Port of Brisbane Seagrass Monitoring Program 2020 - Draft

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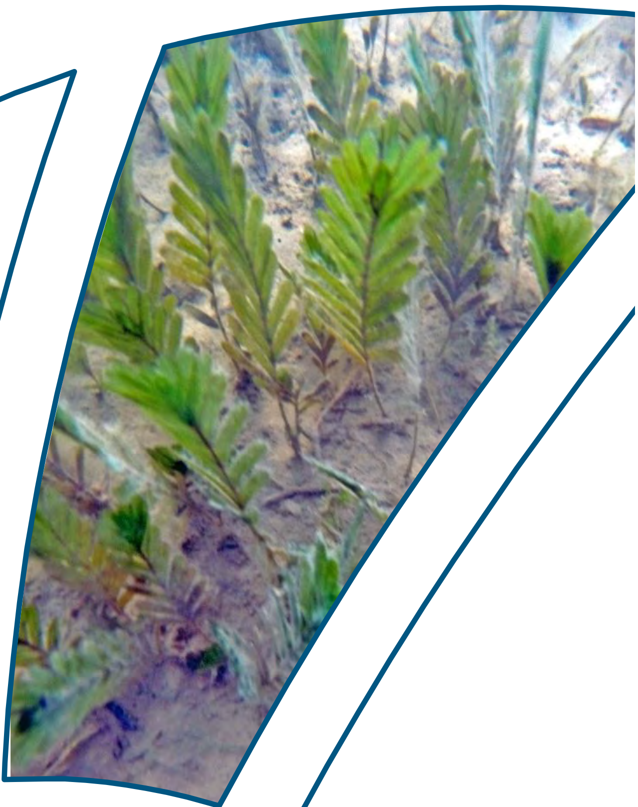

Document Control Sheet

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Synopsis: Findings of the 2020 seagrass monitoring program at Port of Brisbane, Queensland.		

REVISION/CHECKING HISTORY

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Executive Summary

Background

Seagrass meadows located near the Port of Brisbane are important assets that support numerous environmental and community values. These meadows vary in condition and extent over time in response to changes in environmental conditions, especially water quality.

The Port of Brisbane Pty Ltd (Pty Ltd (PBPL) has developed the Port of Brisbane Seagrass Monitoring Program (SMP). Every year, the SMP examines trends in seagrass meadow extent and condition in waters at and adjacent to the Port of Brisbane. This long-term dataset provides a basis to explore potential links between seagrass meadow condition and drivers, including the potential influence of port activities.

SMP Aims

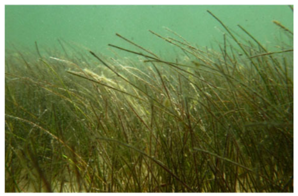
- Map and describe broad-scale spatial patterns in seagrass extent and species distribution at meadows located near the Port of Brisbane at Fisherman Islands, and at control locations located in western Moreton Bay (Manly, Cleveland and Deception Bay)
- Characterise spatial and temporal trends in seagrass condition indicators
- On the basis of the above, identify possible broad-scale operational impacts of port activities on the distribution and extent of seagrass meadows.

This report describes the approach and findings of the 2020 sampling event. The SMP monitors meadows at Fisherman Islands and control locations of Cleveland, Manly and in 2020 Deception Bay. The SMP incorporates field-based (underwater video transects) and remote (aerial and satellite imagery) methodologies.

Findings

Species Composition

- A core set of species occur at all locations over time: the eelgrass *Zostera muelleri*, the paddle-weeds *Halophila ovalis*, *Halophila spinulosa* and (typically) *Halophila decipiens*.
- In 2020 all four of these seagrass species were observed during the field surveys.
- A fifth species, the narrow-leaf seagrass *Halodule uninervis,* is typically detected but was not recorded in 2020.



Zostera muelleri

Halodule uninervis

Halophila ovalis

Halophila spinulosa

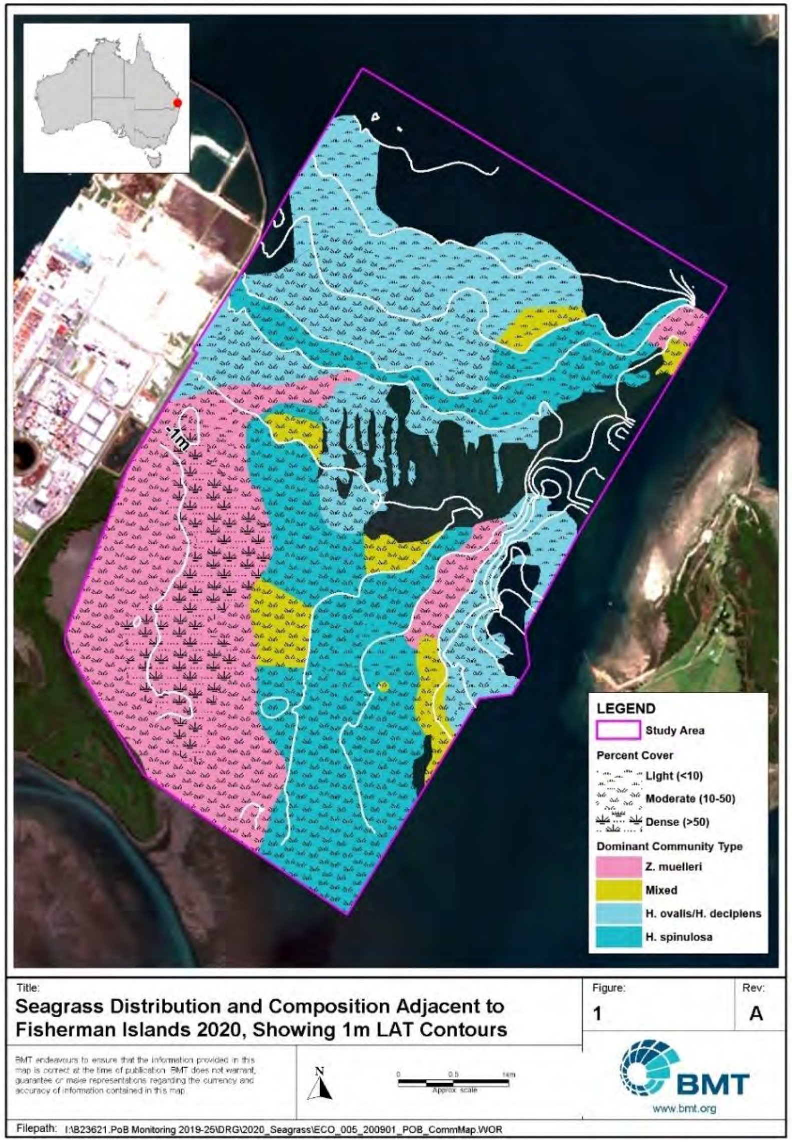
Halophila decipiens

Spatial Patterns in Seagrass Species

- Figure 1 is a map of seagrass meadows at Fisherman Islands in 2020. The map is considered as indicative of patterns in seagrass assemblage structure, but accuracy is constrained by water clarity issues (i.e. >3-5 m depth, especially sparse meadows) and site spacing (500 m grid arrangement).
- Intertidal and shallow subtidal areas were predominately dominated by *Zostera muelleri*.
- Subtidal meadows comprised of mixed communities of *Halophila* and macroalgae species.

Meadow Extent and Condition between 2019 and 2020

- All species were typically recorded at fewer sites in 2020 than 2019 at Fisherman Islands and control locations.
- The upper boundary of *Zostera muelleri* dominated meadows retracted at Fisherman Islands between 2019 and 2020. The seaward boundary of *Zostera muelleri* generally remained stable (all controls and one Fisherman Island transect) or expanded (one Fisherman Islands transect) between 2019 and 2020 (Figure 2).
- *Environmental Protection Policy (Water and Wetland Biodiversity)* sets out water quality objectives (WQO) for the protection of environmental values which includes *Zostera muelleri* seagrass depth range (i.e. maximum depth of *Zostera*) as a benchmark. Fisherman Island and Manly transects met the WQO, whereas those at Cleveland did not (Figure 2



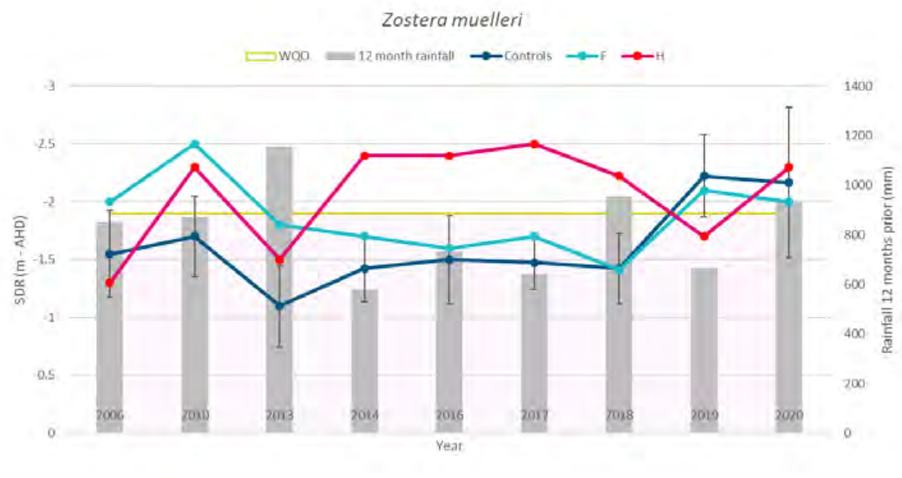


Figure 3 ***Zostera*** **seagrass depth range at Fisherman Islands transect F and H, and the average (±SE) for control sites. Rainfall in the 12 months leading to the survey is also shown**

- There was a reduction in seagrass meadow extent in the northern sector of Fisherman Islands. In 2019 this area had moderate to dense seagrass meadows.
- A variety of algae species were present within the study extents, with filamentous or *Hydroclathrus* typically the dominant algae. *Caulerpa taxifolia* was dominant in the study area during the 2000's but was only observed at Deception Bay.

Long Term Changes in Seagrass Meadow Extent

- The long-term trend of seagrass meadow expansion at Fisherman Islands is consistent with predictions of the Future Port Expansion Impact Assessment Study. This study predicted the land reclamation to enhance seagrass growing conditions.
- Generally, expansion has occurred during drought years and retraction following major flood events in 2011 and 2013.

Key Conclusions

- Seagrass meadows at Fisherman Islands were in good condition in 2020, meeting scheduled water quality objectives.
- There were however areas of decline since 2019, especially the retraction of the landward boundary of *Zostera* and the seaward boundary of meadows in the northern section of Fisherman Islands.

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1 Introduction

1.1 Background

Moreton Bay contains environmental features that support outstanding ecological, social and economic values. In recognition of these values, parts of Moreton Bay are listed as an internationally significant wetland (Moreton Bay Ramsar Site) and Moreton Bay Marine Park (Figure 1-1).

The Port of Brisbane is located adjacent to Waterloo Bay, which contains some of the largest seagrass meadows in western Moreton Bay (Dennison and Abal 1999). The Port of Brisbane Pty Ltd (PBPL) has developed a Seagrass Monitoring Program (SMP) to provide information on the status and condition of seagrass meadows through time to identify if there are any signs of impact from port activity.

The extent and health of seagrass meadows is a useful indicator of water quality change, especially aquatic light climate (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.

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;

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

- 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 port activities on the distribution and extent of seagrass meadows.

1.3 Study Area

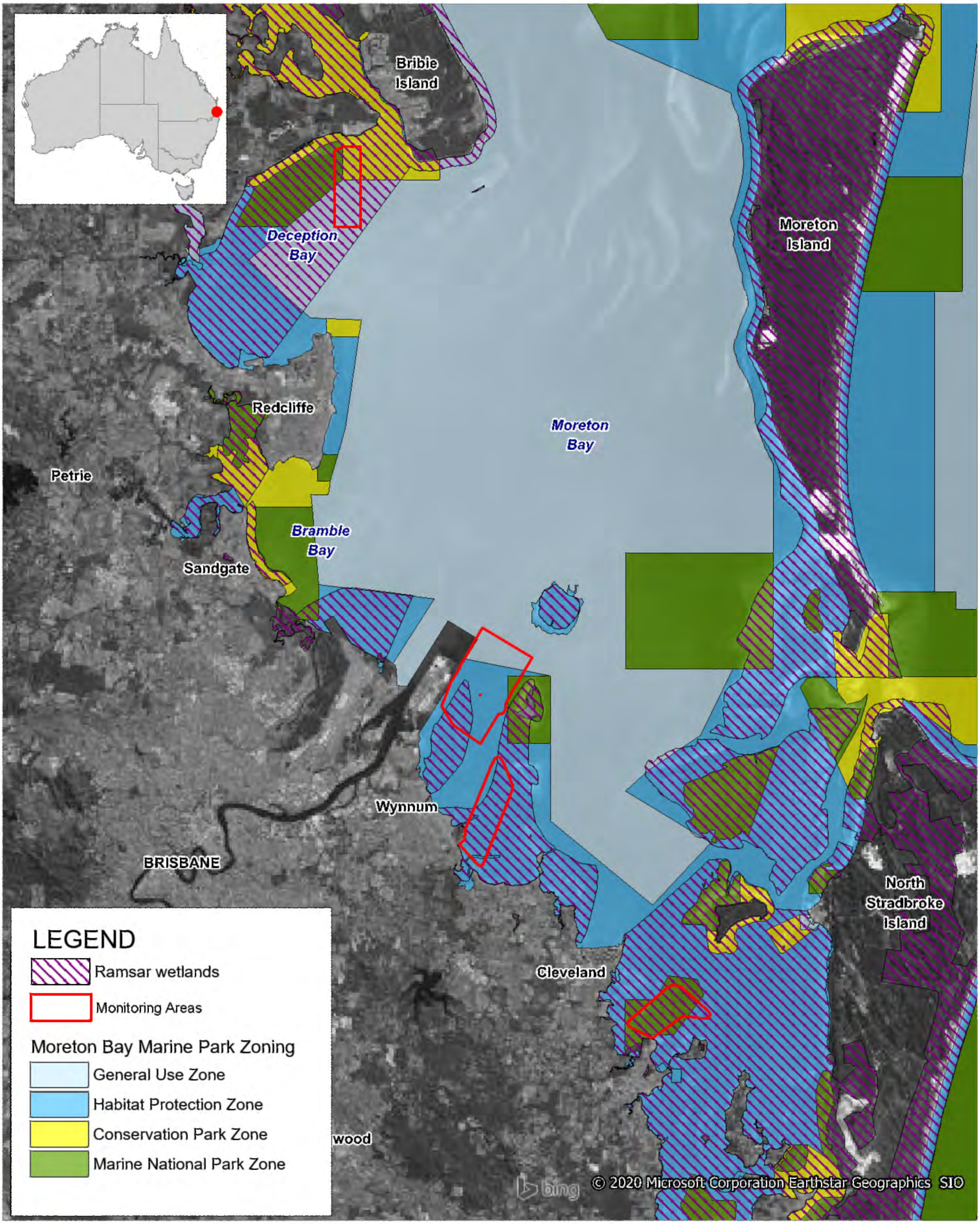
The Port of Brisbane is located on Fisherman Islands which is situated at the mouth of the Brisbane River on the western foreshore of Moreton Bay, Queensland.

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 and western Moreton Bay generally.



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Moreton Bay Ramsar Wetlands and Marine Park Zoning

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2 Methodology

2.1 Timing

Field monitoring in 2020 was undertaken between the 18th and 31st of August. Tidal data from the Tidal Unit, Maritime Safety Queensland was obtained for the Brisbane Bar throughout this study period (Figure 2-1) and was used to correct depth soundings to Australian Height Datum (AHD).

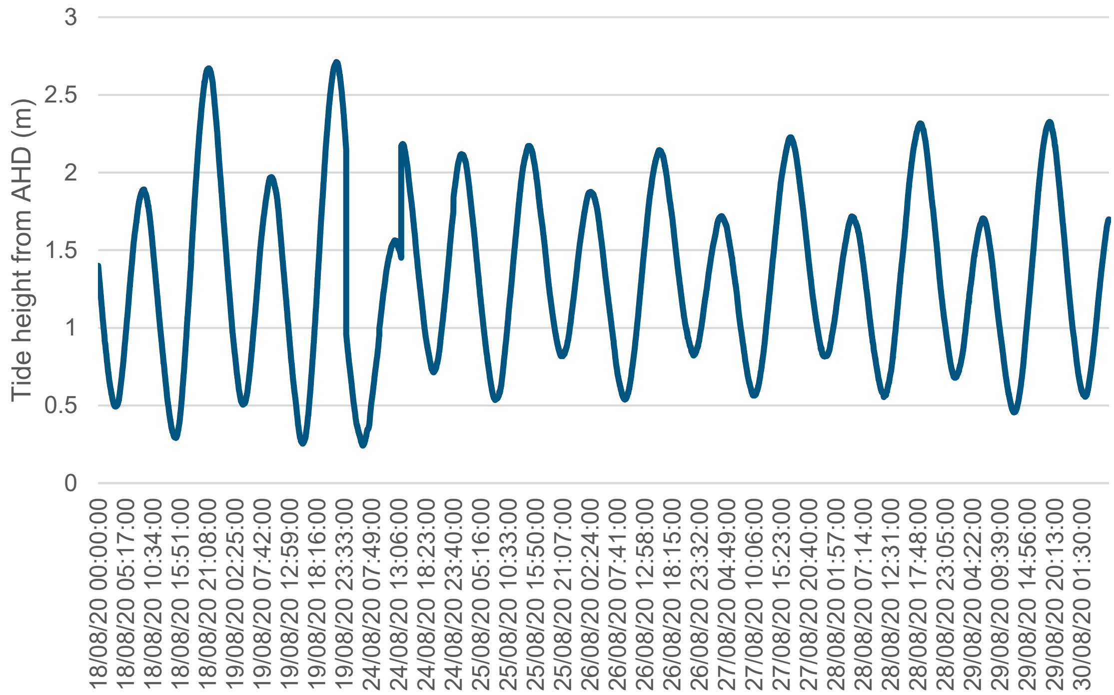


Figure 2-1 Tidal heights of Brisbane Bar during the 2020 survey

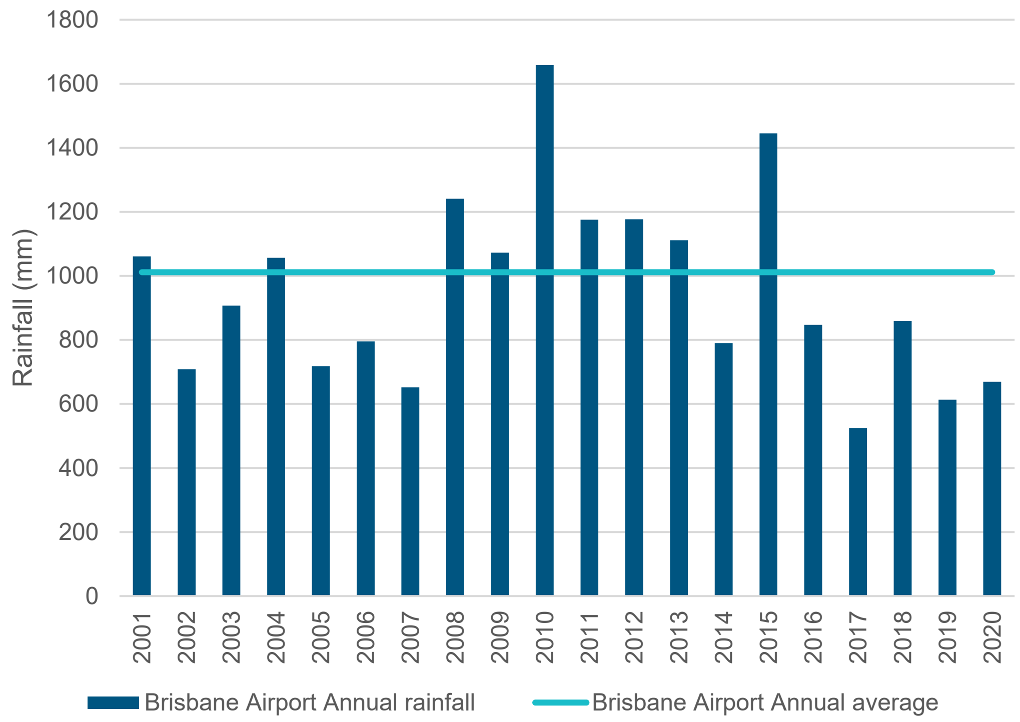


Figure 2-2 Annual rainfall from 2001 to 2019 and to date in 2020 at Brisbane Airport (Source: BoM station: 040842)

2.2 Survey Vessel and Positioning

All sampling was carried out using the BMT research vessel 'Resolution II.' Location and navigation to sites was undertaken using a Garmin GPS.

2.3 Monitoring Locations, Sites and Approach

Monitoring locations for this survey were:

- Test and control locations as defined when the SMP was developed in 2002 (WBM Oceanics Australia 2002), namely Fisherman Islands (putative impact/test), Manly (control), Cleveland (control); and
- An addition control location was included in 2020 (Deception Bay) to better define 'background' conditions in western Moreton Bay, north of the Brisbane River.

Since its development in 2002 the SMP has evolved from edge of bed monitoring to a systematic grid sampling approach. This has developed to utilise remote sensing advances and to allow the mapping of the extent and composition of both intertidal and subtidal seagrass meadows. The seagrass depth profile transects have been maintained to allow consistency in long-term comparisons.

The term 'sites' refers to individual transects at each location.

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), Figure 2-4 (Manly), Figure 2-5 (Cleveland) and Figure 2-6 (Deception Bay).

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

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 3-5).

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, 2018 and 2019.

Two depth profile transects occur at each survey location and run approximately perpendicular to the shoreline (Figure 2-3 to Figure 2-6). At each point along the profile transect, the following parameters were recorded: time, water depth (using the survey vessel's sounder), position (GPS), seagrass species present and macroalgae community composition (a video image was recorded at each point). The depth at each point was converted 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 Assemblages

Seagrass assemblages were determined according to species composition within a meadow. A standard nomenclature system based on Carter and Rasheed (2016) was to assign the community types to each of the sampling sites (Table 2-1). Assemblages correspond with percent composition that each seagrass contributes to the meadow. Seagrass meadow landscape category (Table 2-2) is a method established by James Cook University (see Carter *et. al.* 2015) for long-term monitoring of seagrass meadows over a large area. Nomenclature from Carter *et. al.* (2015) has been adopted, however in many instances' seagrass patches have been mapped at a scale of metres based on the field validation and high-resolution aerial imagery. Therefore, for the present survey some areas of "patchy" cover have been mapped as smaller isolated or aggregated patches with dense or continuous cover, as opposed to broader meadows with aggregated or isolated patches within the meadow boundaries.

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%

Table 2-2 Seagrass meadow categories (Carter *et. al*. 2015)

Meadow landscape category	Description
Isolated seagrass patches	The majority of area within the meadows consisted of unvegetated sediment interspersed with isolated patches of seagrass
Aggregated seagrass patches	Meadows are comprised of numerous seagrass patches but still feature substantial gaps of unvegetated sediment within the meadow boundaries
Continuous seagrass cover	The majority of area within the meadows comprised of continuous seagrass cover interspersed with few gaps of unvegetated sediment

2.4.2 Seagrass Abundance

Consistent with previous monitoring, seagrass species at each survey site was assigned to abundance categories according to overall seagrass percent cover, as described in Figure 3-1 to Figure 3-3. In addition, groupings of overall seagrass cover were used to provide context to the broad community categories described in Section 2.4.1 (Table 2-3).

Table 2-3 Broad seagrass density categories

Density Category	Overall Cover (%)
Light	0-10%
Moderate	10-50%
Dense	>50%

2.4.3 Algae

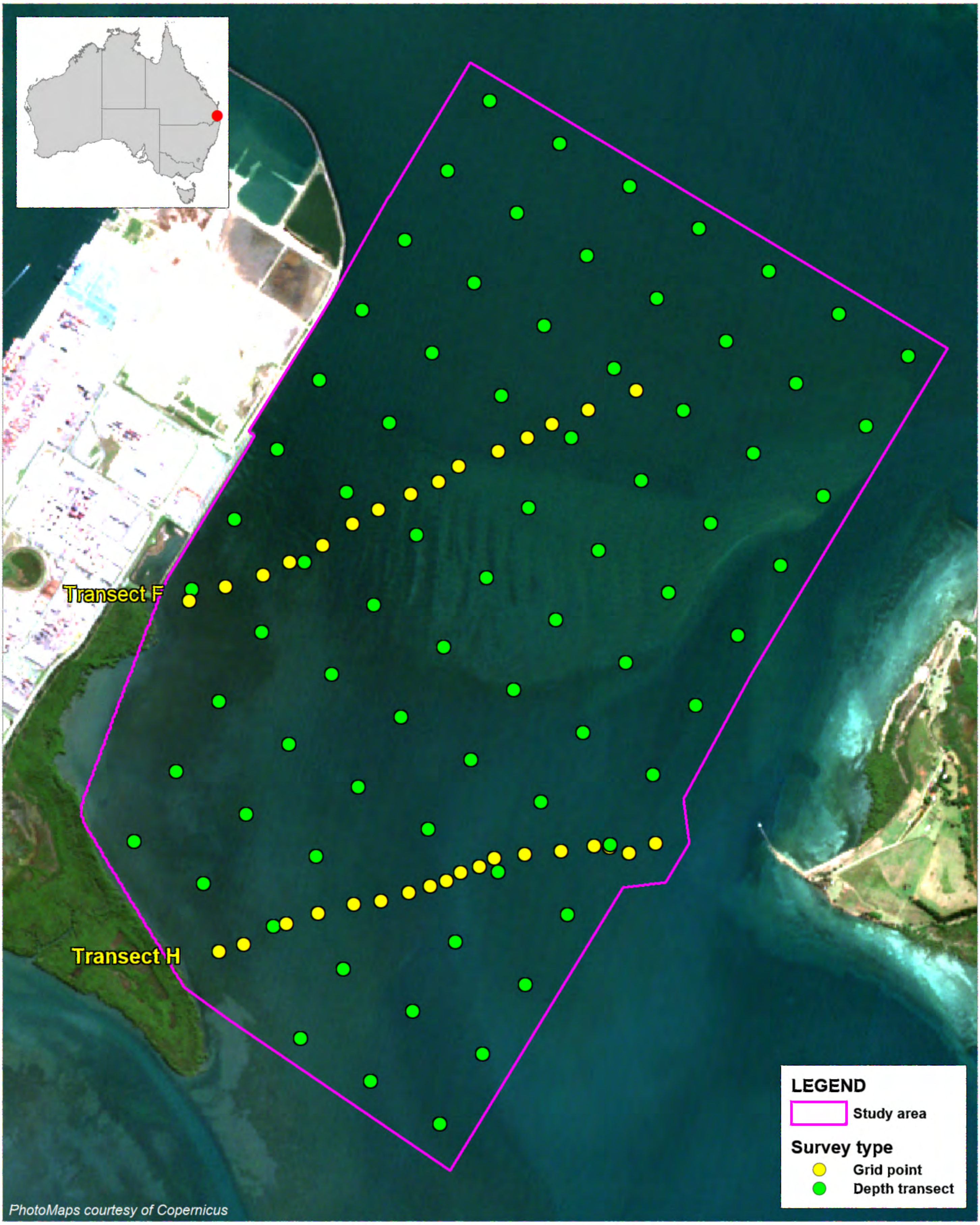
Algae abundance was estimated for two functional groupings: (i) filamentous algae including epiphytic and turfing algae; (ii) other macroalgae (non-filamentous).

2.5 Seagrass Meadow Extent Mapping

The extent of seagrass meadows was mapped adjacent to Fisherman Islands using a combination of remote sensing (satellite and aerial imagery) and field observations.

To remotely sense seagrass communities a Sentinel-2 satellite capture was corrected for water column using the depth invariant index method and classified in ArcGIS (version 10.5). Satellite imagery analysis is beneficial for the continuous spatial coverage however it is constrained by depth and water clarity issues. Remote sensing is accurate in shallow water communities that have at least

15% seagrass cover however, accuracy is reduced in deep water (>5 m) and in sparse communities (<15% cover). Therefore, while remote sensing is effective and reliable for inshore communities the field data was used to estimate the edge of the seagrass meadows. The accuracy of the edge of the meadow extent is limited by the grid spacing.



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Survey points used to map the distribution of seagrass at Fisherman Islands, adjacent to the Port of Brisbane

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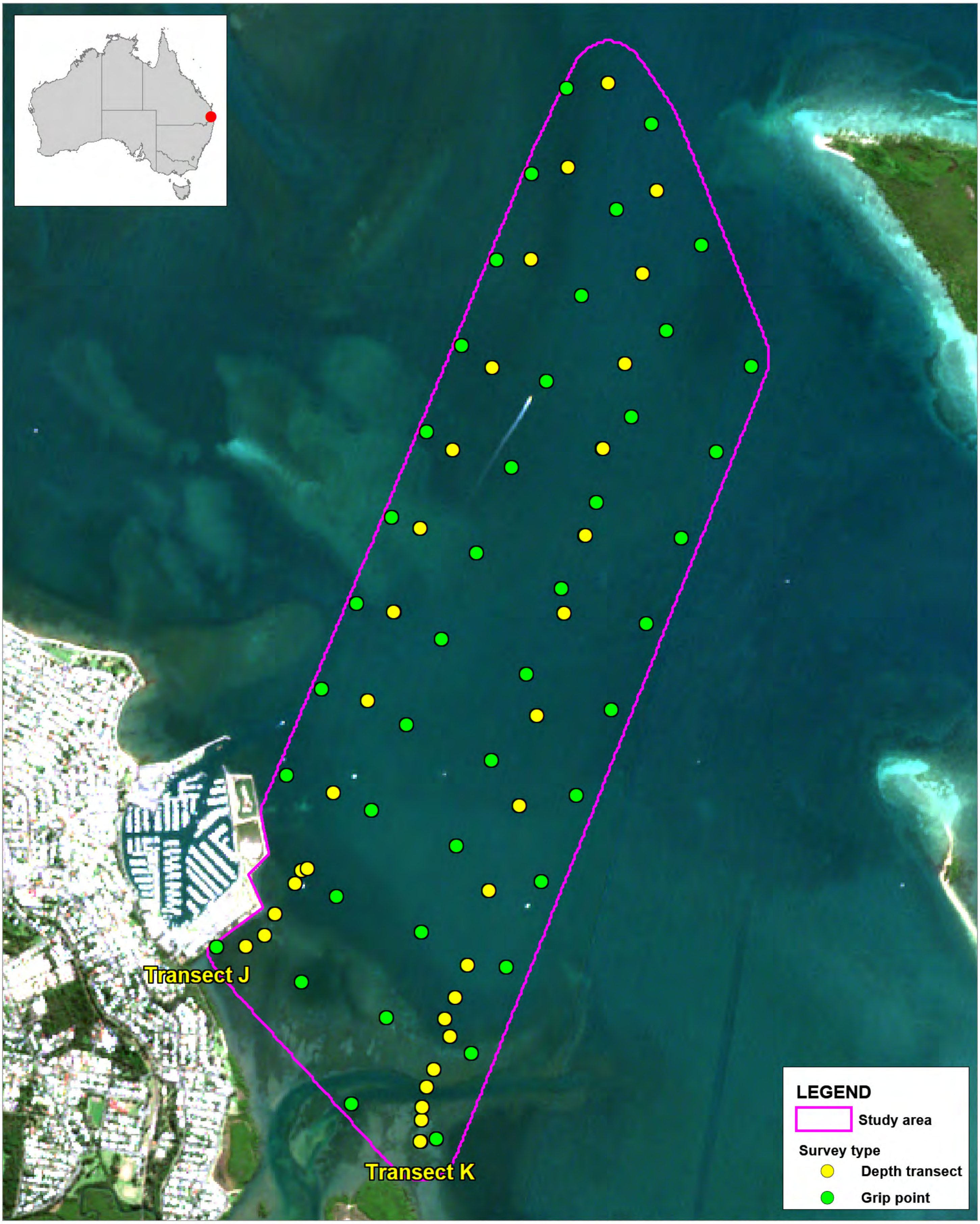

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Survey points used to map the distribution of seagrass adjacent to Manly

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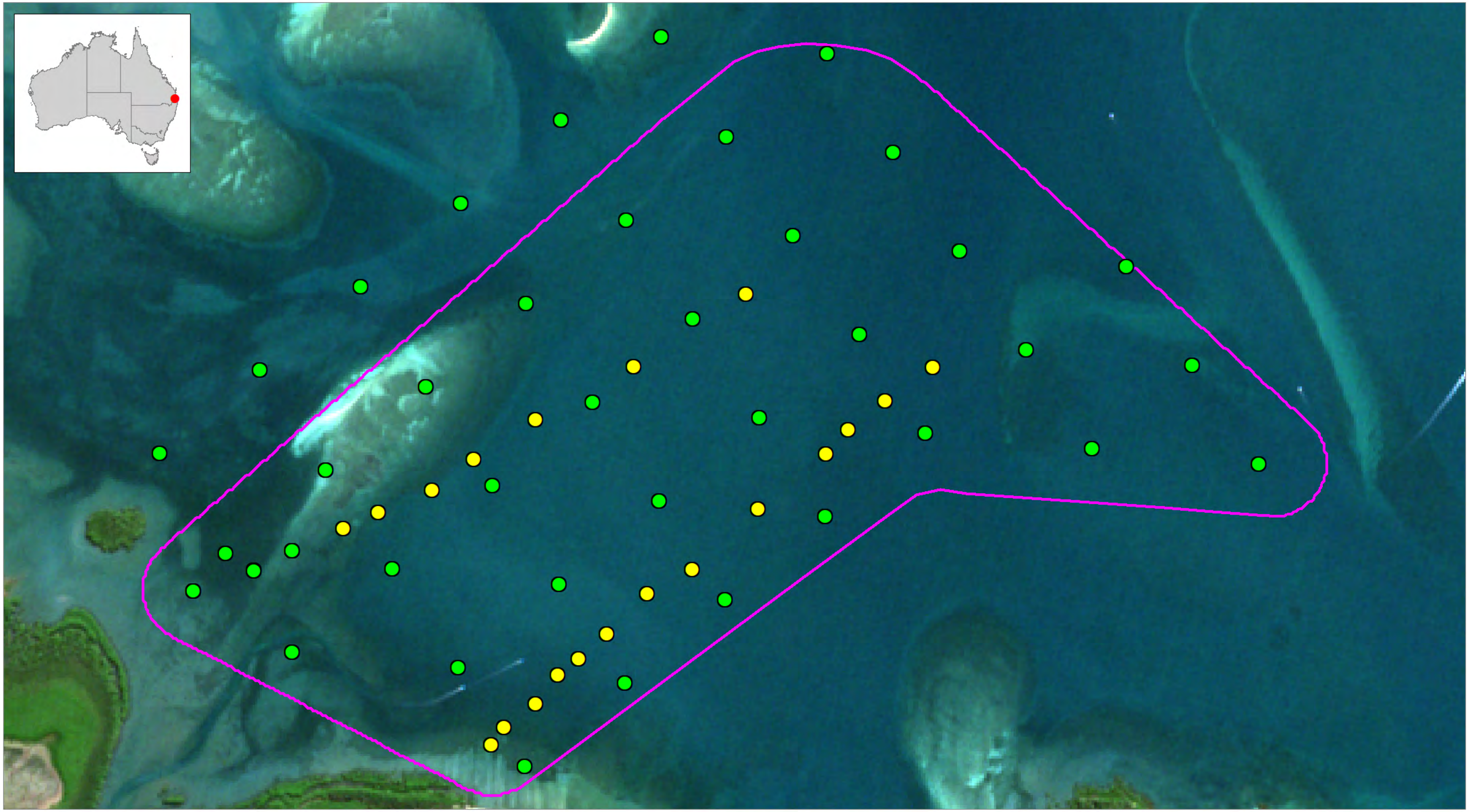

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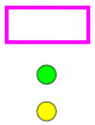

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Survey points used to map the distribution of seagrass adjacent to Cleveland

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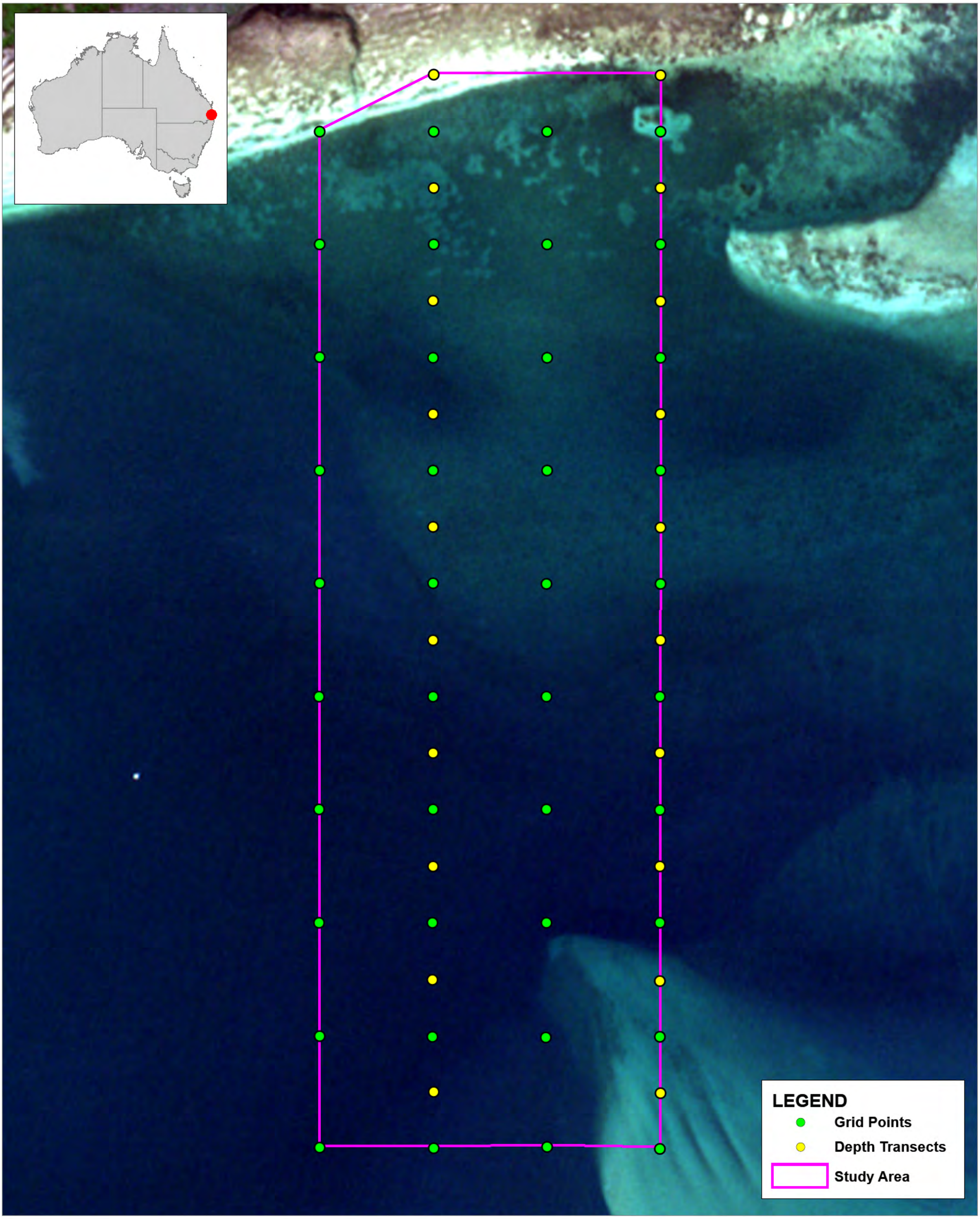

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Survey points used to map the distribution of seagrass in Deception Bay

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3 Results

3.1 Seagrass Spatial Distribution and Percentage Cover

Four of the eight seagrass species known to occur in Moreton Bay were recorded in the 2020 survey: *Zostera muelleri (*subsp. *capricorni), Halophila ovalis, Halophila spinulosa* and *Halophila decipiens.*

Maps showing the spatial distribution of each seagrass species in 2020 survey are shown in Figure 3-1 to Figure 3-4. Seagrass assemblage types at Fisherman Islands derived from survey data, interpretation of Sentinel satellite data and high-resolution aerial photography (Nearmap) is presented in Figure 3-5. Note that due to limitation of remote sensing and survey grid spacing the bare areas may contain some undetected sparse seagrass.

In 2020 there was a general pattern of assemblage structure across the different habitat depths (Figure 3-5):

- *Zostera muelleri* was numerically dominant intertidal and shallow subtidal waters*;*
- *Halophila spinulosa* was numerically dominant or co-dominant in the intertidal - subtidal transitional zone;
- Subtidal areas were numerically dominated by sparse *H. ovalis* and *H. decipiens*.

In comparison to previous surveys there was an overall decrease in *Z. muelleri* dominated meadows and an increase in *H. spinulosa* dominated meadows (Appendix B). The following describes trends in species distribution and cover.

3.1.1 Species Distribution

The findings from the 2020 survey were largely consistent with the 2019 survey, as follows:

- Seagrass was recorded at 73% of the Fisherman Island sites (*n* = 110), 85% of Manly sites (*n* = 75), 81% of Cleveland sites (*n* = 59) and 50% of Deception Bay sites (*n* = 60). The frequency of seagrass detections was higher in 2020 than 2019 (2019: 85%, 96% and 88% of the sites at Fisherman Islands, Manly and Cleveland respectively). A chi-square test of independence was performed to examine the relation between seagrass detections at each location (Fisherman Islands, Manly, Cleveland) and year (2019, 2020). The relationship between these variables was not significant, ($\chi^2_{(d.f.\ 1,\ N\ =\ 508)}$ = 0.09, p = 0.95). This suggests that seagrass detections at each location did not vary over time.
- *Zostera muelleri* was the most frequently recorded species at all locations in both years (Table 3-1).
- *Halodule uninervis* was not recorded in 2020 at any location. During 2019, *H. uninervis* was recorded at 18% (20) of the Fisherman Islands sites, 3% (two) of the Cleveland sites and was not recorded at Manly.
- *Zostera muelleri* dominated meadows were mainly located within the intertidal zone, extending from above LAT at the landward edge into shallow subtidal areas (3.6 m LAT). Intertidal meadows were compromised of mixed meadows of all four present species. Mixed meadows of *Halophila* were more common within subtidal areas.

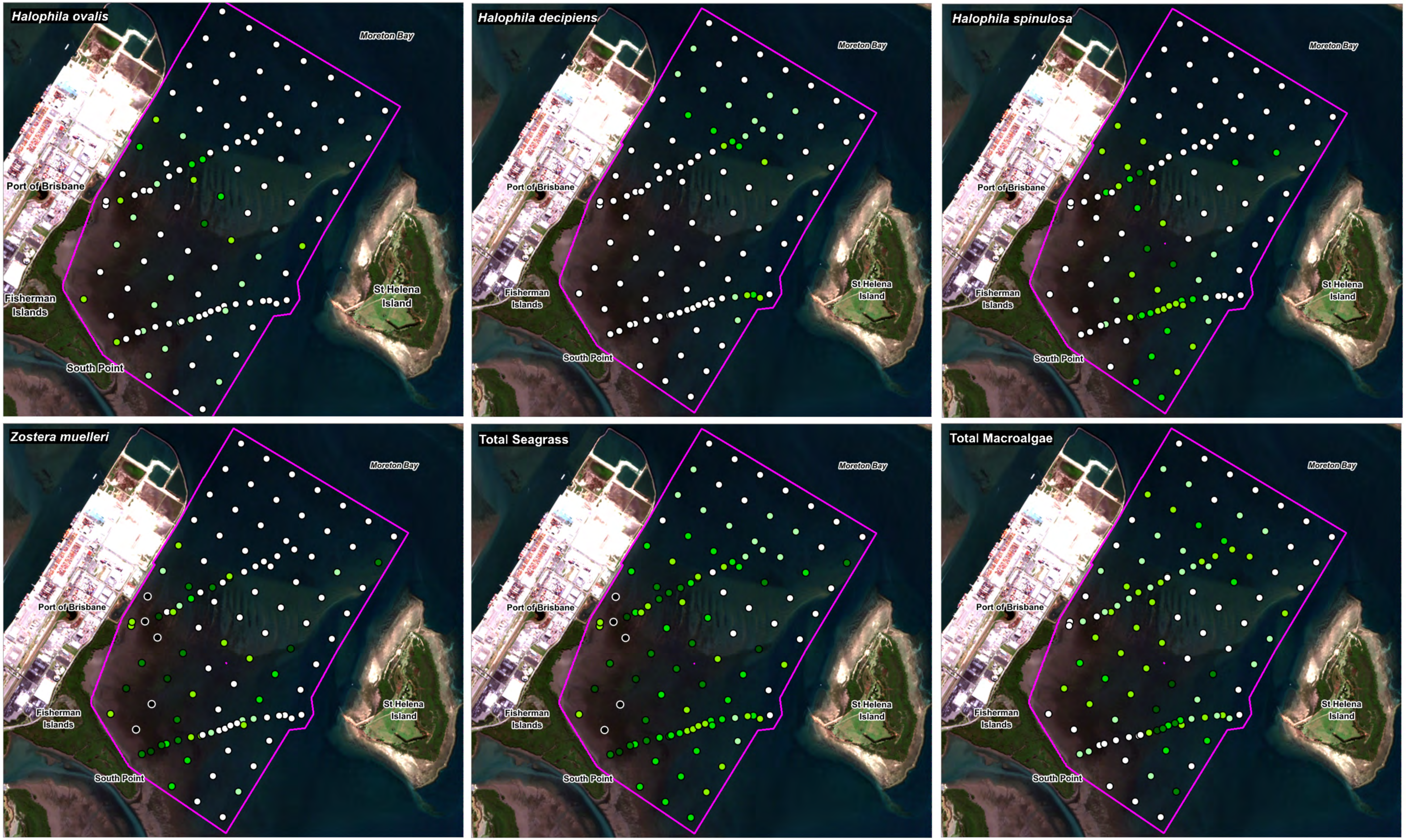
- Isolated patches of *H. ovalis* and *H. decipiens* were recorded on exposed sandy shoals areas. The frequency of *Halophila* detections was lower in 2020 than 2019 at all locations.
- The presence of *H. spinulosa* has decreased at both Fisherman Islands and Manly but was stable at Cleveland (Table 3-1).
- Macroalgae coverage generally decreased at all sites, and were numerically dominated by filamentous algae.

Table 3-1 Seagrass presence at study sites (%)

Site	Species	Number of sites (%) 2020	Number of sites (%) 2019	Trend 2019-20
Fisherman Islands	*H. decipiens*	13	24	↓
	H. ovalis	27	36	↓
	H. spinulosa	42	53	↓
	H. uninervis	-	20	↓
	Z. muelleri	46	40	↑
Manly	*H. decipiens*	6	14	↓
	H. ovalis	11	34	↓
	H. spinulosa	49	51	↓
	Z. muelleri	16	17	↔
Cleveland	*H. decipiens*	21	21	↔
	H. ovalis	-	23	↓
	H. spinulosa	30	29	↔
	Z. muelleri	9	14	↓
Deception Bay	*H. decipiens*	0	-	-
	H. ovalis	21	-	-
	H. spinulosa	2	-	-
	Z. muelleri	21	-	-

3.1.2 Seagrass Cover

Temporal patterns in seagrass cover varied among species and locations (Figure 3-6). The main trend of seagrass cover was a decrease in percentage cover in the shallow intertidal areas with the subtidal areas having both areas of increasing and decreasing percentage cover.



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Percent Cover

- 75 to 100
- 50 to 75
- 25 to 50
- 15 to 25
- 5 to 15
- 1 to 5
- 0 to 1

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Species Distribution at Fisherman Islands, Adjacent to the Port of Brisbane 2020

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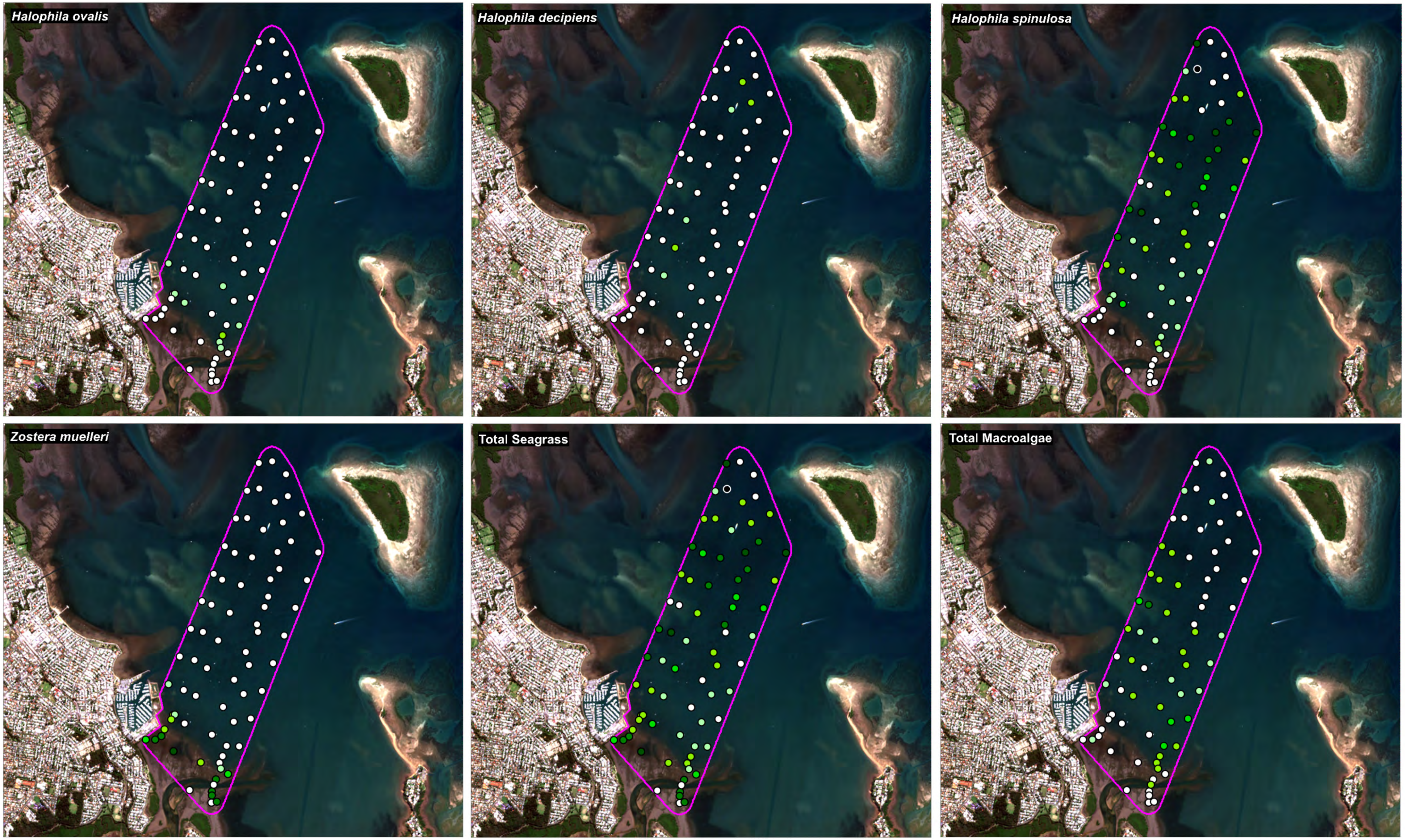

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Percent Cover
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- 50 to 75
- 25 to 50
- 15 to 25
- 5 to 15
- 1 to 5
- 0 to 1

Study Area

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Species Distribution at Manly, in Moreton Bay 2020

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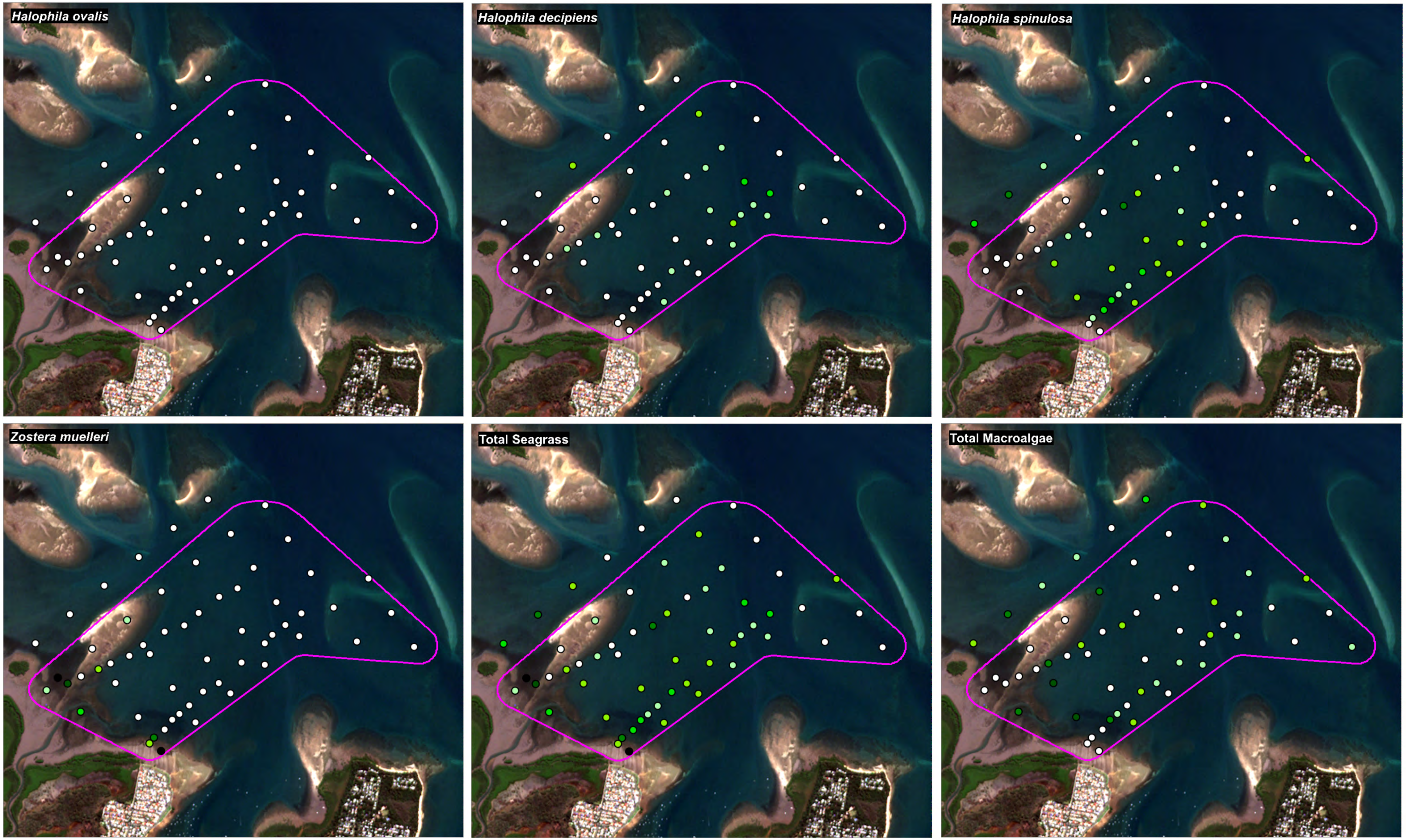

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Percent Cover

●	75 to 100
●	50 to 75
●	25 to 50
●	15 to 25
●	5 to 15
●	1 to 5
○	0 to 1

Study Area

Title:

Species Distribution at Cleveland, in Moreton Bay 2020

Figure: 3-3

Rev: A

N

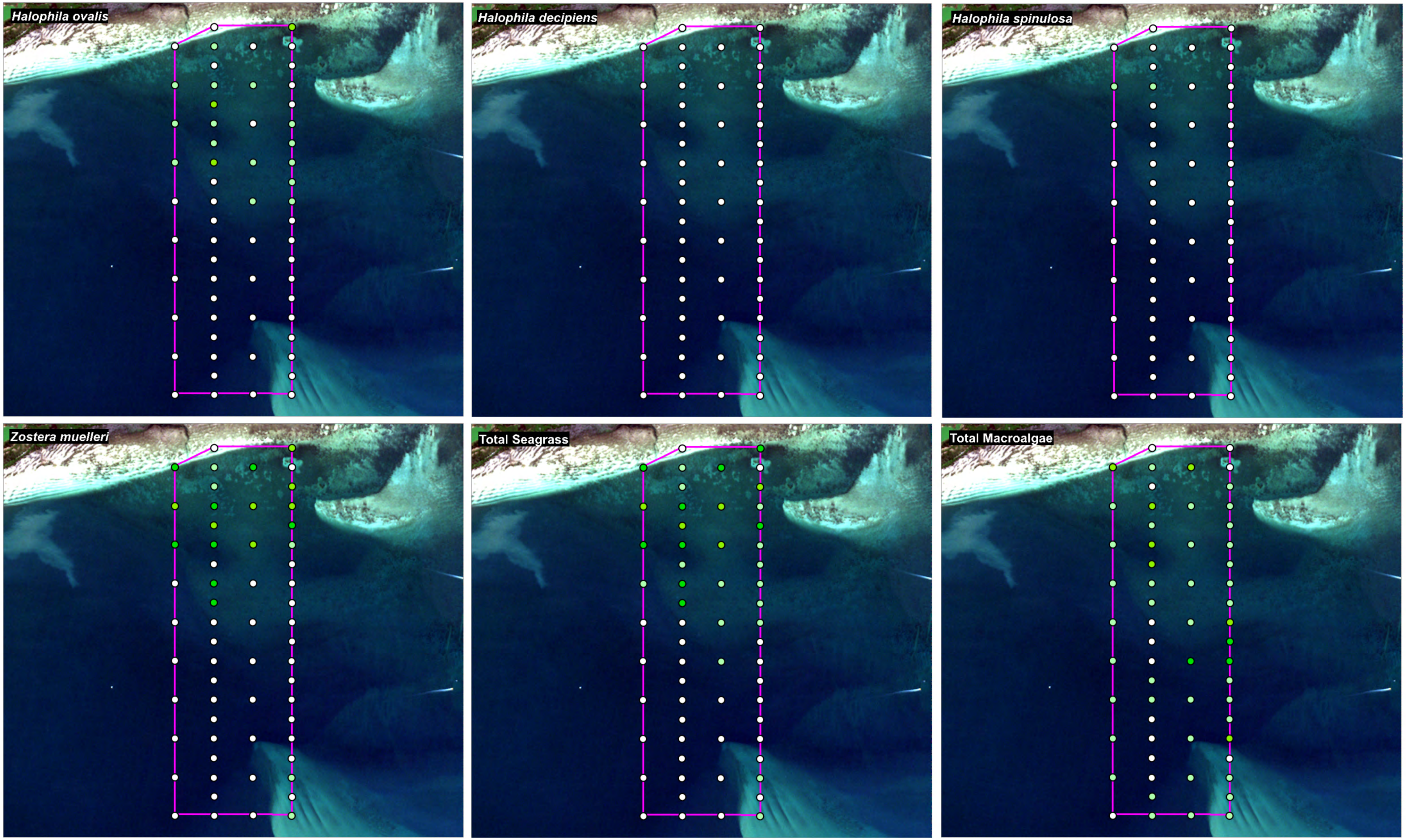
0 1 2km

Approx. scale

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Seagrass\ECO_002_200820_CI_percentage.WOR



LEGEND

Percent Cover

- 75 to 100
- 50 to 75
- 25 to 50
- 15 to 25
- 5 to 15
- 1 to 5
- 0 to 1

Study Area

Title:

Species Distribution at Deception Bay 2020

Figure: 3-4

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.

N

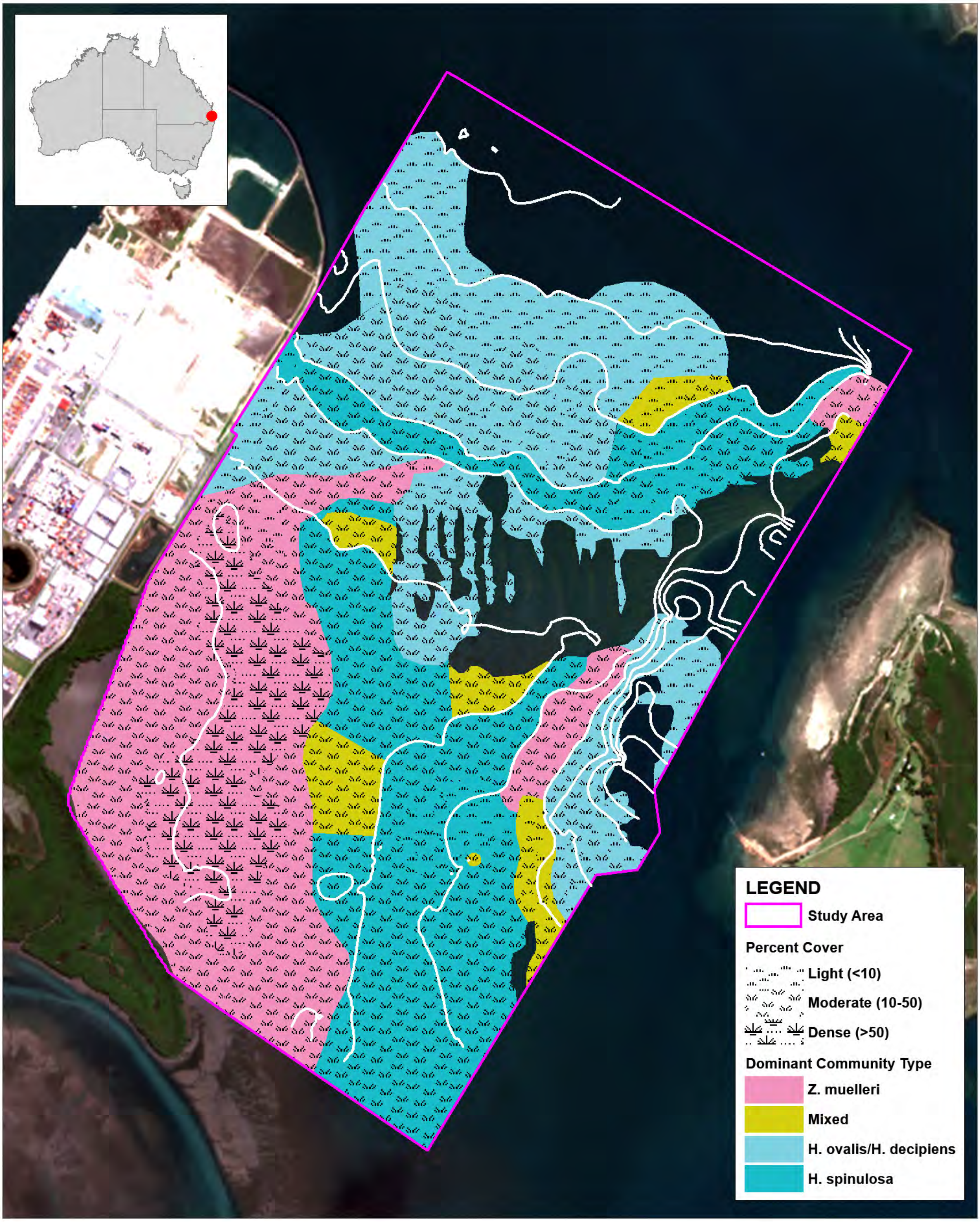
0 1 2km

Approx. scale

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Seagrass\ECO_004_200820_DB_percentage.WOR



Title:

Seagrass Distribution and Composition Adjacent to Fisherman Islands 2020, Showing 1m LAT Contours

Figure: 3-5

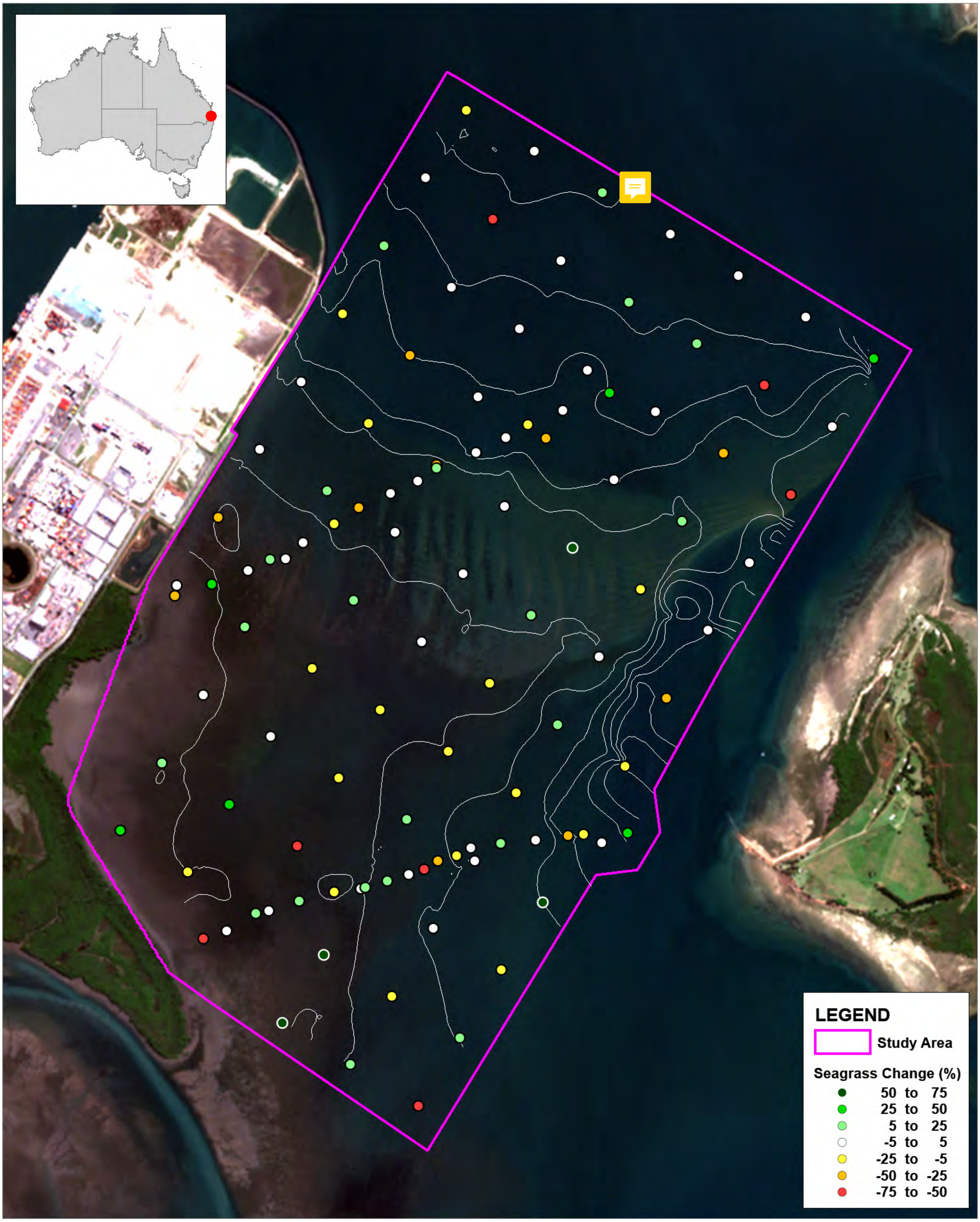
Rev: A

N

0 0.5 1km
Approx. scale

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Seagrass\ECO_005_200901_POB_CommMap.WOR



Title:
Changes in Total Seagrass Cover Between 2019 and 2020, Fisherman Islands

Figure: 3-6

Rev: A

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Seagrass\ECO_007_200902_PoB_Change.WOR

3.2 Seagrass Depth Range (SDR) and Assemblage Structure

Table 3-2 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 *H. 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.

Seagrass assemblage composition and percent cover for the depth transects is shown in Figure 3-7 for Fisherman Islands, Cleveland and Manly and Figure 3-8 for Deception Bay. The majority of the sites have a percent cover between the historical minimum and maximum.

The percentage cover of seagrass species at each location (i.e. grid and depth transect sites) against depth categories are shown in Appendix E.

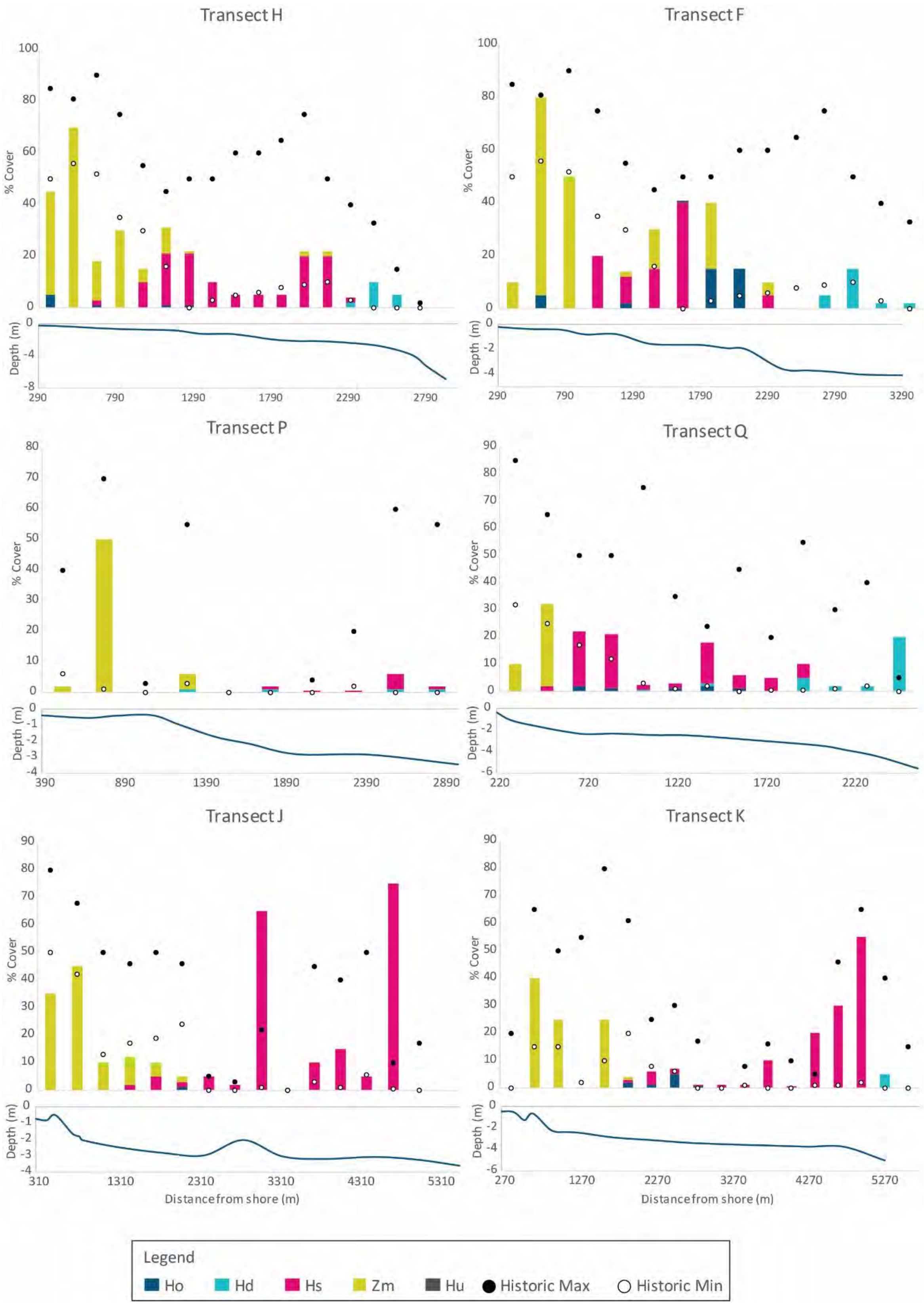


Figure 3-7 Percent cover distribution across depth transects at Fisherman Islands (H & F), Cleveland (P & Q) and Manly (J & K)

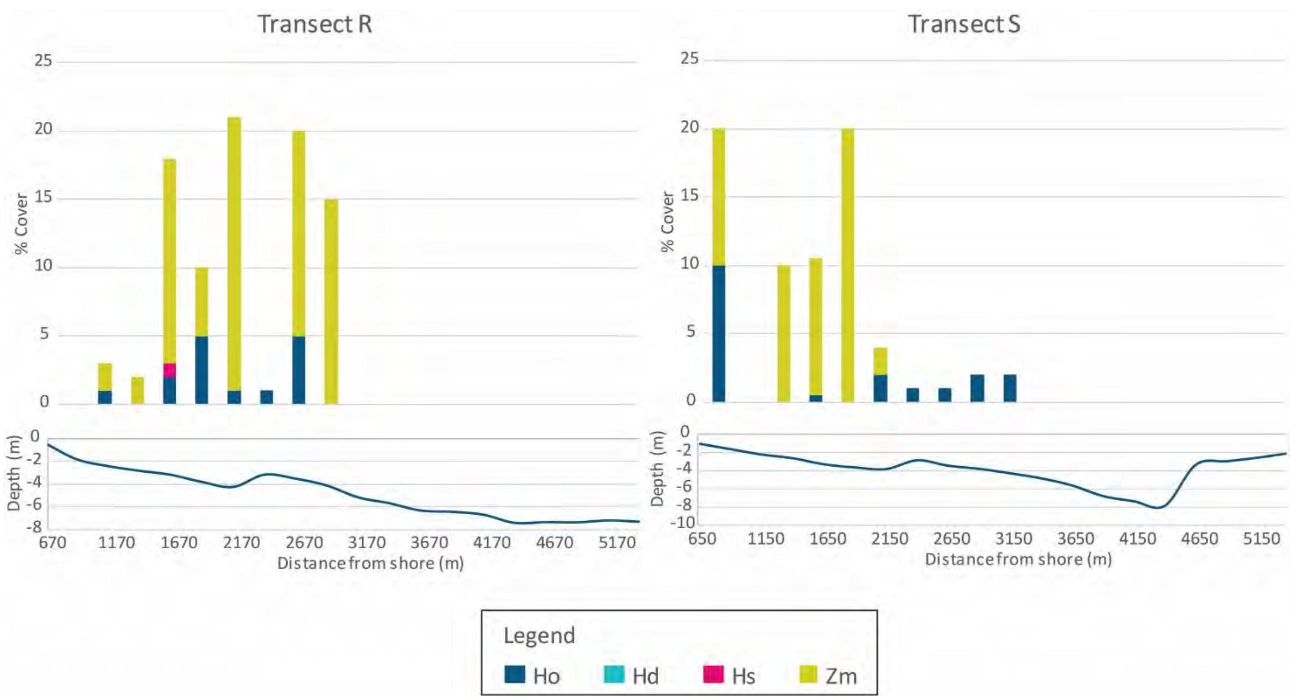


Figure 3-8 Percent cover distribution across depth transects at Deception Bay (R & S)

3.2.1 Spatial Patterns in 2020

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

- *Zostera muelleri* was observed at all locations, with the maximum depths at Fisherman Islands, Cleveland, Manly and Deception Bay of -2.3 m, -1.2 m, -2.1 m and -3.6 m (AHD) respectfully. At Fisherman Islands, Manly and Cleveland, average cover was highest within intertidal meadows (above LAT) than subtidal meadows (below LAT). The greatest depth recorded for *Z. muelleri* was -3.6 m AHD at Deception Bay. *Z. muelleri* formed mono-specific meadows or mixed assemblages with *H. spinulosa*.

- *Halodule uninervis* was not observed at any study sites, where it was previously observed at both Cleveland and Fisherman Islands predominately between -1 m and -2 m LAT in mixed communities at low cover.

- *Halophila spinulosa* was observed at moderate densities at all locations with a maximum depth of -2.8 m, -3.5 m, -3.8 m and -2.8 AHD at Fisherman Islands, Cleveland, Manly and Deception Bay respectively. This species was present at a variety of depths and community compositions, found predominately between -1 m and -4 m AHD.

- *Halophila ovalis* was present at all sites in a range of depths and formed predominately mixed communities with *Z. muelleri* and *H. spinulosa*. The depths that had *H. ovalis* present were: 0 m to -2 m, -2 m to -3 m, -1.5 m to -2.5 m, -1 m to -4 m AHD at Fisherman Islands, Manly, Cleveland and Deception Bay respectively. The highest densities were generally found between -1 m and -3 m AHD.

- *Halophila decipiens* was observed at all locations and the maximum depth range was -5.4 m, -5 m and -5.7 m AHD at Fisherman Islands, Manly and Cleveland respectively. *H. decipiens* generally occurred between -3 m and -4 m AHD. The coverage was predominately sparse to moderate and was generally either in mon-specific stands or mixed communities with *H. spinulosa*.

3.2.1.1 Temporal Patterns

Table 3-2 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.

Zostera muelleri SDR, a key indicator of long-term patterns in water quality, showed complex spatial and temporal patterns. Figure 3-9 shows that:

- The SDR on Transect H rapidly recovered between 2013 and 2014, and continued to improve over time. In 2020 the SDR of Transect H recovered to 2018 levels after a slight decrease in 2019.
- The SDR on Transect F was variable between 2006 and 2018 but has remained relatively stable in 2019 and 2020.

The coefficient of variation (CoV) was calculated to assess the degree of temporal variability in seagrass SDR within transects (Table 3-2). The CoV was similar across all sites (-11 to -51), with a decreased in variation at Manly compared to 2019 (-16 to -80%).

3.2.1.2 SDR Water Quality Objective

The *Z. muelleri* SDR water quality objective (WQO) for Waterloo Bay (Figure 3-9) 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 3-2):

- Fisherman Islands Transect H (2010, 2014, 2016-18 and 2020) and F (2006, 2010, 2019 and 2020);
- Manly Transect J (2006, 2010, 2016, 2018, 2019 and 2020) and K (2006, 2010, 2014, 2016, 2017, 2019 and 2020);
- Cleveland Transect P (2019); and
- Deception Bay Transect R (2020) and Transect S (2020).

In 2020 the SDR met WQO at the same number of sites as the 2019 survey.

[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 3-2 Comparison of SDRs (maximum recorded depth m AHD) of seagrass on permanent transects at each location from 2006 to 2020

Location	Transect	Species*	2006	2010	2013	2014	2016	2017	2018	2019	2020	Mean	CoV
Cleveland	P	Ho	-5.9	-6.4	-6.2	-4.8	-3.6	-3.3	-2.1	-3.6	Absent ↓	-4.5	-35
		Hd			-5.1	-6.4	Absent	Absent	-4.4	Absent	-3.4 ↑	-5.3	-23
		Hs	Absent	-3.4	-3.5	-4.8	Absent	-0.9	Absent	-3.1	-3.4 ↑	-3.2	-40
		Zm	-1.3	-0.8	-0.6	-0.7	-0.7	-0.9	-1.7	-1.9	-0.5 ↓	-1.0	-52
	Q	Ho	-5.7	-6.2	-5.7	-2.7	-2.5	-5	-2.4	-2.8	-2.5 ↓	-3.9	-42
		Hd			-4.6	-4.6	-5.9	Absent	-5.6	-5.8	-5.7↔	-5.5	-11
		Hs	-3.2	Absent	-3.7	-4	-2.9	-3.3	-2.6	-3.1	-3.5↑	-3.3	-13
		Zm	-0.6	-1.5	-1.8	-1.4	-1	-1.4	-1.2	-1.8	-1.2	-1.3	-29
Manly	J	Ho	-2.2	-4.9	-4.5	-2	-2.1	-2.9	-2.1	-3.3	-2.1↓	-2.9	-38
		Hd			-4.5	-4.4	-3.5	-4.8	-4.5	Absent	Absent	-4.1	-23
		Hs	-2.6	-4	-3.4	-3.4	-4.1	-3.4	-4.5	-4.8	-2.1↓	-3.6	-24
		Zm	-2.2	-2.3	-1.6	-1.5	-2.1	-1.6	-2.1	-1.9	-2.1↑	-1.9	-15
	K	Ho	-0.4	-8.8	-5	-2.1	-2.2	-2.4	-1.8	-7.9	-2.5↓	-3.7	-79
		Hd			-5	-3.7	-4	-5.3	-7.7	-4.1	-5↑	-4.9	-49
		Hs	Absent	-4.4	-4	-3.9	-2.2	-2.3	-3.9	-8	-3.8↓	-4.1	-44
		Zm	-2.1	-2.2	-0.4	-2.1	-2.2	-2	-0.7	-3.3	-2.1↓	-1.9	-46
Fisherman Islands	F	Ho	-3.8	-5.7	-2.2	-2	-1.8	-4.7	-1.6	-5.1	-1.9↓	-3.2	-51
		Hd			Absent	-4	-4.1	-4.3	-4.1	-4.2	-4.1↔	-4.3	-14
		Hs	-3.8	-4.3	-2.2	-1.6	-1.8	-3.8	-2.0	-5.1	-2↓	-3.0	-44
		Zm	-2	-2.5	-1.8	-1.7	-1.6	-1.7	-1.4	-2.1	-2↔	-1.9	-17
		Hu	Absent	Absent	Absent	Absent	Absent	Absent	-2.0	-1.6	Absent	-1.8	-14
	H	Ho	-2.6	-4.6	-2.5	-2.4	-2.4	-5.5	-2.2	-4.4	-1.2↓	-3.1	-45
		Hd			-2.9	-5.1	-5	Absent	-7.2	Absent	-5.4↑	-5.1	-30
		Hs	-2.5	-2.3	-2.5	-2.4	-3	-2.5	-3.9	-4.7	-2.8↓	-3.0	-27
		Zm	-1.3	-2.3	-1.5	-2.4	-2.4	-2.5	-2.2	-1.7	-2.3↓	-2.1	-22
		Hu	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-2.8	Absent↓	-2.8	-
Deception Bay	R	Ho	-	-	-	-	-	-	-	-	-4.2	-	-
		Hs	-	-	-	-	-	-	-	-	-2.8	-	-
		Zm	-	-	-	-	-	-	-	-	-3.5	-	-
	S	Ho	-	-	-	-	-	-	-	-	-3.8	-	-
		Zm	-	-	-	-	-	-	-	-	-3.6	-	-
12-month Rainfall (mm)[1]			851	871	1159	582	731	643	955.6	667	934		

SDR relative to historical maximum: Max | 99-80% max | 79-50% max | 49-20% max | <20% max | Absent

Trend since 2019: ↑ improvement, ↔ stable (within 0.1 m of 2019), ↓ 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 species.*

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)

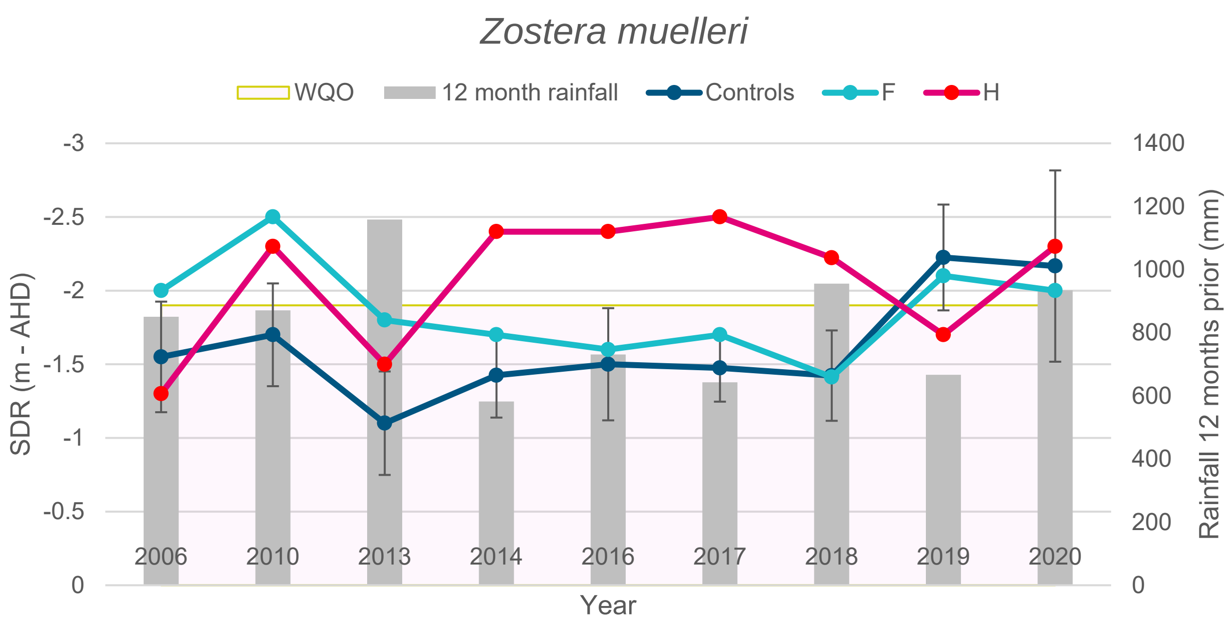


Figure 3-9 *Zostera muelleri* seagrass depth range for Transect F and H at Fisherman Islands and the average (±SE) for control sites. Rainfall in the 12 months leading to the survey is also shown (BoM station number 040913 – Brisbane)

4 Discussion

4.1 Overview

Consistent with 2019 results, the SMP provides the basis to draw out 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 in subtidal waters, but more dynamic near the landward margin.

(4) Sparse *Halophila* species meadows extend to depths down to -8 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 (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 2019 study.

4.3 Spatial and Temporal Patterns in Assemblages

Overall, seagrass meadows at Fisherman Islands slightly decreased in extent between 2019 and 2020 by 0.8 km^2 to 14 km^2 in 2020. This range reduction was seen in the loss of sparse *H. uninervis* on the central shoal and the loss of low density *Halophila* in a few of the deeper study sites. This is different to the trends observed in previous years of a long-term seagrass meadow expansion at this location (Figure 4-1), notwithstanding changes to study area boundaries and survey methodologies over time. Seagrass meadow extent mapping is limited by both the grid spacing and ability to detect sparse seagrass communities in deep water.

LEGEND

Study Area

Seagrass Meadow Extent

Title:

Seagrass Meadow Extent between 2013-20

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.

N

0 1 2km

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4.3.1 *Halophila*

In 2020, there was a slight contraction in *H. ovalis* at Fisherman Islands and Manly in the deeper extents of the study area while *H. ovalis* was not observed at any sites in Cleveland. *Halophila ovalis* was observed in the shallow subtidal ranges of Deception Bay, while *H. decipiens* was not present at this site. *Halophila decipiens* was relatively stable between 2019 and 2020 at Fisherman Islands while Cleveland and Manly observed a slight decrease in the number of sites that *H. decipiens* was present. *Halophila spinulosa* extent at Fisherman Islands, Cleveland and Manly was consistent between 2019 and 2020. *H. spinulosa* was observed in very low percentage cover in at Deception Bay.

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).

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.

4.3.2 *Halodule*

Halodule uninervis was not present at any sites, which is a reduction from the presence at some Fisherman Islands and Cleveland sites during the 2019 survey.

4.3.3 *Zostera*

Zostera muelleri predominately occurred in intertidal and shallow waters of the study area (landward of 2.5 m AHD). *Zostrea 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 site locations, ranging from 0 m to -2.5 m AHD adjacent to Fisherman Islands, 0 m to -1.2 m AHD at Cleveland, -0.5 m to -2 m at Manly and -0.3 m to -3.7 m at Deception Bay. *Z. muelleri* depth range varied between 2019 and 2020, with a slight increase in depth at Fisherman Island and a slight decrease at Cleveland and Manly. 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 *Z. muelleri* 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.

SDR along the depth transects is varied between years at both Fisherman Islands and the control sites. Within the 2020 survey it was observed that Fisherman Island ad and Manly depth range was relatively stable while Cleveland observed a decrease on both transects.

Zostera muelleri depth range is more stable at Fisherman Islands (CoV -13 to -43) and Cleveland (CoV -10 to -49) than Manly (CoV -15 to -79). This suggests that Manly is more prone to disturbance compared to the other sites, which is consistent with the 2019 survey. SDR trends on transect H have differed from all other transects since 2014, where depth range increased on transect H and while the other transects were variable. This may be caused by a variety of factors, the major one being that transect H has a different bathymetric profile to the other transects. Transect H also extends towards St Helena Island which has a different sediment type, this may cause changes in the deeper extent of seagrass. Competition and differentiation during identification of *Z. muelleri* and *H. uninervis* may also be a contributing factor.

4.3.3.1 Decrease in Nearshore *Zostera muelleri*

The landward boundary of *Z. muelleri* meadows at Fisherman Islands is highly variable in time. An inspection of historical aerial photography, together with analysis of satellite imagery, suggests there was an overall retraction in the landward boundary of these meadows between 2019 and 2020 (Appendix D).

Intertidal seagrass meadows are subject to multiple stressors, including:

- Desiccation – desiccation due to exposure at low tide is the ultimate control on the landward margin of seagrass. Tidal planes are broadly consistent from year to year and are unlikely the main driver of inter-annual patterns in expansion-contraction.
- Physical disturbance by wave action and bait worm diggers can uproot and remove seagrass. Aerial photography indicates that bait worm diggers were not working in areas where seagrass retractions occurred and are unlikely the main driver of change. Several severe storm and wind events occurred in the period 2019-20 and may have contributed to seagrass removal.
- High temperatures, especially during low tide, can lead to dieback in intertidal seagrass meadows (Sozou and Rasheed 2018). The summer of 2019-20 was a particularly hot and dry period, and several record hot days occurred. BOM data indicates that the summer of 2019/2020 was hotter than the two previous summers (Figure 4-2).

It is hypothesised that heat stress was the main driver of declines in seagrass cover in the upper distribution limit. Further work would be required to test this hypothesis.

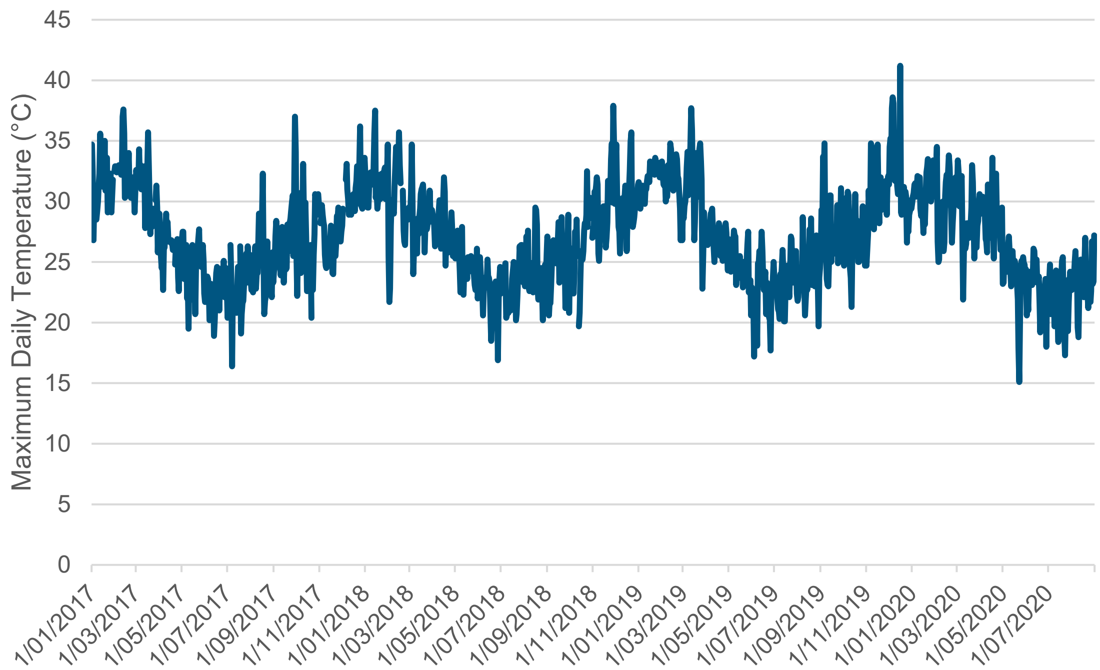

Figure 4-2 Maximum daily temperature between 2017 and 2020

4.3.4 Filamentous Algae and Other Macroalgae

The dominant algae type observed across the survey locations was filamentous algae, other macroalgae observed included *Hydroclathrus clathratus*, *Hypnea* and *Sargassum*. 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. Like seagrass, different macroalgae species show great variation in distribution and cover over time and space.

The average macroalgae cover was highest at Cleveland (6.6%) compared to Fisherman Islands (5.8%), Deception Bay (3%) and Manly (2.7%). However, the Fisherman Islands had the greatest proportion of sites with a recorded presence of macroalgae (65%) compared to Cleveland, Deception Bay and Manly (47%, 78% and 47% respectively). Macroalgae was present at a variety of depths at Fisherman Islands (0.5 m to -6.4 m AHD), Cleveland (-0.9 m to -7.5 m AHD), Deception Bay (-0.5 m to 8.3 m) and Manly (-0.9 m to -5.2 m AHD).

Cleveland has the greatest amount of hard substrate habitat in shallow water habitats that relate to the abundance of reef associated species such as *Sargassum*, *Hydroclathrus clathratus* and *Laurencia majuscule.* Fisherman Islands has shell and rubble fragments that provide substrate for macroalgae while Manly has the least macroalgae as a result of the absent of hard substrates.

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. *Caulerpa taxifolia* was recorded at Deception Bay in low abundance.

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, only the Q and P depth transects at Cleveland did not comply during the 2020 survey. Deception Bay had the highest rate of compliance (100%), although note that these transects have only been surveyed once. Out of the other sites Manly had the highest rate of compliance to the SDR WQO (71% followed by Fisherman Islands (56%) and Cleveland (11%). The non-compliance of Fisherman Islands is most likely due to local hydrodynamic conditions on the F transect, which is not favourable for *Z. muelleri* growth. The low compliance of Cleveland suggests that habitat quality for *Z. muelleri* is low.

WQO were met on more transects across the SMP than during any previous seagrass survey, this is most likely a result of prolonged drought that provides favourable seagrass growing conditions.

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, 2018, 2019). 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 Conclusion

The key findings of the 2020 are:

- Seagrass community composition remains relatively consistent with previous surveys, with *Z. muelleri* dominating intertidal habitat and *Halophila* dominating subtidal areas.
- Overall meadow extent decreased at Fisherman Islands in both the upper (i.e. intertidal) and lower (deep-water seagrass in the northern and eastern sectors) distribution limit.
- SDR was variable between 2019 and 2020 among and between sites.
- *Zostera muelleri* SDR WQO for Waterloo Bay was used as a benchmark to assess seagrass condition. Most transects complied with the WQO, the exception being Cleveland depth transects Q and P. This indicates that seagrass meadows are in good condition. It is likely that the prolonged drought conditions provide favourable seagrass growing conditions, as also observed during the Millennium drought.
- *Caulerpa taxifolia* was abundant during the 2000's when *El Niño* conditions prevailed. Despite the dry conditions over the last year, *Caulerpa taxifolia* was only observed in low abundance Deception Bay.
- Filamentous algae was the most numerically abundant function group of algae at all sites, with a number of macroalgae species also present at the majority of sites.
- The results of the Port of Brisbane SMP suggest that there has been an overall long-term trend of seagrass meadow expansion 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

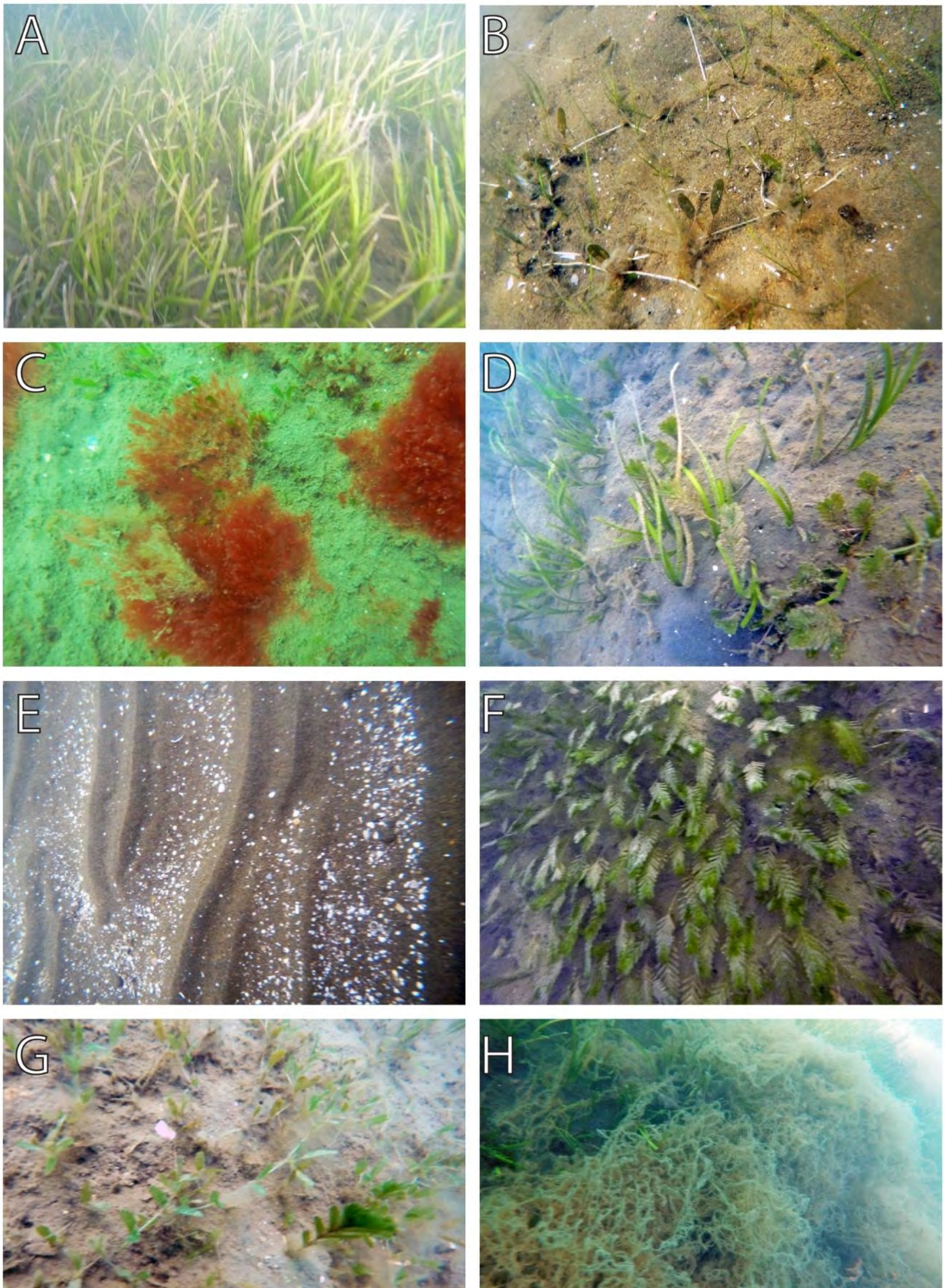


Figure A-1 Fisherman Islands: *Z. mulleri* (A), mixed seagrass community (B), algae and *H. decipiens*, mixed *Z. mulleri* and *H. spinulosa* community (D), bare shoal with shell grit (E); Manly: *H. spinulosa* (F), mixed community (G) and *Hydroclatharus* dominant community.

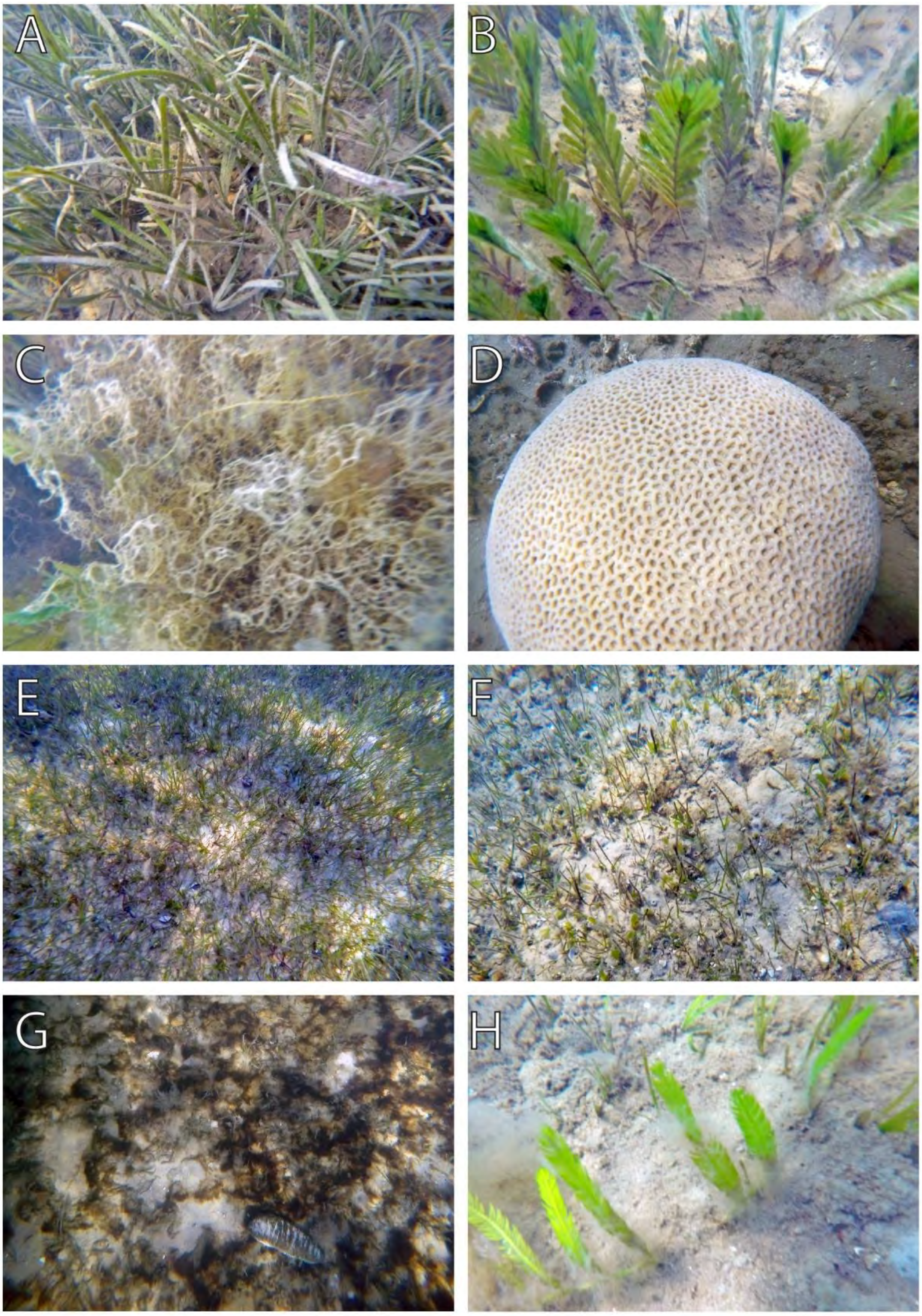
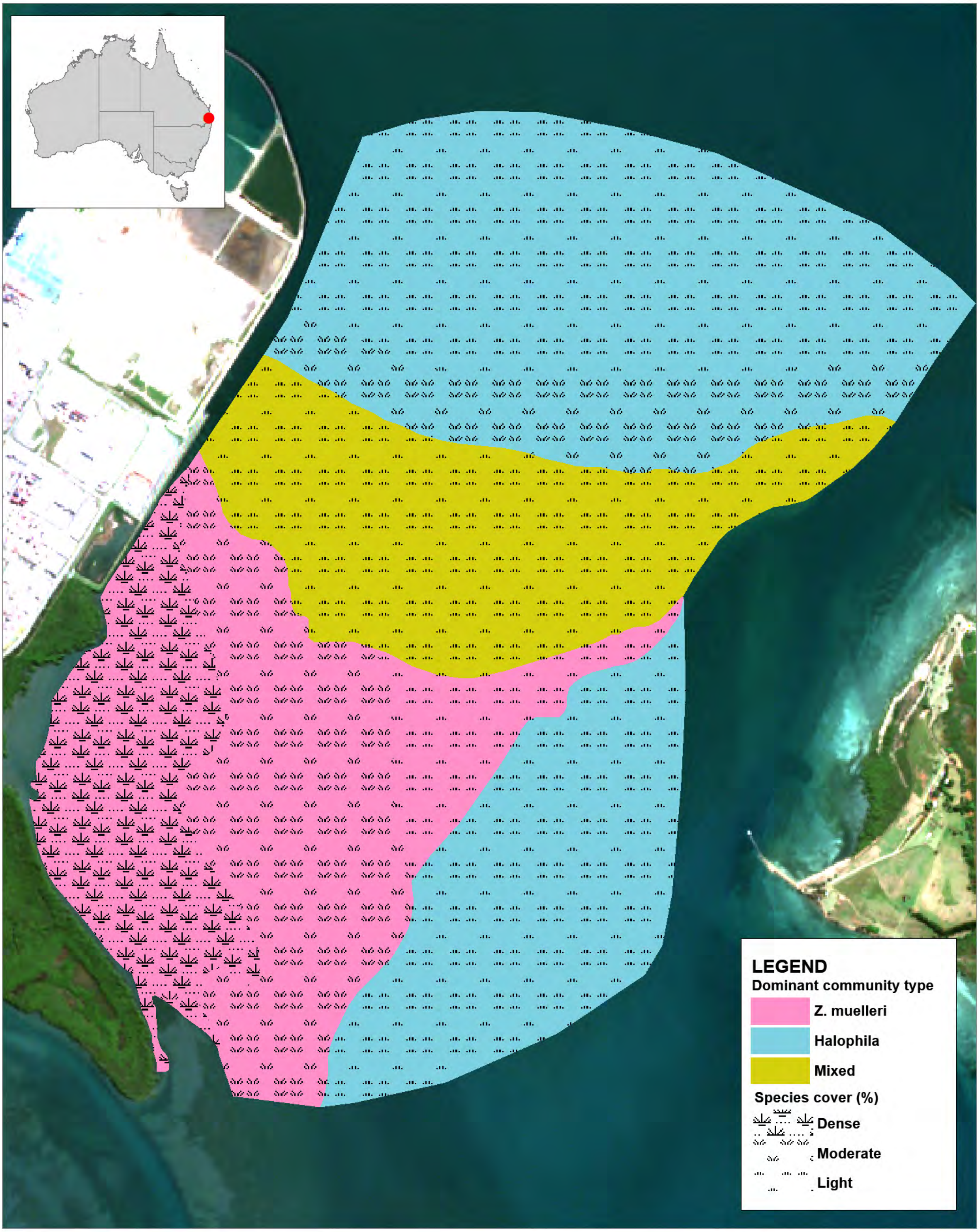


Figure A-2 Cleveland: *Z. muelleri* (A), *H. spinulosa* (B), *Hydroclatharus* (C), hard coral (*Favites*) (D); Deception Bay: *Z. muelleri* dominated mixed community (E), *Z . muelleri* dominated mixed community (F), algae dominated community and sea cucumber (G) and *Caulerpa* (H).

Appendix B Broad scale patterns in seagrass species distribution at the Port of Brisbane 2010, 2013, 2014-2019



Title:

Seagrass distribution and community structure adjacent to Fisherman Islands 2010

Figure: B-1

Rev: A

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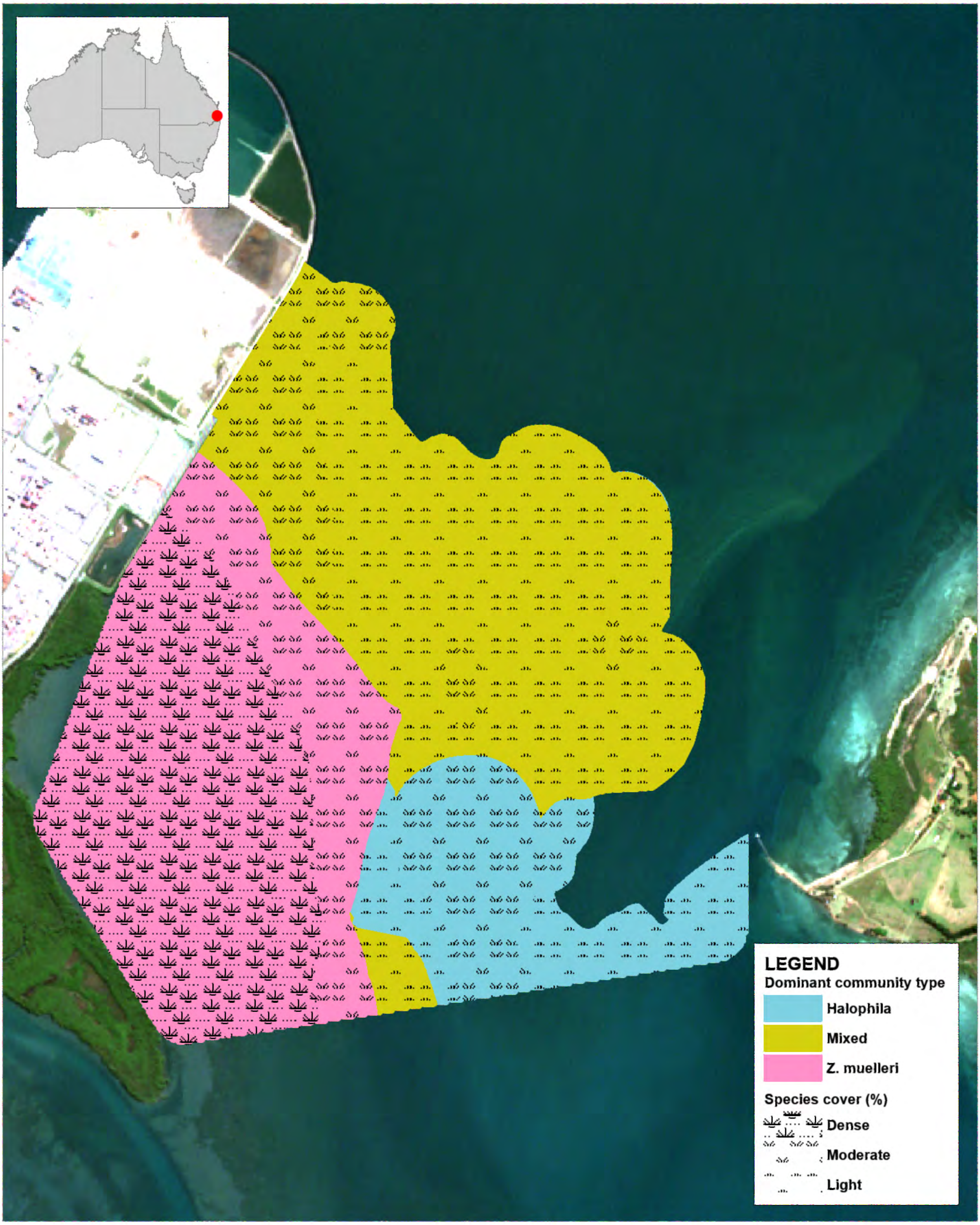

Title:

Seagrass distribution and community structure adjacent to Fisherman Islands 2013

Figure: B-2

Rev: A

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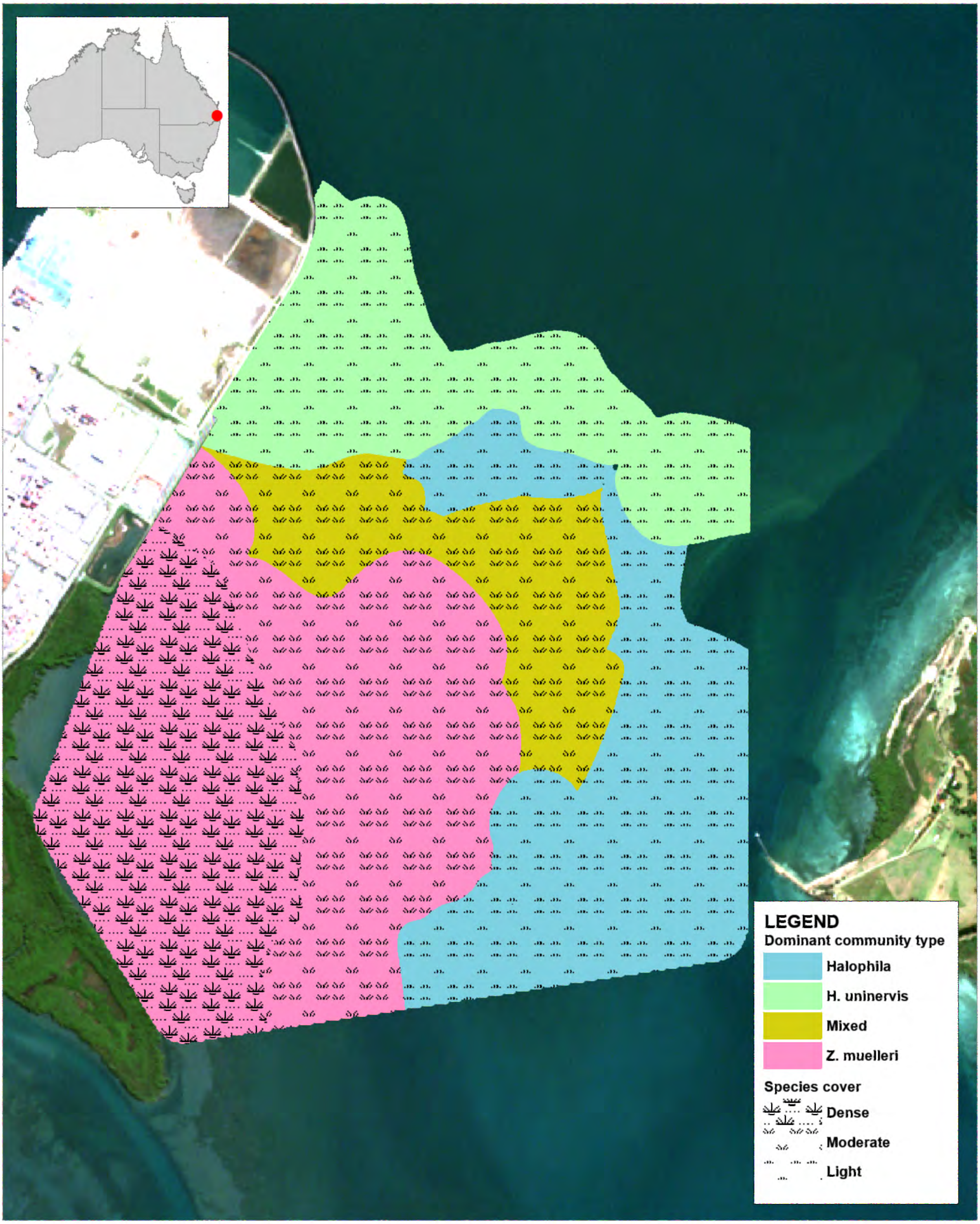

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Seagrass distribution and community structure adjacent to Fisherman Islands 2014

Figure: B-3

Rev: A

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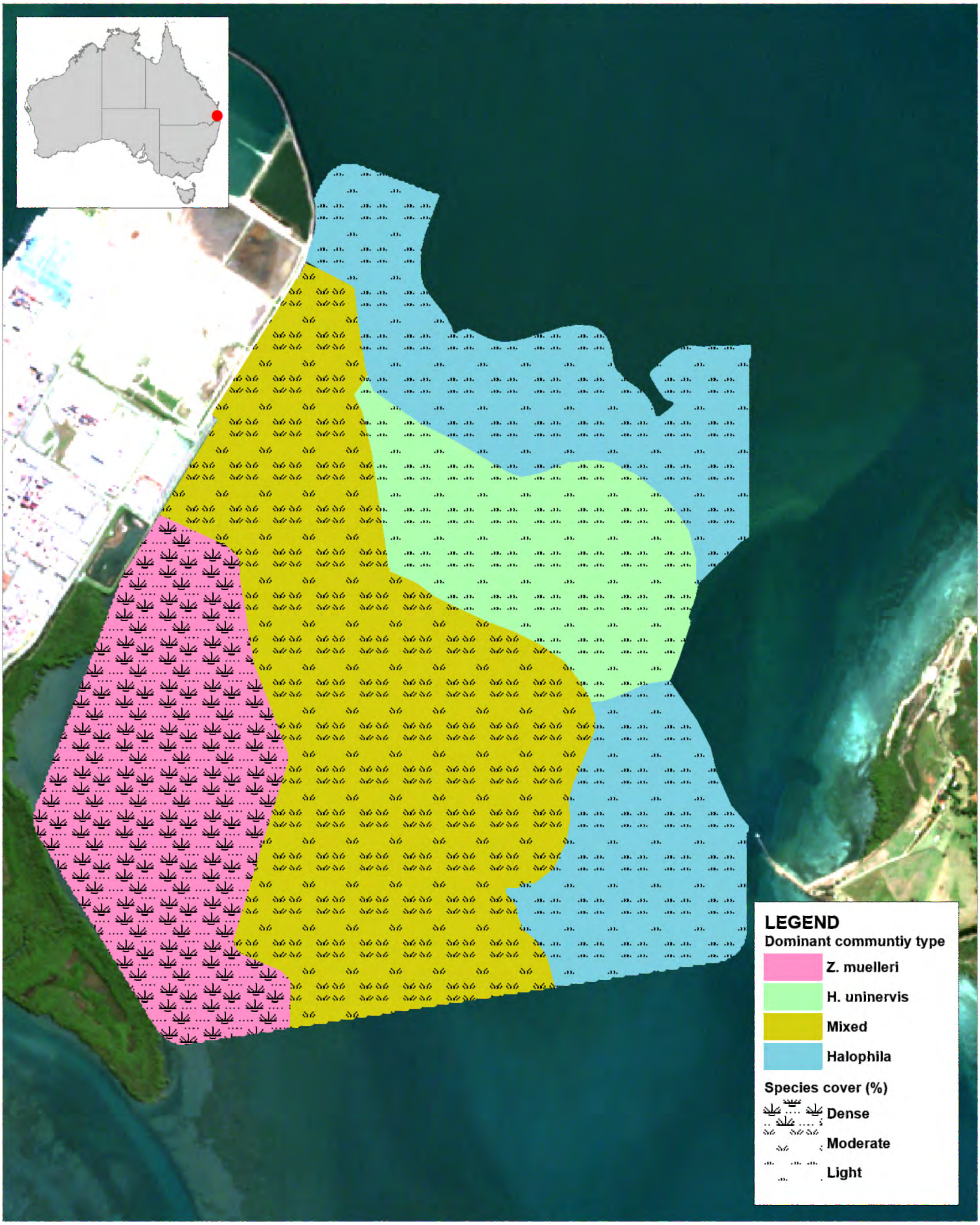

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Seagrass distribution and community structure adjacent to Fisherman Islands 2016

Figure: B-4

Rev: A

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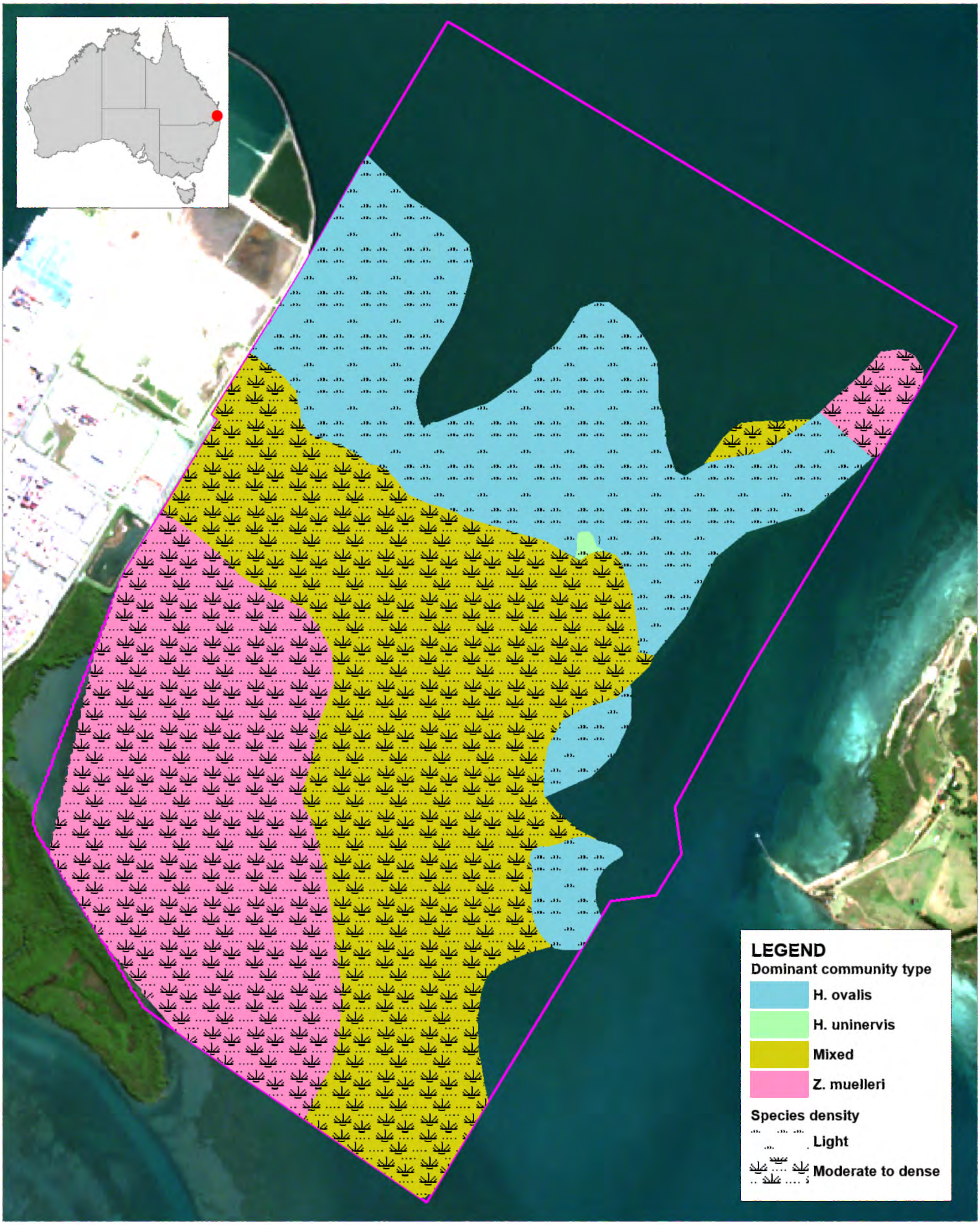

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Seagrass distribution and community structure adjacent to Fisherman Islands 2017

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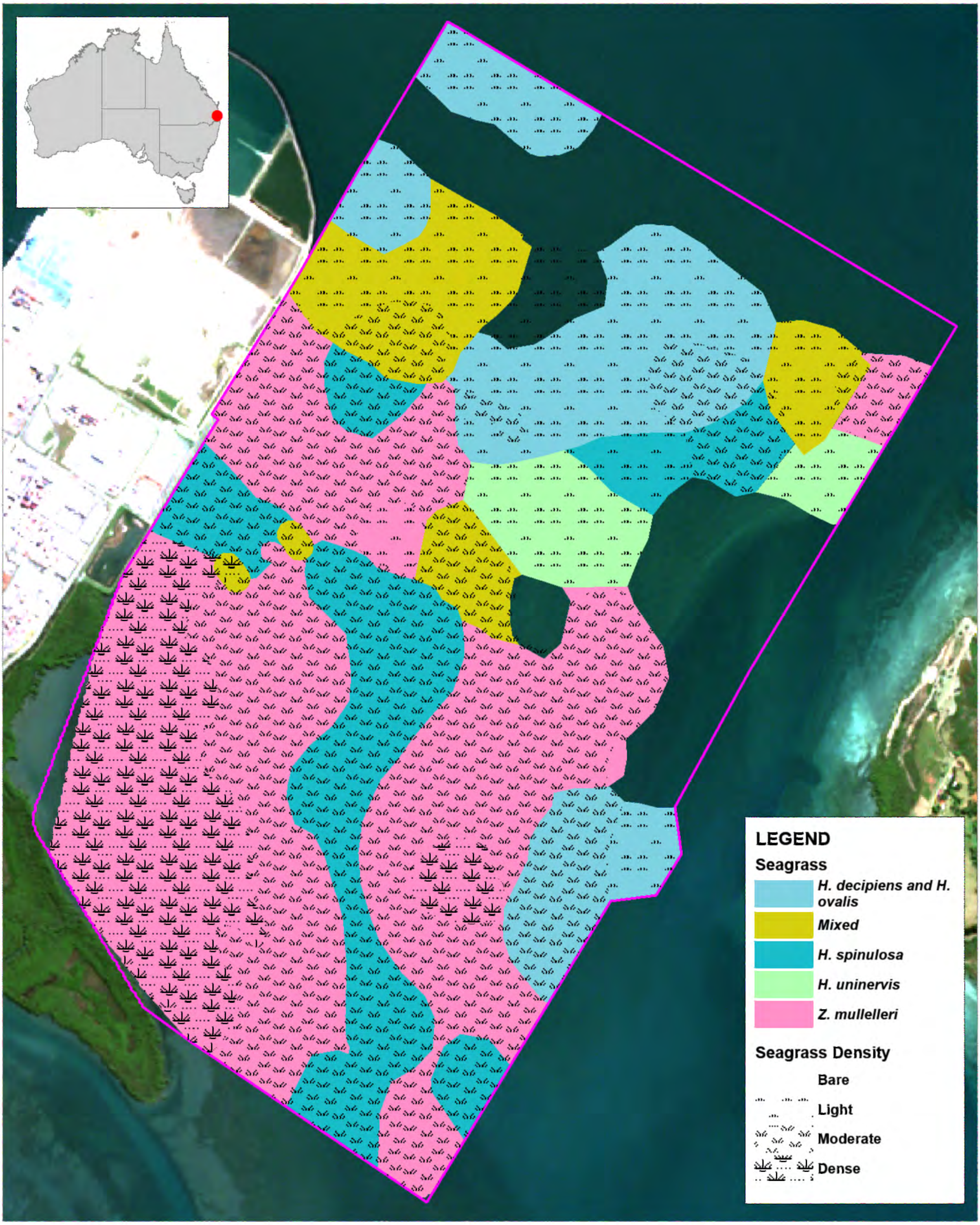

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Seagrass distribution and community structure adjacent to Fisherman Island, 2018

Figure: **B-6**

Rev: **A**

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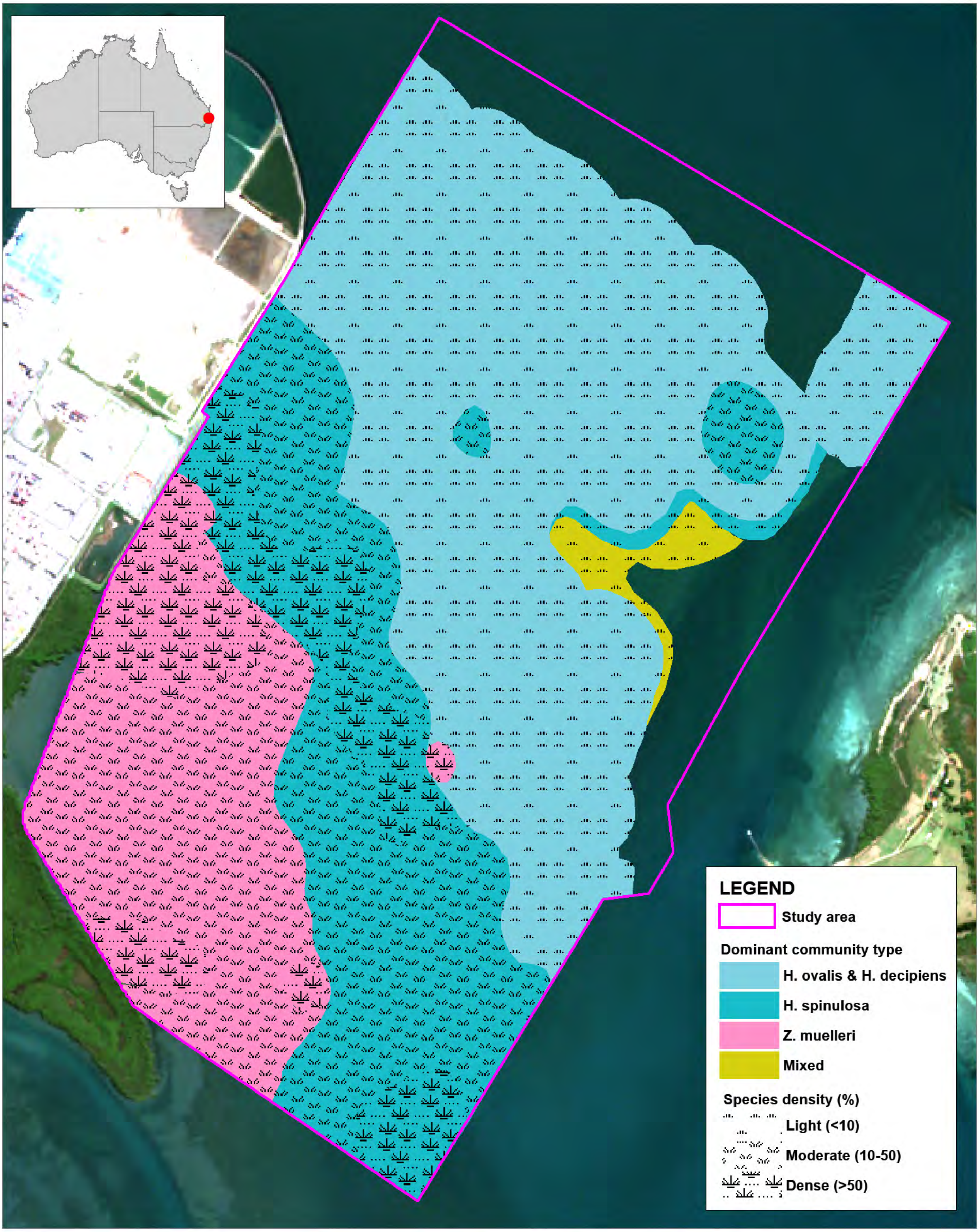

Title:

Seagrass distribution and community structure adjacent to Fisherman Islands 2019

Figure: **B-7**

Rev: **A**

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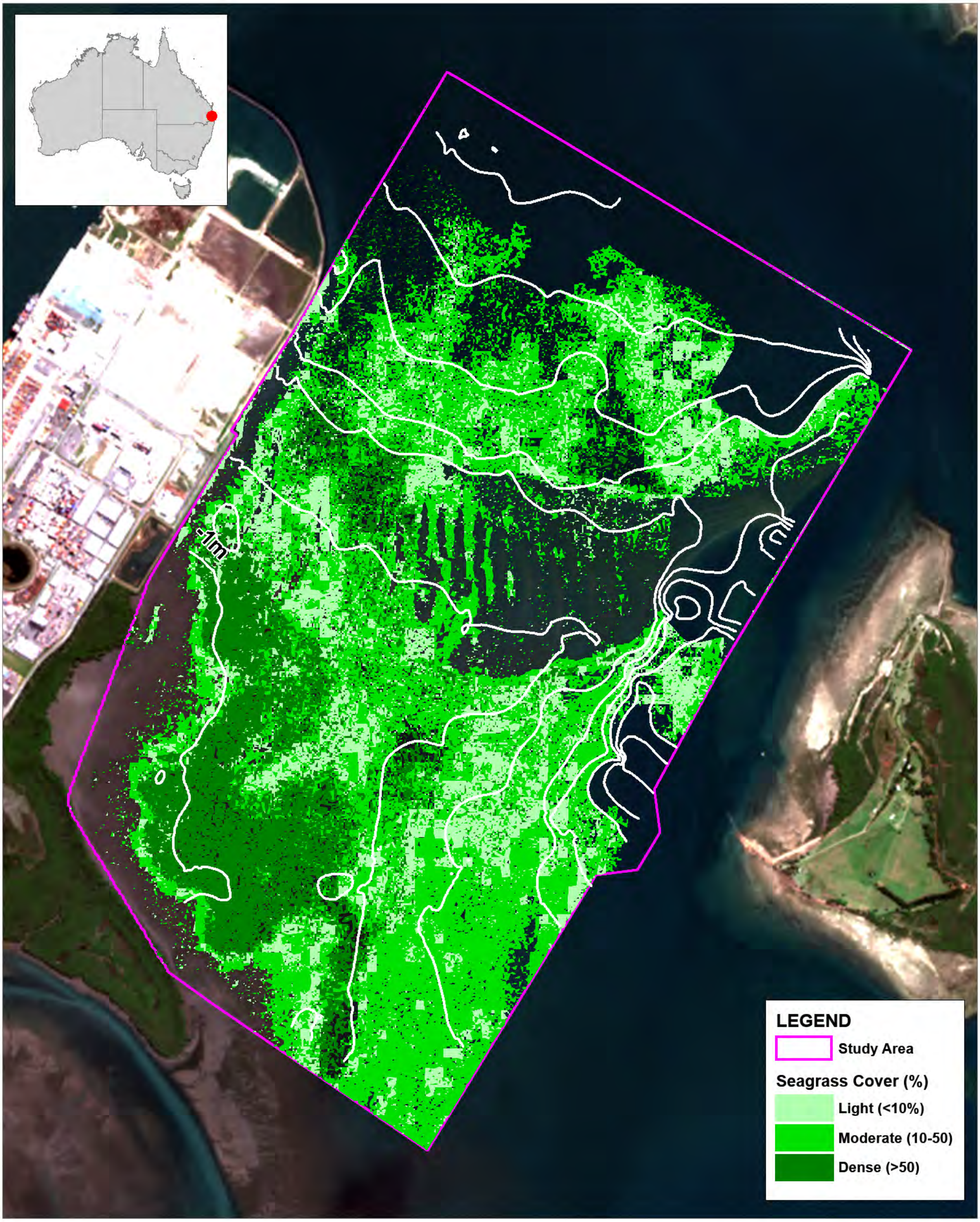
Appendix C Satellite Imagery Classification



Title:

Satellite Imagery Classification Adjacent to Fisherman Islands 2020, Showing 1m LAT Contours

Figure: C-1

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Appendix D Aerial Imagery

Figure D-1 Aerial imagery showing the gradual decrease in percent cover of inshore *Z. muelleri* adjacent to the Port of Brisbane (Nearmap)

Figure D-2 Aerial imagery showing the gradual decrease in percent cover of inshore *Z. muelleri* adjacent to Fisherman Island (Nearmap)

Appendix E Seagrass Percentage Cover – Depth Categories

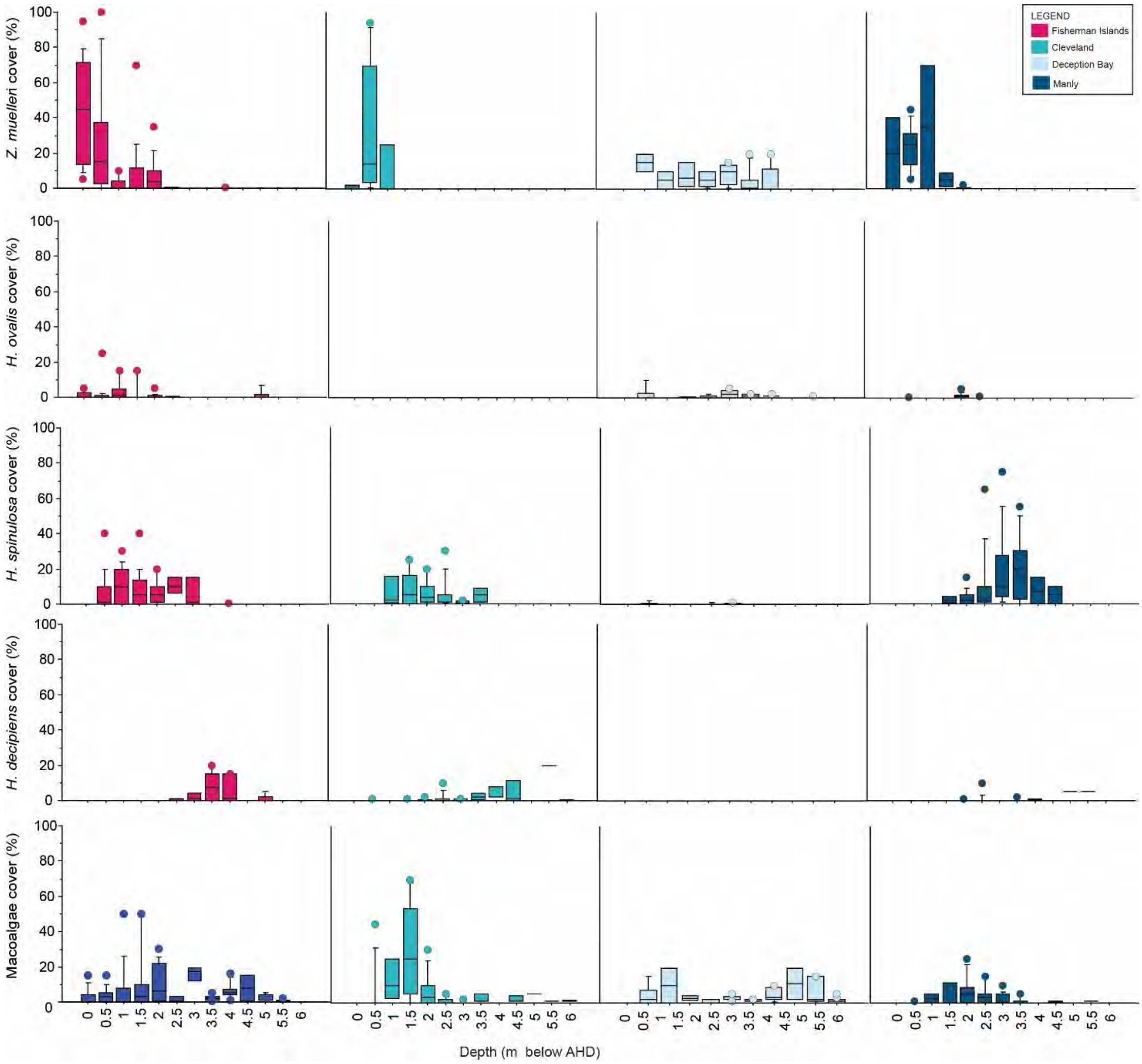

Figure E-1 Percent cover of species at each location and depth category

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