary in terms of their long-term light requirements and tolerances to transient periods of light deprivation. Therefore, the distribution, abundance and composition of seagrasses at any time in a region may be a function of both the long-term trends in light availability and by their ability to survive or regenerate after pulsed or seasonal (i.e. regular) turbidity events (Moore et al. 1997). For this reason, seagrass community monitoring also provides a basis for assessing long term changes in water quality.

1.2 Aims and Objectives

The aims of the SMP are to describe:

- Current broad-scale patterns in seagrass extent and species distribution at the Port of Brisbane (Fisherman Islands), and at the Manly and Cleveland control locations;
- Spatial variations in seagrass extent and species distribution occurring at the three monitoring locations; and
- Temporal trends in seagrass extent and species distribution at the monitoring locations.

[1] This assumes that levels of physical disturbance by waves/currents is within the tolerance limits of the seagrass under consideration

The specific objectives of the SMP were to:

- Map the distribution and extent of seagrass meadows adjacent to Fisherman Islands;
- Characterise spatial and temporal patterns in the vertical (depth, accuracy measured in tens of centimetres) distribution of seagrass meadows at the Port and at control areas;
- Determine whether broad-scale spatial and/or temporal patterns in seagrass extent are consistent among the Port and control areas; and
- On the basis of the above, identify possible broad-scale operational impacts of PBPL activities on the distribution and extent of seagrass meadows.

1.3 Study Area

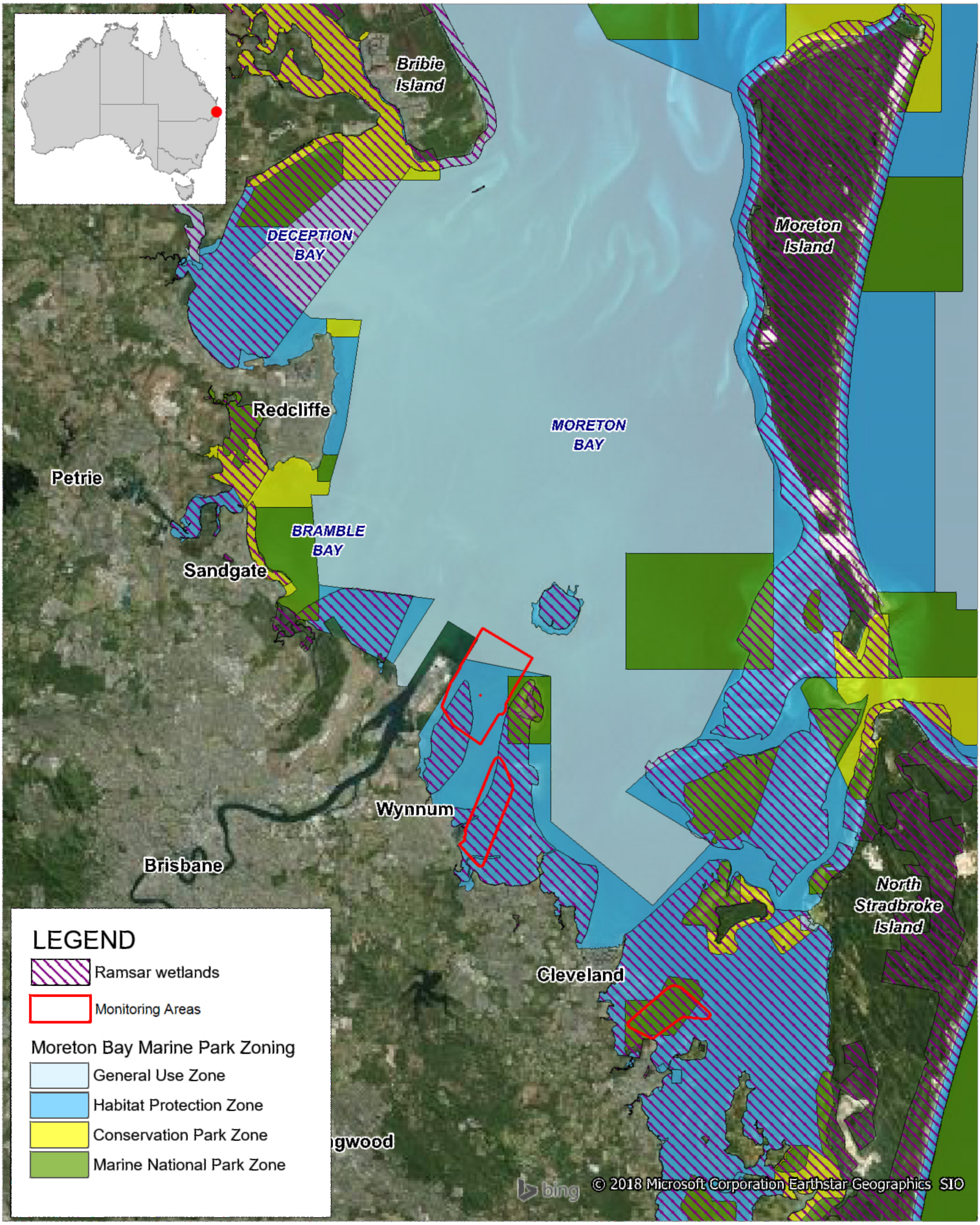
The Port of Brisbane is located at Fisherman Islands (the study area), which is situated at the mouth of the Brisbane River on the western foreshore of Moreton Bay, Queensland.

Port facilities located at the Brisbane River mouth have been established on land reclaimed over a shallow sub-tidal river delta containing a series of low lying mangrove islands, collectively called the Fisherman Islands. The area was reserved for harbour purposes in the 1940's. Reclamation commenced in the late 1960's and the decision was made to re-locate port facilities from the city reaches in the 1970's. The Port of Brisbane is now Queensland's largest container port facility and continues to expand by progressive filling within the existing perimeter bund.

Construction of the present day port facilities over intertidal and subtidal areas has resulted in extensive changes to the environmental attributes of the Fisherman Islands area. However, significant areas of mangrove, saltmarsh and seagrass have also been retained, and form part of the Fisherman Islands wetland complex on the south eastern side of the Port of Brisbane. Moreton Bay Marine Park is situated to the south and east of the FPE seawall, this area is thought to contain one of the largest semi-contiguous seagrass meadows in western Moreton Bay. A Ramsar listed wetland is situated only kilometres to the south of the Port facilities, comprising intertidal portions of the Fisherman Islands wetland complex (Figure 1-1). The seagrass and mudflats of this Ramsar area are recognised for their importance to dugong, marine turtles and migratory and resident shorebirds (BMT WBM 2008).

On the northern side of the Port of Brisbane, dredging occurs within the shipping channel through the Bar Cutting, the Swing Basin and berth areas, which are presently maintained to a declared depth of 14m (relative to Port Datum – Lowest Astronomical Tide, hereafter referred to as LAT). The Port facilities are situated at the mouth of the Brisbane River, which comprises the largest river catchment in Moreton Bay, and experiences freshwater flows and ongoing inputs of sediments and contaminants derived from human activities in its catchment. Two major sewage treatment plants also have their sewage discharges within kilometres of the Port facilities (Luggage Point and Wynnum North wastewater treatment plant).

Control sites for the study are located adjacent to Manly and Cleveland on the western foreshore of Moreton Bay and to the south of the Fisherman Islands monitoring location (see Figure 2-2). At Manly, seagrass meadows extend from the intertidal areas adjacent to the Manly Boat Harbour and Fig Tree Point to the subtidal area close to Green Island. At Cleveland the seagrass habitat extends throughout the bay which is formed between Toondah Harbour and Coochiemudlo Island. Growing conditions at Manly and Cleveland are similar to those experienced at the Fisherman Islands site and western Moreton Bay generally.



Title:
Moreton Bay Ramsar Wetlands and Marine Park Zoning

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2 Methodology

2.1 Timing

The field program for the 2018 seagrass monitoring events was undertaken from the 24th to 26th and on the 30th July 2018. Tidal data from the Tidal Unit, Maritime Safety Queensland was obtained for the Brisbane Bar through this study period (24th to 30th July 2018, inclusive) (Figure 2-1) and was used to correct depth soundings to Australian Height Datum (AHD).

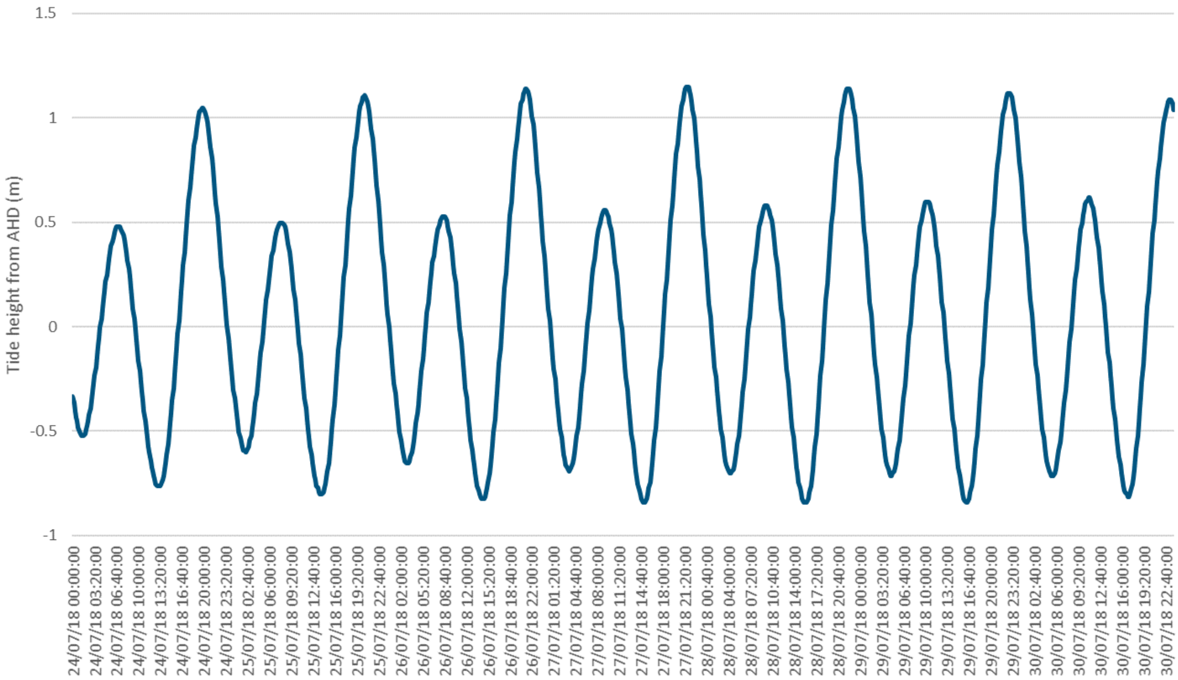

Figure 2-1 Tidal heights at Brisbane Bar during the 2018 survey

Figure 2-2 presents the rainfall data recorded at the Bureau of Meteorology station at Brisbane Airport (Station No.: 040842). In general, since 2008 the study area has experienced above average rainfall, with the exception being 2014, 2016 and 2017. The rainfall year to date was higher than the total annual rainfall in 2017 but was substantially lower than the average annual rainfall.

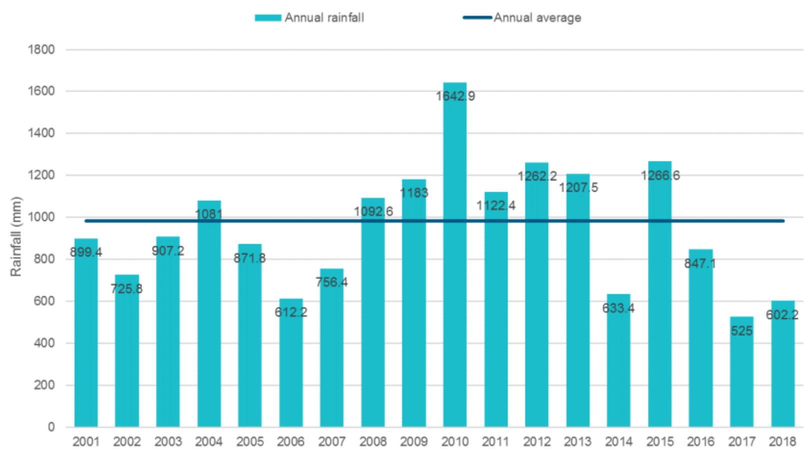

Figure 2-2 Annual Rainfall from 2001 to 2017 and rainfall year to date in 2018 at Brisbane Airport (Source: BoM Station - 040842)

2.2 Survey Vessel and Positioning

All sampling was carried out using BMT vessel '*Resolution II*'. Location and navigation to the sampling sites was undertaken using a real time differential Global Positioning System (dGPS) to provide position-fixing accuracy's of ±1m.

2.3 Monitoring Sites and Approach

Monitoring sites for this survey were modified from those previously used for the Port of Brisbane seagrass monitoring program which was developed in 2002 (WBM Oceanics Australia 2002). A pilot study for the previous monitoring program identified depth profiling and edge of meadow monitoring as the most suitable monitoring techniques. Sampling locations were at Fisherman Islands (putative impact or test), Manly (control) and Cleveland (control) and monitoring sites for edge of meadow, depth profiling and general mapping were established at these locations.

The methodology utilised for the current monitoring has been adapted from the previous techniques, as suggested in the previous monitoring report (BMT WBM 2017). Selection of the new methodology has been made with consideration of:

- Technological advances in monitoring tools, particularly remote sensing and remote monitoring techniques
- Consistency with previous monitoring methods to allow ongoing comparisons with the historic dataset.

The new methods utilise technological advances in remote sensing and remote monitoring techniques. Field based monitoring also serves to complement remote sensing data (from satellite and aerial imagery), acting to provide additional information on community composition and density throughout the respective study areas. A systematic grid style sampling approach has been adopted with a monitoring grid developed at each study area. The adopted grids have been built on a grid interval of 500 m. These two study components will allow mapping of the extent and composition of both intertidal and subtidal seagrass meadows in the study areas.

In order to retain consistency with previous monitoring, seagrass depth profile transects have been retained and will be completed alongside the systematic grid style sampling, as per previous monitoring campaigns.

2.3.1 Ground-truthing

Mapping information generated from remote sensing data were ground-truthed using a systematic grid style sampling approach. 500 m survey grids were developed at each study area and are shown in Figure 2-3 (Fisherman Islands/Port of Brisbane), Figure 2-4 (Manly) and Figure 2-5 (Cleveland).

At each point in the survey grids the following parameters were recorded: time, water depth (using the survey vessel's sounder), position (dGPS), seagrass species present and macroalgae community composition (a video image was recorded at each point). The depth at each point was reduced to Australian Height Datum to enable comparisons between locations.

In addition, single beam bathymetry was also collected throughout the field campaign and used to develop a DEM specific to each of the study areas. This data was reduced to Australian Height Datum based on tidal predictions and tidal planes from the Australian Hydrographic Service.

Ground truthing data were then used along with remote sensing data to develop mapping of the extent and composition of seagrass meadows at Fisherman Islands (Figure 3-4).

2.3.2 Seagrass Depth Profiles

Seagrass depth profiles are used to monitor any variations in seagrass depth distribution and extent of seagrass species at each of the study locations. Depth profiles were originally monitored on a six-monthly basis throughout the FPE project but were unable to be completed in 2004 due to adverse weather conditions. Subsequent sampling has occurred in 2005, 2006, 2010, 2013, 2014, 2016, 2017 and 2018.

Two depth profile transects occur at each survey location and run approximately perpendicular to the shoreline (Figure 3-3 to Figure 3-5). At each point along the profile transect, the following parameters were recorded: time, water depth (using the survey vessel's sounder), position (dGPS), seagrass species present and macroalgae community composition (a video image was recorded at each point). The depth at each point was reduced to Australian Height Datum to enable comparisons between locations.

The alignments of the two Manly depth profiles were adjusted in May 2003 to ensure each profile extended beyond the outer edge of the seagrass meadows. These alignments end near Green Island, which acts as a natural barrier to seagrass distribution.

2.4 Data Analysis

2.4.1 Seagrass community types

Seagrass community types were determined according to species composition within a meadow. A standard nomenclature system, based on Carter and Resheed 2016 was to assign the community types to each of the sampling sites (Table 2-2). Community types correspond with percent composition that each seagrass contributes to the meadow.

Table 2-1 Nomenclature for seagrass community classes

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 C	Species A is <40%

2.4.2 Seagrass density

Consistent with previous monitoring, seagrass species at each survey site was assigned to density categories according to overall seagrass percent cover, as described in Figure 3-1 to Figure 3-3.

In addition, simple groupings of overall seagrass cover were used to provide context to the broad community categories described in section 2.4.1 above (Table 2-2).

Table 2-2 Broad seagrass density categories

Density category	overall % cover
light	0-10%
moderate	10-50%
dense	>50%

2.4.3 Algae

Algae cover was divided into two categories based on functional groupings:

- Filamentous algae including epiphytic and turfing algae
- Other macroalgae (non-filamentous).

Title:

Survey Points Used to Map the Distribution of Seagrass at Fisherman Islands, Adjacent to the Port of Brisbane

Figure: 2-3

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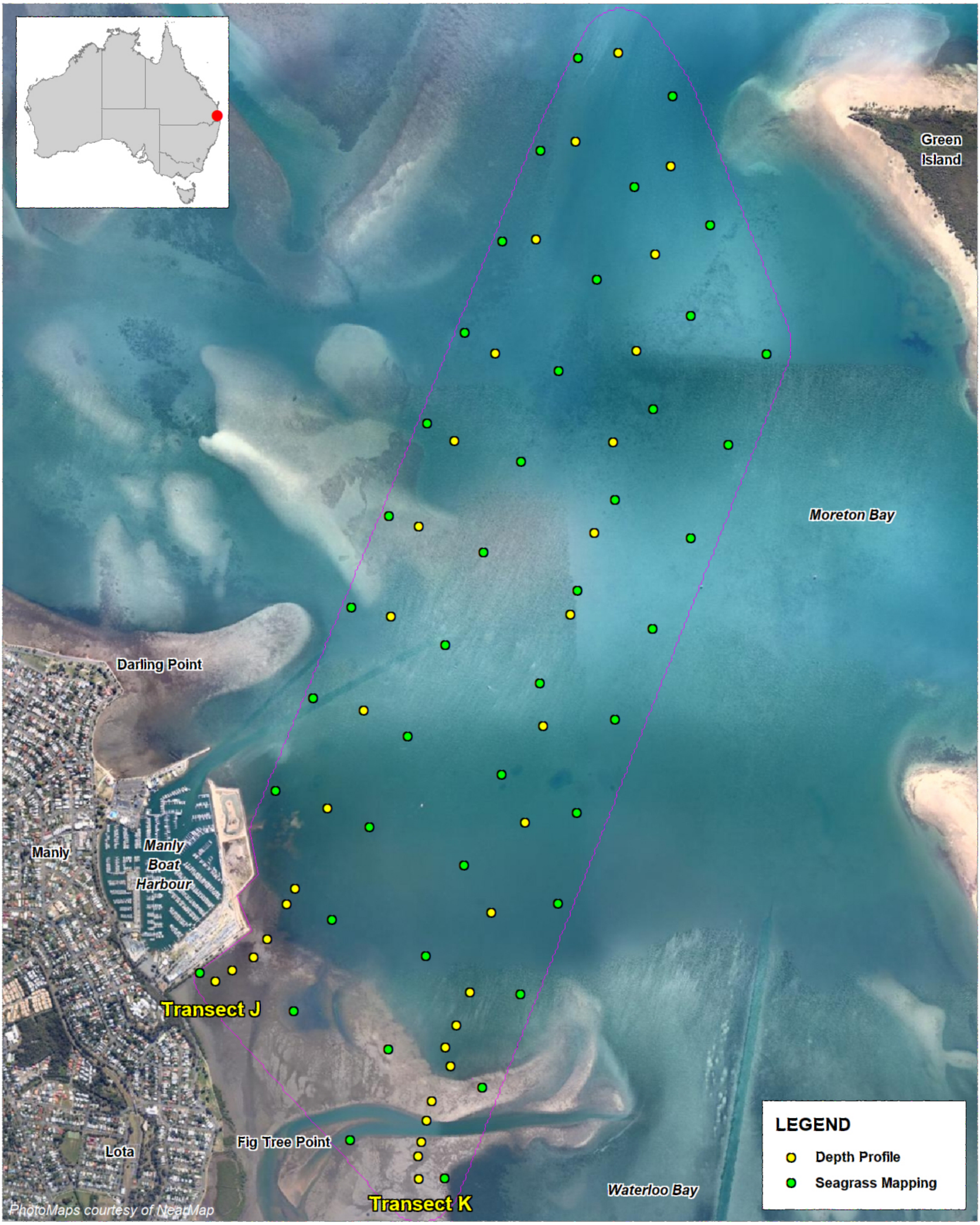

Title:
Survey Points Used to Map the Distribution of Seagrass Adjacent to Manly

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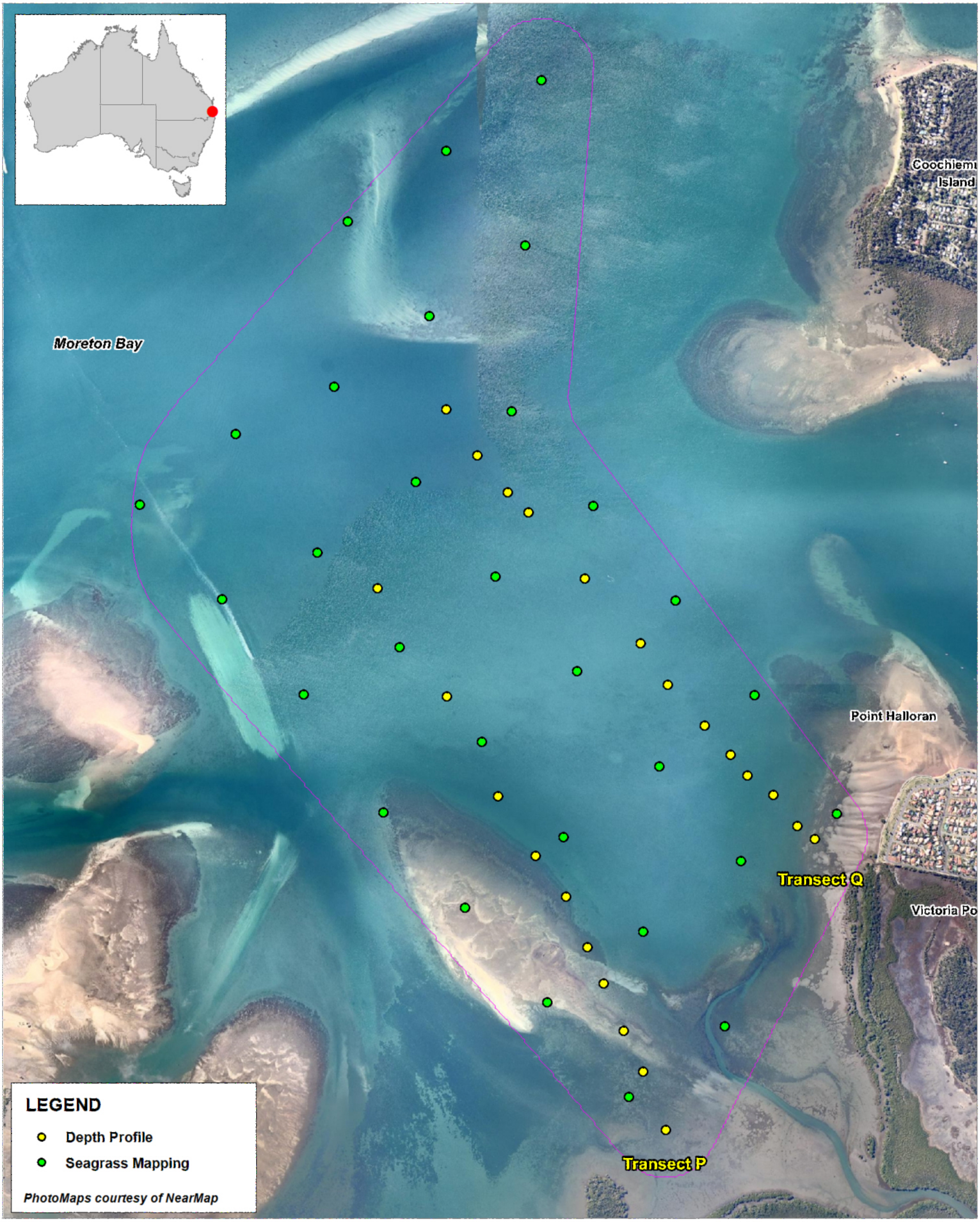

Title:

Survey Points Used to Map the Distribution of Seagrass Adjacent to Cleveland

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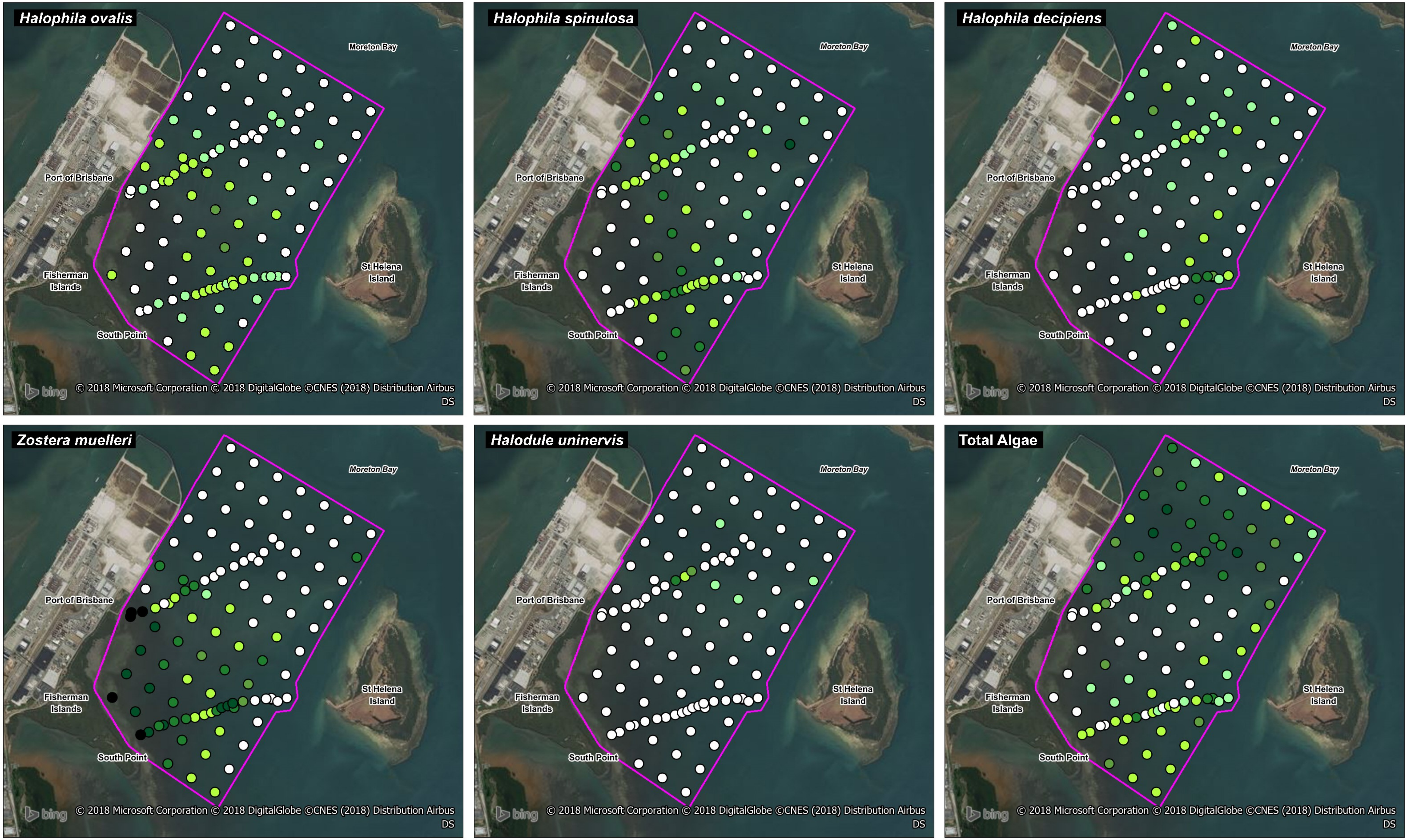
3 Results

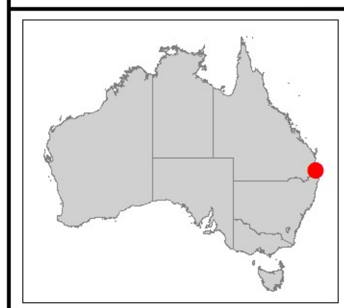
3.1 Seagrass Species and their Distribution in 2018

Five of the eight seagrass species know to occur within Moreton Bay were recorded in the 2018 survey: *Zostera muelleri (*subsp*. capricorni), Halodule uninervis, Halophila ovalis, Halophila spinulosa,* and *Halophila decipiens.* Notably, *H. uninervis* was only detected at Fisherman Islands during the 2018 survey.

Maps showing the spatial distribution of each seagrass species recorded during the current survey are shown in Figure 3-1 to Figure 3-3. Seagrass community types at Fisherman Islands derived from survey data, interpretation of sentinel satellite data and high-resolution aerial photography (Nearmap) is presented in Figure 3-4. General findings from the current survey are broadly consistent with previous monitoring event in 2017 and show that:

- Seagrass was present at 86% of the Fisherman Islands sites (n = 108); 91% of the Manly sites (*n* = 75) and 80% of the Cleveland sites (*n* = 59). In comparison with the 2017 survey, seagrass was present at 71%, 82% and 62% of sites sampled from Fisherman Island, Manly and Cleveland respectively.
- In general, seagrass beds were continuous in their habitat structure and there was no substantial difference in the level of bare ground observed between the survey locations.
- *Zostera muelleri* and *H. spinulosa* were the most frequently recorded species at all site across at Fisherman Island, observed in 49% and 46% of the sites, respectively. *H. ovalis* and *H. decipiens* were equally distributed, with both observed at 35% of the sites sampled. The most frequently recorded species at Manly and Cleveland were *H. decipiens* (54% and 51%) and *H. spinulosa* (39% and 27%).
- *Halodule uninervis* was present at Fisherman Islands and distribution was limited to the subtidal areas, observed at seven of the sites sampled. The distribution at Fisherman Islands was more limited this year than in 2017. *H. uninervis* was not recorded at Manly or Cleveland.
- *Zostera muelleri* dominated meadows were more extensive within the intertidal zone (i.e. above LAT) at the landward edge at each location and often extended slightly seaward into the shallow subtidal zone. Intertidal beds were comprised largely of dense mono-specific stands of *Z. muelleri* with occasional patches of *H. ovalis*. Mixed meadow community types were more common within the deeper subtidal water, comprising mainly of *Z. muelleri, H. ovalis* and *H. spinulosa*. Isolated communities dominated by *H. ovalis* and *H. decipiens* occurred in the more exposed areas with predominately sandy substrate.
- The distribution of *H. decipiens* had increased at Fisherman Islands and Cleveland compared to the previous survey, however, the greatest densities remained within the deeper subtidal zone.
- The distribution of *H. ovalis*, *H. decipiens* and *H. spinulosa* were similar to the 2017 survey at Fisherman Islands and Manly. *Halophila* dominated seagrass communities were generally restricted to subtidal areas.
- Macroalgae was widely distributed at all sites and coverage was similar to the 2017 survey.





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- 1 to 5
- 5 to 15
- 15 to 25
- 25 to 50
- 50 to 75
- \> 75

Study Area

Title:

Species Distributions at Fisherman Islands, adjacent to the Port of Brisbane in 2018

Figure: **3-1**

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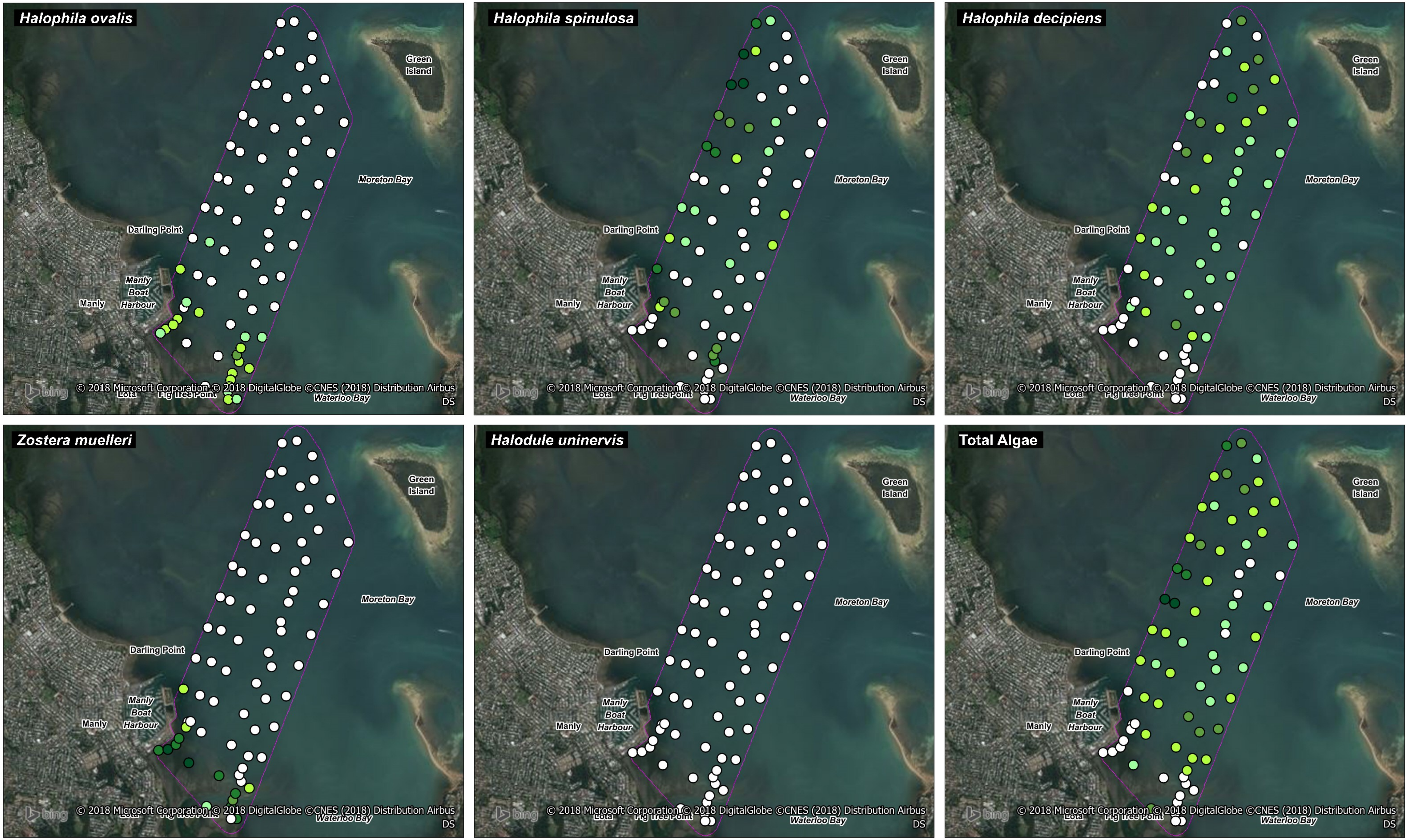

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- 50 to 75
- > 75

Study Area

PhotoMaps courtesy of NearMap

Title:
Species Distributions at Manly, Waterloo Bay in 2018

Figure: 3-2

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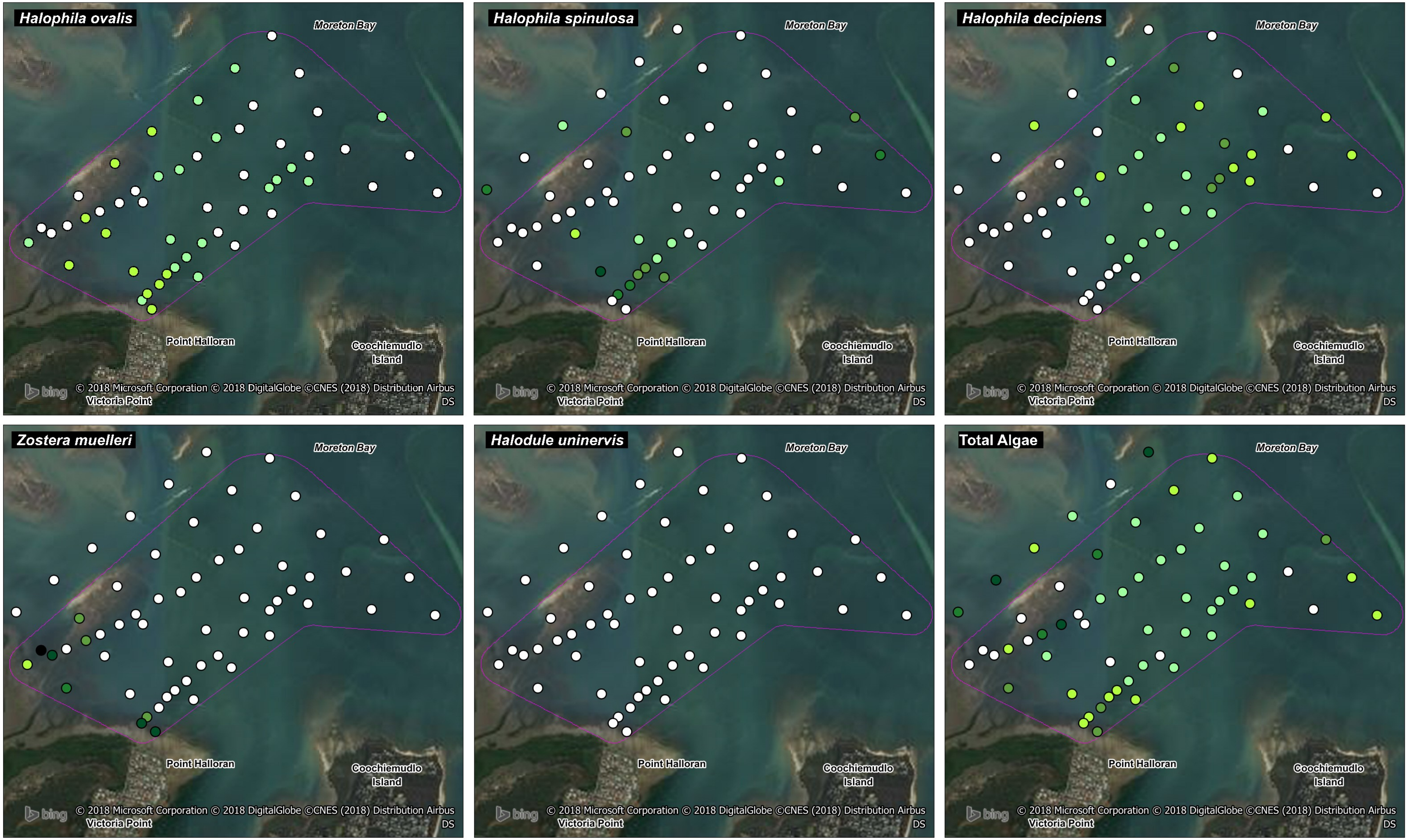

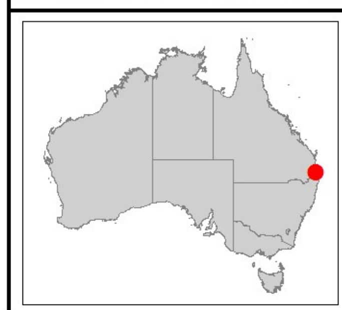

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- 15 to 25
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- > 75

Study Area

PhotoMaps courtesy of NearMap

Title:

Species Distributions at Cleveland, Moreton Bay in 2018

Figure: **3-3**

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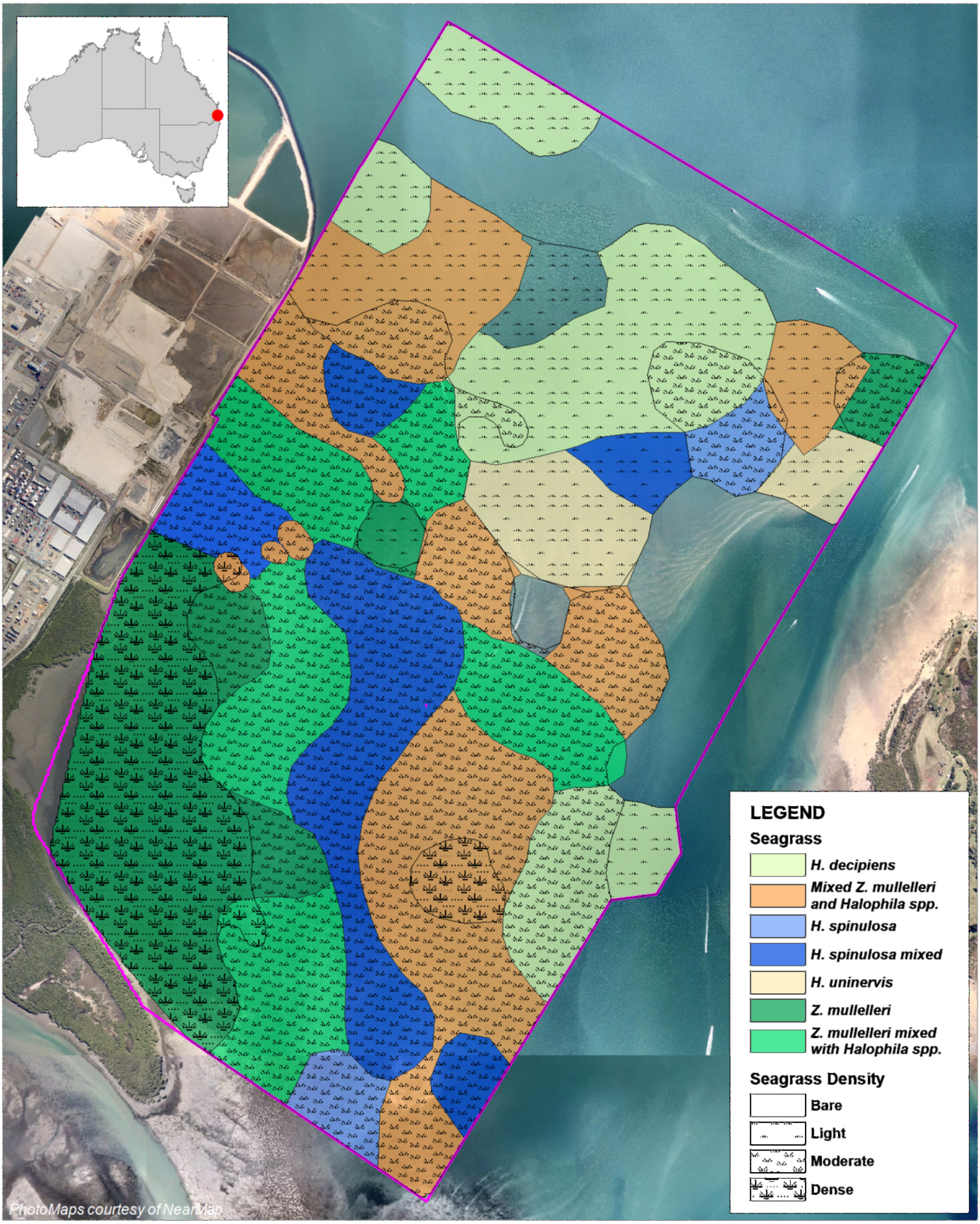

Title:

Seagrass Distribution and Community structure Adjacent to Fisherman Island, 2018

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3.2 Seagrass Depth Range (SDR) and Assemblages Structure

Table 3-1 presents the maximum recorded depths of seagrass species (seagrass depth range – SDR) on depth transects in the period 2006 to present, along with a rating based on the SDR for each period relative to the historical maximum recorded SDR. The mean and coefficient of variation (CoV) is also displayed. Note that as *Halophila ovalis* and *H. decipiens* were grouped together prior to 2013, the SDR rating for these species is based on the maximum value recorded SDR for either of these species.

Conceptual diagrams showing changes in seagrass meadow assemblages and extent along each transect are provided in Appendix D. The percentage cover of seagrass species at each location (i.e. grid and depth transect sites) against depth categories are shown in Appendix E.

3.2.1 Spatial Patterns in 2018

Key patterns in seagrass composition and distribution along depth transects are as follows:

- *Zostera muelleri* was observed at all locations, with maximum depths at Fisherman Island, Cleveland and Manly of -2.2 m, -1.7 m and -2.1 m (AHD), respectively. At all locations, average cover was highest within intertidal meadows (above LAT) than subtidal meadows (below LAT). Within individual depth categories, average cover at depths below <0.5 m AHD were higher at Fisherman Islands (~60%) than the control locations (~30% and 33% at Manly and Cleveland respectively). In contrast, the average cover between -0.5 m and -1.0 m AHD was greater at the control locations than Fisherman Island. *Z. muelleri* was not detected below -2.5 m AHD at any locations. *Zostera muelleri* grew mainly in mono-specific meadows but below the LAT level formed mixed meadow communities with *Halophila spinulosa* and *Halophila ovalis.*
- *Halodule uninervis* was found to occur within the shallow subtidal zones (i.e. near LAT) at Fisherman Island. *H. uninervis* occurred at water depths of -1.56 m to -1.95 m AHD at Fisherman islands, occurring in sparse patches with on average <20% in mixed meadow beds. This finding was consistent with the 2017 survey. *H. uninervis* was not observed at Manly or Cleveland.
- *Halophila spinulosa* was recorded in low densities (<10% coverage) at all locations, with maximum recorded depth of -3.9 m, -4.3 m and 2.6 m AHD at Fisherman Islands, Manly and Cleveland. Seagrass density varied considerably between the transects and depths at Fisherman Islands and Manly. In general, no constant patterns over the depth range was observed, with cover ranging from sparse to moderate at some depths and absents at other depths along the same transect. The exception being Transect Q at Cleveland where a gradual decline in seagrass cover was observed along the depth gradient.
- *Halophila ovalis* was present in both intertidal (above LAT) and subtidal (below LAT) areas, forming mixed meadow beds with *Z. muelleri* and *H. spinulosa.* Transects showed *H. ovalis* occurred across similar depth range, occurring between -0.1 m to -2.2 m AHD, 0.2 m to -2.3 m AHD and -0.3 m and -1.6 m at Fisherman Island, Cleveland and Manly, respectively. *Halophila ovalis* had sparse cover, ranging from 5-15% at all locations at water depths below -3 m LAT, and was not present at depths greater -3 m LAT.

- *Halophila decipiens* was observed at all locations and the maximum depth range was -7.2 m, -7.7 m and -5.6 m AHD at Fisherman Island, Manly and Cleveland respectively. *H. decipiens* generally occurred within deeper subtidal areas (i.e. water depth >2 m AHD) however was found in intertidal zone at a depth of -0.92 m AHD (Fisherman Islands Transect H). The coverage was typically sparse to moderate and mostly formed either mono-specific meadows or mixed meadows with *H. spinulosa* in subtidal zone (below LAT).

3.2.1.1 Temporal Patterns

Table 3-1 shows SDR values for each species over time on permanent transects. A condition rating has been provided with reference to the maximum SDR values recorded historically for each species on each transect.

The *Zostera muelleri* SDR, a key indicator of long-term patterns in water quality, showed complex spatial and temporal patterns. The current survey indicates that *Z. muelleri* SDR was higher (i.e. in better condition) or equal than the average of control in all years surveyed (Figure 3-5). Consistent with previous surveys, *Z. muelleri* SDR at Transect H has recovered to pre-2013 levels, however, levels were slightly lower than the 2017 survey. Likewise, *Zostera* SDR levels at Transect F were lower in the current survey and levels continue to be below pre-2013 levels.

The coefficient of variation (CoV) was calculated to assess the degree of temporal variability in seagrass SDR within transects (Table 3-1). Consistent with the 2017, the CoV for SDR was generally higher at Manly (17-86%) compared to the other locations. Fisherman Islands and Cleveland reported similar CoV's of <41%. This indicates that SDR was typically more stable at Fisherman Islands and Cleveland than at Manly.

3.2.1.2 SDR Water Quality Objective

The *Z. muelleri* SDR water quality objective (WQO) for Waterloo Bay (Figure 3-5) was used as a benchmark[2] to assess seagrass condition. Compliance with the WQO varied over time and at a variety of spatial scales. Transects that met the WQO were (Table 3-1):

- Fisherman Islands Transect H (2010, 2014, 2016, 2017 and 2018) and F (2006 and 2010)
- Manly Transect J (2006, 2010, 2016 and 2018) and K (2006, 2010, 2014, 2016, 2017).

Note, none of the Cleveland transects met the WQO.

[2] the WQO was derived based on the median value using reference site data. While the WQO applies only to High Ecological Value waters in the State Protection Policy, it has been adopted here as a general benchmark of seagrass condition

Table 3-1 Comparison of SDRs (Maximum Recorded Depth in Meters relative to AHD) of Seagrass Species on Permanent Transects at each Location from 2006 to 2018

Location	Transect	Species*	2006	2010	2013	2014	2016	2017	2018	Mean	CoV
Cleveland	P	Ho	-5.9	-6.4	-6.2	-4.8	-3.6	-3.3	-2.1 (↓)	-4.6	-36
		Hd			-5.1	-6.4	Absent	Absent	-4.4 (↑)	-5.6	-15
		Hs	Absent	-3.4	-3.5	-4.8	Absent	-0.9	Absent (↓)	-3.2	-52
		Zm	-1.3	-0.8	-0.6	-0.7	-0.7	-0.9	-1.7 (↑)	-1.0	-42
	Q	Ho	-5.7	-6.2	-5.7	-2.7	-2.5	-5	-2.4 (↓)	-4.3	-40
		Hd			-4.6	-4.6	-5.9	Absent	-5.6 (↑)	-5.4	-12
		Hs	-3.2	Absent	-3.7	-4	-2.9	-3.3	-2.6 (↓)	-3.3	-15
		Zm	-0.6	-1.5	-1.8	-1.4	-1	-1.4	-1.2 (↓)	-1.3	-30
Manly	J	Ho	-2.2	-4.9	-4.5	-2	-2.1	-2.9	-2.1 (↓)	-3.0	-42
		Hd			-4.5	-4.4	-3.5	-4.8	-4.5 (↓)	-4.1	-23
		Hs	-2.6	-4	-3.4	-3.4	-4.1	-3.4	-4.5 (↑)	-3.6	-17
		Zm	-2.2	-2.3	-1.6	-1.5	-2.1	-1.6	-2.1 (↑)	-1.9	-17
	K	Ho	-0.4	-8.8	-5	-2.1	-2.2	-2.4	-1.8 (↓)	-3.2	-86
		Hd			-5	-3.7	-4	-5.3	-7.7 (↑)	-5.0	-55
		Hs	Absent	-4.4	-4	-3.9	-2.2	-2.3	-3.9 (↑)	-3.5	-27
		Zm	-2.1	-2.2	-0.4	-2.1	-2.2	-2	-0.7 (↓)	-1.7	-47
Fisherman Islands	F	Ho	-3.8	-5.7	-2.2	-2	-1.8	-4.7	-1.6 (↓)	-3.1	-52
		Hd			Absent	-4	-4.1	-4.3	-4.1 (↓)	-4.3	-16
		Hs	-3.8	-4.3	-2.2	-1.6	-1.8	-3.8	-2.0 (↓)	-2.8	-41
		Zm	-2	-2.5	-1.8	-1.7	-1.6	-1.7	-1.4 (↓)	-1.8	-19
		Hu	Absent	Absent	Absent	Absent	Absent	Absent	-2.0 (↑)	N/A	N/A
	H	Ho	-2.6	-4.6	-2.5	-2.4	-2.4	-5.5	-2.2 (↓)	-3.2	-41
		Hd			-2.9	-5.1	-5	Absent	-7.2 (↑)	-5.1	-35
		Hs	-2.5	-2.3	-2.5	-2.4	-3	-2.5	-3.9 (↑)	-2.7	-20
		Zm	-1.3	-2.3	-1.5	-2.4	-2.4	-2.5	-2.2 (↓)	-2.1	-23
12-month Rainfall (mm)[1]			850.6	870.6	1158.6	582	731.2	642.8	955.6		

SDR relative to historical maximum:

Max	99-80% max	79-50% max	49-20% max	<20% max	Not applicable

Trend since 2016: ↑ improvement, ↔ stable (within 0.1 m of 2017), ↓ decline

* Ho *Halophila ovalis*, Hd *Halophila decipiens*, Hs *Halophila spinulosa*, Zm *Zostera muelleri*. Note video transects in 2006-10 did not provide sufficiently detailed imagery to discern *H. ovalis* and *H. decipiens*, and were therefore grouped together

Red text – SDR does not achieve the SDR WQO for HEV waters in Waterloo Bay of -1.9m AHD (generic benchmark for the purpose of this study)

1 – Rainfall data sourced from BoM station 040913 (Brisbane)

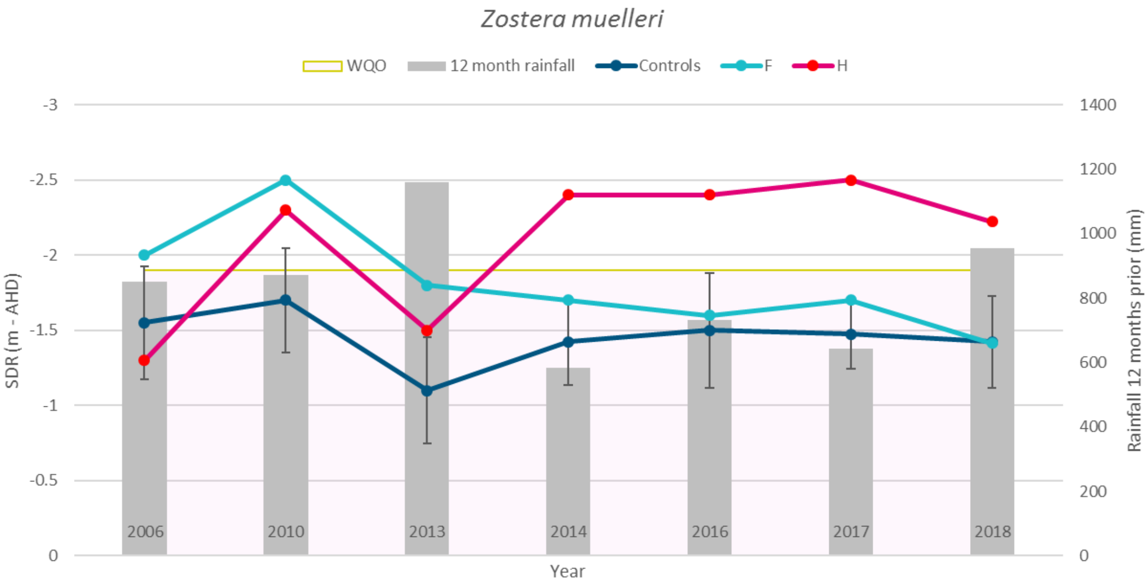


Figure 3-5 ***Zostera muelleri*** **seagrass depth range for Transect F and H at Fisherman Islands and the average (±SE) for control sites. Rainfall in the 12 months leading to the survey is also shown (BoM station number 040913 – Brisbane)**

4 Discussion

4.1 Overview

Based on the findings of the SMP to provide a conceptual framework and drawing on the international literature, we have derived five general principles about the ecology of seagrass meadows at Fisherman Islands and western Moreton Bay. These are:

(1) Meadows are numerically dominated by a core set of widely distributed tropical and tropical-temperate species. Tropical vagrants occur from time to time but are uncommon.

(2) All species have adaptations that allow rapid recovery following disturbance.

(3) *Zostera muelleri* is restricted to shallow waters (<2 m below LAT), forming dense meadows that are comparatively stable over time.

(4) Sparse *Halophila* species and *Halodule uninervis* meadows extend to depths down to -7 m below LAT and show great variability in assemblage structure among years.

(5) Seagrass meadows show cyclic changes in extent in response to flood-drought cycles. There has been a long-term expansion in overall seagrass meadow extent at Fisherman Islands, with 2018 representing the maximum recorded extent to date (Figure 4-1).

These are described in the following section.

4.2 Species Composition

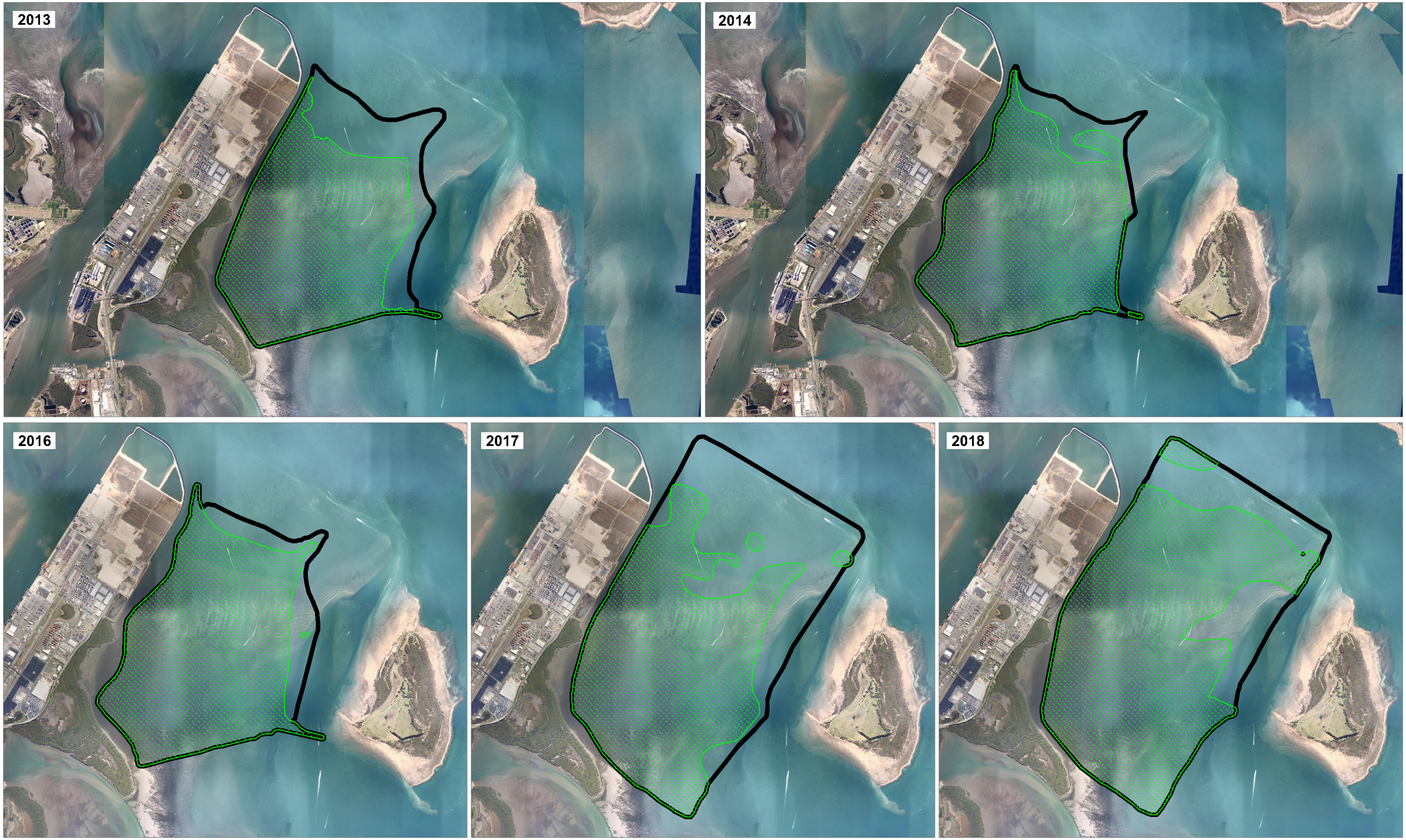
Eight seagrass species have been reported within broader Moreton Bay (Young and Kirkman 1975; Hyland *et al*. 1989, Davie, 2011): *Zostera muelleri (subsp. capricorni), Halophila ovalis, Halophila decipiens, Halophila spinulosa, Halodule uninervis, Cymodocea serrulata, Syringodium isoetifolium* and *Halophila minor.*

Cymodocea serrulata, Syringodium isoetifolium and *Halophila minor* have not been recorded in the Port of Brisbane SMP. Moreton Bay is the southern-most distribution limit of *S. isoetifolium*, *H. uninervis*, *H. spinulosa C. serrulate* and *H. minor* (Kirkman, 1997). *Halophila minor* has only been recently discovered in Broadwater, Gold Coast in 2006 by GHD and is considered uncommon, possibly having a similar disjunct geographical distribution as *C. serrulata* and *S. isoetifolium* (Davie and Phillips 2008). *Halophila minor* is a pioneering species and if present would have likely formed mono-specific communities following the Brisbane River floods in 2013. No additional species compared to previous studies were recorded in the 2018 study.

4.3 Spatial and Temporal Patterns in Assemblages

4.3.1 *Halophila* and *Halodule*

In 2018, an overall expansion in *Halophila decipiens* was observed at all locations (i.e. Fisherman Islands, Manly and Cleveland) and no substantial changes in other *Halophila* species were observed compared to 2017. Consistent with previous surveys, *Halodule uninervis* was only observed at Fisherman Islands and a substantial decline in distribution was observed.



LEGEND

Study Area

Seagrass Meadow Extent

Aerial Photography by nearmap

Title:

Seagrass Meadow Extent between 2013-18

Figure: **4-1**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Halophila species are among the least tolerant species of seagrass to reductions in light availability, with declines occurring during sustained wind events and sediment re-suspension, events which are common in western Moreton Bay. These species are also primary colonisers that can rapidly colonise deep water areas during extended periods of clear water, or high light availability (Longstaff *et al.* 1999). The results of the 2018 survey suggest that overall growing conditions for *Halophila* species were generally favourable over most (but not all) of the study area in the period leading up to the survey.

There was also a high degree of small-scale heterogeneity in the distribution of different *Halophila* species (i.e. differences among transects within locations). Several processes can interact to control small-scale heterogeneity in seagrass meadows, most notably biological interactions including competition for space with other seagrass species and macroalgae, and grazing (by dugongs and green turtles). Differences in TSS concentrations (and light availability) can also occur among transects, varying in response to proximity to channels and sand banks.

Overall, seagrass meadow extent expanded by approximately two square kilometres at Fisherman Islands between 2017 and 2018 surveys.

4.3.2 Zostera

Zostera mulleri predominantly occurred and was most dense in the intertidal and shallow subtidal waters (<2.5 m below AHD) of the study area. *Zostera muelleri* has a high light requirement compared to other seagrass species found within the study area (e.g. Abal and Dennison, 1996; Collier and Waycott 2009). This limits *Z. muelleri* to intertidal and shallow subtidal habitats where it is a dominated species.

SDR was found to vary among the locations, ranging from -1.2 m to -1.7 m at Cleveland, -0.7 m to -2.1 m at Manly, and -1.4 m to -2.2 m below AHD at Fisherman Island. There was greater variability in SDR of *Z. muelleri* at Manly during 2018 compared to 2017. No substantial changes were observed at Fisherman Islands and Cleveland. Differences in SDR among locations are likely to reflect:

- Differences in the availability of suitable (and stable) habitat - Physical habitat conditions, including hydrodynamic processes and substrate stability, are key controls on seagrass meadows. Fisherman Islands has broad intertidal and subtidal sand and mud banks, within the preferred depth zone of *Z. muelleri*. By contrast, Manly and Cleveland have short and steep intertidal/shallow subtidal shore profiles and coarse sediments, and therefore less potential *Zostera* habitat. A consequence of this has been that the depth distributions among locations may reflect changes in sediment quality and other factors (e.g. exposure to wave re-suspension/ boat wash and channels) as well as being driven by the availability of light in deeper waters.
- Differences in water quality conditions among (and possibly within) locations. The three sampling locations are influenced to different degrees by river flows and wave-generated sediment resuspension.

There were great spatial and temporal differences in *Z. muelleri* SDR between transects at Fisherman Islands. Transect F, located in the northern sector Fisherman Islands has shown a decrease in *Z. muelleri* SDR levels since 2010 but has remained relatively stable since. Transect F is located on a sand shoal that represents the remnant mouth of the Brisbane River, which is exposed to prevailing north-easterly wind waves and tidal currents (BMT WBM 2015) and is therefore a physically dynamic environment that has not always contained well developed *Zostera* meadows. By contrast, the southern Fisherman Islands transect (Transect H) is located in a more sheltered environment (BMT WBM 2015), providing more suitable (and physically stable) habitat conditions for *Zostera* growth.

Notwithstanding this, *Z. muelleri* meadow extent and SDR was more stable in 2018 within transects at Fisherman Islands (CoV 19-23%) than Cleveland (CoV 30-42%) and Manly (CoV = 17-47%). This suggests that the seagrass meadows at the Cleveland control location is more prone to disturbance than at Fisherman Islands and Manly.

4.3.3 Filamentous Algae and other Macroalgae

Macroalgae has remained a dominant element of the benthic vegetation communities at Fisherman Islands, Manly and Cleveland throughout the survey period. Like seagrass, different macroalgae species show great variation in distribution and cover over time and space.

Filamentous algae, including epiphytic algae attached to seagrass, was typically the most abundant functional algae group at all three locations. The highest cover of filamentous algae was recorded at Fisherman Islands (median ~17%), whereas median cover at Manly and Cleveland was relatively similar (median ~10%). Filamentous algae can proliferate under nutrient enriched conditions, leading to reductions in available light and loss of seagrass (Han and Liu 2014). Fisherman Islands is located directly adjacent to several major nutrient sources (i.e. Luggage Point WWTW, Wynnum WWTW and catchment inflows from the Brisbane River), which likely to promote filamentous algae productivity at this location.

There were great variations in algae assemblages among and within locations. Cleveland had the most abundant macroalgae assemblages, with highest cover recorded in shallow waters (<1 m). The shallow waters of Cleveland provide not only suitable light climate for macroalgae, together with hard substrate habitat for reef associated species such as *Sargassum*, *Hydroclathrus clathratus* and *Laurencia majuscula.* The shallow waters of Fisherman Islands also had shell and rubble fragments that provided suitable substrate for small reef-associated macroalgae species, but hard substrate habitat and macroalgae cover was lower than at Cleveland. Manly does not support significant hard substrate habitat, and subsequently macroalgae low cover was lower.

The most notable temporal change observed over time has been cyclic changes in the green alga *Caulerpa taxifolia.* *Caulerpa taxifolia* was a dominant component of the benthic community throughout the study area during the 2000’s when *El Niño* conditions prevailed, and sewage discharges were of a poorer quality than present day. The distribution and density of *C. taxifolia* declined across the study area post-2010 and since 2016 has only be recorded at <5% of all surveyed sites. During the 2018 survey, *C. taxifolia* only recorded at Manly and Cleveland. Burfeind (2012) reported that the Brisbane River flood in 2011 led to a significant decline of *C. taxifolia* within Moreton Bay, in agreement with the temporal patterns found in the present study.

4.4 Existing Seagrass Condition

Seagrass meadow condition was assessed with reference to:

- SDR water quality objective (WQO) for Waterloo Bay (State Protection Policy – HEV waters for Waterloo Bay)
- Local 'reference' value; in this instance, the maximum recorded SDR for each species on individual transects.

Based on the SDR (WQO) of -1.9 m AHD, Cleveland achieved zero percent compliance, Manly achieved 64% compliance, and Fisherman Islands achieved 50% compliance during the period between 2006 to 2018 (Table 3-1). This suggests that habitat quality at Cleveland is not optimal for *Z. muelleri*. At Fisherman Islands, the WQO had not been met since 2010 at Transect F, and was met in 2010 and 2014- 2018 on Transect H. As discussed earlier, it is likely that hydrodynamic processes at Transect F are not especially favourable for *Z. muelleri* growth. The SDR for most species declined in 2018 on Transect F at Fisherman Islands and remained below the historical maximum SDR (Table 3-1).

These results indicate that despite the expansion of deep water meadows at Fisherman Islands between 2017 and 2018, seagrass meadows in the wider study area remain under stress. The extensive cover of filamentous algae on seagrass (see Section 4.3.3) suggest that water quality is likely to be a key stressor.

4.5 Impacts of the FPE Seawall

The results of the SMP again indicate an overall long-term trend of a net expansion in seagrass meadow extent at Fisherman Islands since the FPE seawall construction (see BMT WBM 2016 for details). Consistent with the predictions of the FPE IAS (WBM 2000), the results of the Port of Brisbane SMP suggest that port expansion activities (both the FPE and previous reclamations at Fisherman Islands) have led to localised alterations to hydrodynamic processes that favour the development of seagrass meadows. Key controlling processes are expected to include:

- Enhanced protection from northerly waves. The FPE seawall provides more protection from prevailing wind generated waves from the northerly direction.
- Deposition of fine sediment. The extension of the FPE seawall appears to be enhancing the deposition of fine sediments within the embayment north and east of Fisherman Islands (BMT WBM 2010; 2015; 2016; 2017). The effects of fine sediment deposition on the ambient light climate and nutrients availability, and flow on effects to seagrass, remains unresolved.
- Separation from the Brisbane River. The seawall extension has effectively moved the mouth of the Brisbane River further from the Fisherman Islands seagrass meadows, possibly enhancing water clarity and reducing the impacts of low salinity flood waters.

5 Conclusions

The key findings of the 2018 survey are:

- Seagrass assemblage structure remains consistent with previous surveys, with dense Z. *muelleri* meadows occurring within the intertidal and shallow subtidal habitat, and *Halophila* species and *Halodule uninervis* forming mixed meadows in deeper subtidal habitats.
- Overall meadow extent at all locations increased by approximately two square kilometres between the 2017 and 2018 surveys. This followed a period of significant seagrass meadow expansion in 2010 and seagrass declines in 2011 and 2013, which were coincident with flooding events. Since this time there has been ongoing recovery at most transects over time.
- Trends in SDR for individual species between 2017 and 2018 showed inconsistent patterns among sites.
- *Zostera muelleri* SDR WQO for Waterloo Bay was used as a benchmark to assess seagrass condition. Fisherman Islands Transect H and Manly Transect J met the WQO in 2018, whereas all other transects did not meet the WQO.
- Macroalgae were numerically sub-dominant to seagrass throughout the study area, except in deep waters (>3 m) where filamentous algae were more abundant. These patterns suggest that at least some filamentous algae have lower light requirements than seagrass.
- Filamentous algae were typically the most abundant functional algae group at all three locations and had the highest cover at Fisherman Islands. The higher filamentous algae load at Fisherman Islands is possibly a response to nutrient enrichment from catchment (i.e. Brisbane River) and point sources (WWTW discharges).
- *Caulerpa taxifolia* was a dominant component of the benthic community throughout the study area during the 2000's when *El Niño* conditions prevailed. However, the distribution and density of *C. taxifolia* declined across the study area post-2010, and since 2016 only recorded at <5% of all surveyed sites. During the current survey, *C. taxifolia* was present at Manly and Cleveland and distribution was limited the shallow subtidal habitats. *C. taxifolia* was not observed at Fisherman Island.
- The results of the Port of Brisbane SMP to date do not suggest that Port activities have resulted in seagrass meadows loss at Fisherman Islands. Rather, the overall long-term trend to date has been a net expansion in seagrass meadow extent at Fisherman Islands. This trend is consistent with the predictions of the FPE IAS (WBM 2000) that port expansion activities (both the FPE and previous reclamations at Fisherman Islands) have led to localised alterations to hydrodynamic processes that favour the development of seagrass meadows.

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Appendix A Photo Plates

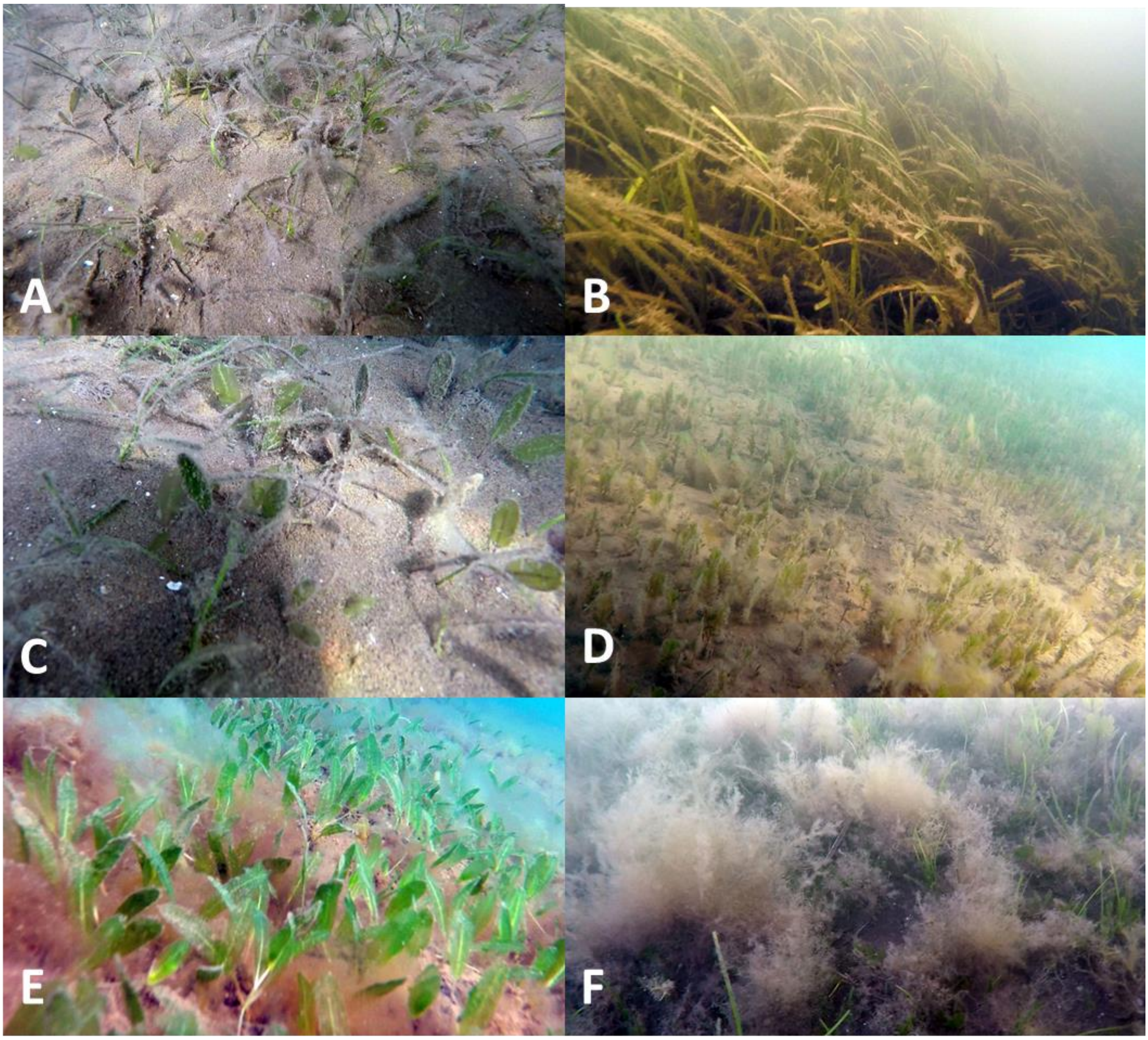


Figure A-1 Seagrass species: *Halodule uninervis and H. ovalis* (A), dense *Zostera muelleri* (B), *H. ovalis* (C), *Halophila spinulosa* and filamentous algae, (D) *Halophila decipiens* and filamentous algae (E) *H. uninervis* and filamentous algae

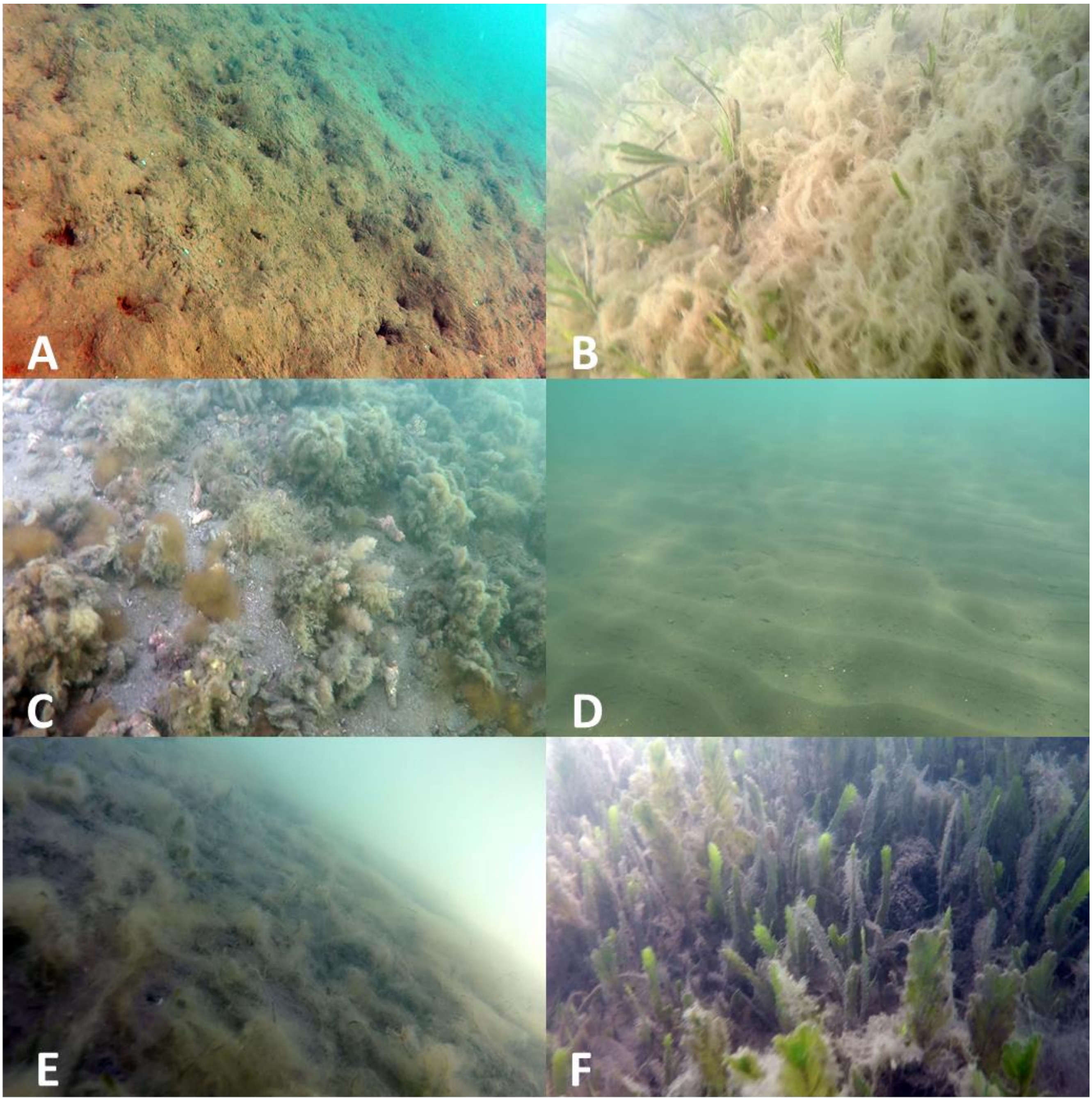
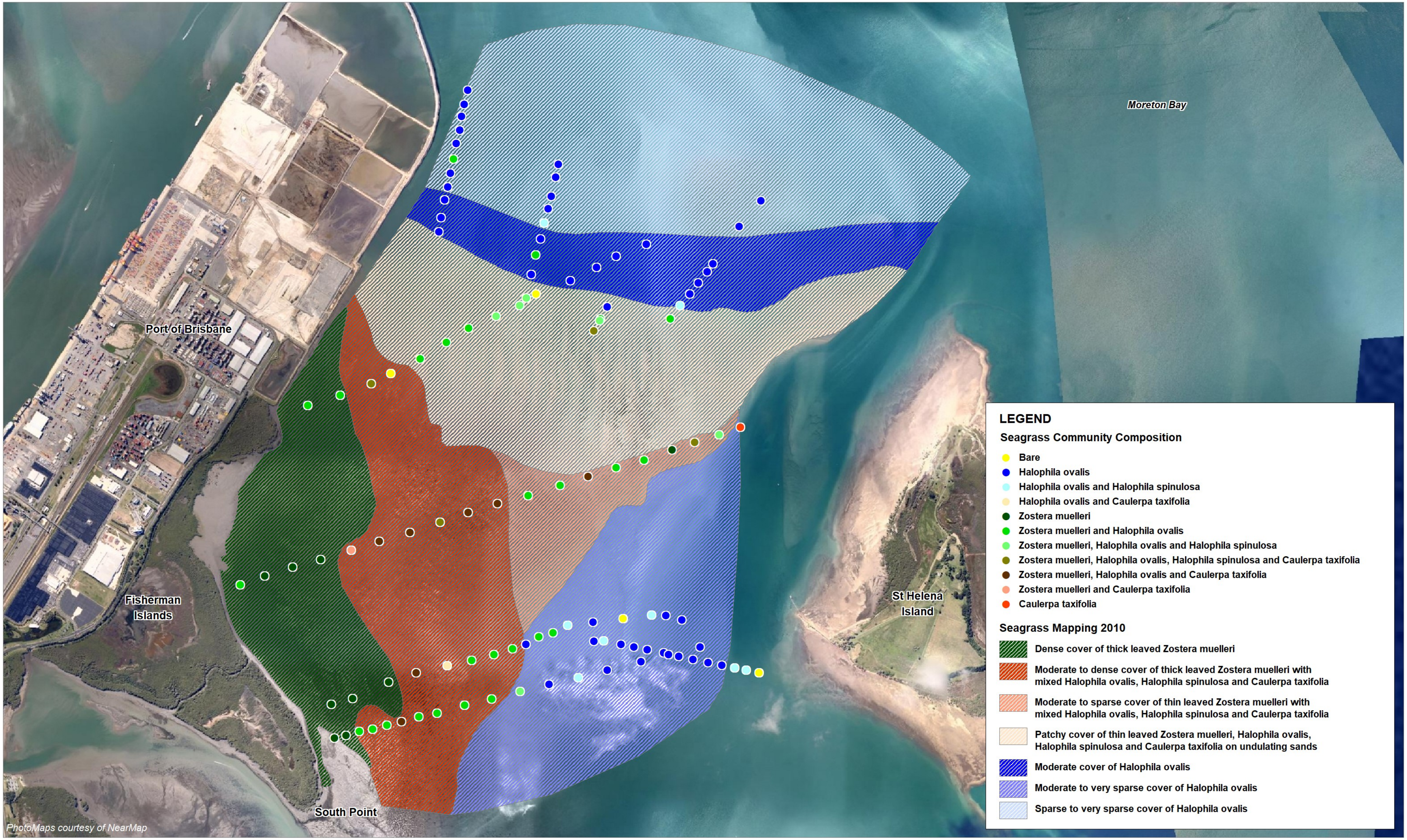


Figure A-2 Bare muddy substrate, Fisherman Island (A), *Zostera muelleri* with c-f *Hydroclathrus, clathratus,* (B) high cover of mixed macro-algae at Cleveland (C), bare sand bar Fisherman Island (D), *Zostera muelleri* with filamentous algae, Cleveland (E) and *H. spinulosa* with *Caulerpa taxifolia*, Cleveland (F).

Appendix B Broad Scale Pattern in Seagrass Species Distribution at the Port of Brisbane 2010, 2013, 2014, 2016 and 2017



Title:

Broadscale Patterns in Seagrass Distribution and Community Structure Adjacent to Port of Brisbane

Figure: B-1

Rev: A

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Approx. Scale

BMT

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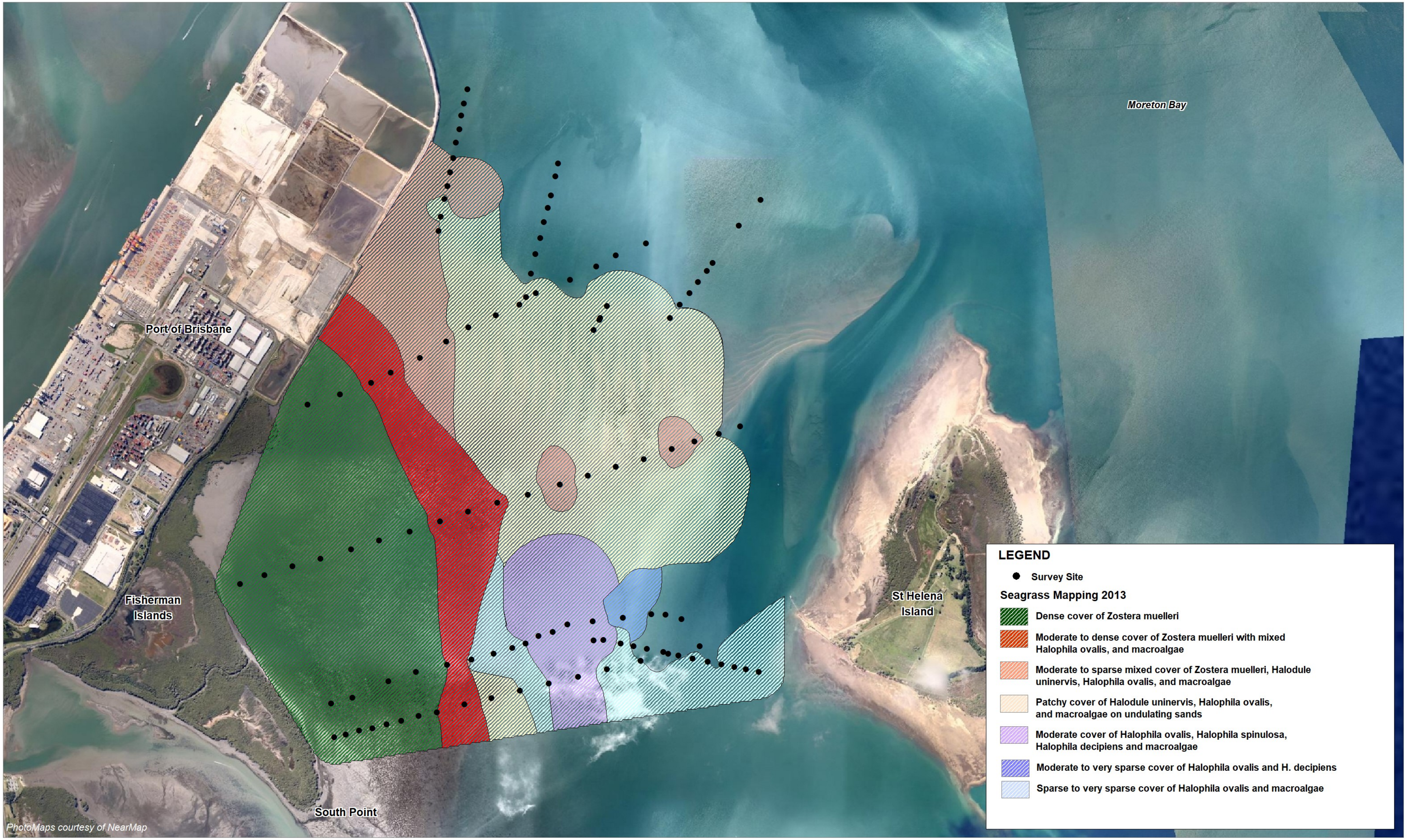

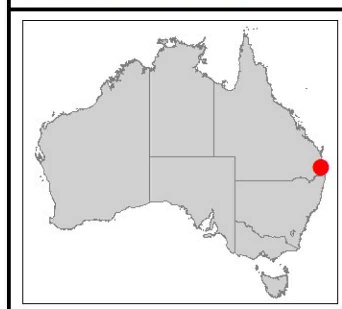

Title:

Seagrass Distribution and Community Structure Adjacent to Port of Brisbane

Figure: **B-2**

Rev: **A**

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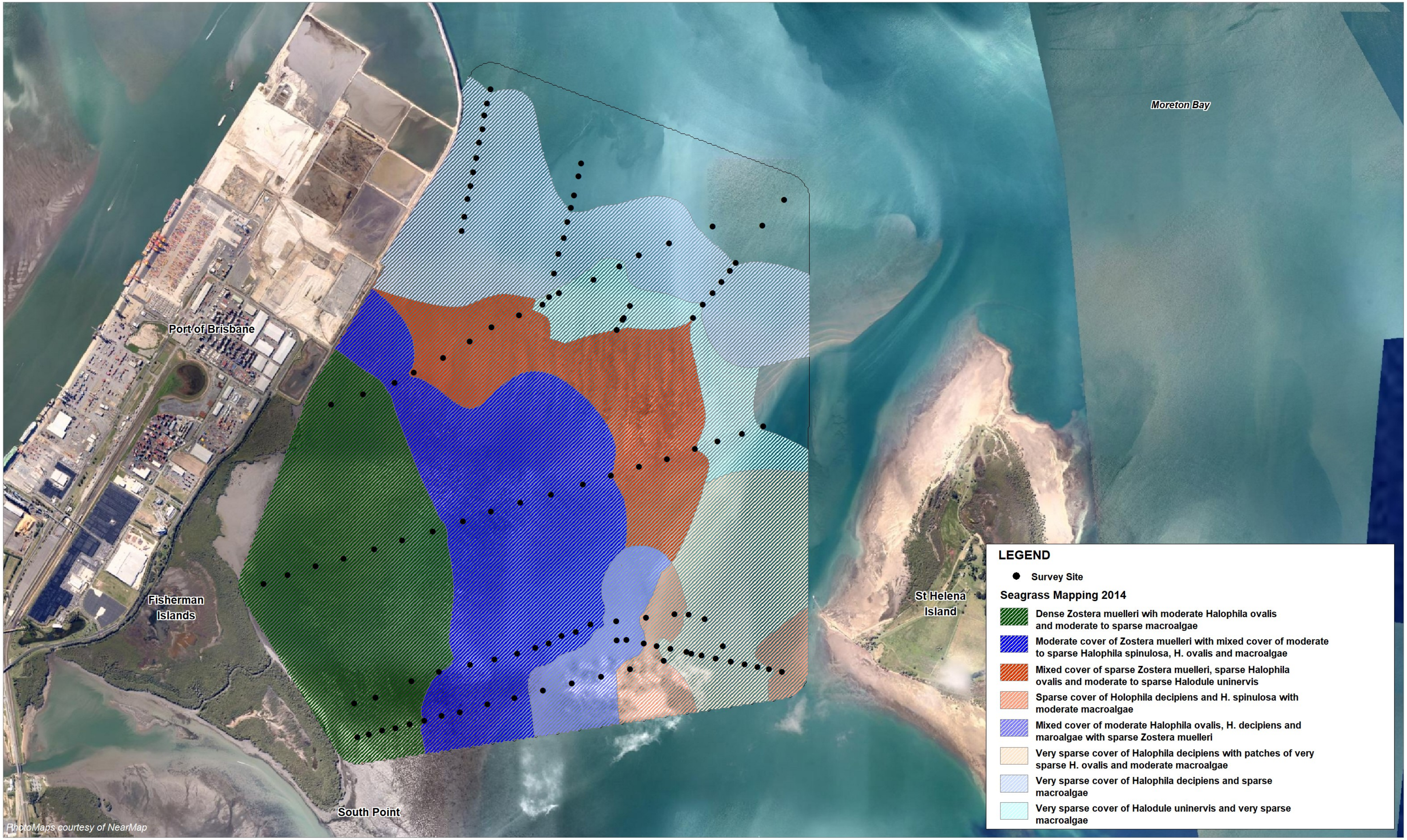

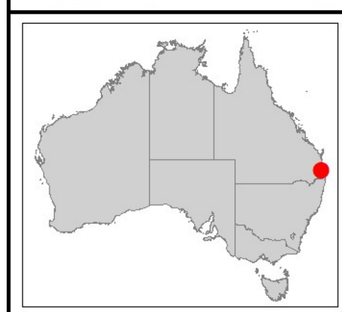

Title:

Seagrass Distribution and Community Structure Adjacent to Port of Brisbane in 2014

Figure: **B-3**

Rev: **A**

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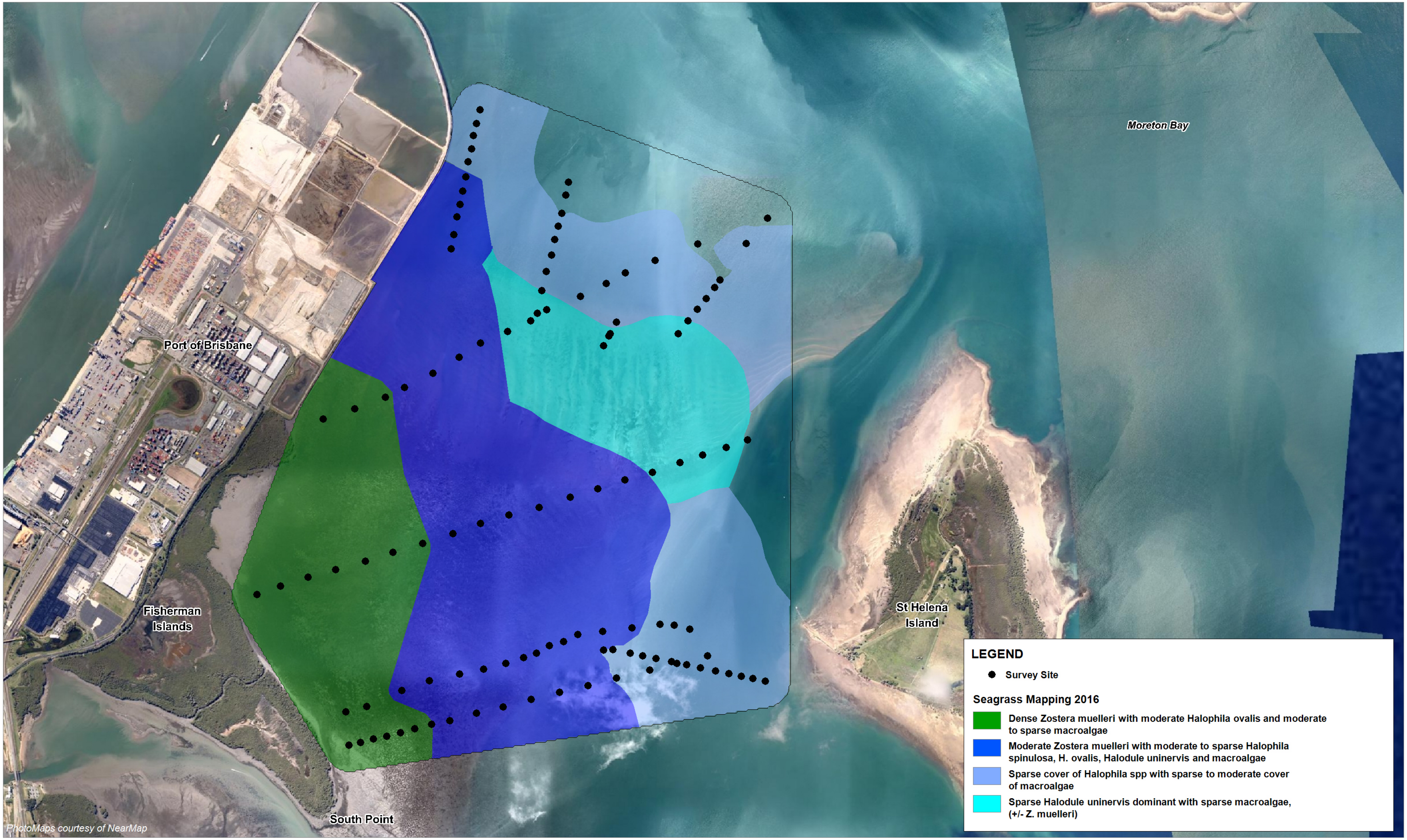

Title:

Seagrass Distribution and Community Structure Adjacent to Port of Brisbane in 2016

Figure: **B-4**

Rev: **B**

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Approx. Scale

BMT

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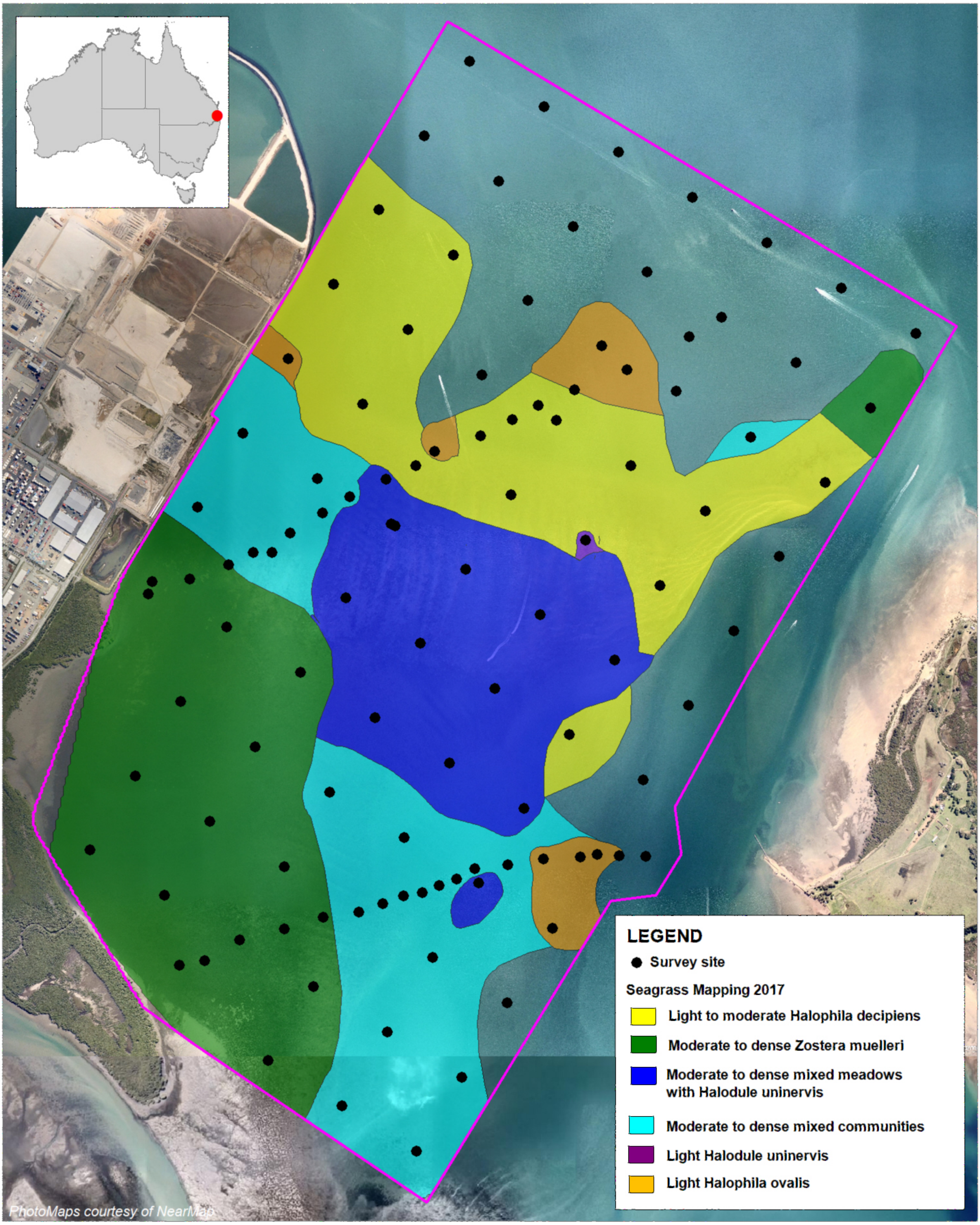

Title:

Seagrass Distribution and Community Structure Adjacent to Fisherman Islands 2017

Figure: **B-5**

Rev: **A**

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Appendix C Seagrass Videos

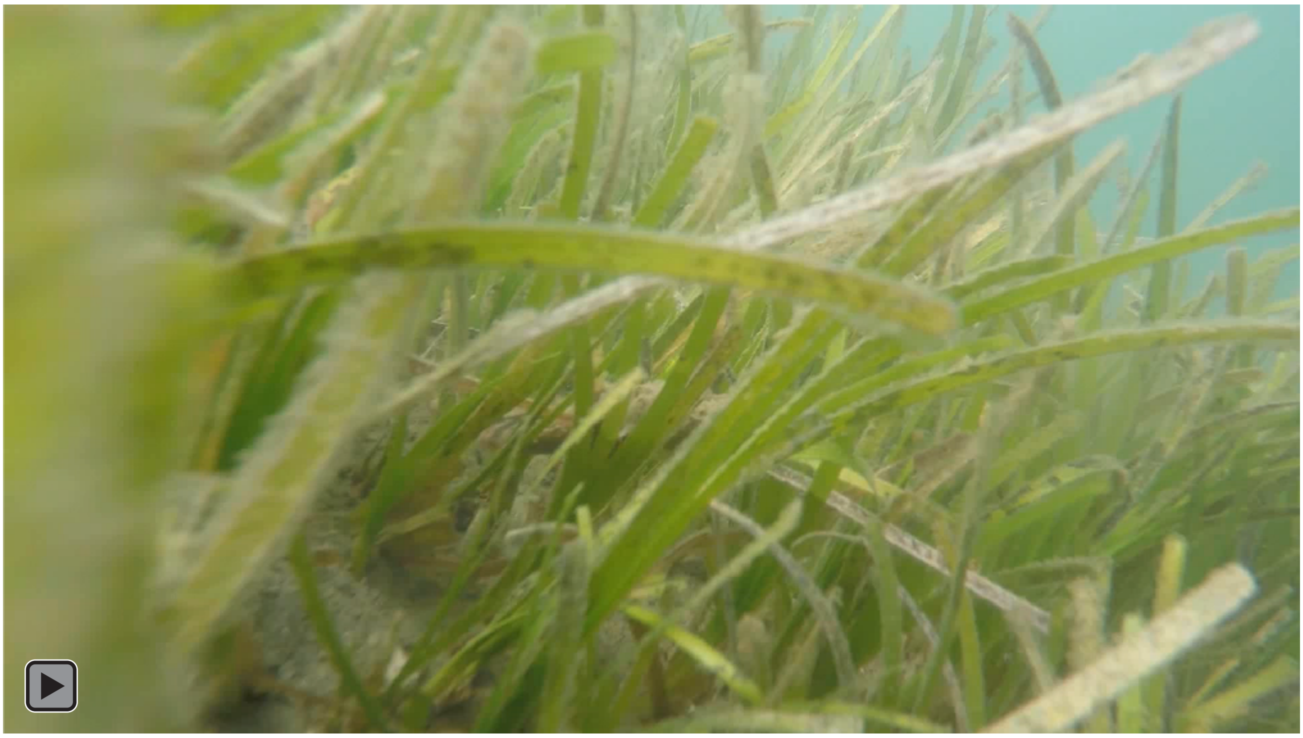

Figure C-1 Dense *Zostera muelleri* meadows at Fisherman Islands

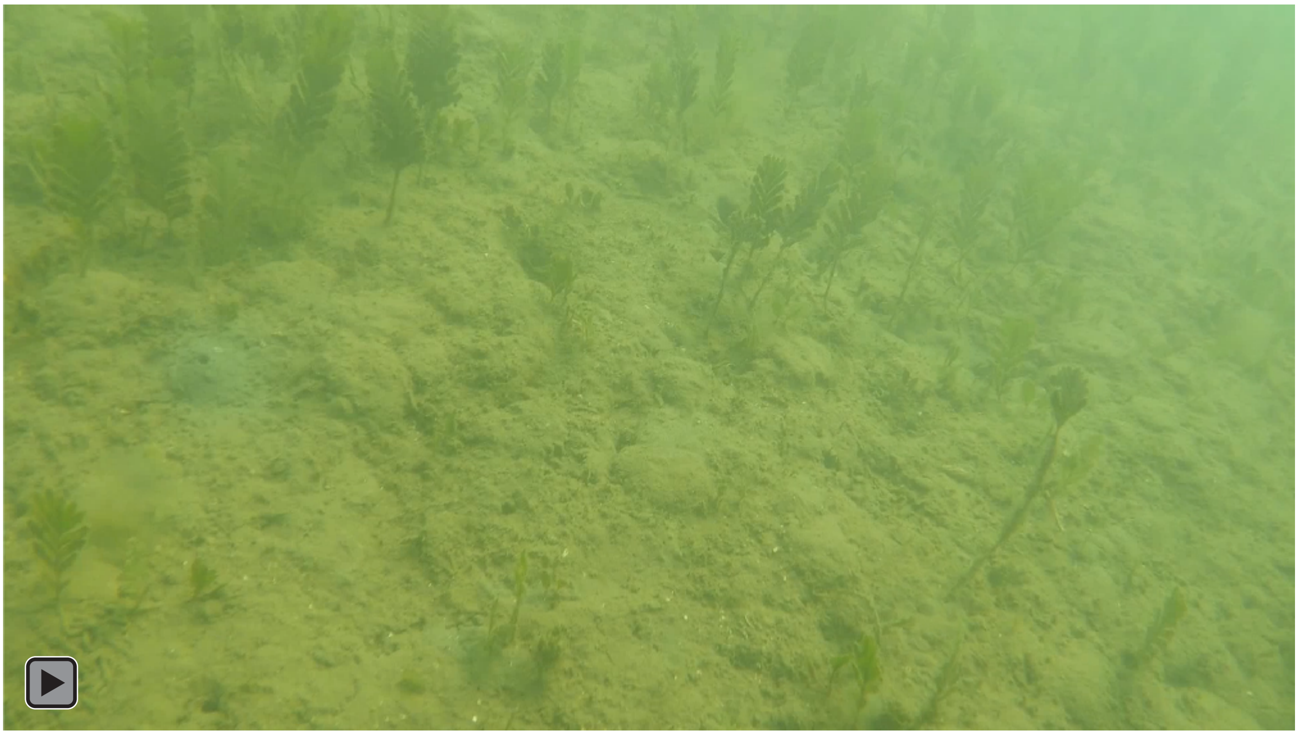

Figure C-2 Mixed meadow of *Halophila spinulosa* and *Halophila ovalis* at Fisherman Islands

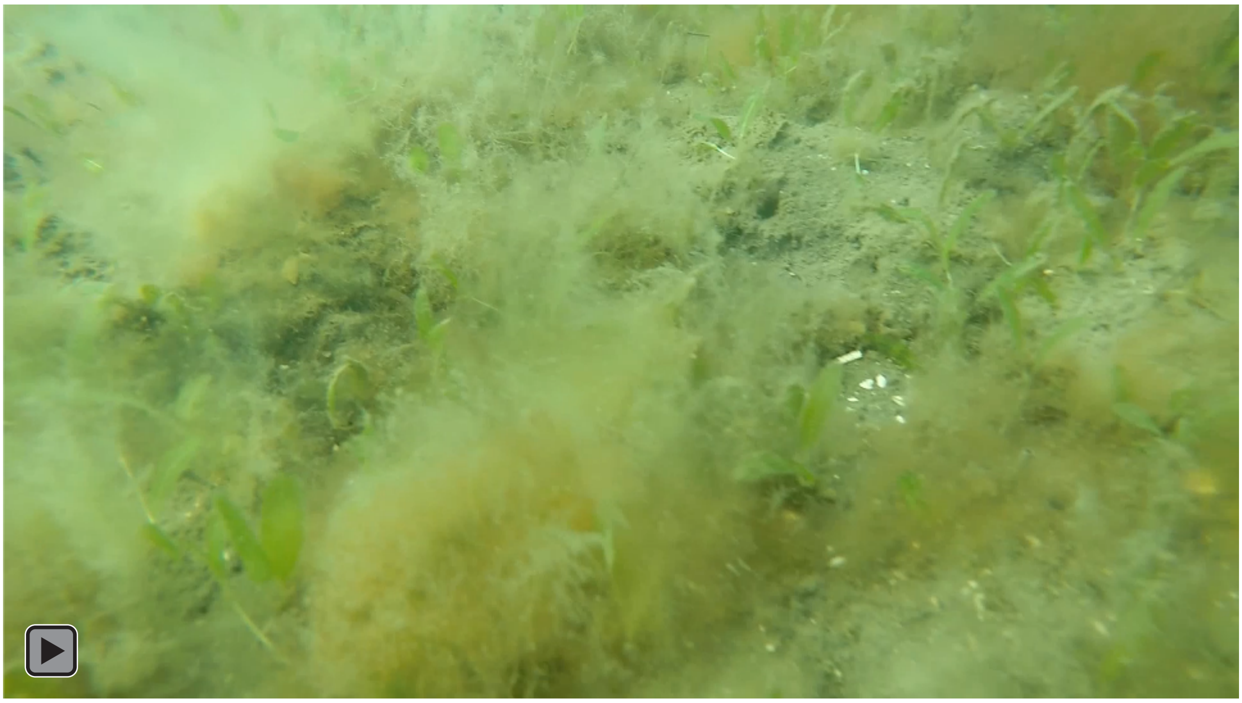

Figure C-3 Sparse to moderate Halophila decipiens meadows with dense filamentous algae

Appendix D Conceptual Seagrass Illustrations

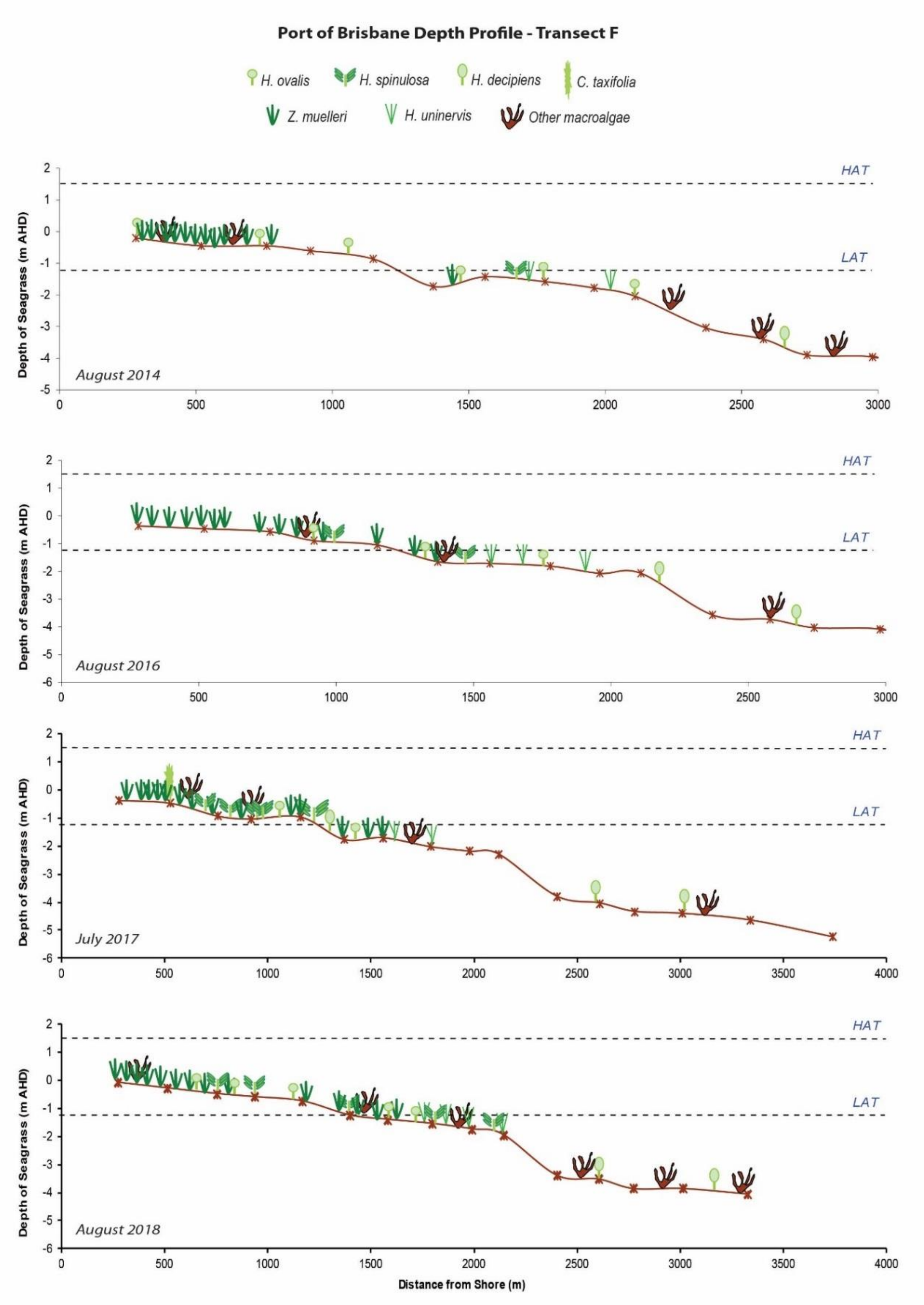

Figure D-1 Schematic Representation of Seagrass Species Distribution From 2013 to 2014 and 2016 to 2018 at Depth Profiling Transect F, Fisherman Island

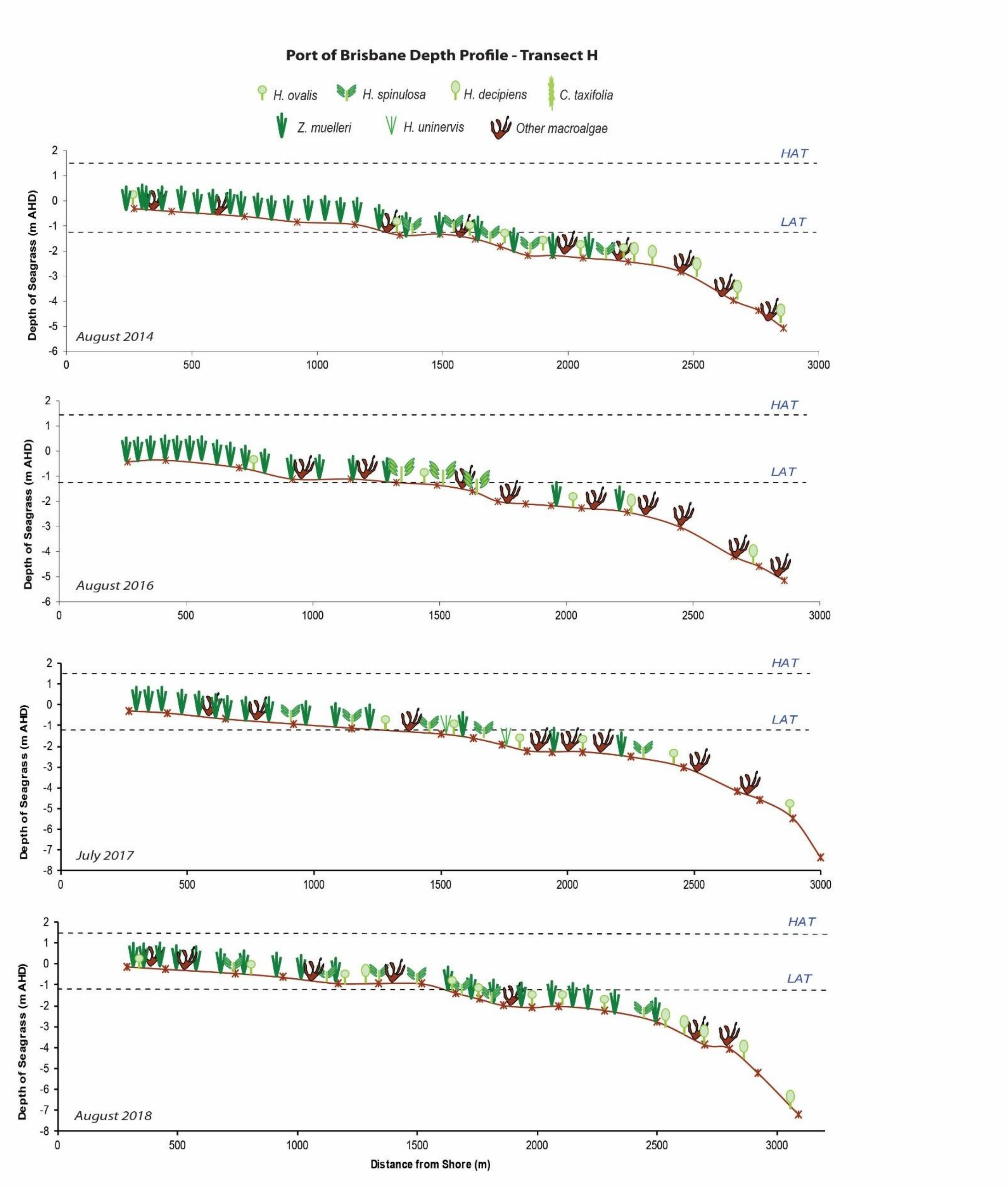

Figure D-2 Schematic Representation of Seagrass Species Distribution From 2013 to 2014 and 2016 to 2018 at Depth Profiling Transect H, Fisherman Island

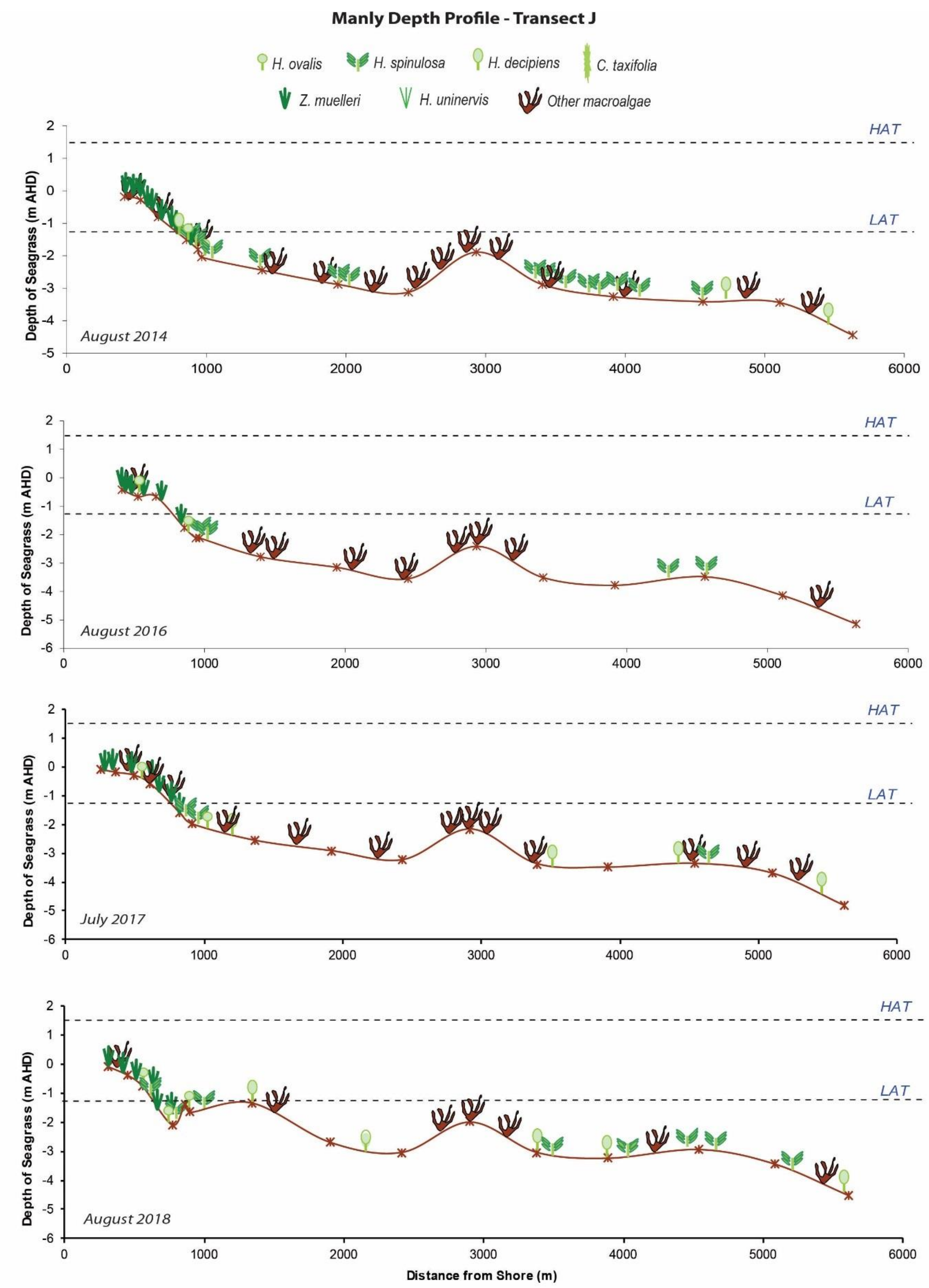

Figure D-3 Schematic Representation of Seagrass Species Distribution From 2013 to 2014 and 2016 to 2018 at Depth Profiling Transect J, Manly

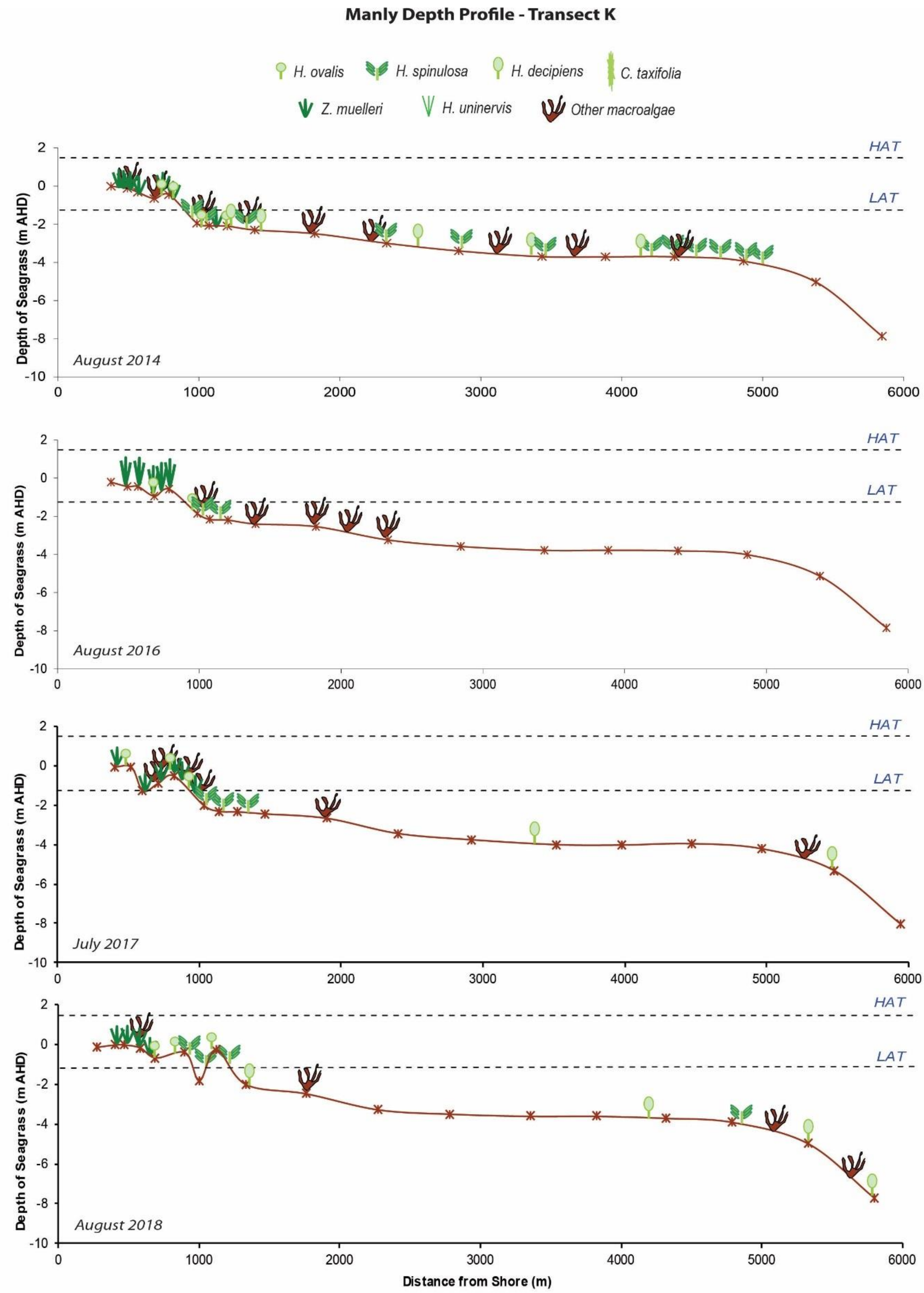

Figure D-4 Schematic Representation of Seagrass Species Distribution From 2013 to 2014 and 2016 to 2018 at Depth Profiling Transect K, Manly

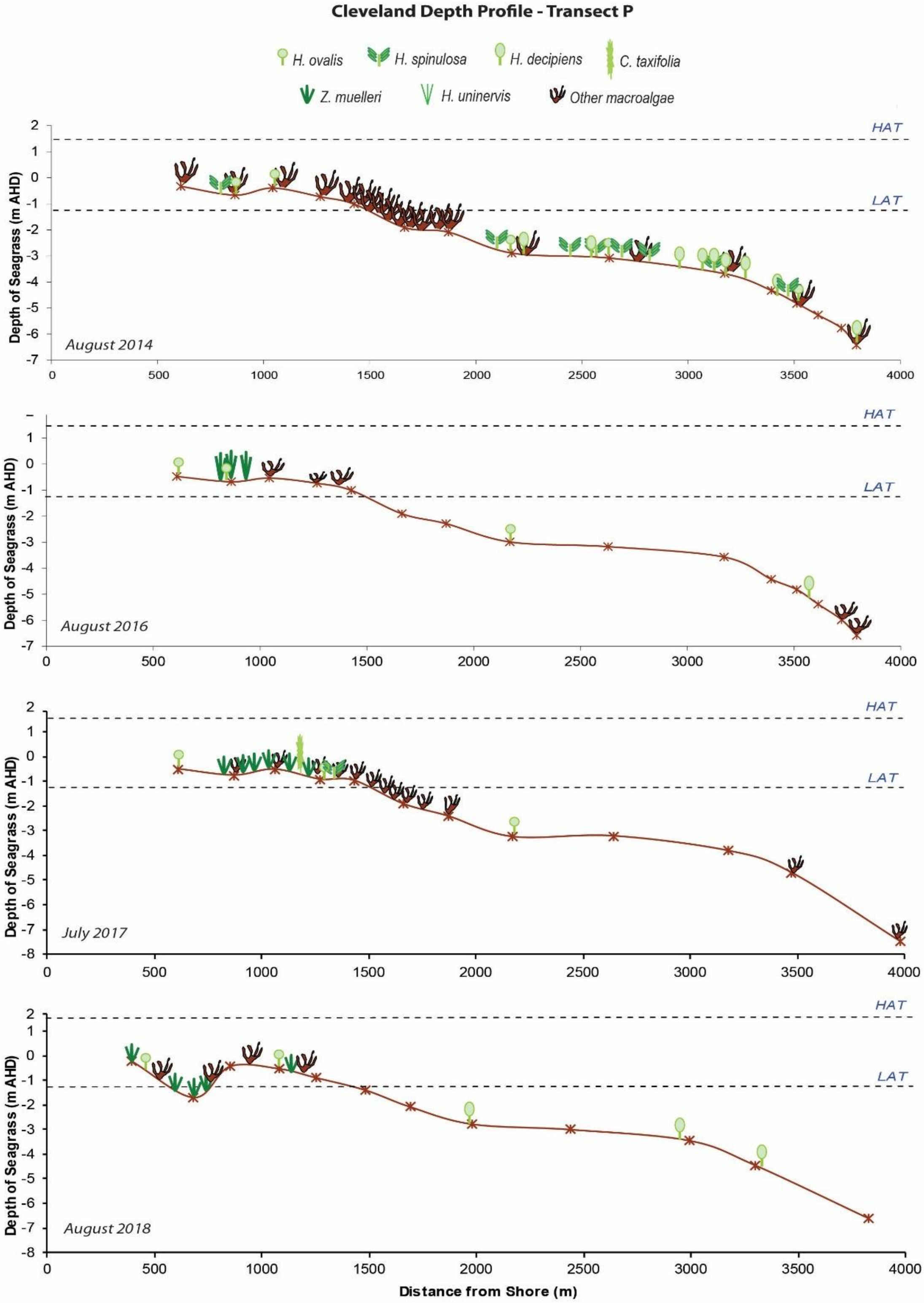

Figure D-5 Schematic Representation of Seagrass Species Distribution From 2013 to 2014 and 2016 to 2018 at Depth Profiling Transect P, Cleveland

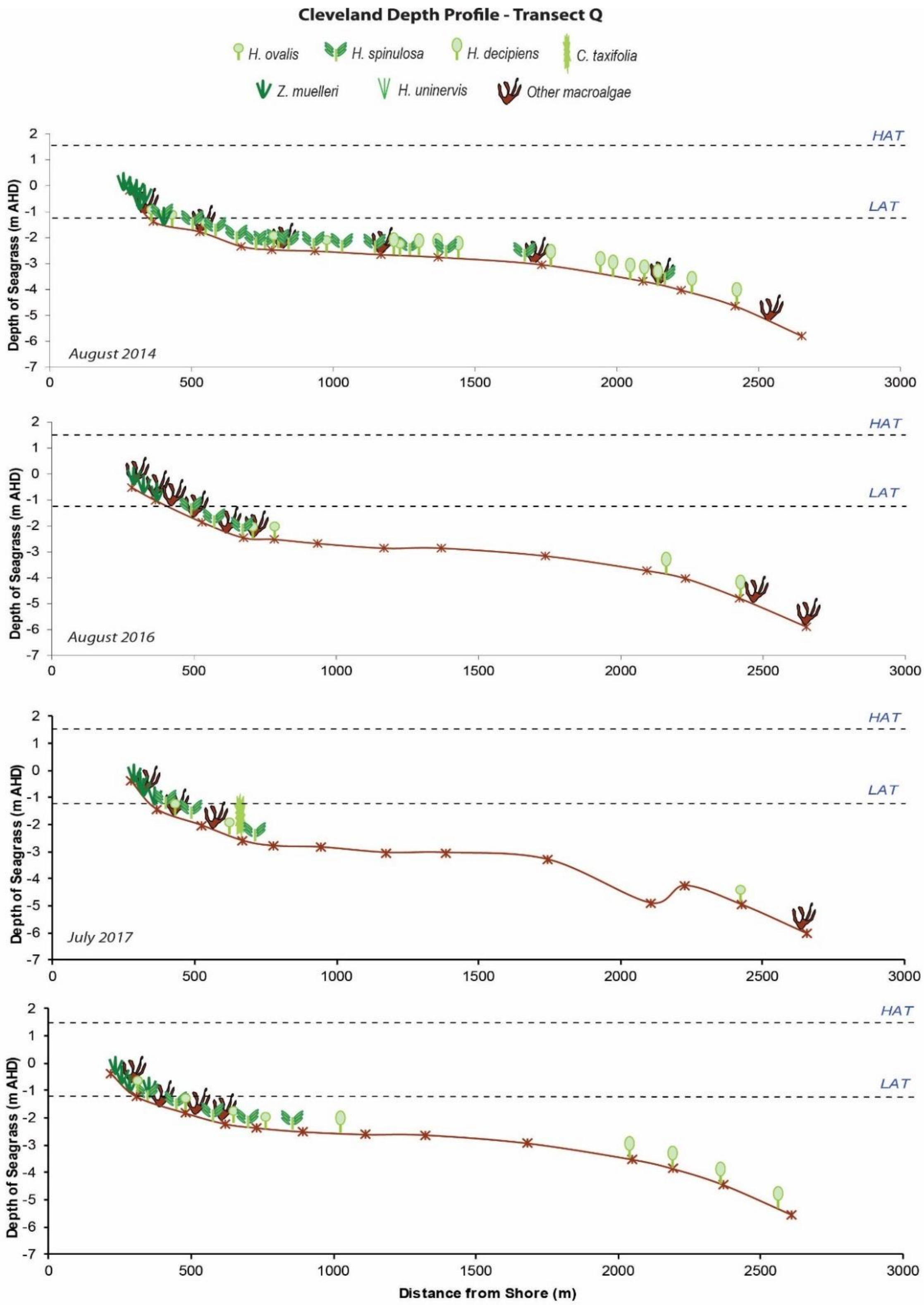

Figure D-6 Schematic Representation of Seagrass Species Distribution From 2013 to 2014 and 2016 to 2018 at Depth Profiling Transect Q, Cleveland

Appendix E Seagrass Percentage Cover – Depth Categories

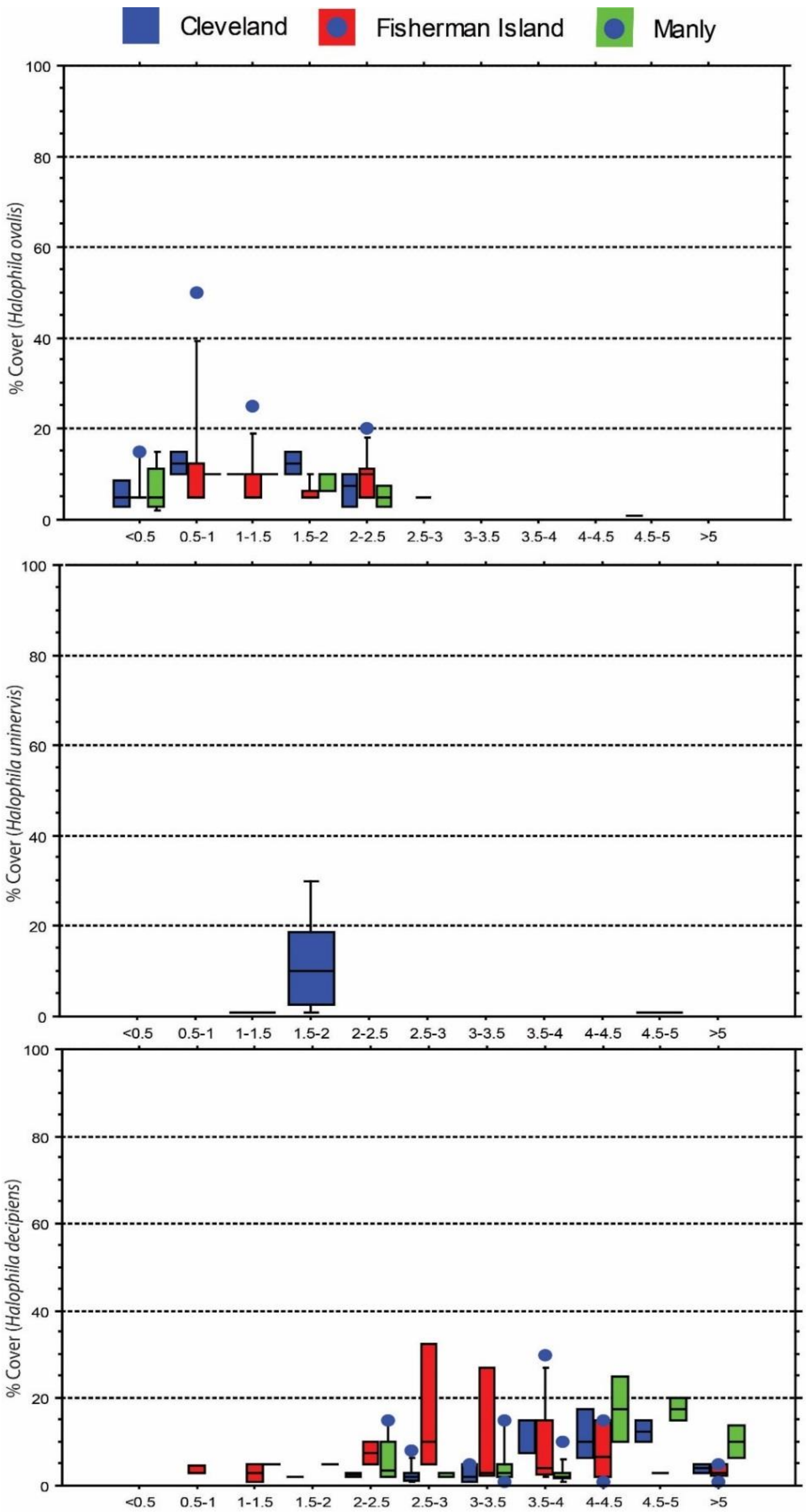

Figure E-1 Percentage Cover of *Halophila ovalis* (upper plot), *H. uninervis* (middle plot) and *H. decipiens* (lower plot) at Each Location and Depth Category (m in -AHD)

Seagrass Percentage Cover – Depth Categories

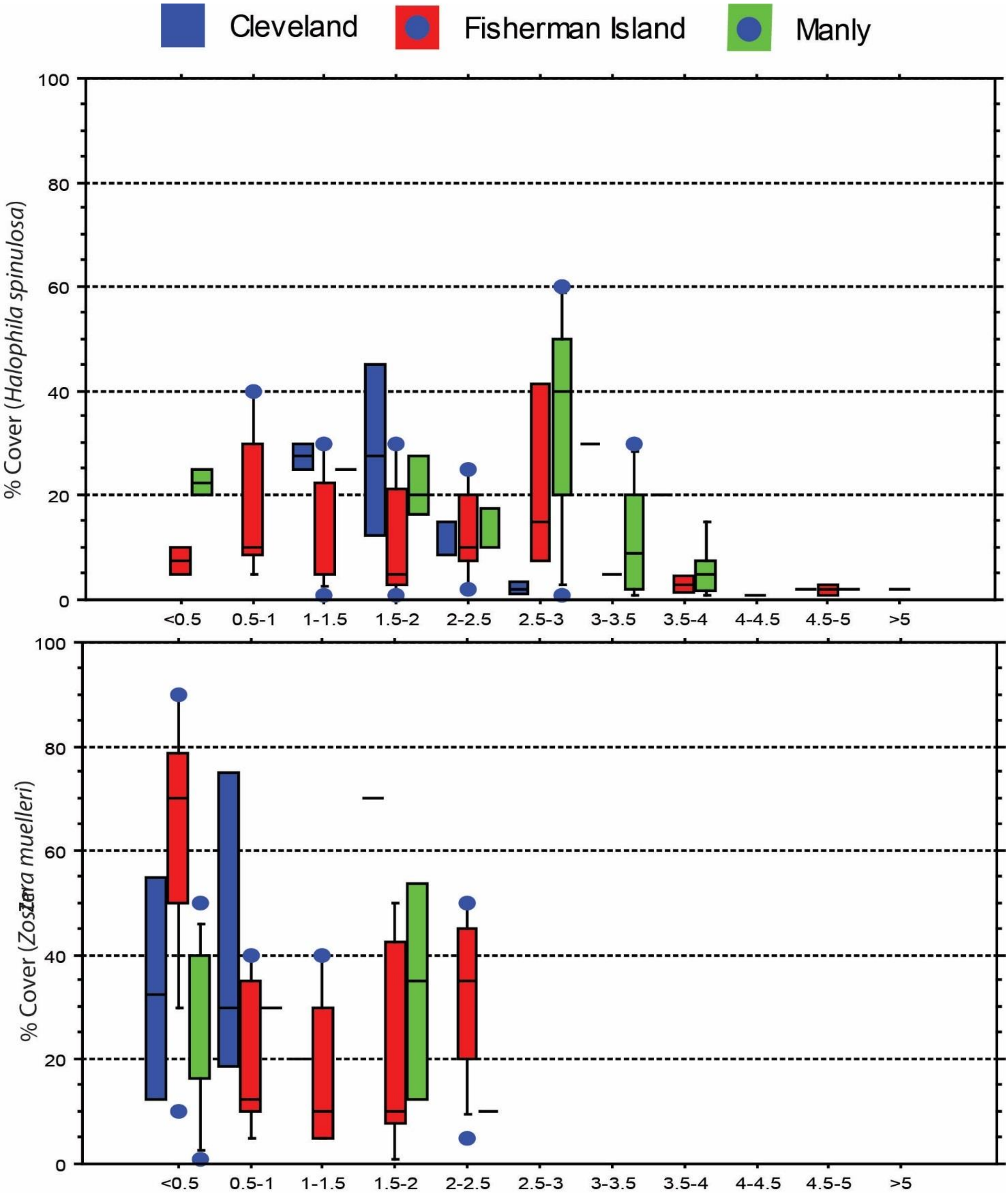

Figure E-2 Percentage Cover of *Halophila spinulosa* (upper plot) and *Zostera muelleri* (lower plot) at Each location and Depth Category (m in -AHD)

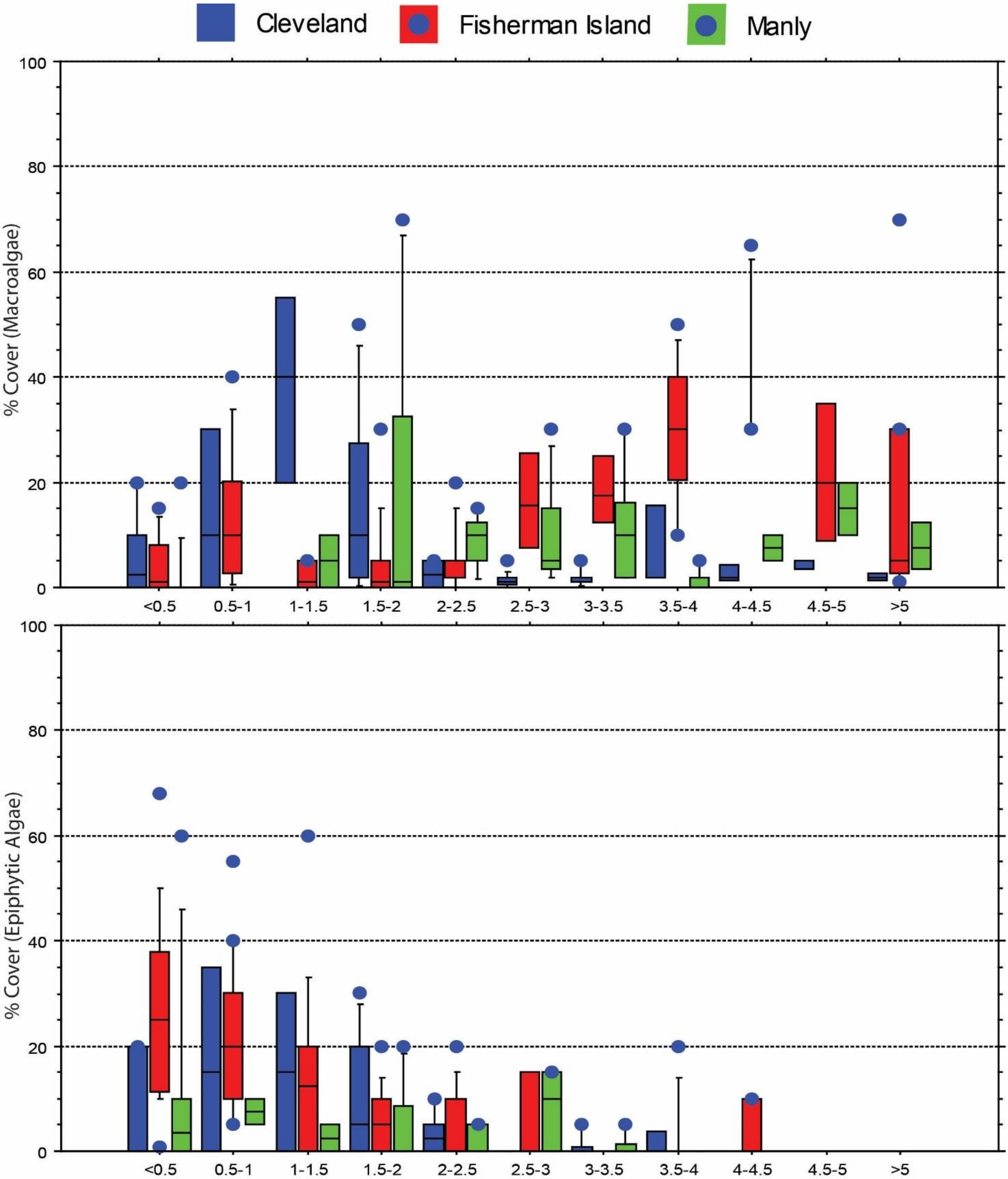

Figure E-3 Percentage Cover of 'Macroalgae' and Epiphytic Algae at each Location and Depth Category (m in -AHD)

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