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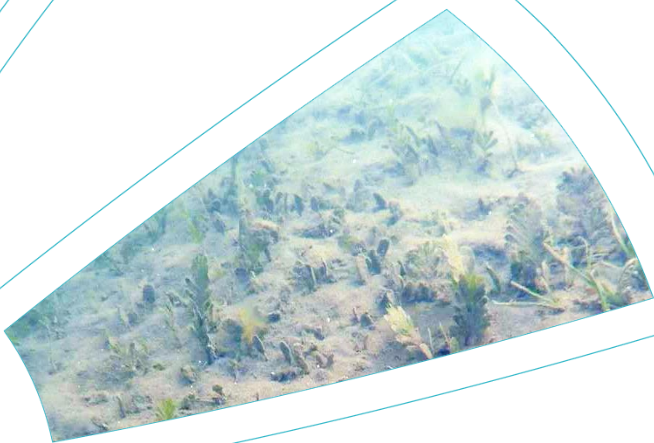
Port of Brisbane Seagrass Survey 2022



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Executive Summary

This report describes the approach and findings of the 2022 Port of Brisbane Seagrass Monitoring Program (SMP) event. The SMP monitors meadows at Fisherman Islands and control locations of Cleveland, Manly and Deception Bay using field-based (underwater video transects) and remote (aerial imagery) methodologies.

- Species composition: A core set of species occurred at all locations over time: the eelgrass *Zostera muelleri*, the paddle-weeds *Halophila ovalis*, *Halophila spinulosa* and (typically) *Halophila decipiens*. All four seagrass species were observed in the 2022 field surveys. A fifth species, the narrow-leaf seagrass *Halodule uninervis,* is an ephemeral species. This species has been periodically recorded in the survey area and was recorded in 2022.

- Spatial Patterns: Figure 1 is a map of seagrass meadows at Fisherman Islands in 2022. Intertidal and shallow subtidal areas were numerically dominated by *Zostera muelleri*, either as a monospecific meadows or a mixed meadows with one or more *Halophila* species sub-dominant. Subtidal meadows were comprised of mixed communities of *Halophila* and macroalgae species. Similar pattens in structure have been observed since the commencement of seagrass mapping in the 1980s.

- Subtidal Meadow Retraction in 2021-22: The seaward boundary of Halophila seagrass meadows contracted at all sites during this period. It is likely that major flooding during March 2022, and the associated sediment loading and reduced light availability, was the main driver of deepwater seagrass meadow losses.

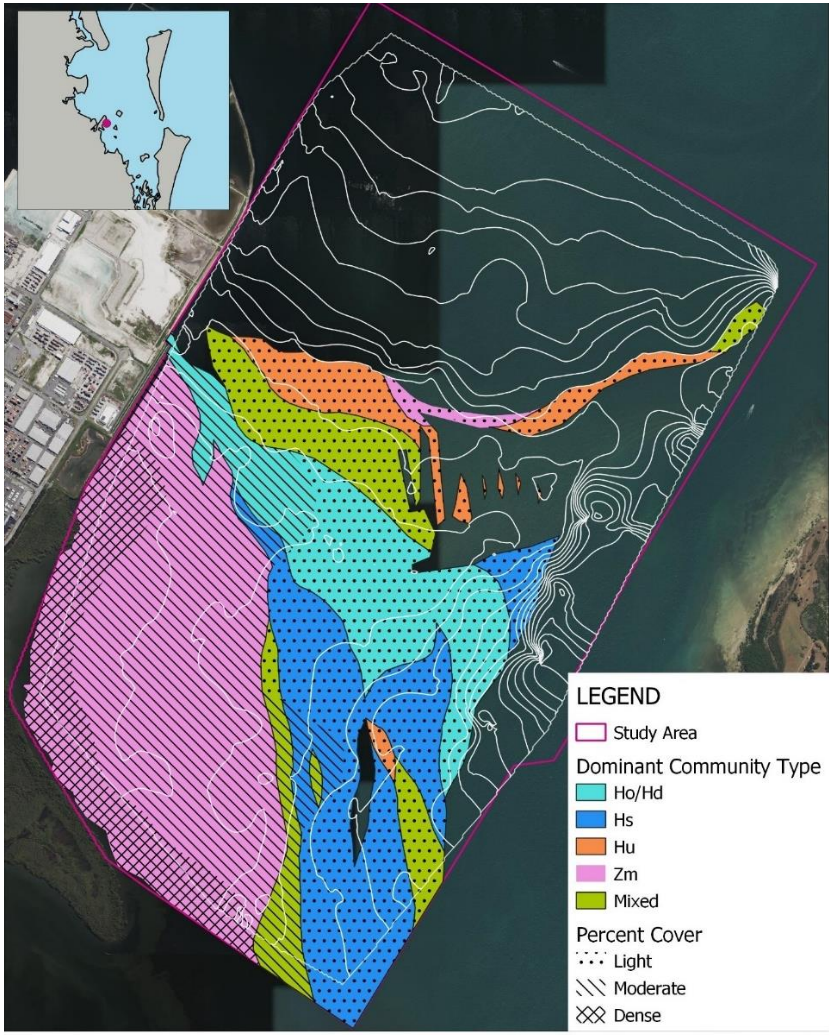

Figure 1. Seagrass Distribution and Composition Adjacent to Fisherman Islands 2021, Showing 1 m LAT Contours

- *Zostera* Depth Range Reductions in 2021-22: The maximum seagrass depth range (SDR) of *Zostera mulleri* also contracted in the monitoring period at all sites, most likely due to broad-scale reductions in light climate. SDR in 2022 was similar to levels recorded following major flooding in 2013 (Figure 2). Based on trends between 2013-21, *Zostera* meadow recovery would be expected to occur in the order of 2-6 years in the absence of further floodevents, varying among sites.

- Upper Limit of Seagrass Meadows. The landward margin of *Zostera muelleri* meadows expanded at Fisherman Islands between 2021 and 2022. It is hypothesised that lower than average maximum temperatures provided favourable seagrass growing conditions in shallow waters during 2021-22.

- Macroalgae Beds. A variety of macroalgae species were recorded, with the fleshy brown algae *Hydroclathrus and Sargassum,* and the red alga *Hypnea,* typically the most abundant. The native green alga *Caulerpa taxifolia* replaced large areas of seagrass in western Moreton Bay during 2000s, but has been sparse to absent since 2009. This species is intolerant of low salinity, and its disappearance from the study area coincided with major flood events (2010 and 2013).

- FPE Effects. Since the construction of the FPE, there has been a long-term trend of seagrass meadow expansion at Fisherman Islands. The long-term trend of seagrass meadow expansion is consistent with predictions of the Future Port Expansion Impact Assessment Study, which suggested that land reclamation would enhance growing conditions for nearby seagrass meadows.

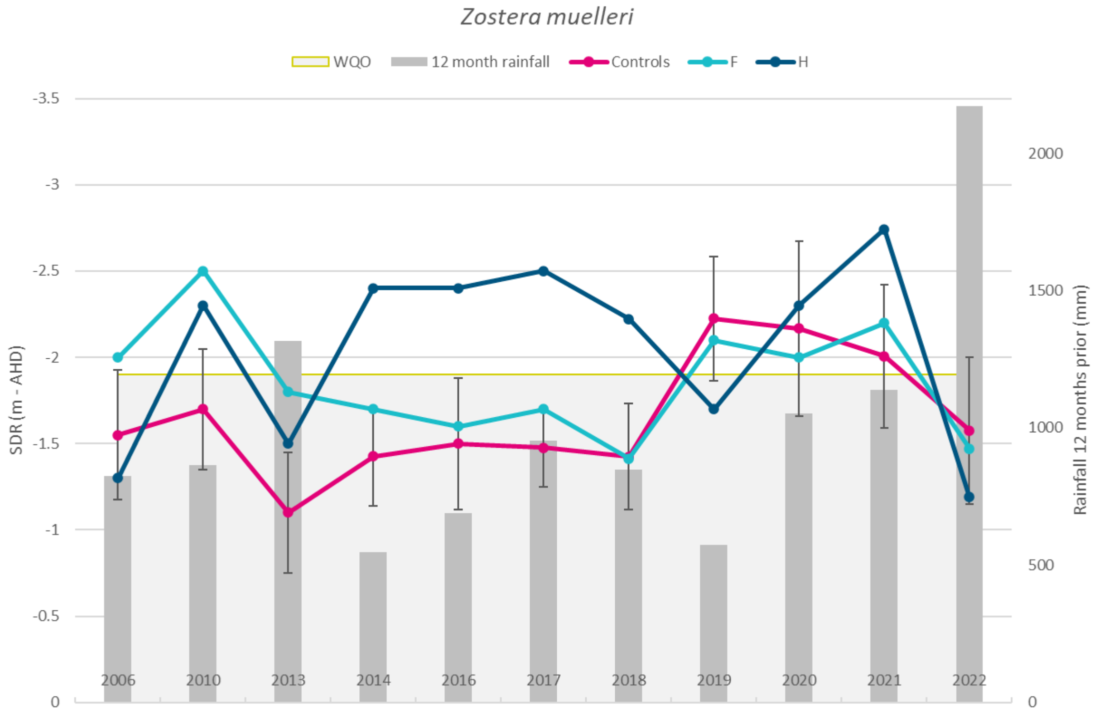

Figure 2. *Zostera* seagrass depth range at Fisherman Islands transect F and H, and the average (±SE) for control sites. Rainfall in the 12 months leading to the survey is also shown

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1 Introduction

1.1 Background

Moreton Bay contains a mosaic of marine habitats supporting 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, Cleveland and Deception Bay control locations;
- Spatial variations in seagrass extent and species distribution occurring at the four 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;

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

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

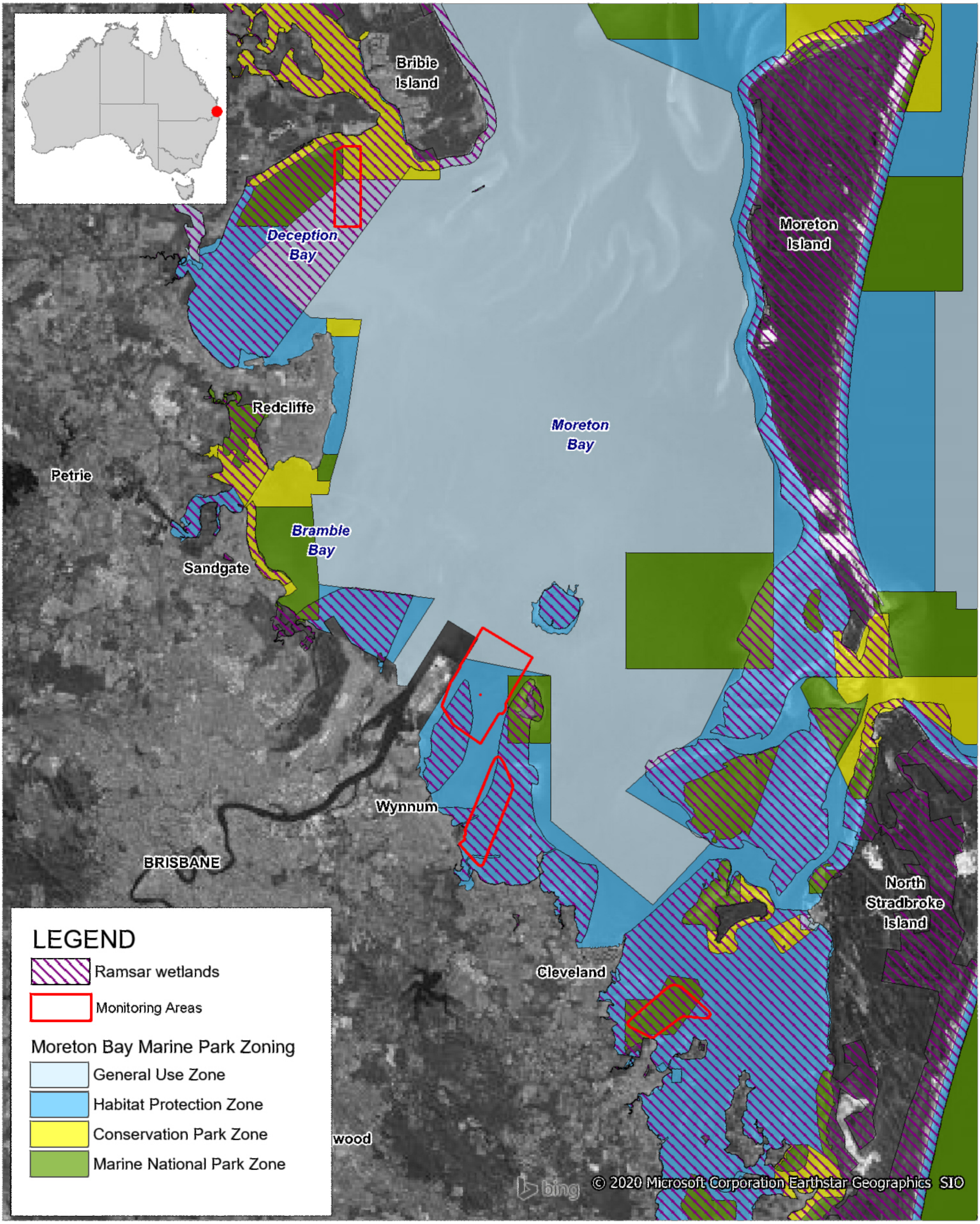
1.3 Study Area

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 southeastern 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 site 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 14 m (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 are located on the western foreshore of Moreton Bay at Manly, Cleveland and Deception Bay (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. Deception Bay was included as an additional site in the 2020 and 2021. Previous surveys of Deception Bay have characterised this seagrass community as light to moderate coverage consisting of the following species: *Zostera muelleri (subsp. capricorni)*, *Halodule uninervis*, *Halophila ovalis* and *Syringodium isoetifolium* (Kirkman 1975; OzCoasts 2004).



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Moreton Bay Ramsar Wetlands and Marine Park Zoning

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2 Methodology

2.1 Timing

Field sampling in 2022 was undertaken between the 30th of June to the 5th of July. 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).

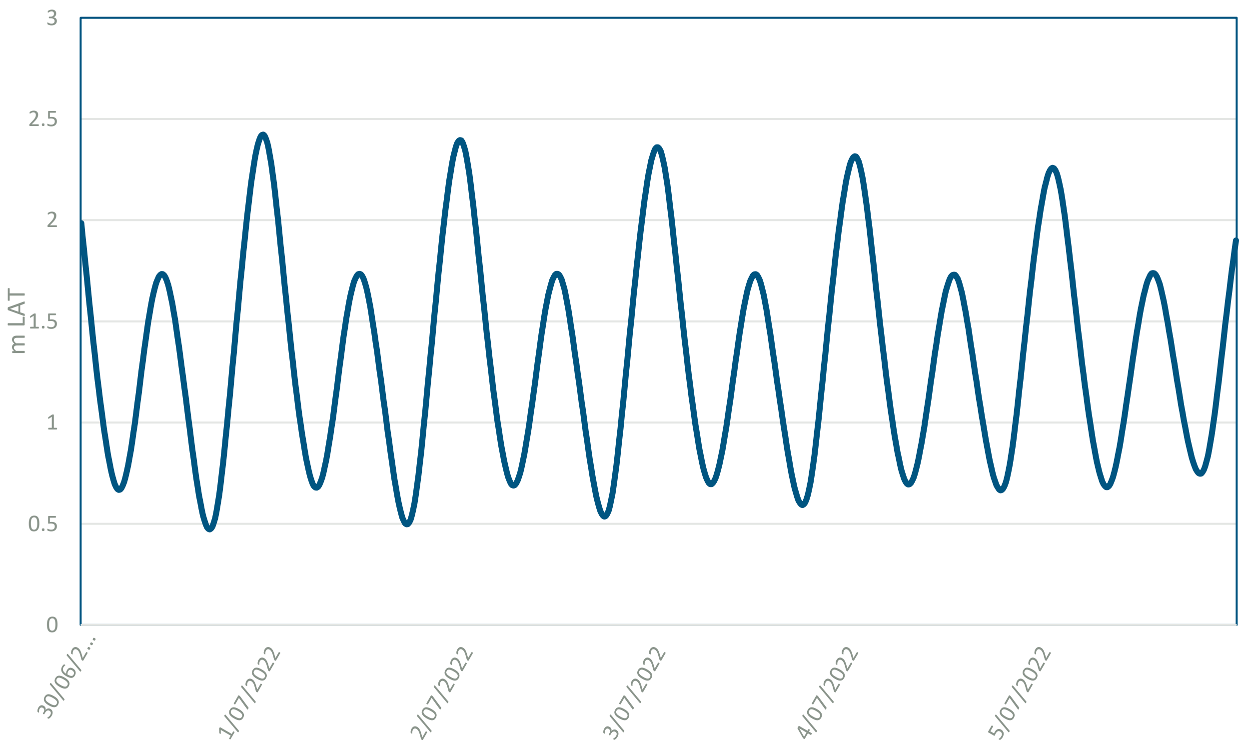


Figure 2.1 Tidal heights of Brisbane Bar during the 2022 survey

Figure 2.2 shows: (i) Average annual rainfall; (ii) cumulative 12 month rainfall for 2001-2022, and (iii) monthly rainfall, for the period 2001-22, together with mean annual maximum temperature for the period 1995-22.

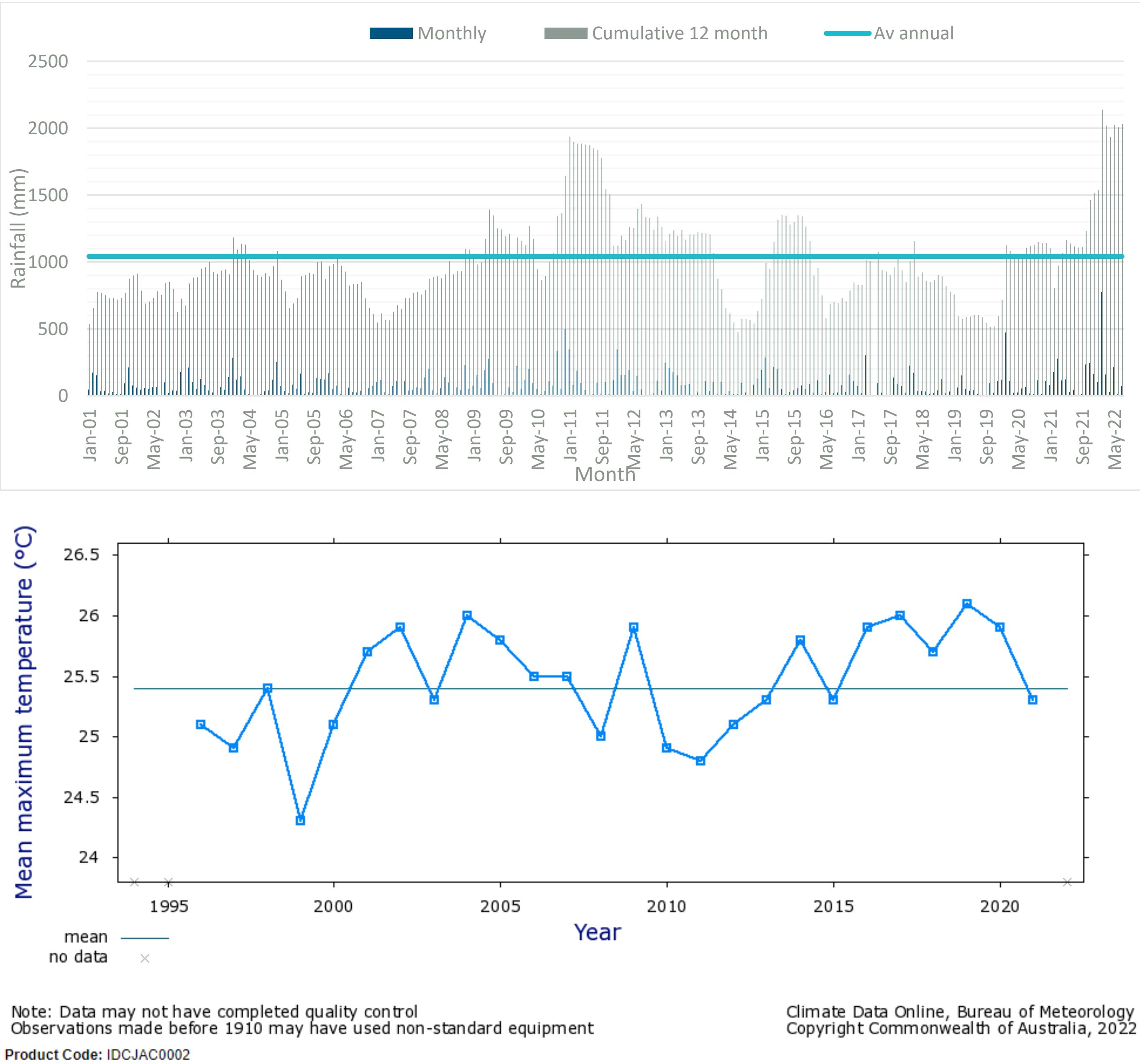


Figure 2.2 Monthly and 12 month cumulative rainfall from 2001 to 2022 (top) and annual mean maximum air temperature (bottom) at Brisbane Airport (Source: BoM station: 040842)

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 and 2021 (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.

Ground-truthing

Field sampling was conducted 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 2.3).

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, 2019 and 2020.

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

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

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 3.4. In addition, groupings of overall seagrass cover were used to provide context to the broad community categories described in Table 2.3.

Table 2.3 Broad seagrass density categories

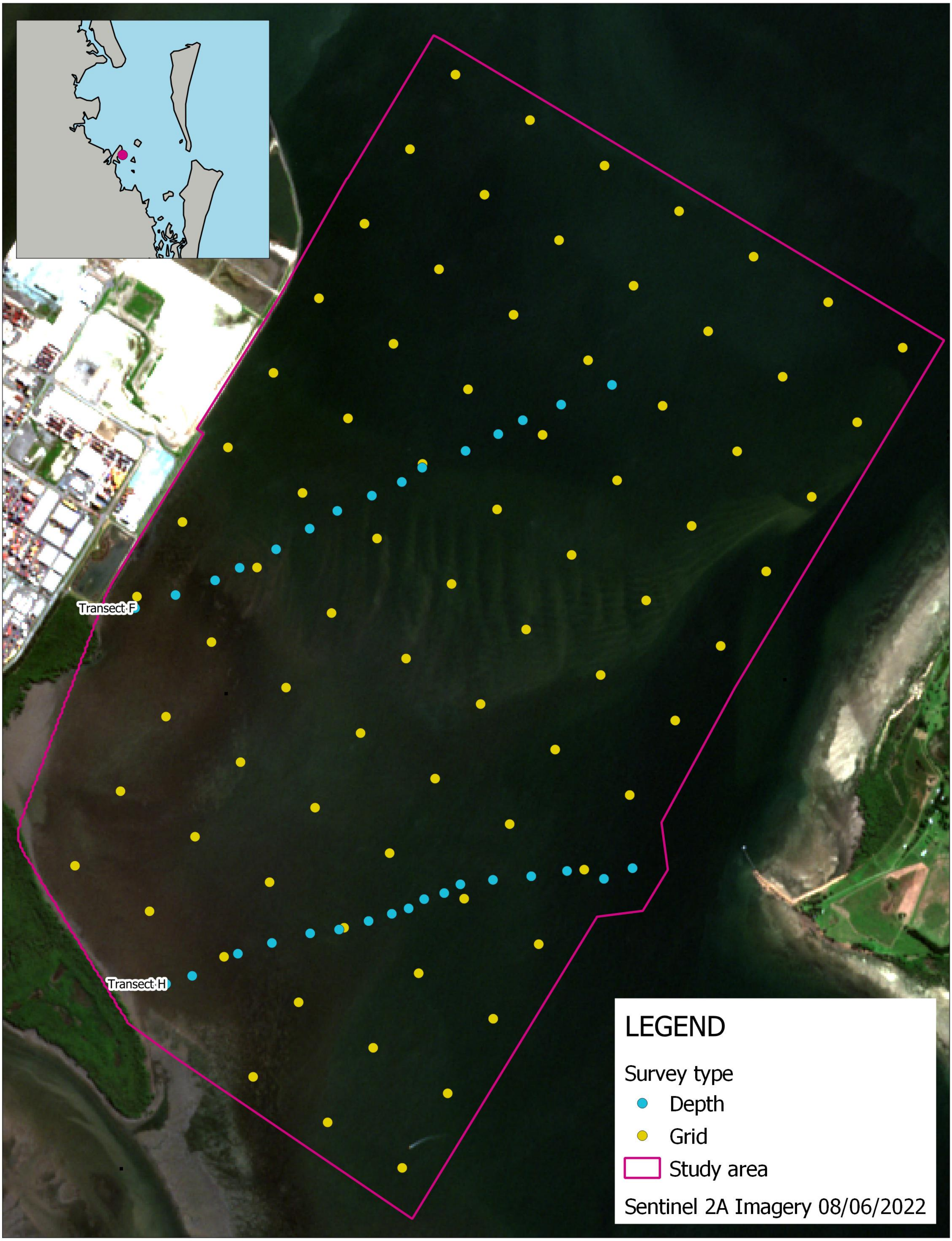
Density Category	Overall Cover (%)
Light	0-10%
Moderate	10-50%
Dense	>50%

Algae

Algae relative abundance was estimated for the following groups: (i) filamentous algae including epiphytic and turfing algae; and (ii) other macroalgae (non-filamentous). Abundant macroalgae species were documented.

2.5 Seagrass Meadow Extent Mapping

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



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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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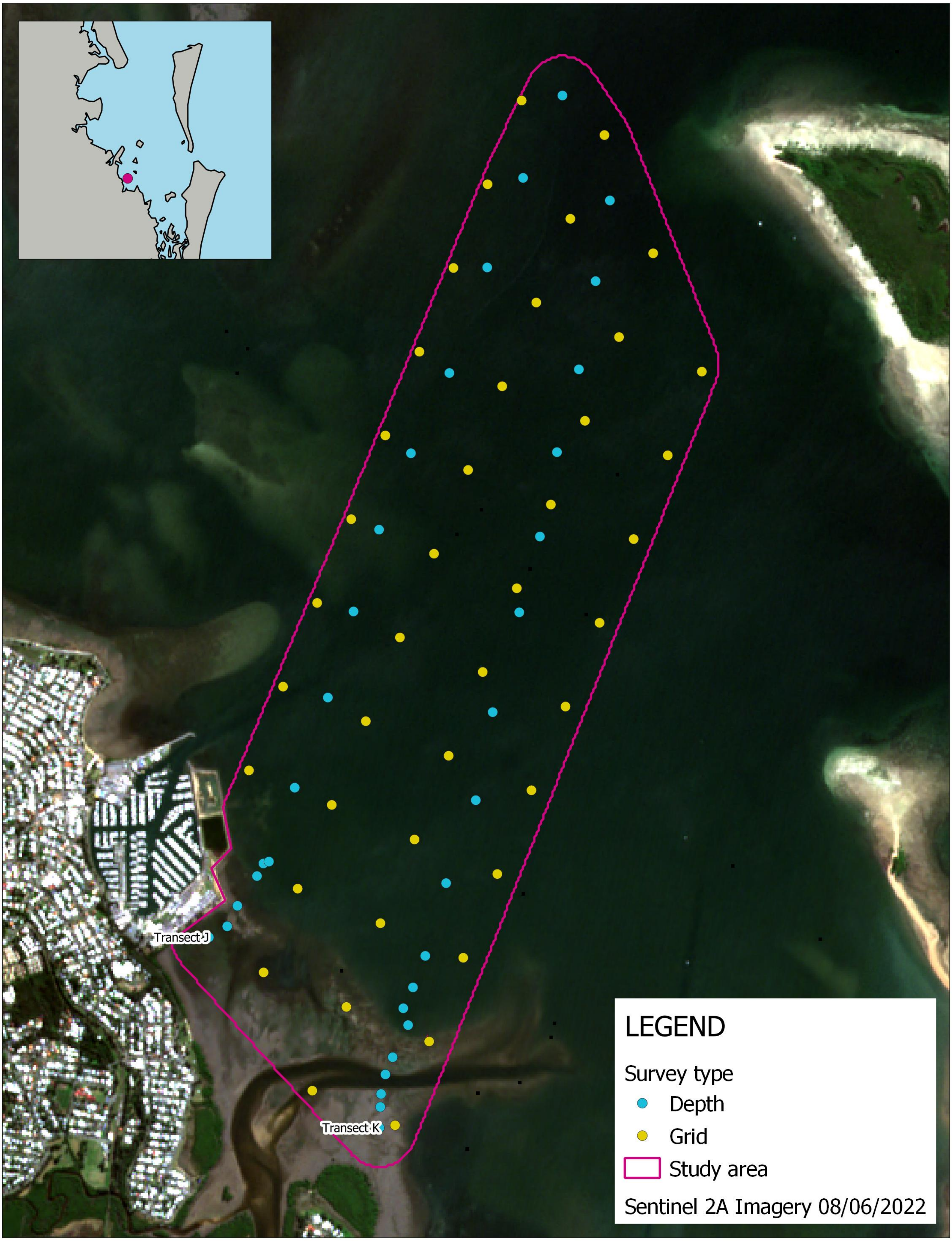

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Survey points used to map the distribution of seagrass at Manly

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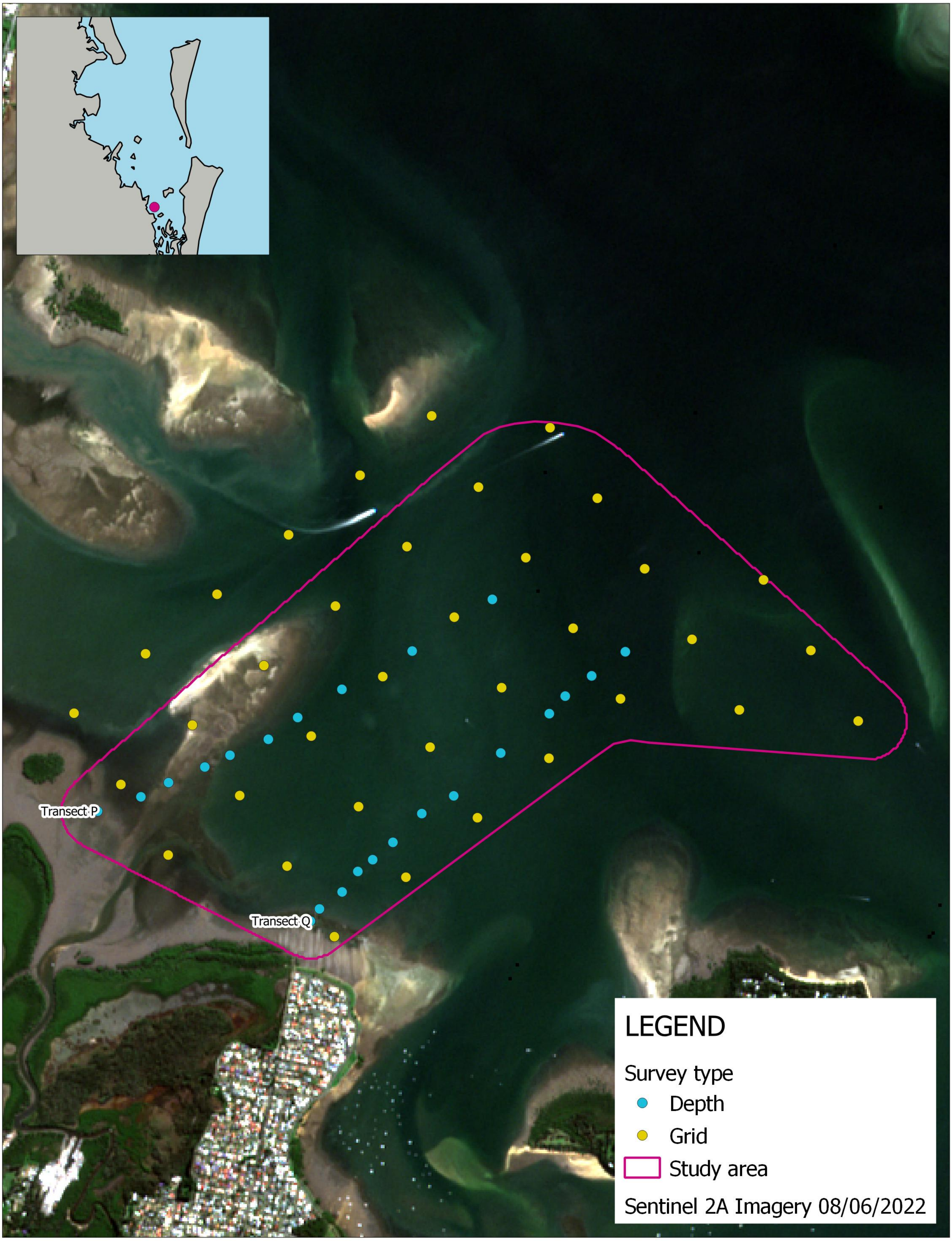

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Survey points used to map the distribution of seagrass at Cleveland

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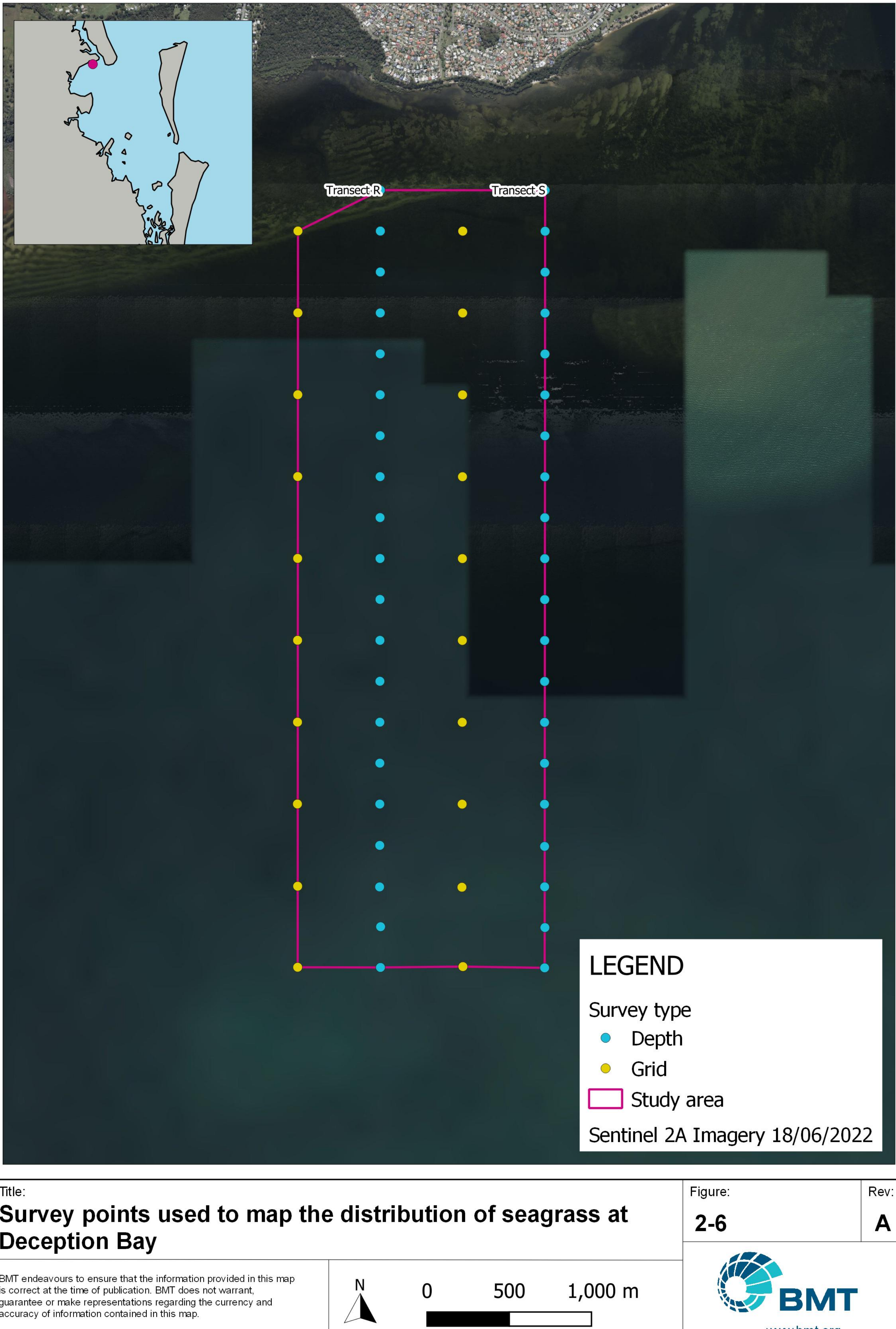

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Survey points used to map the distribution of seagrass at Deception Bay

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3 Results

3.1 Seagrass Spatial Distribution and Percentage Cover

Five of the eight seagrass species known to occur in Moreton Bay were recorded in the 2022 survey: *Zostera muelleri* (subsp. *capricorni*), *Halophila ovalis, Halophila spinulosa, Halophila decipiens* and *Halodule uninervis*. *Cymodocea serrulata* was recorded in the 2021 survey but not observed in 2022.

Maps showing the spatial distribution of each seagrass species in 2022 survey are shown in Figure 3.1 to Figure 3.4. The general pattern of assemblage structure across the depth zones at Fisherman Islands was as follows (Figure 3.5):

- *Zostera muelleri* numerically dominated 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*.

The following describes trends in species distribution and cover.

Species Distribution

The findings from the 2022 survey showed a decrease in seagrass in comparison to the 2021 survey, as follows:

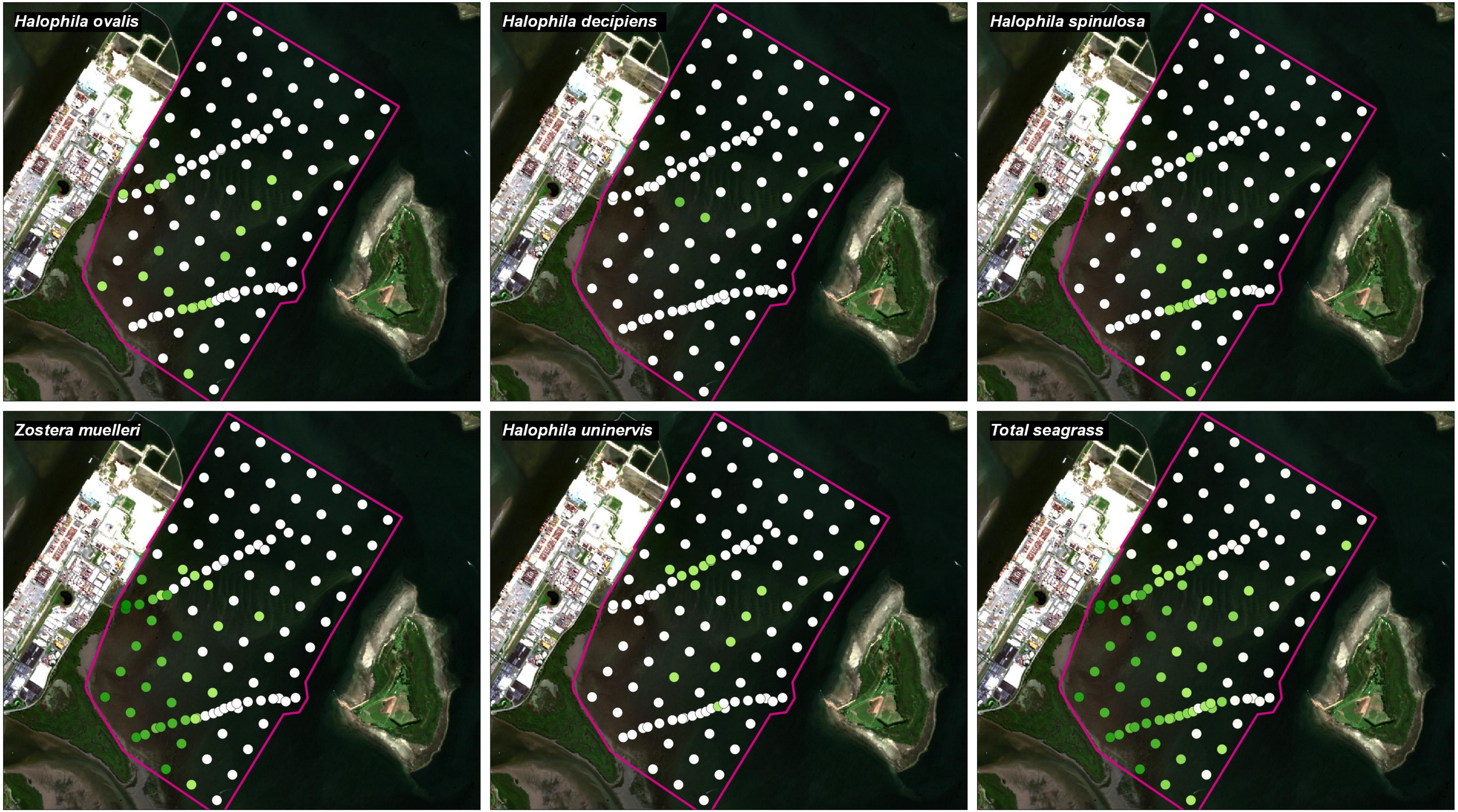
- Seagrass was recorded at 58% of the Fisherman Island sites (*n* = 110), 60% of Manly sites (*n* = 75), 51% of Cleveland sites (*n* = 59) and 43% of Deception Bay sites (*n* = 60). The frequency of seagrass detections in 2021 was 75%, 81%, 69% and 47% of the sites at Fisherman Islands, Manly, Cleveland and Deception Bay respectively. A chi-square test of independence was performed to examine the relation between seagrass detections at each location (Fisherman Islands, Manly, Cleveland, Deception Bay) and year (2021, 2022). There was no significant association between time and locations (χ^2 (df = 1, *N* = 8) = 0.75, *p*=0.86), indicating temporal trends were consistent over the survey area (i.e. between control sites and Fisherman Islands).
- *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 in subtidal areas.
- *Zostera muelleri* was the most frequently recorded species in 2022, but the number of detects declined between 2021 and 2022 (Table 3.1).
- *Halodule uninervis* was recorded at 16% of Fisherman Island sites in 2022, an increase from 7% of sites in 2021.
- Isolated patches of *H. ovalis* and *H. decipiens* were recorded on exposed sandy shoals. *Halophila* frequency has been variable between years with a decrease in *H. decipiens* at Fisherman Island and Cleveland but relatively stable at other sites. While *H. ovalis* showed no consistent trends.

- The frequency of *H. spinulosa* detections decreased at Fisherman Islands between 2021 and 2022, which was consistent across all locations (Table 3.1).
- Macroalgae detections generally decreased at all sites.

Table 3.1 Seagrass presence at study sites (%)

Site	Species	No. of sites (%) 2019	No. of sites (%) 2020	No. of sites (%) 2021	No. of sites (%) 2022	Trend 2021-22
Fisherman Islands	*H. decipiens*	24	13	6	6	↔
	H. ovalis	36	27	28	18	↓
	H. spinulosa	53	42	39	20	↓↓
	H. uninervis	20	0	7	18	↑↑
	Z. muelleri	40	46	38	38	↔
	C. serrulata	0	0	1	0	↓
Manly	*H. decipiens*	14	6	24	0	↓↓
	H. ovalis	34	11	23	11	↓↓
	H. spinulosa	51	49	56	39	↓↓
	Z. muelleri	17	16	20	18	↓
Cleveland	*H. decipiens*	21	21	17	3	↓↓
	H. ovalis	23	-	2	10	↑
	H. spinulosa	29	30	51	34	↓↓
	Z. muelleri	14	9	12	19	↑
Deception Bay	*H. decipiens*	Not sampled	0	8	0	↓
	H. ovalis	Not sampled	32	18	18	↔
	H. spinulosa	Not sampled	3	18	2	↓↓
	Z. muelleri	Not sampled	25	18	29	↑
	H. uninervis	Not sampled	10	30	14	↓↓

single arrow = difference <10% cover; two arrows = difference >10% cover



LEGEND

Seagrass Cover (%) — Study Area

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

Title:

Species Distribution at Fisherman Islands, Adjacent to the Port of Brisbane 2022

Figure: 3-1

Rev:

N

0 2 4 km

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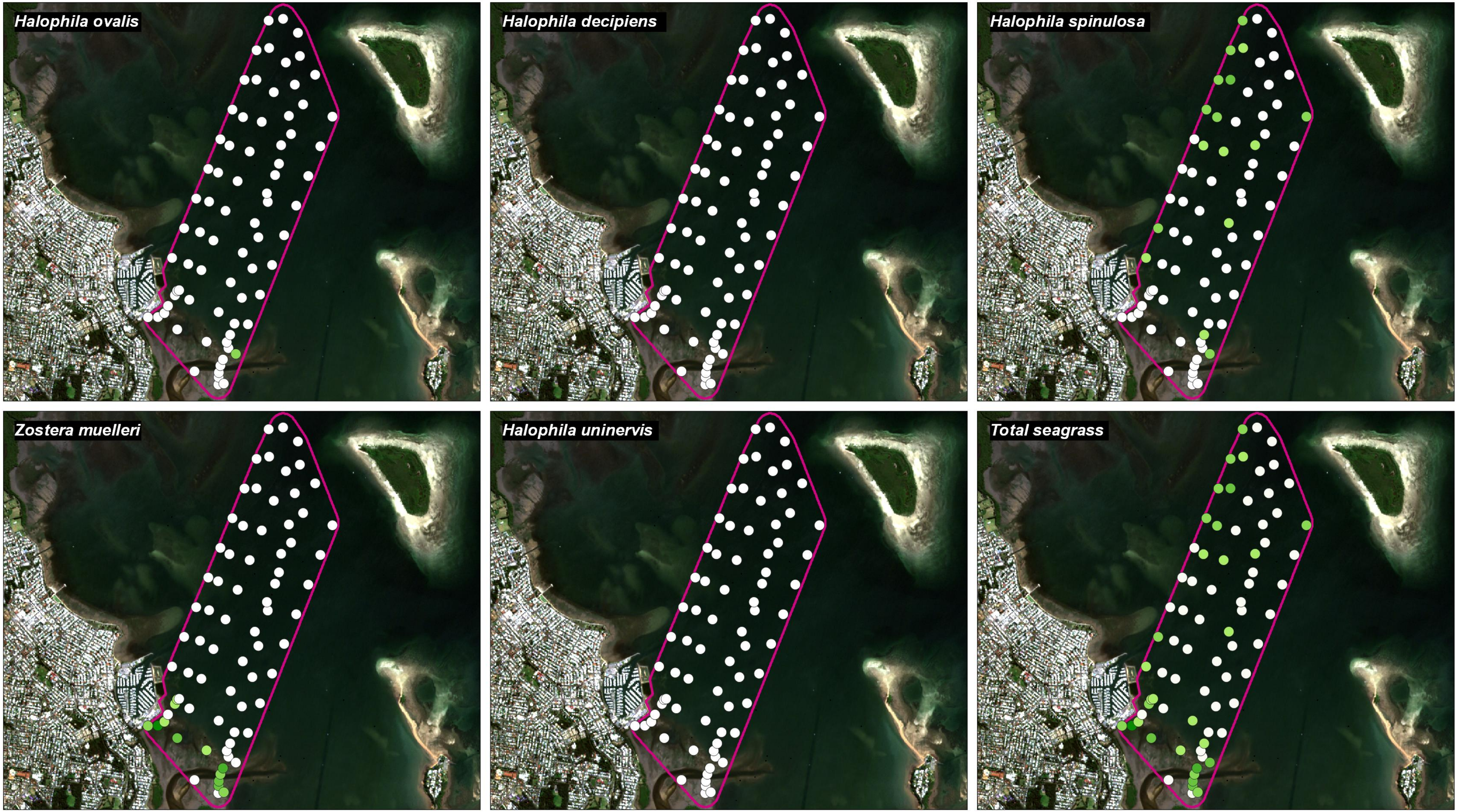

LEGEND

Seagrass Cover (%) — Study Area

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

Title:

Species Distribution at Manly, in Waterloo Bay 2022

Figure: **3-2**

Rev:

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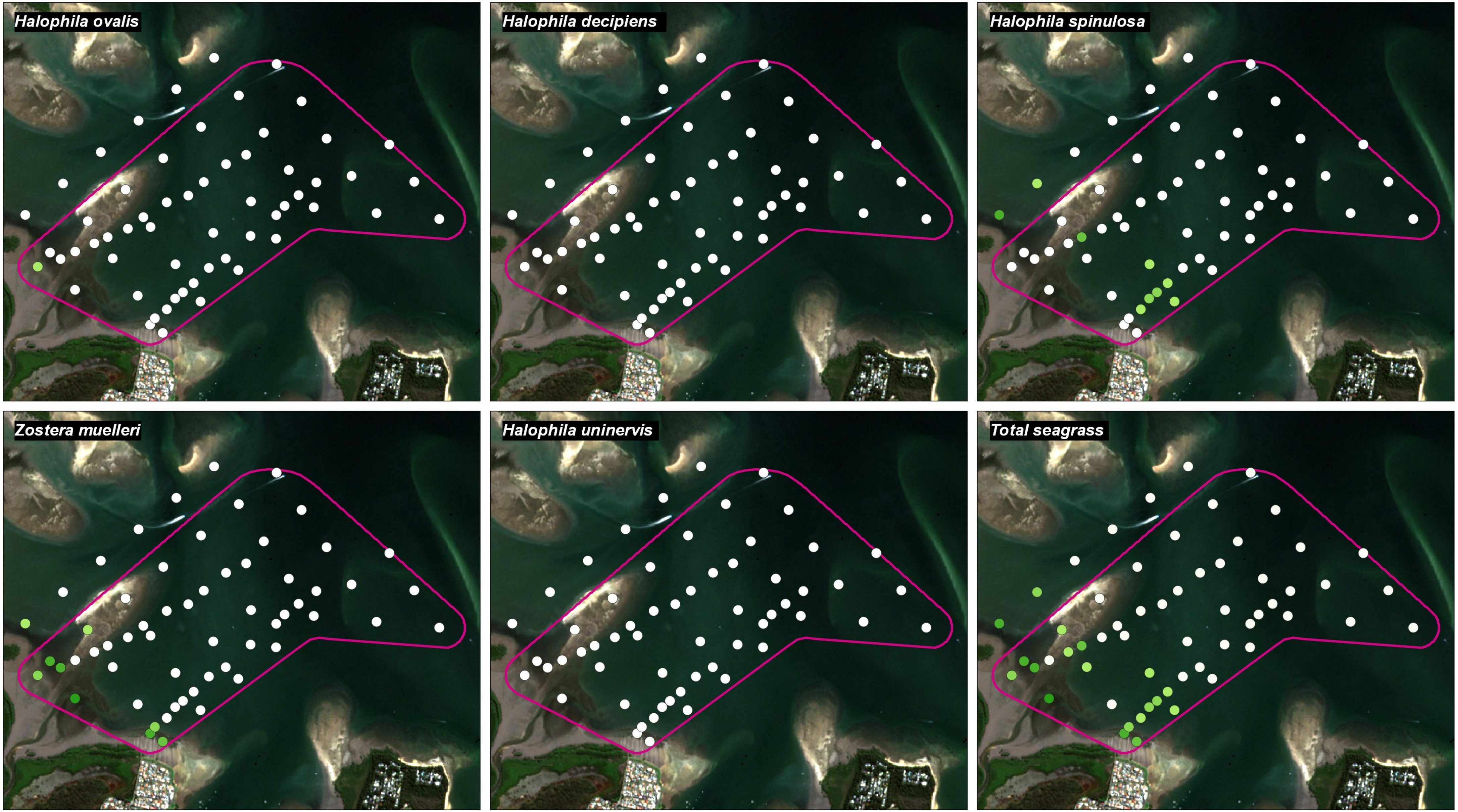

LEGEND

Seagrass Cover (%)
- 0 - 1
- 1 - 5
- 5 - 15
- 15 - 25
- 25 - 50
- 50 - 75
- 75 - 100

Study Area

Title:

Species Distribution at Cleveland, in Moreton Bay 2022

Figure: 3-3

Rev:

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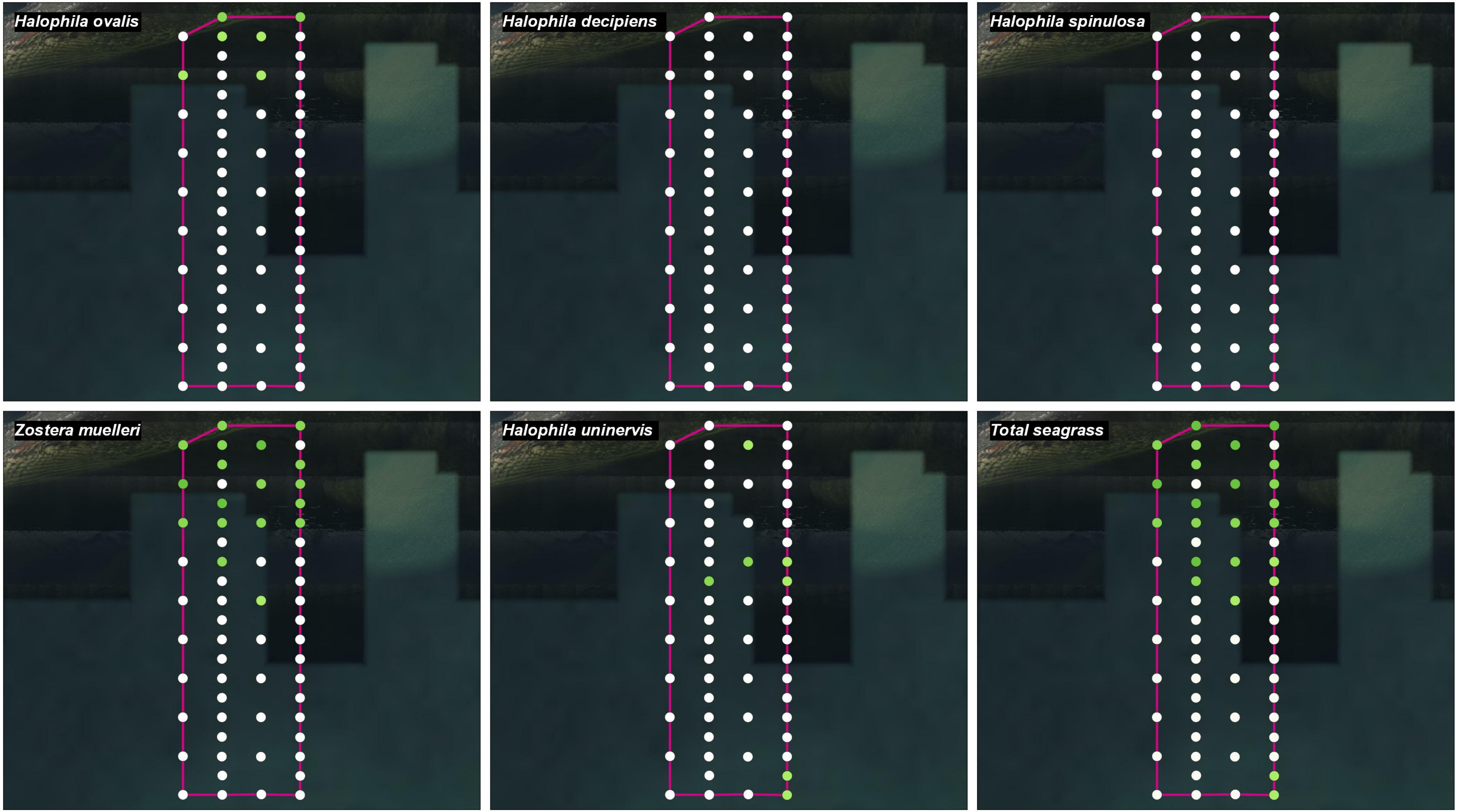

LEGEND

Seagrass Cover (%)
- 0 - 1
- 1 - 5
- 5 - 15
- 15 - 25
- 25 - 50
- 50 - 75
- 75 - 100

Study Area

Title:

Species Distribution at Deception Bay 2022

Figure: 3-4

Rev:

N 0 1 2 km

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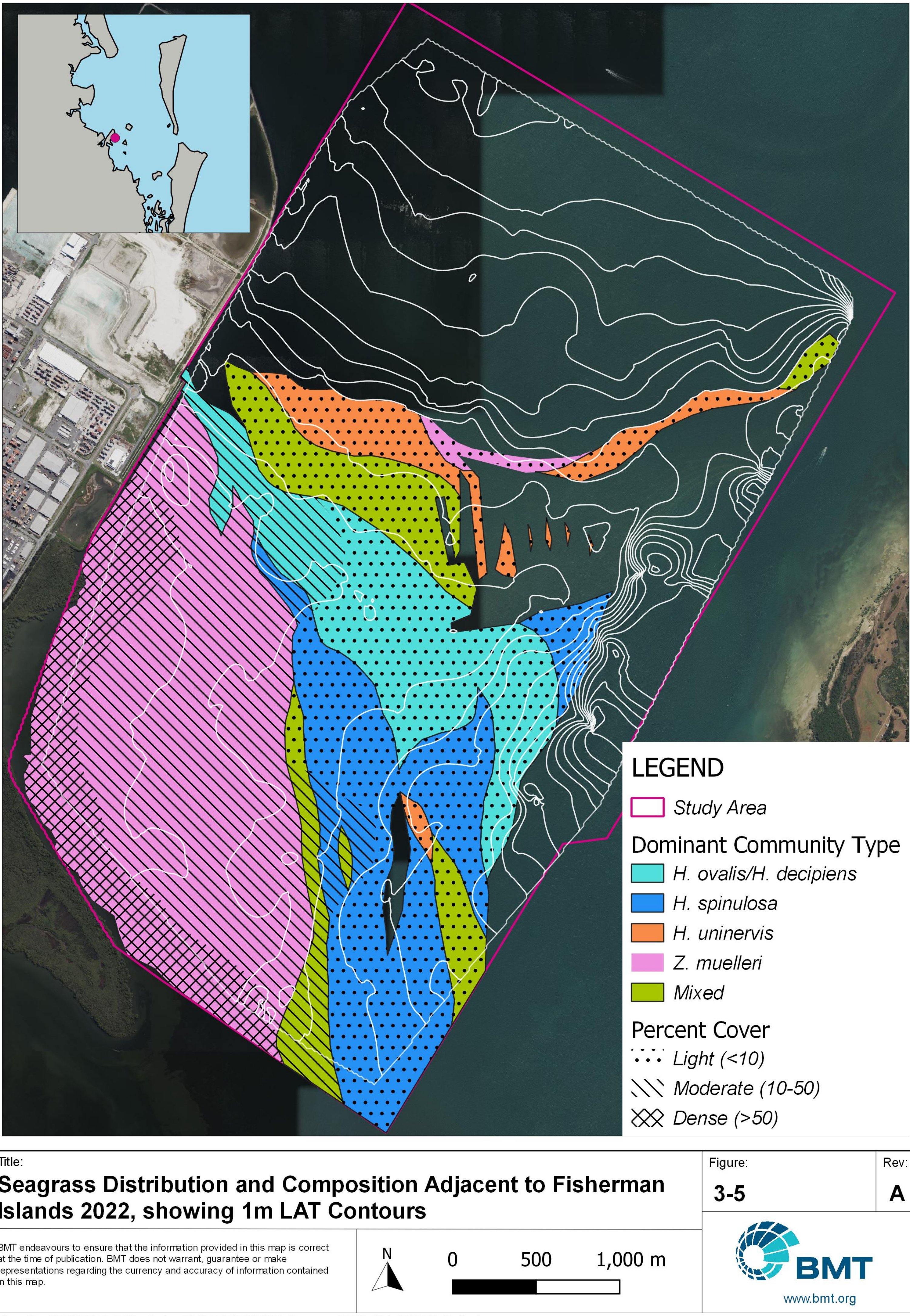

Title:

Seagrass Distribution and Composition Adjacent to Fisherman Islands 2022, showing 1m LAT Contours

Figure: 3-5

Rev: A

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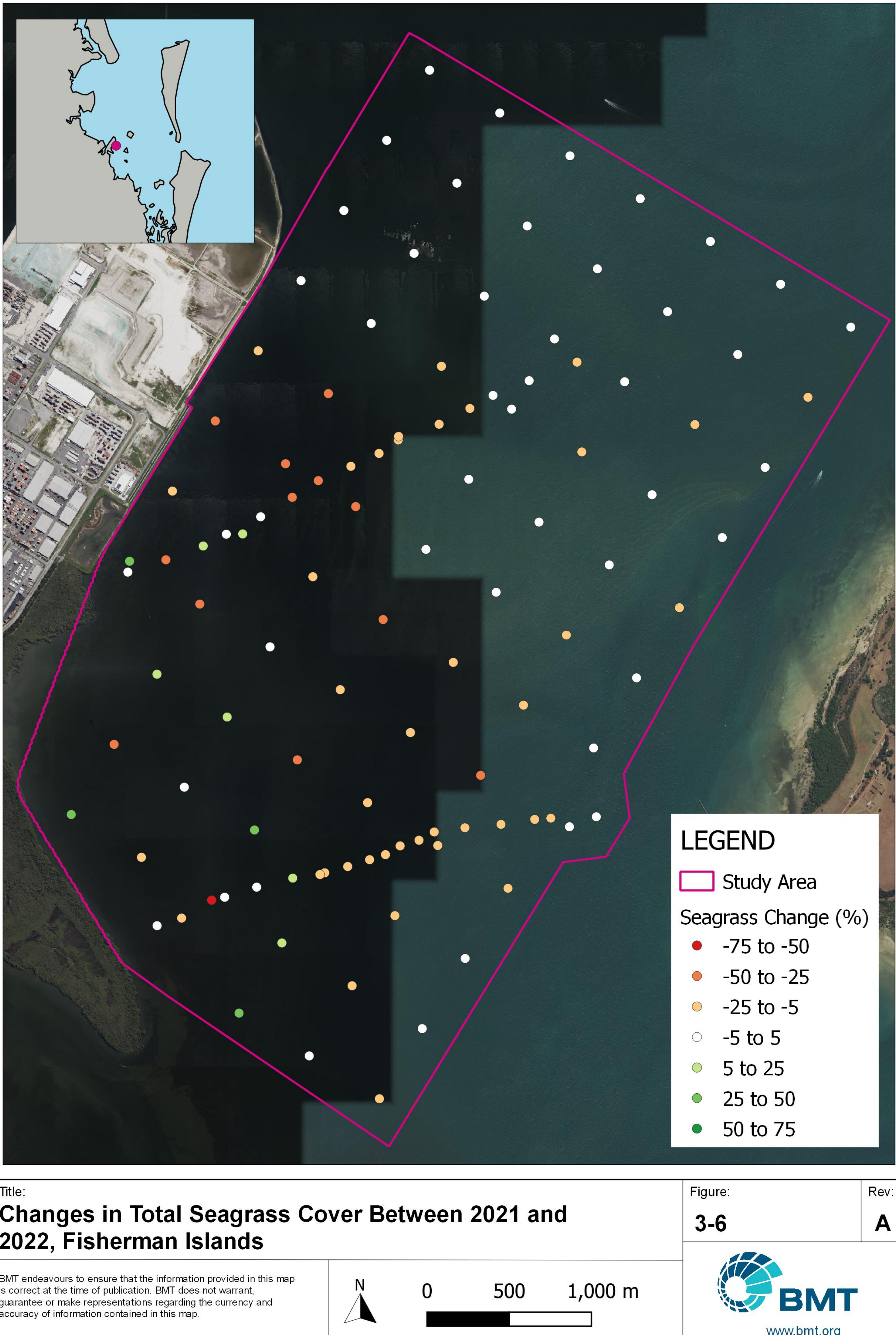
Seagrass Cover

Figure 3.6 shows the change in total seagrass cover between 2021 and 2022 at Fisherman Islands. Most sites had a decline in seagrass cover, with the largest changes in seagrass cover occurring in areas supporting dense seagrass meadows. While there was a retraction in the seaward extent of Fisherman Islands seagrass meadows, the magnitude of change in seagrass cover was low due to the sparse seagrass cover in 2021. Several intertidal sites had increased seagrass cover between 2021 and 2022.

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 permanent 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 shown. 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. Most sites have a percent cover between the historical minimum and maximum.



Title:

Changes in Total Seagrass Cover Between 2021 and 2022, Fisherman Islands

Figure: **3-6**

Rev: **A**

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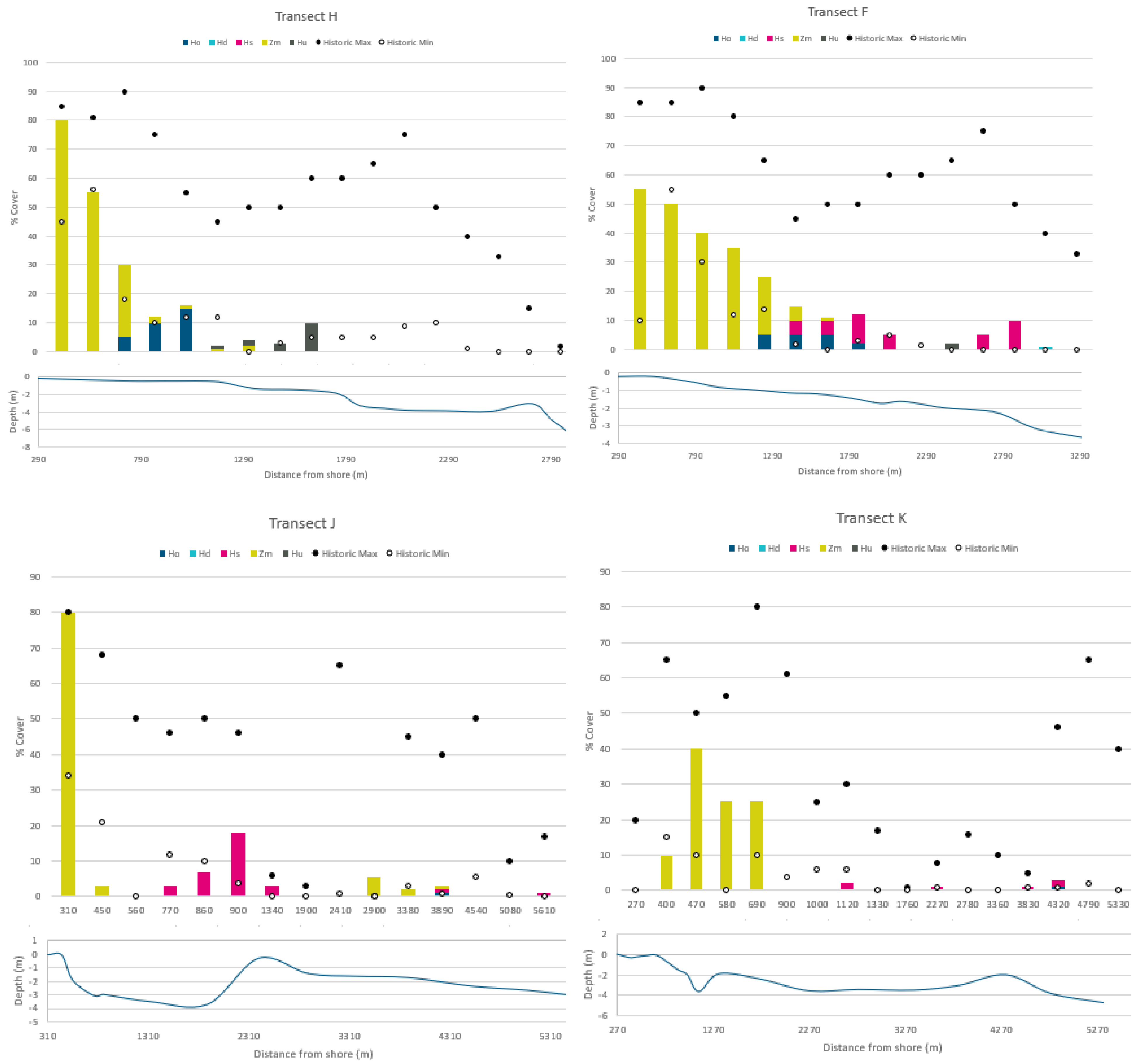


Figure 3.7 Percent cover distribution across depth transects at Fisherman Islands (H & F) and Manly (J & K)

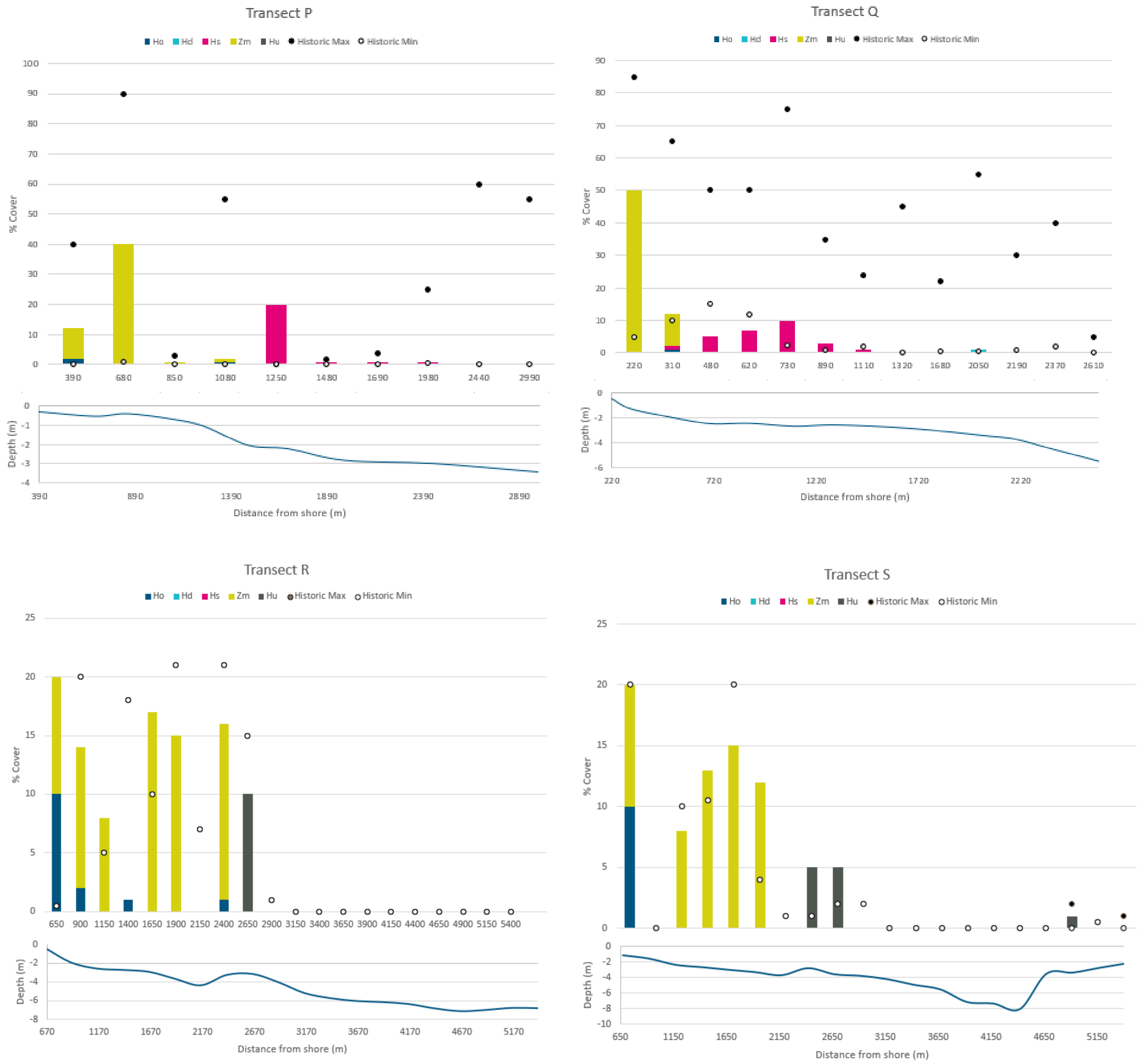


Figure 3.8 Percent cover distribution across depth transects at Cleveland (P & Q) and Deception Bay (R & S)

Spatial Patterns in 2022

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 –1.71 m, -1.72 m, -1.23 m and -3.62 m (AHD) respectfully. At Fisherman Islands, Manly, Cleveland and Deception Bay, average cover was highest within intertidal meadows (above LAT) than subtidal meadows (below LAT). The greatest depth recorded for *Z. muelleri* was -3.62 m AHD at Deception Bay. *Zostera muelleri* formed mono-specific meadows or mixed assemblages with *Halophila* species.

- *Halodule uninervis* was recorded at a small number of Fisherman Islands sites and at Deception Bay. Previously it has also been 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 -3.17 m, -3.86 m, -2.9 m and -3.5 m 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 -1.42 m, -0.4 m to -1.42 m, -1.42 m, -0.3 m to -3.5 m AHD at Fisherman Islands, Manly, Cleveland and Deception Bay respectively. The highest densities were generally found between -0.5 m and -1 m AHD.

- *Halophila decipiens* was observed at all Fisherman Island and Cleveland and the maximum depth range was -3.17 m, -3.43 m AHD respectively. *H. decipiens* generally occurred between -3 m and -4 m AHD. The coverage was predominately sparse to moderate and was generally either in monospecific stands or mixed communities with *H. spinulosa*.

Temporal Patterns

Table 3.2 shows SDR values for each species over time on permanent transects. *Zostera muelleri* SDR, a key indicator of long-term patterns in water quality, showed complex spatial and temporal patterns.

Figure 3.9 shows that:

- Deception Bay had the highest *Zostera muelleri* SDR values.

- The SDR on Transect H has been variable through time with 2010, 2014-2017 and 2020 having the highest values. Between 2021 to 2022 there was a decrease in SDR across all sites.

- The SDR on Transect F was variable between 2006 and 2018 but has remained relatively stable in 2019 and 2020 before slightly increasing in 2021 and then decreasing in 2022.

Table 3.2 shows that:

- *Halophila ovalis/decipiens* – Cleveland tended to have the lowest SDR values

- *Halophila spinulosa* – Cleveland tended to have the lowest SDR values

Pearson Product-Moment correlation analysis was undertaken to assess potential associations between antecedent 12-month rainfall and periods of potential low seagrass condition (SDR non-detects/lowest Zostera SDR). There was no significant correlation between the lowest *Zostera* SDR and antecedent rainfall (r = 0.41, p >0.05) however, there was a significant correlation between the frequency of non-detects and antecedent rainfall (r = 0.89, p <0.001).

SDR Index and 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:

- Fisherman Islands Transect H (2010, 2014, 2016-18, 2020 and 2021) and F (2006, 2010, 2019, 2020, 2021);
- Manly Transect J (2006, 2010, 2016, 2018, 2019, 2020 and 2021) and K (2006, 2010, 2014, 2016, 2017, 2019, 2020);
- Cleveland Transect P (2019); and
- Deception Bay Transect R (2020, 2021 and 2022) and Transect S (2020, 2021 and 2022).

SDR only met the WQO in 2022 at Deception Bay. Transect H at Fisherman Islands failed to meet the WQO for the first time since 2013. Transect F at Fisherman Islands has generally not met the WQO in most years.

[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 2021

Species*	Location	Transect	2006	2010	2013	2014	2016	2017	2018	2019	2020	2021	2022	Mean	CoV
Zm	Fisherman Island	F	-2	-2.5	-1.8	-1.7	-1.6	-1.7	-1.4	-2.1	-2	-2.2	-1.5	-1.9	-18
		H	-1.3	-2.3	-1.5	-2.4	-2.4	-2.5	-2.2	-1.7	-2.3	-2.7	-1.2	-2.1	-26
	Manly	J	-2.2	-2.3	-1.6	-1.5	-2.1	-1.6	-2.1	-1.9	-2.1	-2.4	-1.7	-2.0	-16
		K	-2.1	-2.2	-0.4	-2.1	-2.2	-2	-0.7	-3.3	-2.1	-0.7	-0.3	-1.6	-59
	Cleveland	P	-1.3	-0.8	-0.6	-0.7	-0.7	-0.9	-1.7	-1.9	-0.5	-1.1	-0.7	-1.0	-47
		Q	-0.6	-1.5	-1.8	-1.4	-1	-1.4	-1.2	-1.8	-1.2	-1.7	-1.2	-1.4	-27
	Deception Bay	R	-	-	-	-	-	-	-	-	-3.8	-2.8	-2.5	-3.0	-22
		S	-	-	-	-	-	-	-	-	-3.3	-3.3	-3.0	-3.2	-6
Ho	Fisherman Island	F	-3.8	-5.7	-2.2	-2	-1.8	-4.7	-1.6	-5.1	-1.9	-4.2	-0.6	-3.1	-56
		H	-2.6	-4.6	-2.5	-2.4	-2.4	-5.5	-2.2	-4.4	-1.2	-3.2	-1.4	-3.0	-46
	Manly	J	-2.2	-4.9	-4.5	-2	-2.1	-2.9	-2.1	-3.3	-2.1	-2.8	-2.4	-2.8	-35
		K	-0.4	-8.8	-5	-2.1	-2.2	-2.4	-1.8	-7.9	-2.5	-2.9	-2.0	-3.5	-77
	Cleveland	P	-5.9	-6.4	-6.2	-4.8	-3.6	-3.3	-2.1	-3.6	Absent	Absent	-0.67	-4.1	-48
		Q	-5.7	-6.2	-5.7	-2.7	-2.5	-5	-2.4	-2.8	-2.5	Absent	-1.2	-3.7	-48
	Deception Bay	R	-	-	-	-	-	-	-	-	-4.2	-0.8	-0.4	-1.8	-118
		S	-	-	-	-	-	-	-	-	-3.8	-4.0	-1.1	-3.0	-55
Hd	Fisherman Island	F	-3.8	-5.7	Absent	-4	-4.1	-4.3	-4.1	-4.2	-4	-4.6	Absent	-4.3	-13
		H	Absent	Absent	-2.9	-5.1	-5	Absent	-7.2	Absent	-5.4	-3.7	-3.2	-4.6	-32
	Manly	J	-2.2	-4.9	-4.5	-4.4	-3.5	-4.8	-4.5	Absent	Absent	-3.6	Absent	-4.1	-22
		K	-0.4	-8.8	-5	-3.7	-4	-5.3	-7.7	-4.1	-5	-2.7	Absent	-4.7	-51
	Cleveland	P	-5.9	-6.4	-5.1	-6.4	Absent	Absent	-4.4	Absent	-3.4	-4.0	Absent	-5.1	-23
		Q	-5.7	-6.2	-4.6	-4.6	-5.9	Absent	-5.6	-5.8	-5.7	-5.1	Absent	-5.5	-10
	Deception Bay	R	-	-	-	-	-	-	-	-	Absent	Absent	Absent	-	-
		S	-	-	-	-	-	-	-	-	Absent	-4.6	Absent	-4.6	-
Hs	Fisherman Island	F	-3.8	-4.3	-2.2	-1.6	-1.8	-3.8	-2.0	-5.1	-2	-2.5	-1.8	-2.8	-43
		H	-2.5	-2.3	-2.5	-2.4	-3	-2.5	-3.9	-4.7	-2.8	-3.2	-2.3	-2.9	-26
	Manly	J	-2.6	-4	-3.4	-3.4	-4.1	-3.4	-4.5	-4.8	-2.1	-4.3	-3.5	-3.7	-22
		K	Absent	-4.4	-4	-3.9	-2.2	-2.3	-3.9	-8	-3.8	-5.5	-3.7	-4.2	-40
	Cleveland	P	Absent	-3.4	-3.5	-4.8	Absent	-0.9	Absent	-3.1	-3.4	-4.0	-2.8	-3.2	-35
		Q	-3.2	Absent	-3.7	-4	-2.9	-3.3	-2.6	-3.1	-3.5	-3.8	-2.7	-3.3	-15
		R	-	-	-	-	-	-	-	-	Absent	Absent	Absent	-	-

Species*	Location	Transect	2006	2010	2013	2014	2016	2017	2018	2019	2020	2021	**2022**	Mean	CoV
	Deception Bay	S	-	-	-	-	-	-	-	-	Absent	-4.0	Absent	-4.0	-
Hu	Fisherman Island	F	Absent	Absent	Absent	Absent	Absent	Absent	-2.0	-1.6	Absent	-2.5	-2.0	-2.0	-19
		H	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-2.8	Absent	Absent	-2.0	-2.4	-25
	Deception Bay	R	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-
		S	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-
Rainfall (12months before the survey)			824	865	1318	549	689.5	952.2	848.8	572.2	1053	1138.6	2009.2		

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)

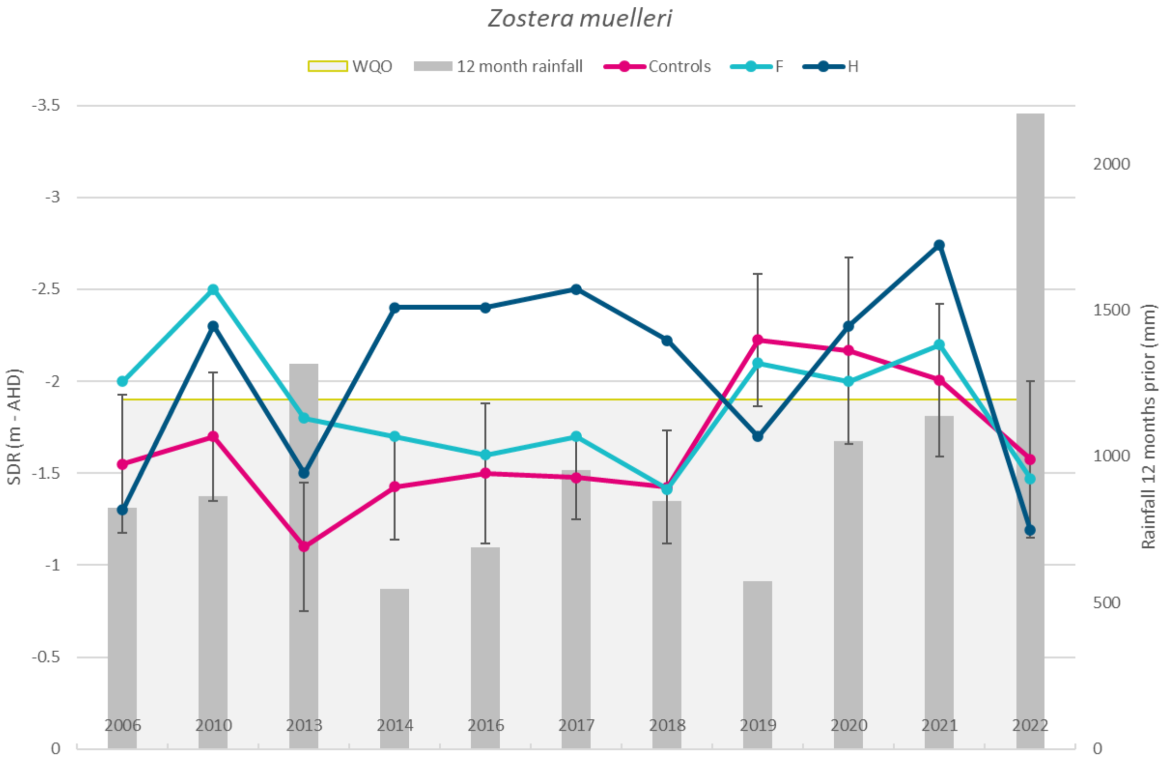


Figure 3.9 *Zostera muelleri* seagrass depth range (SDR) for Transect F and H at Fisherman Islands and the average (±SE) for control sites. Rainfall in the 12 months leading to the survey is also shown (BoM station number 040913 – Brisbane)

4 Discussion

4.1 Overview

The SMP demonstrates that seagrass meadows at Fisherman Islands and western Moreton Bay had the following ecological characteristics:

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 (Kilminster *et al*. 2015). This is a necessary requirement for living in dynamic environments as occurs in Moreton Bay.
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 -4 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.
6. There has been a net long-term expansion in overall seagrass meadow extent at Fisherman Islands since the construction of the FPE (Figure 4.1).

These are described in the following section.

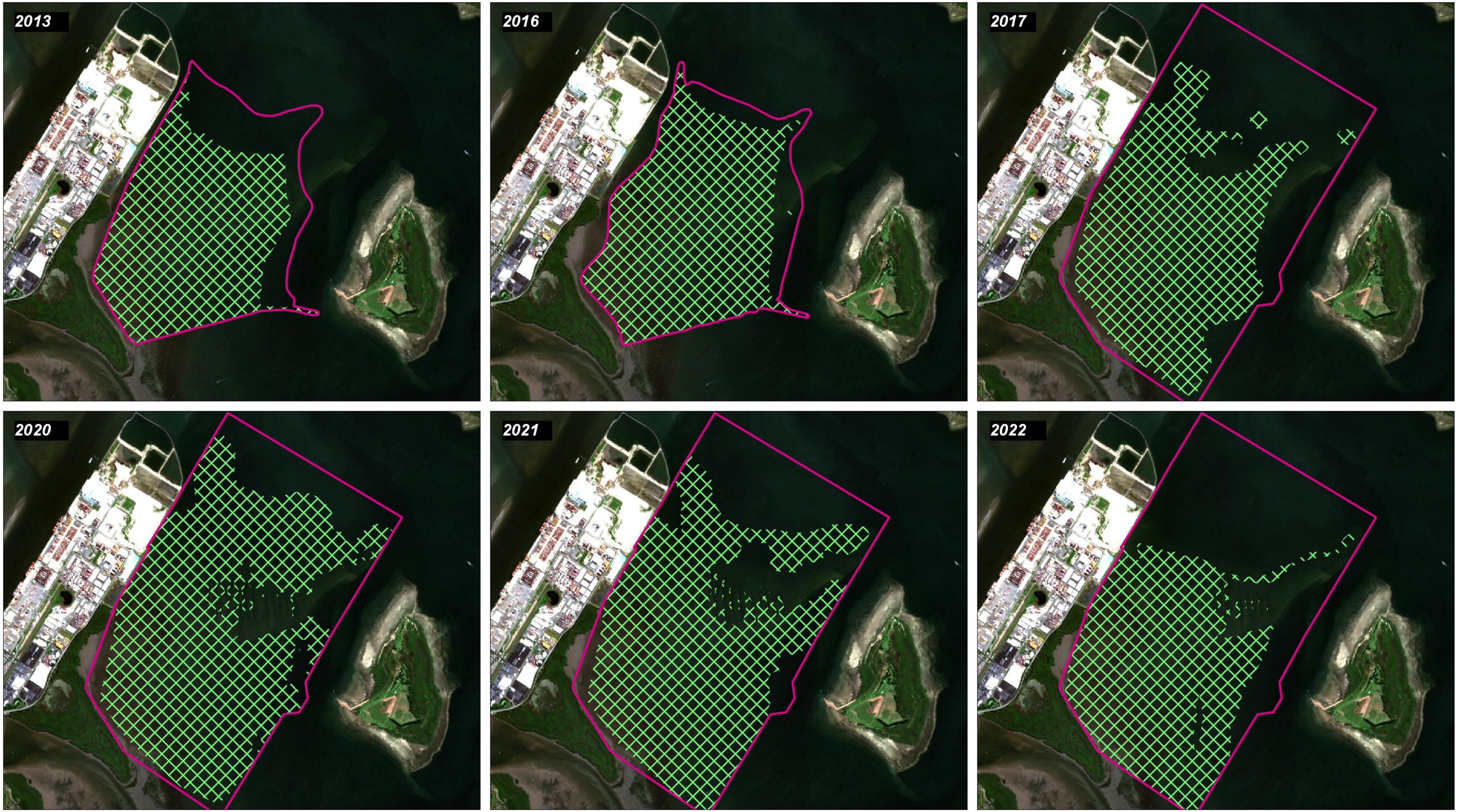
4.2 Species Composition

Eight seagrass species have been reported in 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*.

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. serrulata* and *H. minor* (Kirkman, 1997). *Halophila minor* was detected in the 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). *Cymodocea serrulata*, was recorded at Fisherman Island in the 2021 survey but was not observed in the 2022 survey.

4.3 Spatial and Temporal Patterns in Assemblages

Overall, seagrass meadows at Fisherman Islands decreased in extent between 2021 and 2022 by 2.9 km^2 to 9.9 km^2 in 2022. This reduction was seen predominately in the contraction of the seaward edge of the meadow (Figure 4.1).



LEGEND

Study Area

Seagrass Extent

Title:

Seagrass meadow extent between 2013-2022

Figure: **4-1**

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Halophila species

The distribution and cover of *Halophila* species generally decreased across all sites in 2022. This indicates that the dominant process/es controlling this species was operating over broad spatial scales (i.e. across western Moreton Bay), most likely flooding related increases in sediment concentrations.

Halophila species are considered colonising species, capable of rapid recovery following disturbance but low physiological resistance, especially to low light conditions (Kilminster *et al*. 2015). The results of the SMP demonstrate that these species are highly dynamic in time and space, colonising deep waters during sustained periods of high water clarity, and declining following floods and other disturbance events (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 suspended solid concentrations (and associated light availability) can also occur among transects, varying in response to proximity to channels and sand banks.

Halodule uninervis

Halodule uninervis, like *H. ovalis*, is an ephemeral, pioneer species that grows rapidly and survives well in unstable or depositional environments (Carruthers *et al.* 2002). This species has adaptations that enable it to grow in the intertidal zone (Waycott *et al.* 2004) and unstable subtidal shoals, as occurs in the study area. As *Halodule* has a similar growth form to *Z. muelleri*, it is possible that this species may be undetected due to misidentified when viewed *in situ* via underwater camera (a sample is generally needed to confirm identification).

Several drivers control *H. uninervis* growth and recruitment, including:

- Seasonality - In tropical environments *H. uninervis* exhibits strong seasonality, with a minima occurring in August to September (Lanyon *et al.* 2004). Seasonal patterns in *H. uninervis* abundance in Moreton Bay are undefined. Assuming seasonal patterns in the local population are similar to those in tropical environments, the SMP (July-August) would occur around the time of the *H. uninervis* seasonal minima.

- Temperature, light and exposure - *H. uninervis* abundance is sensitive to a range of stressors, such as high temperatures, too much or too little light, variations in rainfall and high wind (Lanyon *et al.* 1994; Collier *et al.* 2016). *Halodule uninervis* was recorded exclusively in subtidal environments in 2019, and therefore not subject to atmospheric exposure and associated stressors (desiccation, high temperatures). *Halodule uninervis* has a higher light requirement than *Halophila* species (Longstaff and Dennison 1999), and may therefore be sensitive to periods of low light in deeper waters.

Zostera muelleri

Zostera muelleri predominately occurred in intertidal and shallow waters of the study area (waters shallower than 2.5 m AHD). *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 was the numerically dominant species.

SDR varied among locations, ranging from 0 m to -1.77 m AHD at Fisherman Islands, 0 m to -1.23 m AHD at Cleveland, 0 m to -1.72 m at Manly and -0.3 m to -3.62 m at Deception Bay. Differences in SDR among locations are likely to reflect differences in the availability of suitable (and stable) habitat and differences in water quality conditions among (and possibly within) locations (see BMT 2021).

SDR along the depth transects varied between years at both Fisherman Islands and the control sites. *Zostera* SDR decreased at all transects between 2021-22, again most likely due to flood-related increases in suspended sediment concentrations.

Zostera muelleri depth range is more stable at Fisherman Islands (CoV -18 to -26), Cleveland (CoV -27 to -47) and Deception Bay (CoV –6 to -22) than Manly (CoV -16 to -59). This suggests that Manly is more prone to disturbance and/or habitat heterogeneity compared to the other sites, which is consistent with the 2020 and 2021 survey. In comparison to previous years Fisherman Islands Transect H was showed a similar trend to Transect F which previously differed. While both the Fisherman Islands transects had a decreased SDR, this was also observed at the control sites.

Nearshore *Zostera muelleri*

The SMP focusses on quantifying the maximum seagrass depth range as an indicator of long-term water quality changes. The SMP has been incidentally noted that the landward margin of *Z. muelleri* meadows were variable over time. BMT (2020; 2021) observed a retraction in the landward margin of the Fisherman Islands meadow between 2019-21, which was hypothesised to related to be related to exposure during hot days, and possibly other environmental drivers such as rainfall.

An inspections of aerial photography suggests that between July 2021 and July 2022, the landward boundary of the Fisherman Islands seagrass meadows expanded landward (see example images in Figure 4.2). The 2021-22 was cooler than average (see Figure 2.3), potentially providing better growing conditions. Further assessments would be required to test for potential links between long term patterns in seagrass meadow, temperature and solar radiation.

Figure 4.2 Change in Nearshore Zostera between July 2021 (left) and July 2022 (right)

Cymodocea serrulata

A small inshore patch of *Cymodocea serrulata* was recorded at Fisherman Islands in 2021 but not in the 2022 survey. This is the first record of this species in the SMP. This species typically lives in intertidal and shallow subtidal areas with either sandy or muddy substrates, and is often found in mixed communities. This species can rapidly out-compete *Halophila* species as part of a natural succession (Young and Kirkman 1975) and is considered an opportunistic species (Kilminster *et al*. 2015).

This species has been recorded elsewhere in Moreton Bay. Young and Kirkman (1975) recorded a monospecific *C. serrulata* meadow in eastern Moreton Bay in similar habitat conditions to the Fisherman Islands meadow (sandy substrate, approximately 3 m deep). The Atlas of Living Australia has less than 15 records of this species in Moreton Bay with the most recent being at the tip of North Stradbroke Island in 2020.

Drought-Flood Cycles in Seagrass Meadow Extent

A reduction in seagrass meadow extent below 0 m LAT was observed across all locations between 2021 and 2022. An example of this contraction is shown in Figure 4.3 in the area adjacent to the Bird Hide at Fisherman Islands.

The results of the SMP indicate that seagrass meadows of western Moreton Bay show cyclic changes in extent in response to flood-drought cycles. Reductions in seagrass meadow extent were observed at Fisherman Islands and control sites following major flood events in 2010, 2013 and 2022. The magnitude of change in seagrass meadow extent and seagrass depth range in 2022 was similar to that observed in 2013. Seagrass losses were reported elsewhere in the region between 2021-22, including Hervey Bay (TropWATER 2022).

Flooding is a key driver of seagrass meadow changes. Flooding results in a reduction in seagrass through limiting light, increase in silt, organic matter and nutrients. The duration, frequency and intensity of disturbance influences the amount of loss and also the recovery time (Campbell and McKenzie 2004). With small disturbances recovering in weeks to months whereas larger disturbances can take more than two years to recover (Bulthuis 1981; Birch and Birch 1984; Preen *et al*., 1995; Onuf 2000; Blake and Ball 2001). Therefore, if no major disturbance events occur in the next few years seagrass meadow extent will likely be recovered within the next several years.

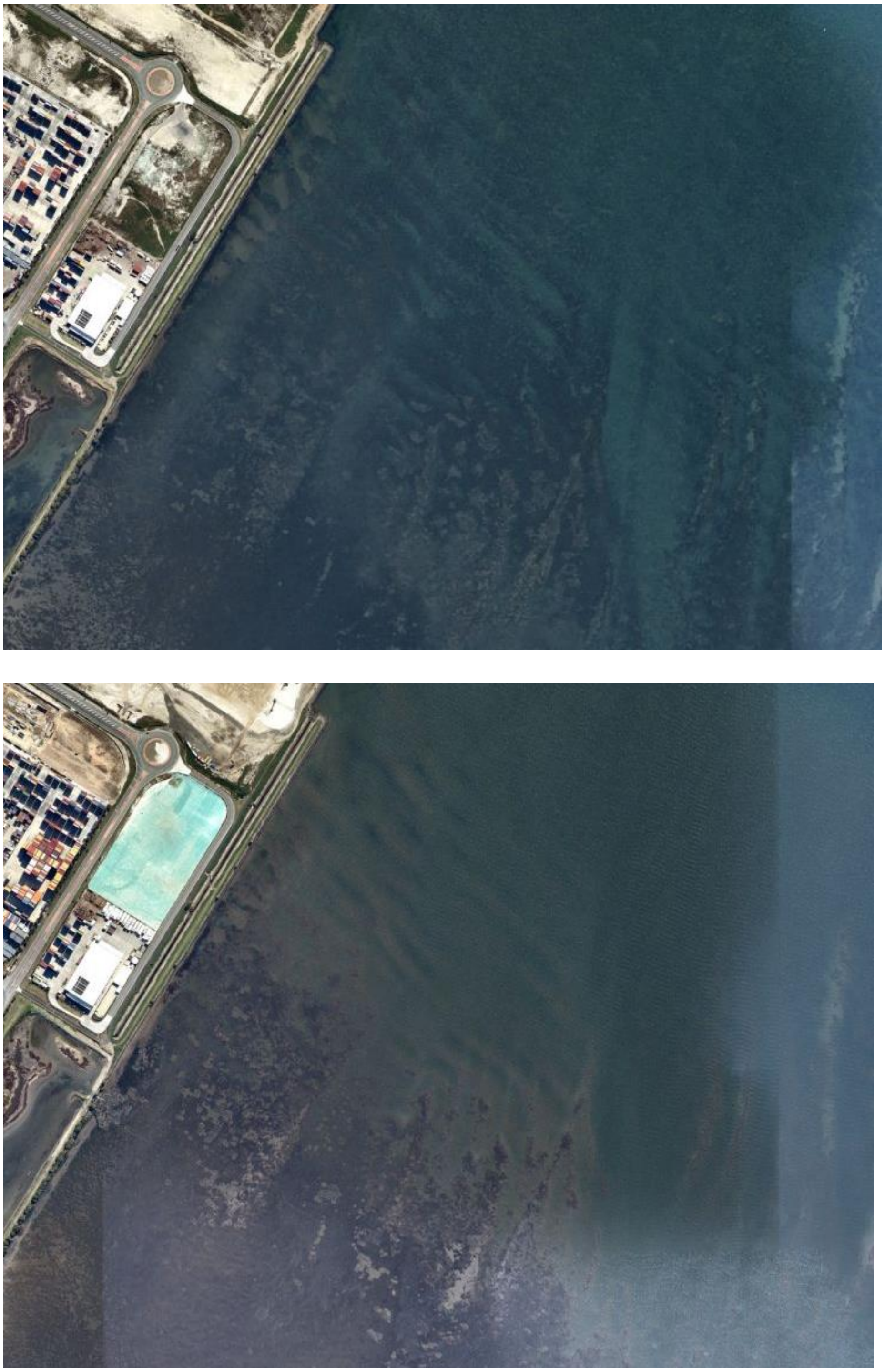

Figure 4.3 Change in seagrass meadows in areas below 0 m LAT between July 2021 (top) and July 2022 (bottom)

Filamentous Algae and Other Macroalgae

Filamentous algae was the dominant algae group across the survey locations. Filamentous algae can proliferate under nutrient enriched conditions, leading to reductions in available light and loss of seagrass (Han and Liu 2014). Nutrient inputs into Moreton Bay originate from a range of sources including urban land, aquaculture, wastewater treatment and general catchment runoff which likely to promote filamentous algae productivity. However, if epiphyte cover becomes too high then this can restrict the light available to the seagrass, therefore limiting growth. Epiphyte cover was observed at 3% of Fisherman Island sites at an average cover of 12%.Like seagrass, different macroalgae species show great variation in distribution and cover over time and space.

The most abundant macroalgae 'seaweed' genera were *Hypnea* and *Sargassum.* The average macroalgae cover was highest at Cleveland (1.3%) compared to other sites including Fisherman Islands (0.2%). There was an overall decrease in macroalgae presence and cover between 2021-22. Macroalgae was present at a variety of depths at Fisherman Islands (-3 m to -8 m AHD), Cleveland (-1 m to -5 m AHD).

Lyngbya is a species of cyanobacteria that occurs in Moreton Bay attached to seagrass beds. Some strains of Lyngbya are capable of making toxins and cause skin irritation. A small patch of Lyngbya was observed in the subtidal areas of Manly.

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. *Caulerpa taxifolia* can replace seagrass during extended dry periods. The distribution and density of *C. taxifolia* declined across the study area post-2010 and was not observed in 2022.

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.

The only transects that met the SDR (WQO) of -1.9 m AHD was both Deception Bay transects. Deception Bay has been surveyed three times to date and met the WQO on all occasions. Of the other sites, Manly transects most frequently met the SDR WQO, followed by Fisherman Islands and Cleveland. Fisherman Islands transect F infrequently met the WQO, most likely as local hydrodynamic conditions were not favourable for *Z. muelleri* growth (mobile sandy bed).

The SDR WQO was met less frequently in 2022 than 2021 due to higher antecedent rainfall in 2022. As shown in Figure 3.9, the 12 month cumulative antecedent rainfall in 2022 (2010 mm) was higher than in all years of the SMP. There was no correlation between long term SDR and antecedent rainfall, however further analysis is required.

4.5 Impacts of the FPE Seawall

The results of the SMP 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) up until 2022 where flood conditions resulted in a major contraction of seagrass extent although it still remains larger than 2013. Despite the contraction of the seagrass extent in 2022, the 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 south and east of Fisherman Islands (BMT WBM 2010; 2015; 2016; 2017, 2018, 2019, 2020). 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 2022 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 lower (deep-water seagrass in the northern and eastern sectors) distribution limit.
- SDR reclined between 2021 and 2022 on all transects. This suggests that the driver/s leading to changes between 2021 and 2022 were operating over broad scales throughout western Moreton Bay and were therefore unrelated to Port activities.
- *Zostera muelleri* SDR WQO for Waterloo Bay was used as a benchmark to assess seagrass condition. Only the Deception Bay transects met the WQO, all other transects at control sites did not.
- The results of the Port of Brisbane SMP suggest that there was a long-term expansion in seagrass meadows at Fisherman Islands which has stabilised in recent years and then contracted in 2022 due to flooding. 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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Annex A Photo Plates

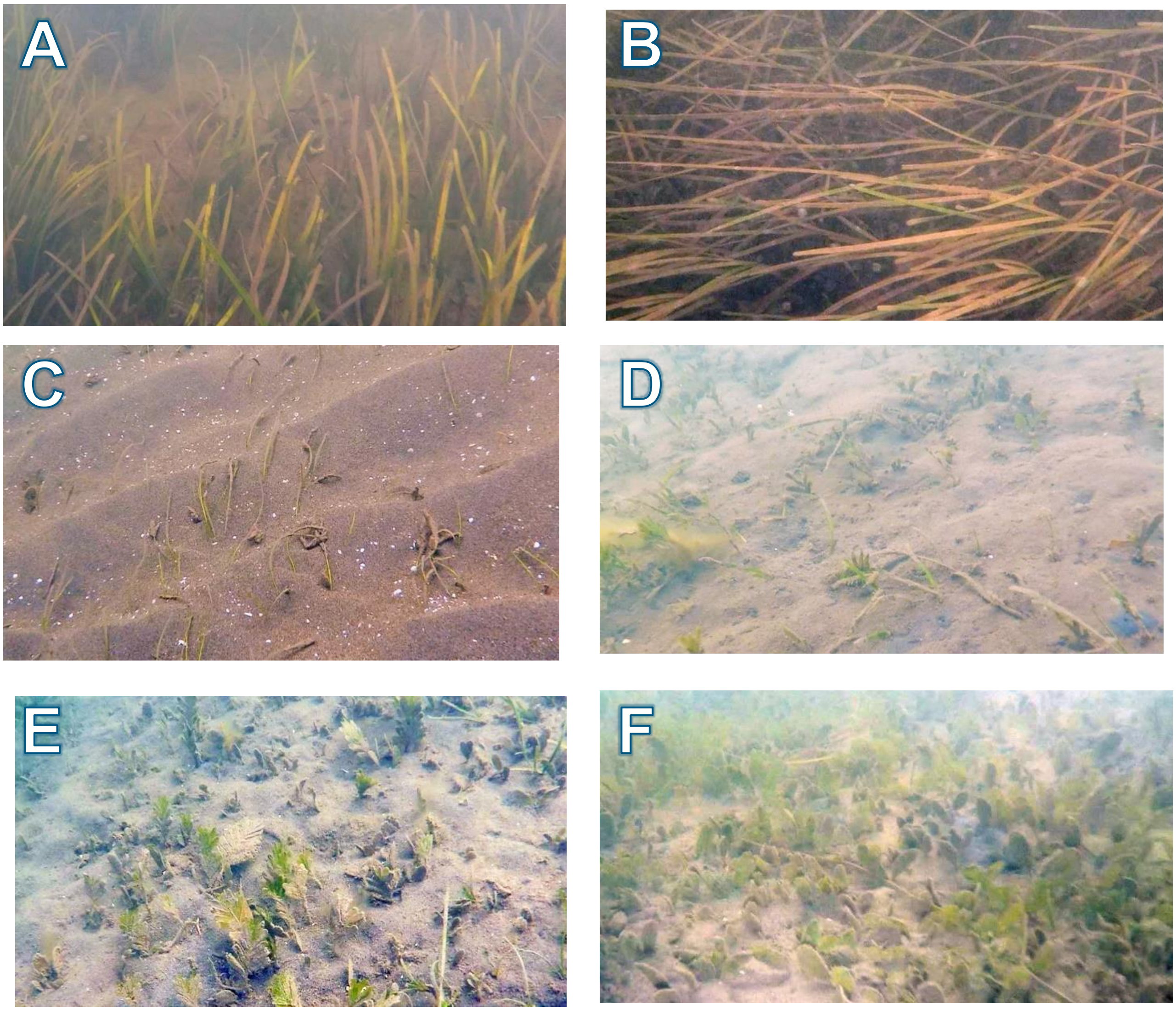


Figure A.1 Fisherman Islands: moderate inshore *Zostera muelleri* (A), dense inshore *Zostera muelleri* (B), *Halodule uninervis* (C), sparse mixed community (D and E) and *Halophila ovalis* (F).

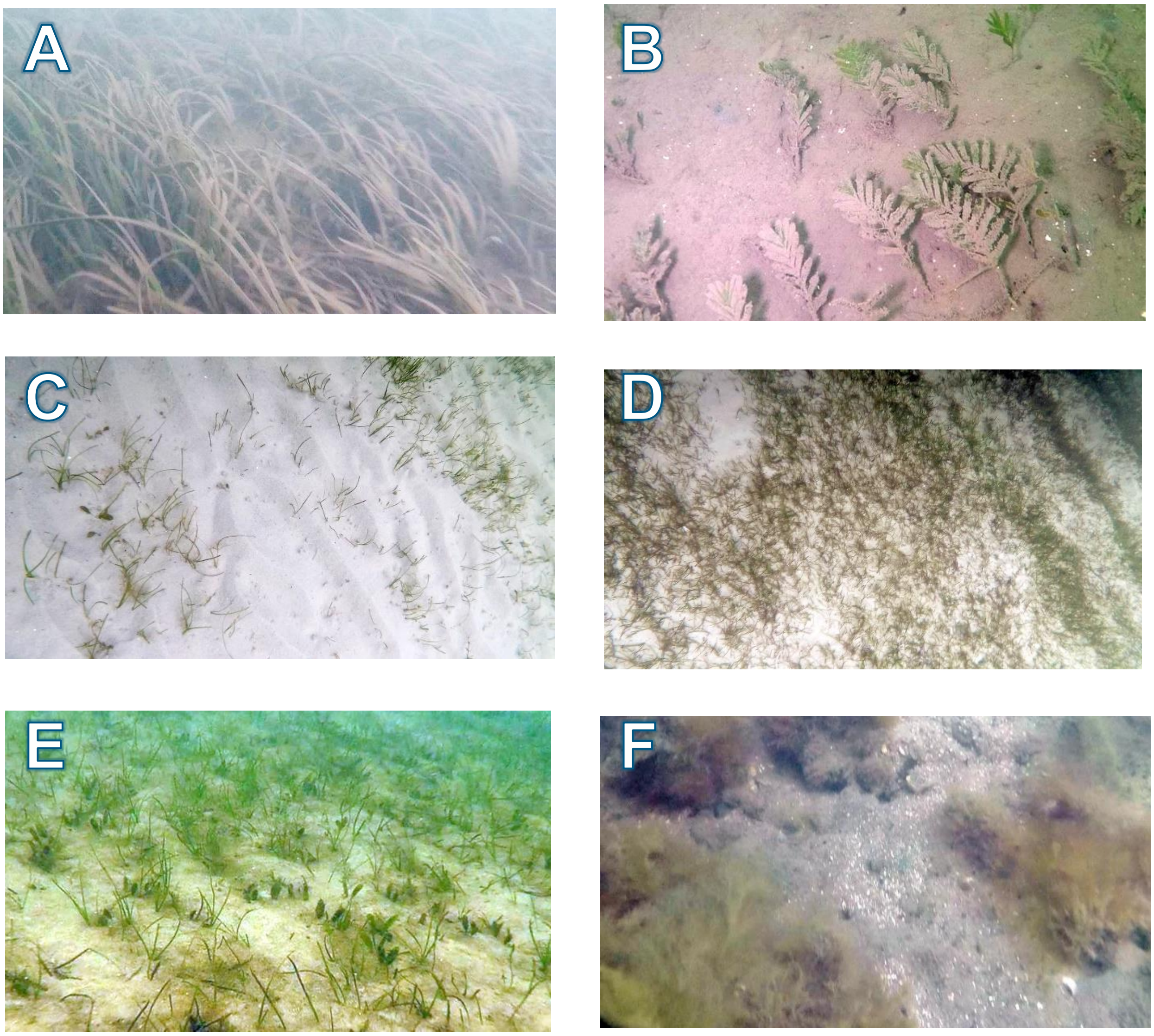
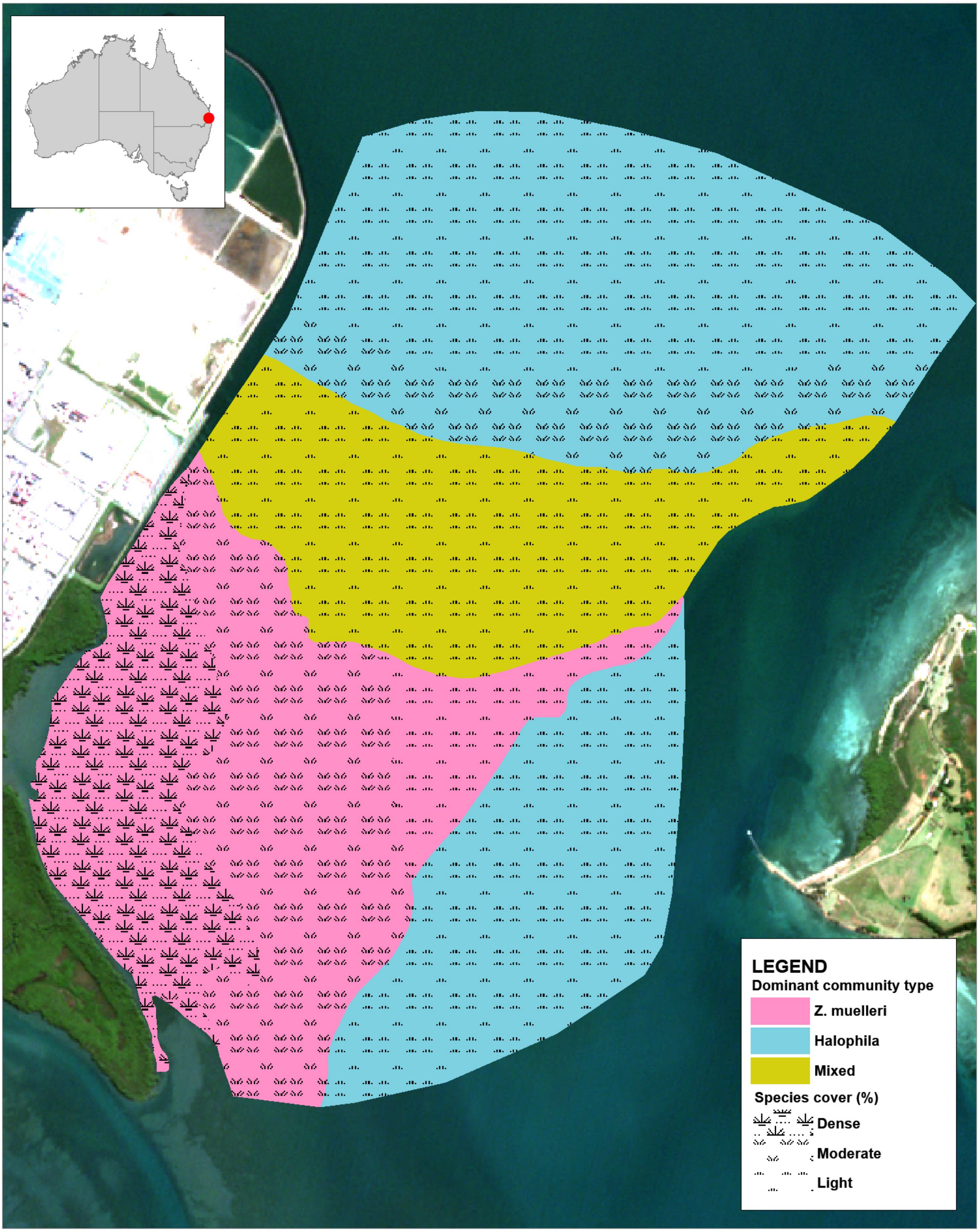


Figure A.2 Dense *Zostera* at Cleveland (A), deep *Halophila spinulosa* at Manly (B), sparse mixed community at Deception Bay (C); short *Zostera* at Deception Bay (D), mixed community at Deception Bay (E) and *Lyngbya* at Manly (F)

Annex B Broad scale patterns in seagrass species distribution at the Port of Brisbane 2010, 2013-2020



Title:

Seagrass distribution and community structure adjacent to Fisherman Islands 2010

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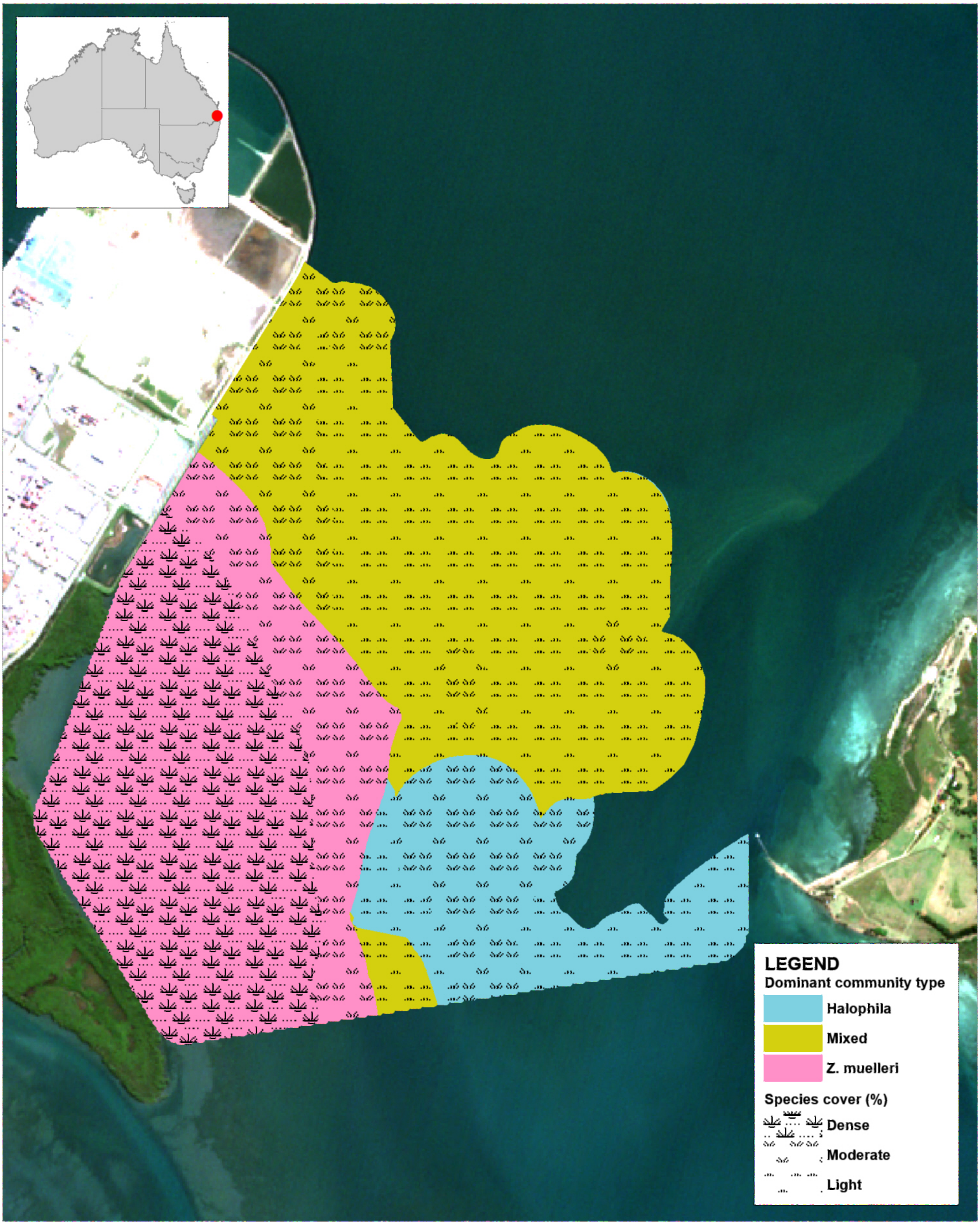

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Seagrass distribution and community structure adjacent to Fisherman Islands 2013

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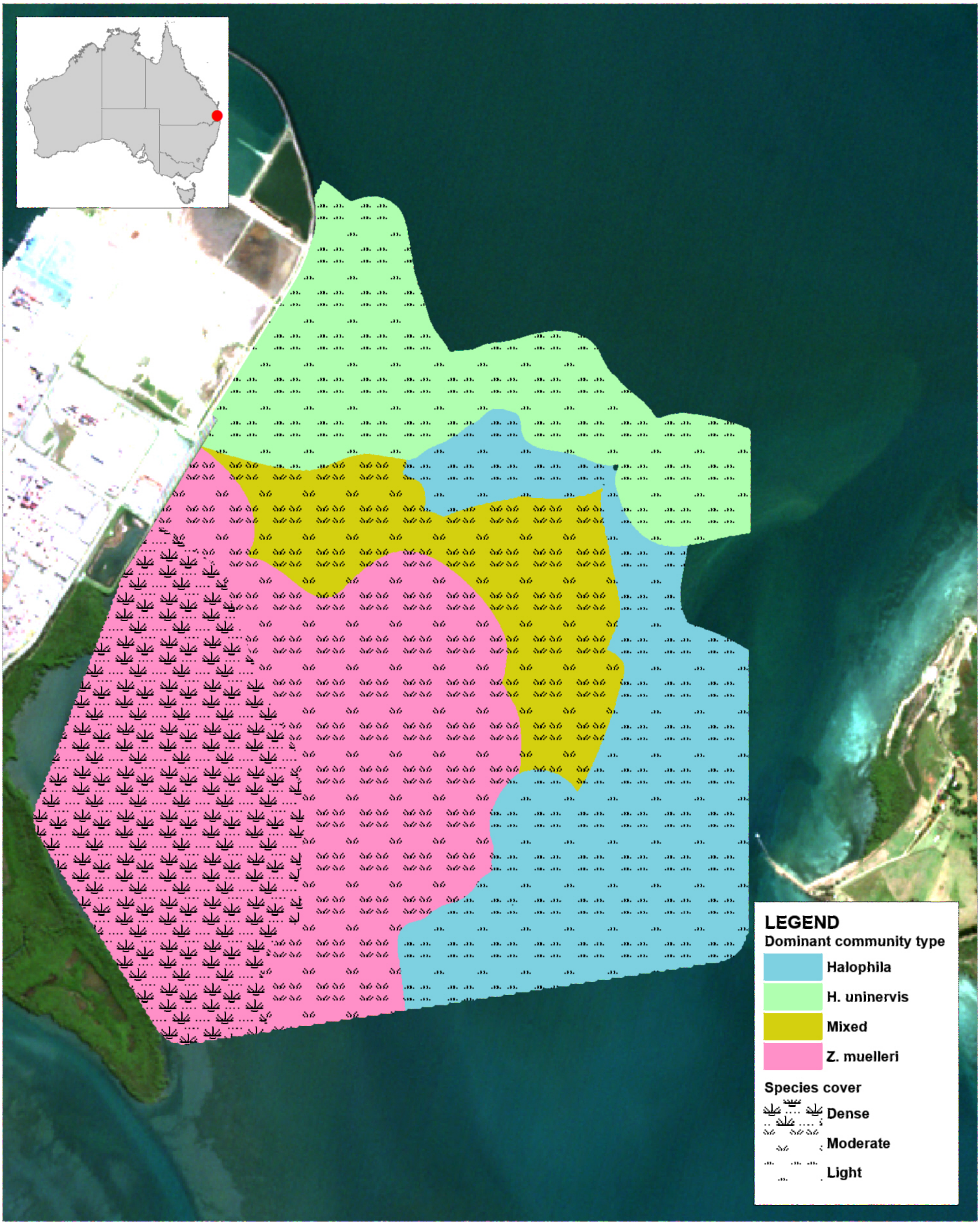

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Seagrass distribution and community structure adjacent to Fisherman Islands 2014

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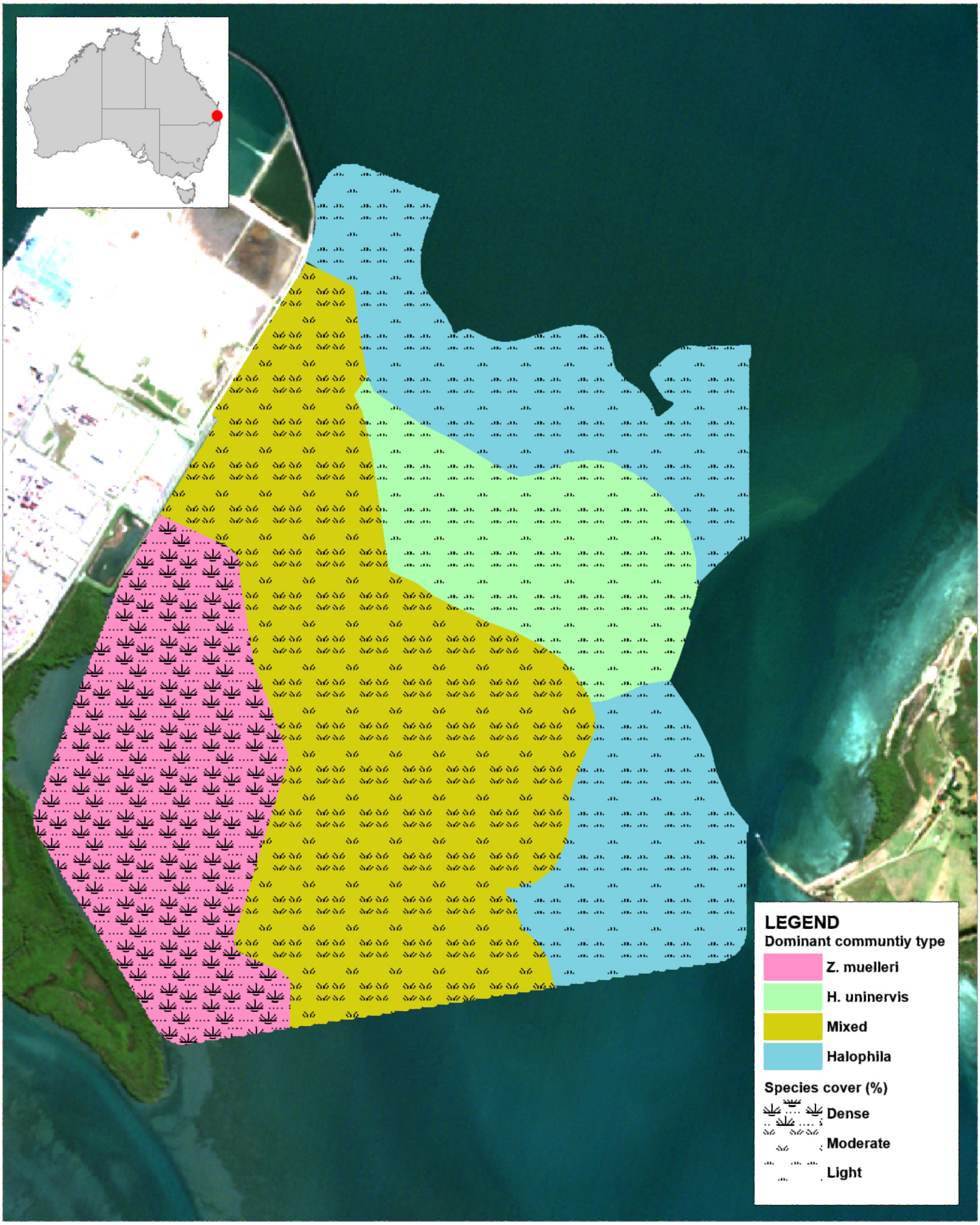

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Seagrass distribution and community structure adjacent to Fisherman Islands 2016

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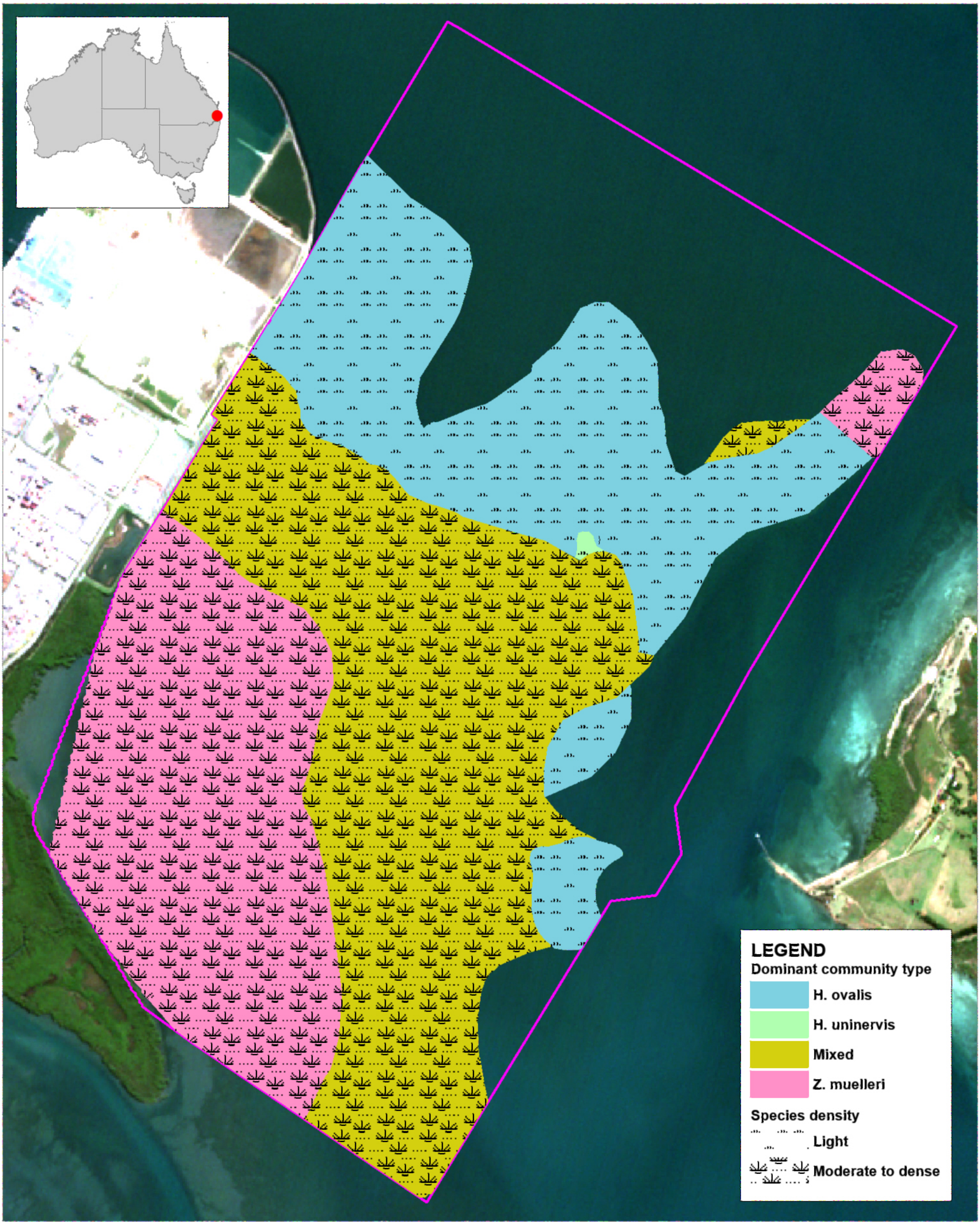

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Seagrass distribution and community structure adjacent to Fisherman Islands 2017

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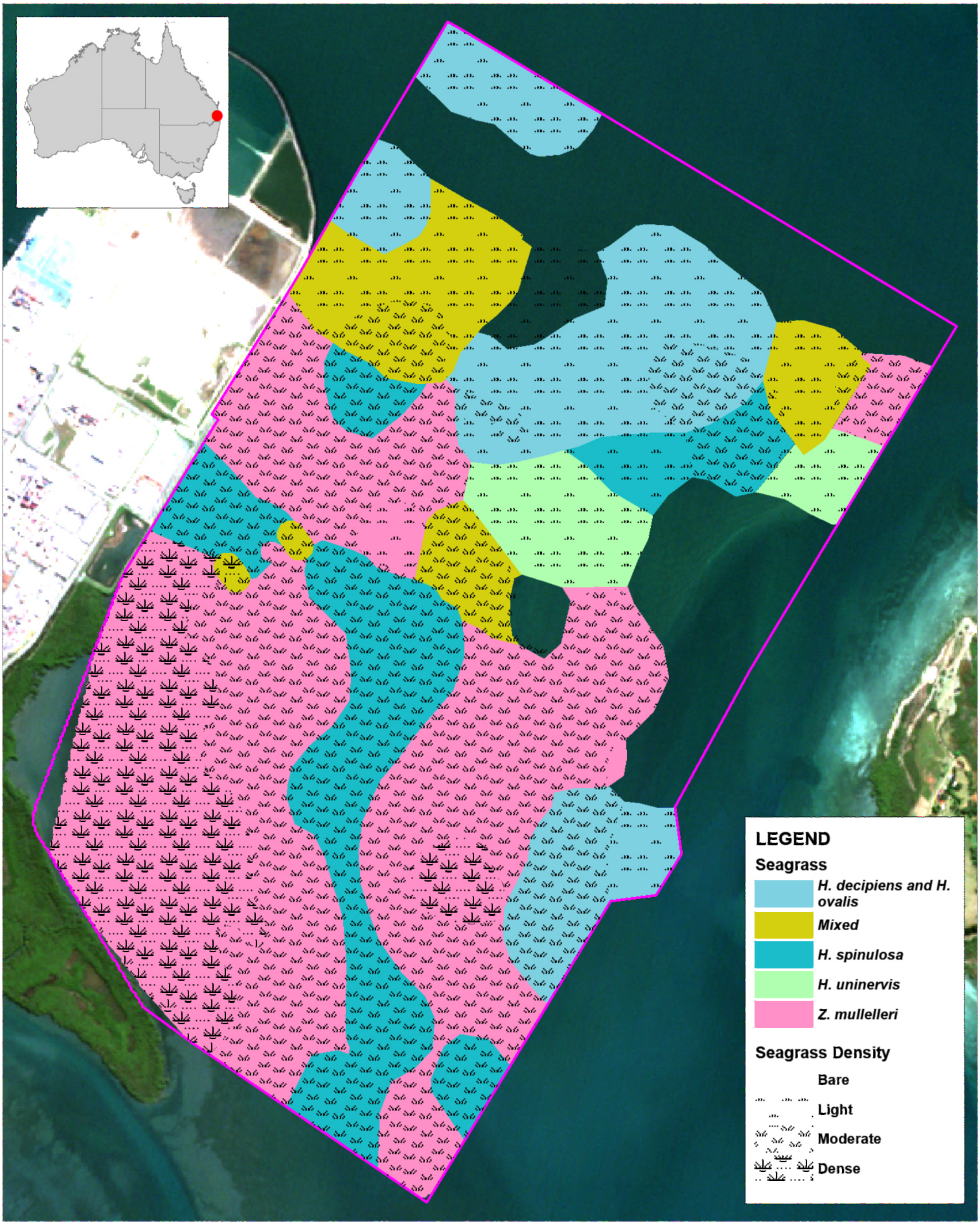

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Seagrass distribution and community structure adjacent to Fisherman Island, 2018

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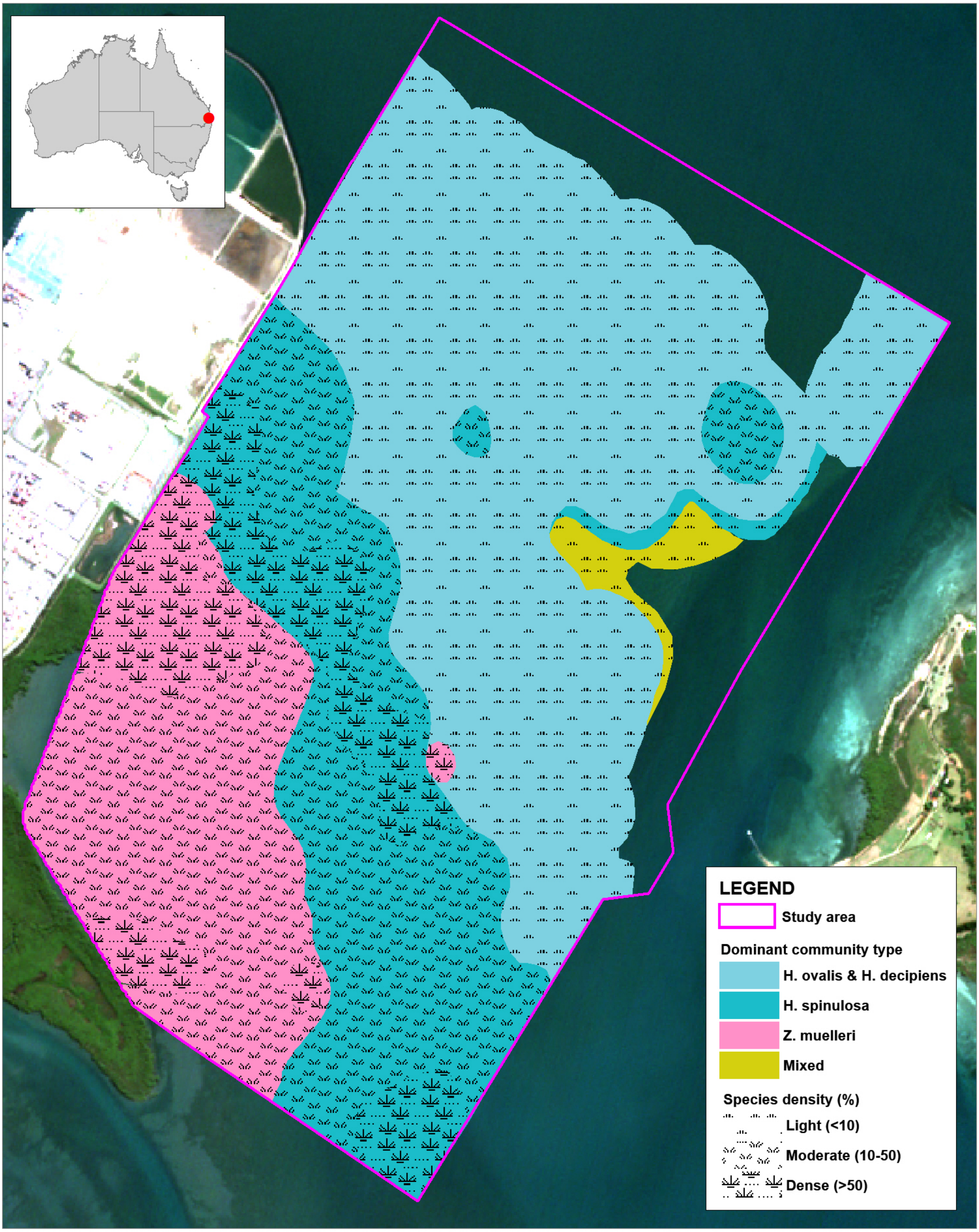

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Seagrass distribution and community structure adjacent to Fisherman Islands 2019

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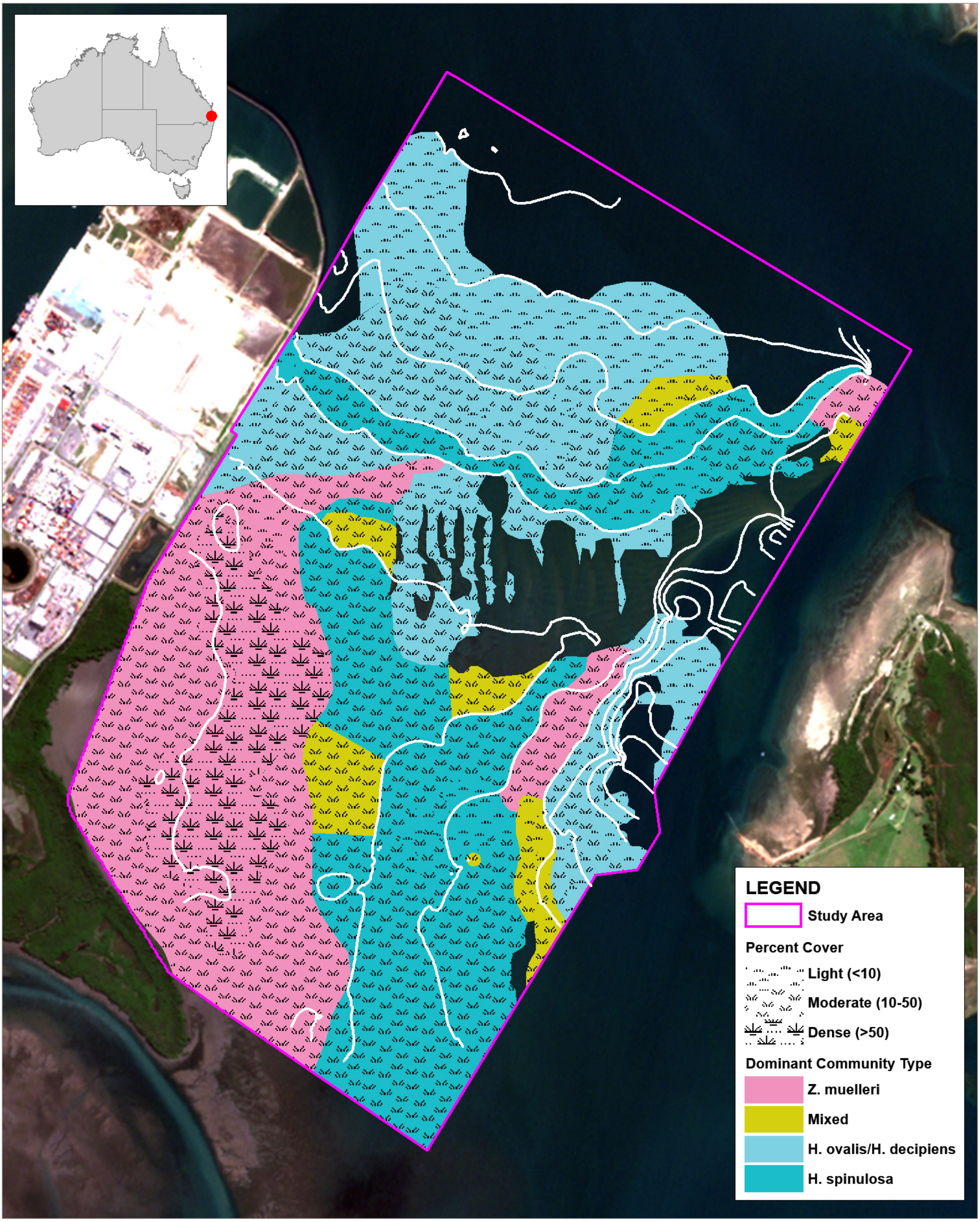

Title:

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

Figure: B-8

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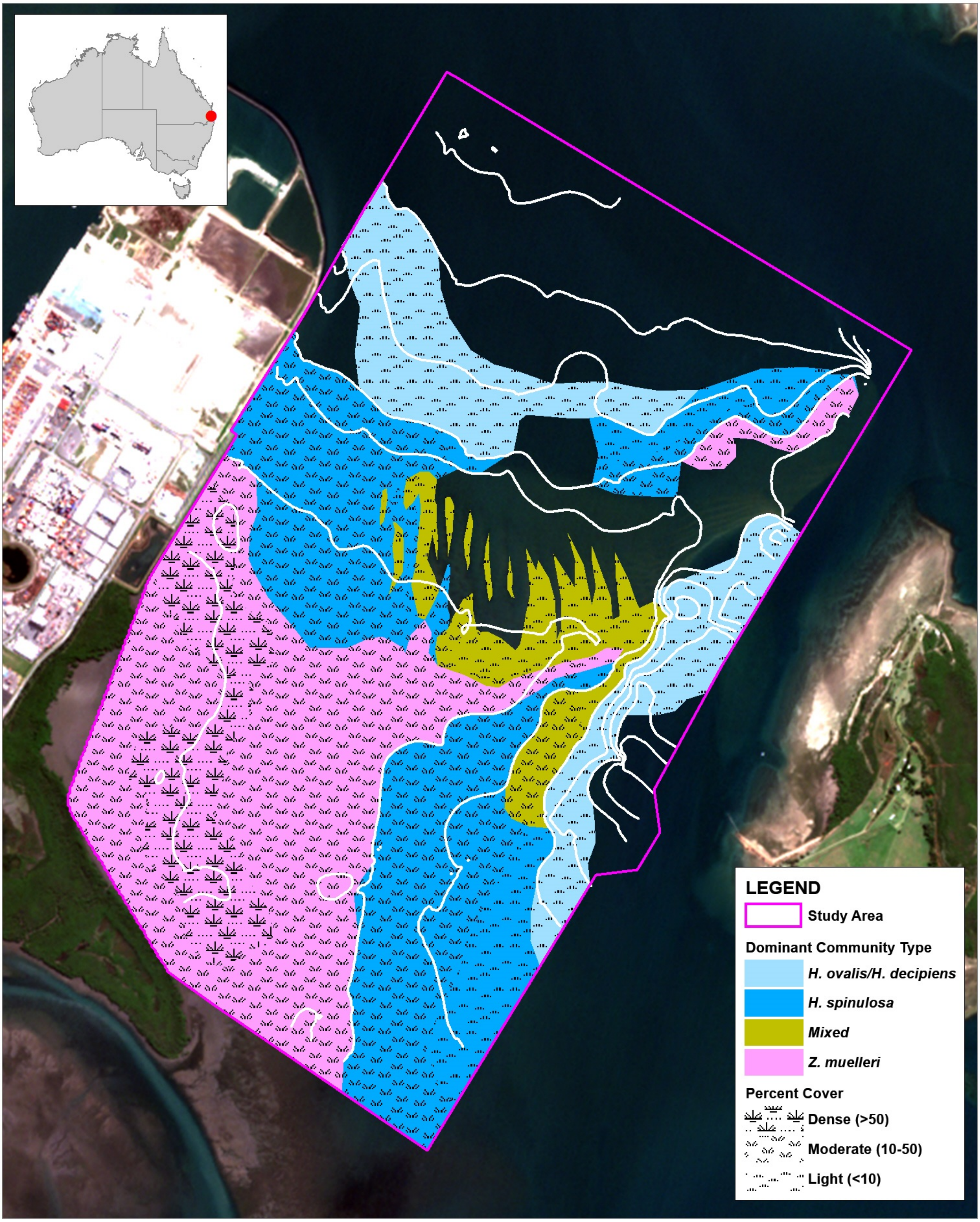

Title:

Seagrass Distribution and Composition Adjacent to Fisherman Islands 2021, Showing 1m LAT Contours

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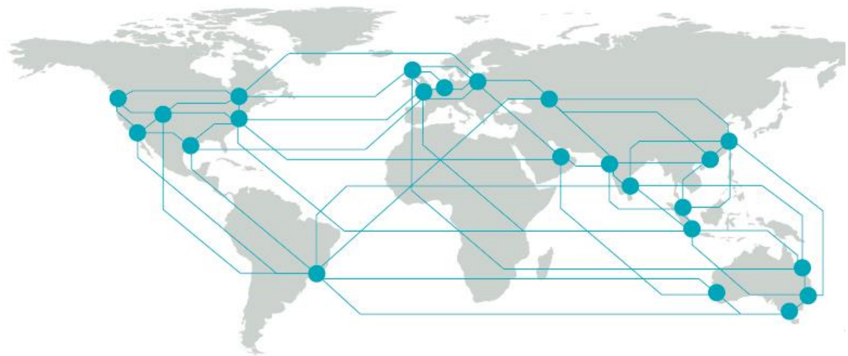

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