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Port of Brisbane Seagrass Monitoring Program Report 2024

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Executive Summary

This report describes the approach and findings of the Port of Brisbane Seagrass Monitoring Program (SMP) 2024 sampling event. The SMP monitors meadows at Fisherman Islands and control locations of Cleveland, Manly and Deception Bay using field (underwater video transects) and desktop-based methodologies. Improved remote-sensing mapping techniques were used in 2024, which were also re-applied to 2021 and 2023 datasets to provide comparable mapping data-sets.

- **Species Composition**: A core set of seagrass species have occurred at all locations over time: the eelgrass *Zostera muelleri*, the paddle-weeds *Halophila ovalis*, *Halophila spinulosa* and *Halophila decipiens*. The narrow-leaf seagrass *Halodule uninervis* is an ephemeral species that was recorded in 2024, whereas *Cymodocea serrulata* has only been recorded on one occasion (2021) survey.

- **Spatial Patterns**: Figure 1 is a map of seagrass meadows at Fisherman Islands in 2024. Intertidal and shallow subtidal areas were numerically dominated by *Zostera muelleri* meadows and *Halophila spinulosa*. Subtidal meadows were comprised of sparse, mixed *Halophila* assemblages. Similar pattens have occurred since the commencement of seagrass mapping in the 1980s.

- The Fisherman Islands seagrass meadows covered an area of 16.7 km^2 in 2024, which was an increase from 2023 (14.8 km^2) and 2022 (11.15 km^2). Most of the gains were in sparse, deepwater *Halophila decipiens* dominated meadows in the northern and western sections of the study area. Seagrass meadow extent in 2024 was the highest on record, reflecting a combination of good (drier) growing conditions since the 2022 Brisbane River flood, and improvements to mapping methodologies.

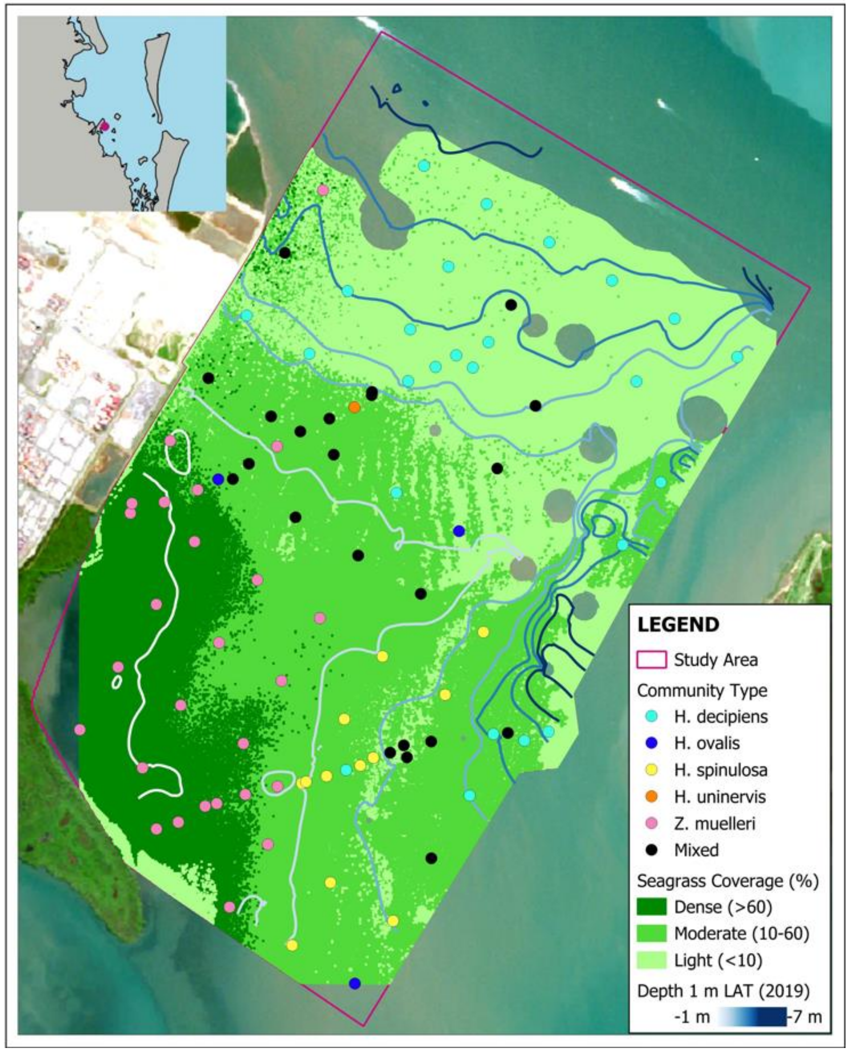


Figure 1 Seagrass distribution and community structure, and 1m LAT contours, adjacent to Fisherman Islands, 2024

- ***Zostera* Seagrass Depth Range (SDR) (Figure 2)**: *Zostera* SDR at Fisherman Islands Transect H (-1.3m AHD) was near the historical minimum and was less than the average control site SDR for the period. *Zostera* SDR at Fisherman Islands transect F (-2.0 m AHD) was the same as the average of control sites and near the historical maxima. The contraction in *Zostera* SDR at Fisherman Islands Transect H in 2024 coincided with increased frequency of filamentous algae detections.

- **Upper Limit of Seagrass Meadows**: The landward margin of *Zostera muelleri* meadows expanded at Fisherman Islands between 2023 and 2024. Average maximum temperatures in 2023-24 were within the optimal temperature range of *Zostera*.

Overall, the increase in seagrass meadow extent between 2022 and 2024 indicates that *Halophila* species have recovered since the 2022 flood. *Zostera* however was in variable condition, and there is a need to closely monitor changes in *Zostera* changes and potential linkages to epiphytic algae loading. At decadal time scales, there has been a long-term trend of seagrass meadow expansion at Fisherman Islands since the early 2000s, as predicted by the Future Port Expansion Impact Assessment Study.

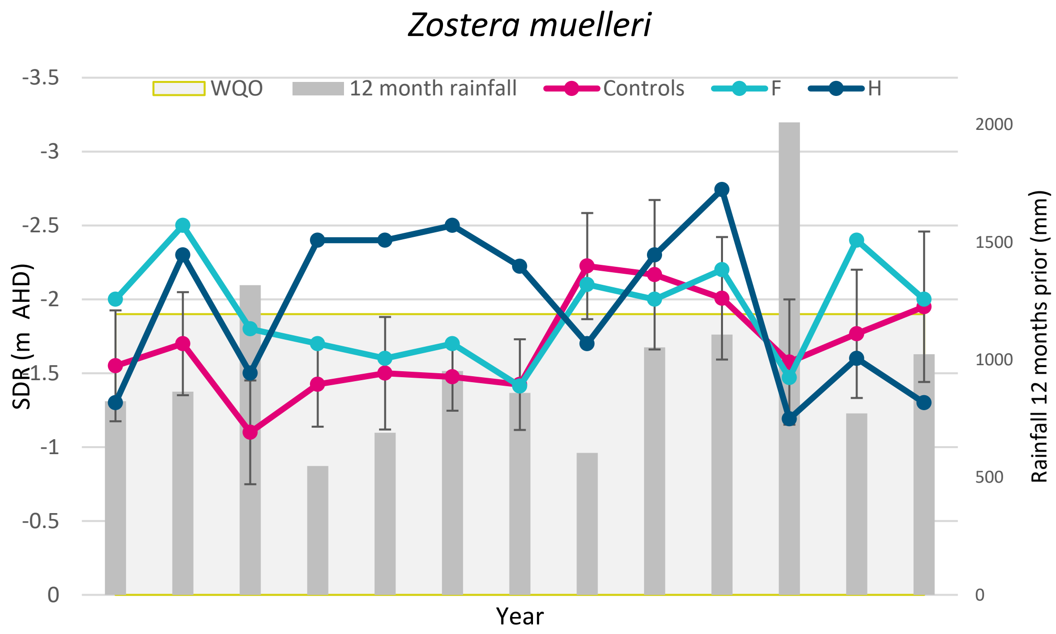


Figure 2 *Zostera* seagrass depth range at Fisherman Islands transect F and H, and the average (±SE) for control sites. Rainfall in the 12 months leading to the survey is also shown

Contents

1 Introduction

1.1 Background

Moreton Bay is home to 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, located adjacent to Waterloo Bay, 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 long-term data on the status and condition of seagrass meadows through time to identify if there are any signs of impact from port activities.

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 (Abal and Dennison 1996). A reduction in light availability below the requirements of a particular seagrass species can reduce plant energy production (through the process of photosynthesis), typically resulting in the loss 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 control locations at Manly, Cleveland and Deception Bay;
- 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;
- Characterise spatial and temporal patterns in the vertical (depth, accuracy measured in tens of centimetres) distribution of seagrass meadows at the Port and control locations;
- Determine whether broad-scale spatial and/or temporal patterns in seagrass extent are consistent among the Port and control locations; and
- On the basis of the above, identify possible broad-scale operational impacts of port activities on the distribution and extent of seagrass meadows.

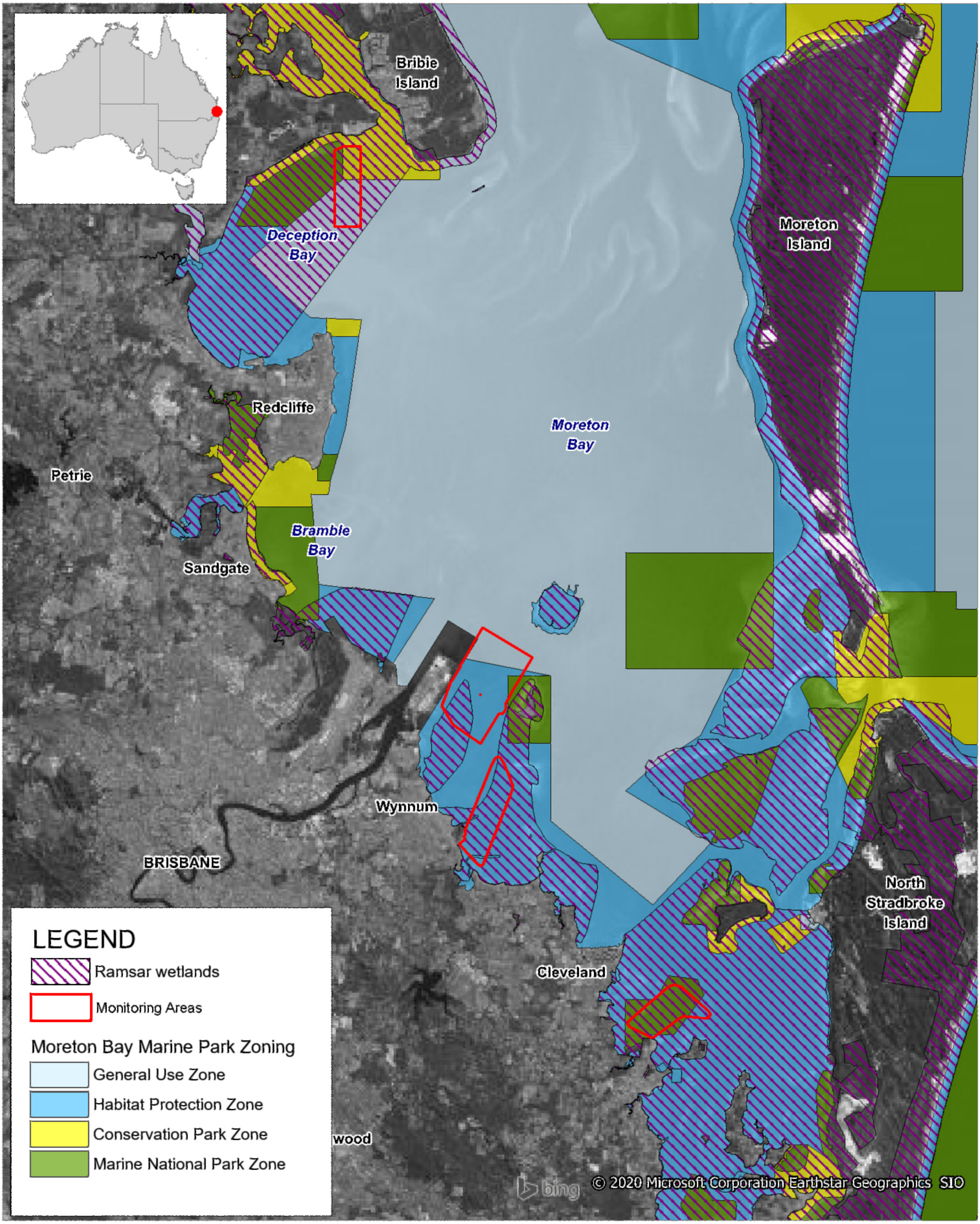
1.3 Study Area

The Port of Brisbane, located on Fisherman Islands at the mouth of the Brisbane River along the western shore of Moreton Bay, was established on land reclaimed from a shallow sub-tidal river delta that once consisted of low-lying mangrove islands. Originally reserved for harbor purposes in the 1940s, reclamation of the area began in the late 1960s, with the relocation of port facilities from the city reaches occurring in the 1970s. Today, the Port of Brisbane is Queensland's largest container port, continuing to expand through progressive land reclamation within its existing perimeter bund.

The construction of the Port of Brisbane has significantly altered the environmental landscape of Fisherman Islands, impacting intertidal and subtidal areas. Despite these changes, substantial areas of mangrove, saltmarsh, and seagrass have been preserved as part of the Fisherman Islands wetland complex, located 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 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).

The control locations for the study, named western Moreton Bay sites (Manly, Cleveland and Deception Bay), 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 to Figure 2.5). 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 location in 2020. Previous surveys of Deception Bay have characterised this seagrass community as light to moderate cover comprised of *Zostera muelleri* (subsp. capricorni), *Halodule uninervis*, *Halophila ovalis* and *Syringodium isoetifolium* (Kirkman 1995; 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 was undertaken between 9 July and 7 August 2024. Tidal data from the Tidal Unit, Maritime Safety Queensland was obtained for the Brisbane Bar throughout this study period (between 9 July and 7 August 2024) and was used to correct depth soundings to Australian Height Datum (AHD).

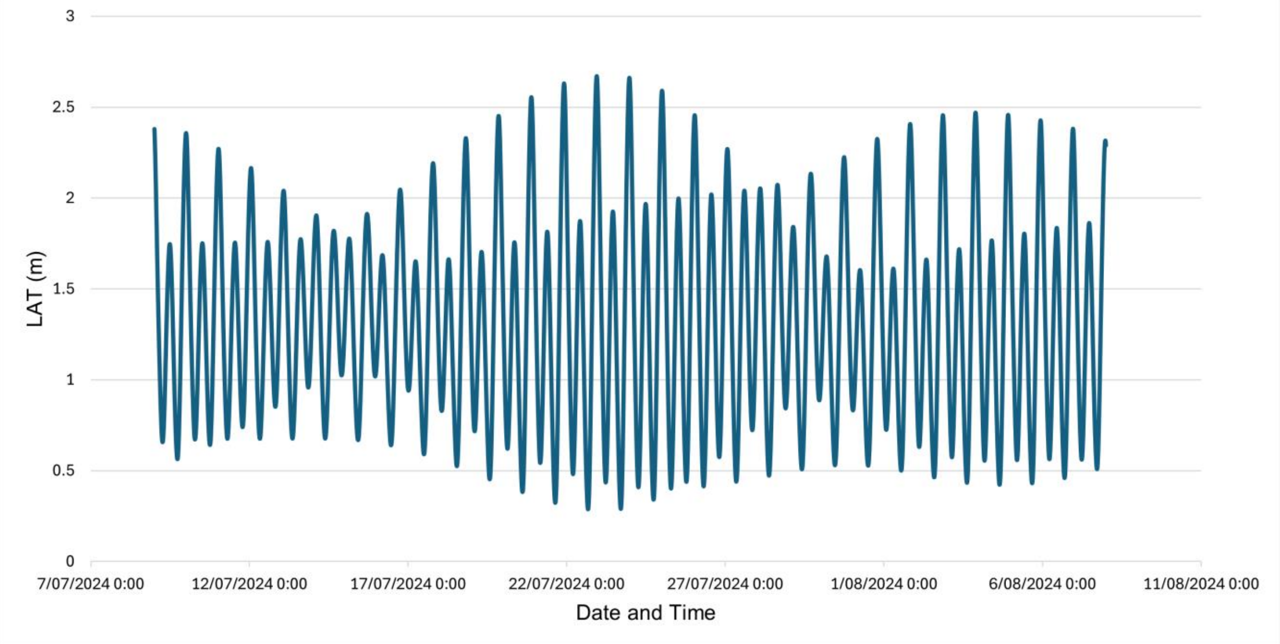


Figure 2.1 Tidal Heights at Brisbane Bar

2.2 Survey Vessel and Positioning

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

2.3 Monitoring Locations, Survey Points 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, 2021, 2022, 2023 and 2024 (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.

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 in Figure 2.2 (Fisherman Islands), Figure 2.3 (Manly), Figure 2.4 (Cleveland) and Figure 2.5 (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 2.2).

It should be noted that one intertidal survey point (C_F2) in the Cleveland study area was unable to be sampled in 2024 due to tidal conditions being too low for the research vessel. Notes have been included on the relevant maps (Figure 2.2 and Figure 2.5).

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, 2020, 2021, 2022 and 2023.

Two depth profile transects occur at each survey location and run approximately perpendicular to the shoreline (Figure 2.2 to Figure 2.5). 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

Remote sensing data

Imagery was captured for July in 2021-2024 at low tide from Sentinel-2 satellites (Sentinel-2A and Sentinel-2B). Level-1C (L1C) images were selected which include 0% cloud cover, orthorectified, geolocated, and radiometrically calibrated top-of-atmosphere reflectance.

Image post-processing

Imagery underwent the following processing steps:

1. Atmospheric correction for water, targeting multispectral bands capable of penetrating water and detecting submerged aquatic vegetation (SAV). The atmospheric correction process utilised the dark spectrum fitting (DSF) method, which is particularly effective for aquatic environments (Vanhellemont, 2019). This process converted the L1C, top-of-atmosphere reflectance, images into Level-2A (L2A) image, providing bottom-of-atmosphere reflectance. The correction was performed in two stages:

- Rayleigh correction— Correction for scattering caused by air molecules.
- Aerosol correction— Assumed black SWIR bands over water due to the high absorption by pure water and applied an exponential spectrum to account for multiple scattering aerosol reflectance.

The output provided water-leaving radiance reflectance, or water reflectance, in all the necessary bands for SAV analysis at a 10-meter resolution. The Blue, Green, and Red bands originally had a resolution of 10 meters, while the Red-Edge band, initially at 20 meters, was resampled to match the 10-meter resolution of the other bands.

2. Sun glint effects removal to eliminate distortions caused by sun-glint (Hedley *et al*., 2005).
3. Depth invariant indices (DII) (Lyzenga, 1978) were used to correct for the influence of water depth on reflectance by selecting two spectral bands to calculate the deep-water reflectance, and determining the ratio of attenuation coefficients using least squares regression. Three DIIs were created using combinations of Blue/Green, Blue/Red, and Green/Red bands.
4. Water-adjusted vegetation index (WAVI) and normalised difference aquatic vegetation index (NDAVI) were utilised to highlight features relevant to seagrass habitats. The red edge band was used instead of the near-infrared band, as the red edge band penetrates further into the water. The following equations were used:

$$\mathrm{NDAVI} = (Red\ Edge\ Band - \mathrm{Green\ Band})/(\mathrm{Red\ Edge\ Band} + \mathrm{Green\ Band})$$

$$\mathrm{WAVI} = (Red\ Edge\ Band - \mathrm{Blue\ Band})/(\mathrm{Red\ Edge\ Band} + \mathrm{Blue\ Band} + \mathrm{L}) * (1 + L)$$

where L is the vegetation correction factor of 0.5.

Image classification

The nine individual bands generated for image classification (Blue, Green, Red, Red Edge, DII Blue/Green, DII Blue/Red, DII Green/Red, NDAVI, and WAVI) were used to classify the images through an unsupervised cluster image classification method. Clusters were then compared against field survey point data for further validation and refinement This classification categorized seagrass density coverage, described below.

Seagrass abundance

Consistent with previous monitoring, seagrass species at each survey point 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 density coverage were used to provide context to the broad community categories including:

- Light—0-10% coverage
- Moderate—10-60% coverage
- Dense—60% coverage

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 within each of the sampling locations (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% of composition

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

Macroalgae

Marcoalgae presence or absence was estimated for the following groups: (i) filamentous algae including epiphytic and turfing algae; and (ii) other macroalgae (non-filamentous).

Seagrass meadow extent mapping (Fisherman Island)

The extent of seagrass meadows was mapped adjacent to Fisherman Islands using a combination of remote sensing techniques extracted from the classified imagery and field sampling points collected.

2.5 Statistical Analysis

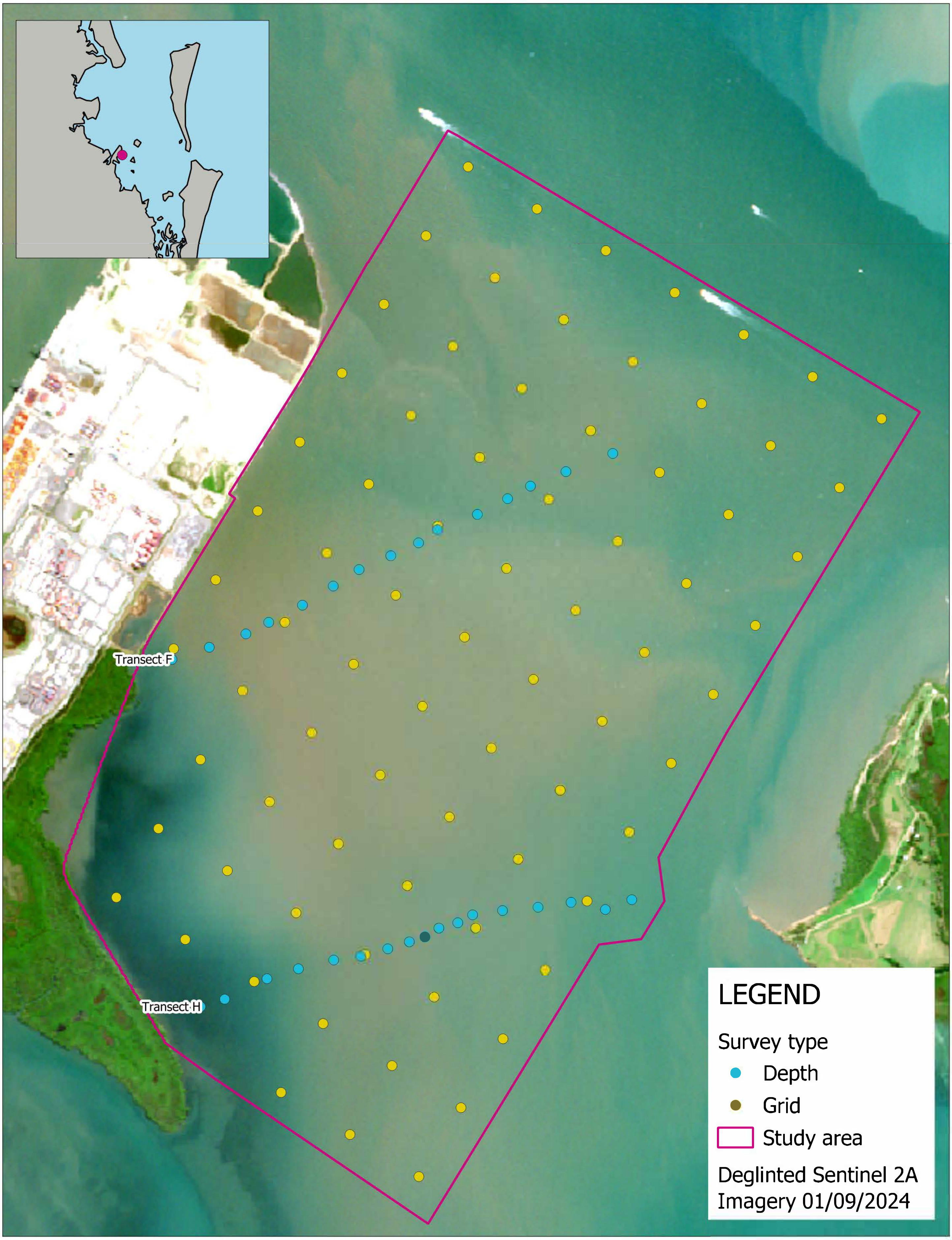
Chi-squared test

A binomial regression (generalised linear model) was used to test for differences in the prevalence of seagrass (presence or absence) in each transect among different years and locations (i.e. Fisherman Islands 2023 vs 2024). The analysis was conducted in R Studio using the "glmmTMB" package (Brooks *et al*., 2017), with seagrass presence modelled as a function of the interaction between year and location. Non-detects were treated as zeros, while all other levels of cover were classified as presence. Post-hoc independent contrasts between locations and years were assessed using the "emmeans" package (Lenth *et al*., 2024). To evaluate the significance of the linear predictors, a Type II

Wald Chi-squared test was conducted with the "car" package (Fox *et al*., 2019). Model residuals were examined using the DHARMa package to ensure the appropriateness of the linear predictor and verify that error distribution was homogenous across the model.

Pearson product moment correlation

Cumulative rainfall in the 12-month period leading up to each survey episode (2006-2024, n = 13) was sourced from the Bureau of Meteorology weather station at Fort Lytton (Station 040320). For each year, the cumulative rainfall was subtracted from the long-term average 12-month rainfall value (1192 mm/annum), to derive a cumulative rainfall departure value for each year. The mean *Zostera* seagrass depth range (SDR) value for each year (locations pooled) was then calculated. Pearson Product-Moment correlation analysis was used to explore the relationship between cumulative rainfall departure value rainfall and mean SDR (samples = survey episodes).



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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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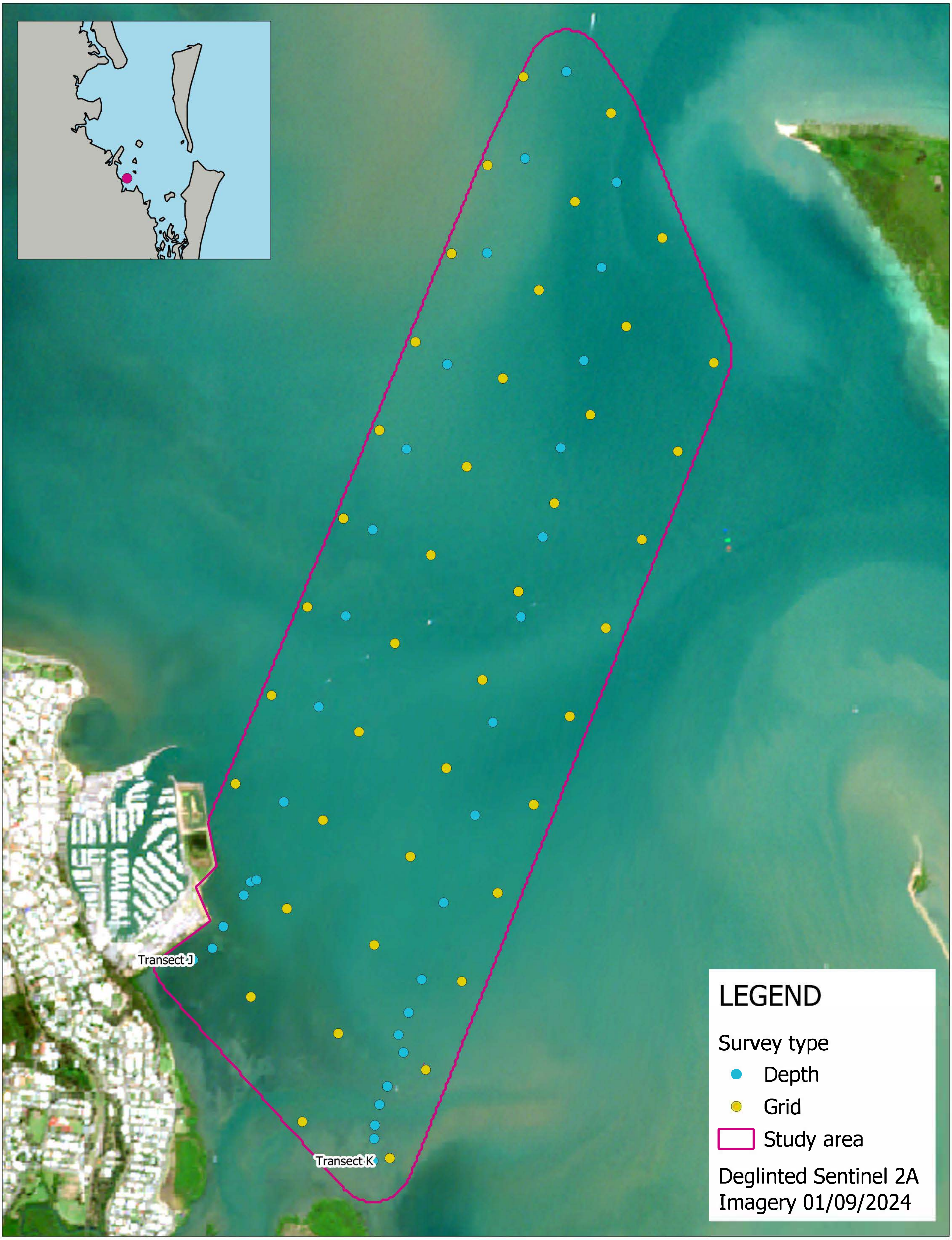

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Survey points used to map the distribution of seagrass adjacent to Manly

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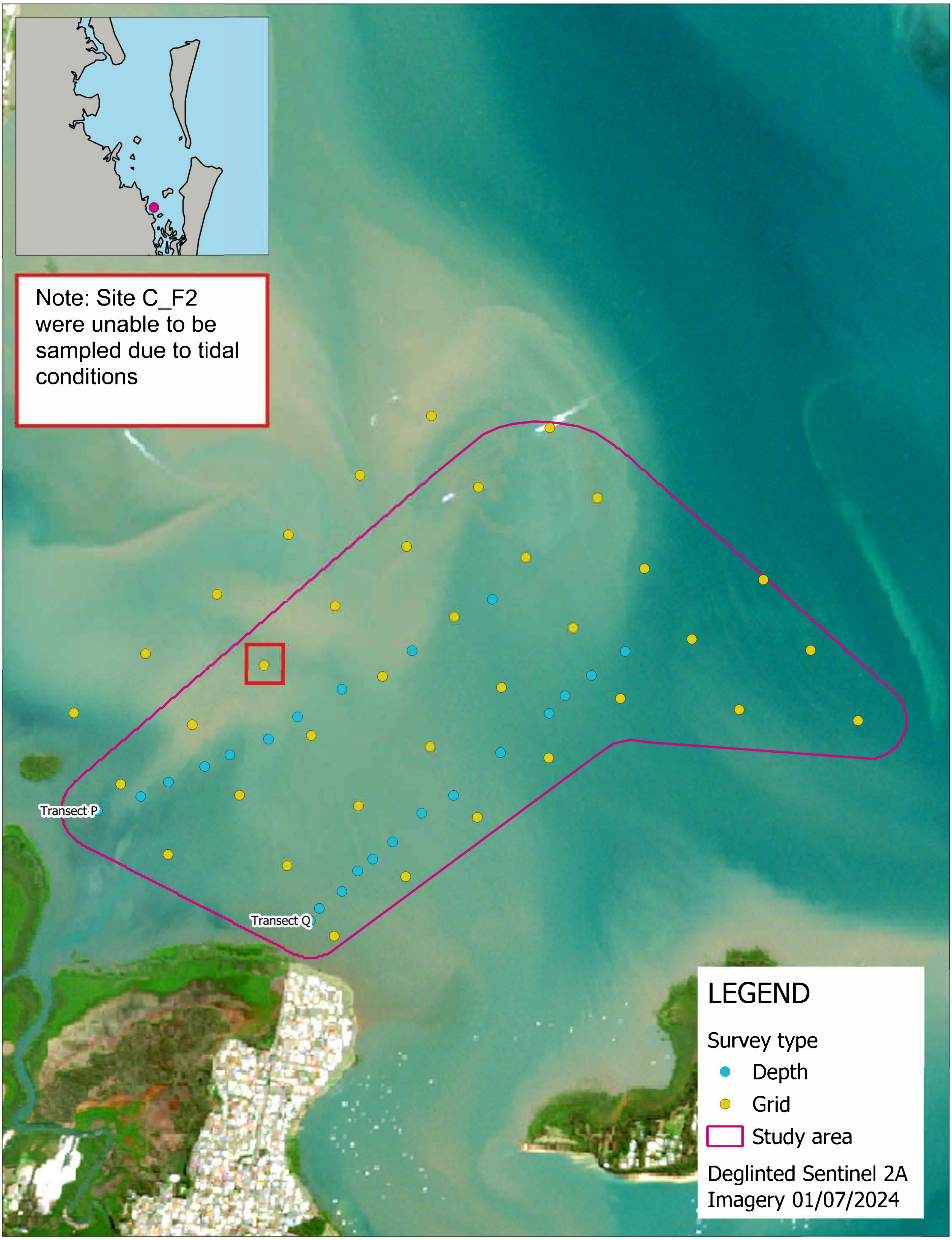

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Survey points used to map the distribution of seagrass at Cleveland

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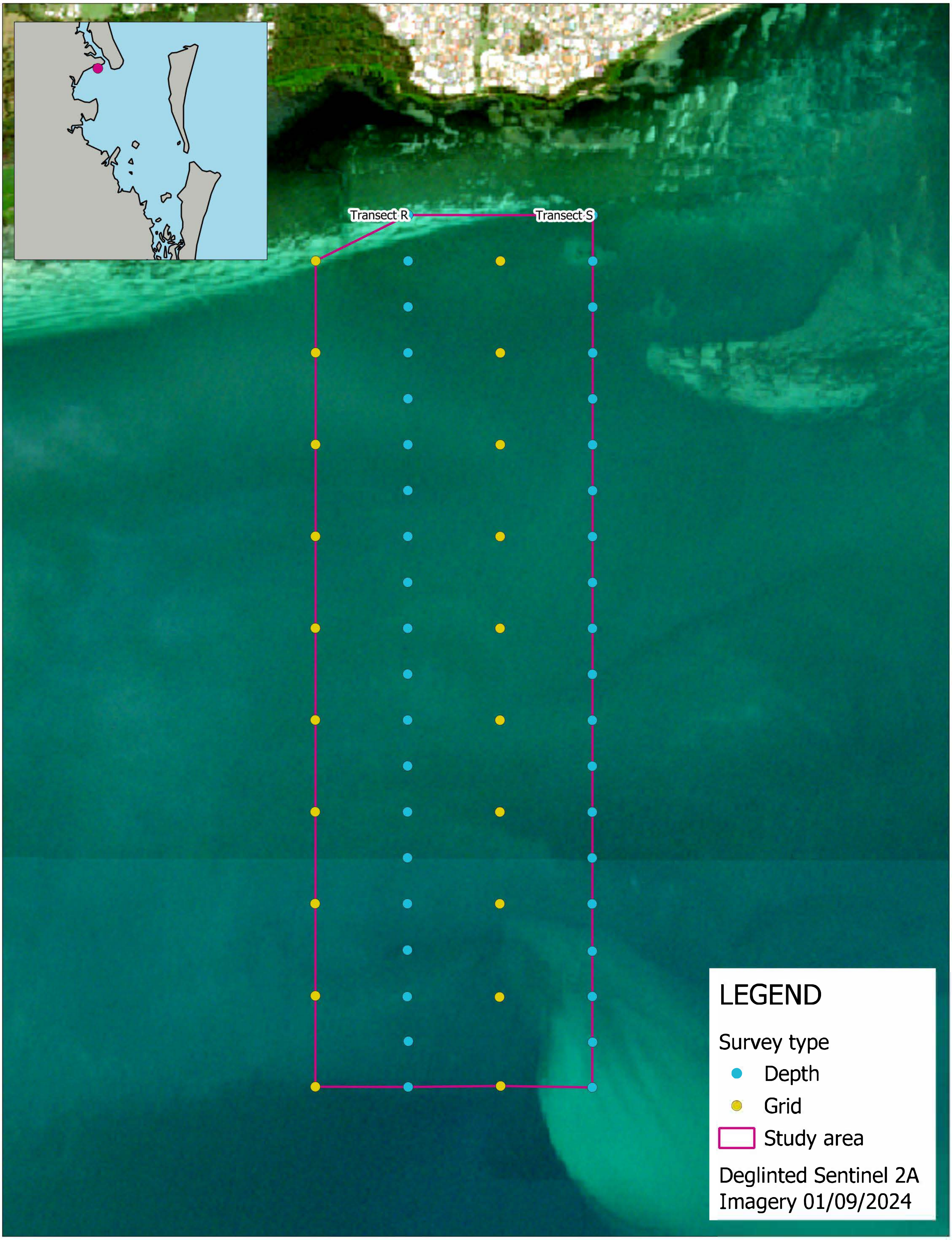

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Survey points used to map the distribution of seagrass at Deception Bay

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3 Results

3.1 Climatic Conditions

Total monthly and annual rainfall in the period 2001 to June 2024 is shown in Figure 3.1. Annual rainfall in the three of the four years leading up to the survey (2020, 2021, 2022) was above the long term average, with major flood event recorded in February 2022. Annual average rainfall in 2023 (673.4 mm) was well below the long-term annual average (1068.4 mm). In the 12 months leading up to the survey, monthly rainfall was above the average monthly in July, November and December in 2023, January and March in 2024 and below average in August—October 2023 and February, April—June 2024 (Figure 3.2).

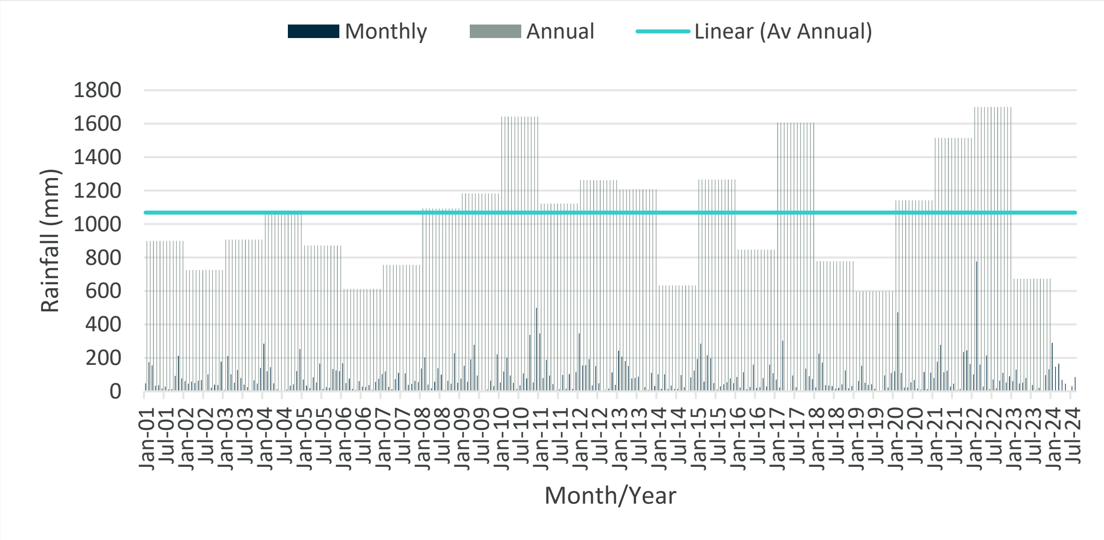


Figure 3.1 Monthly and annual total rainfall between 2001 and July 2024 at Brisbane Aero Station 040842 (Data source: BOM 2024)

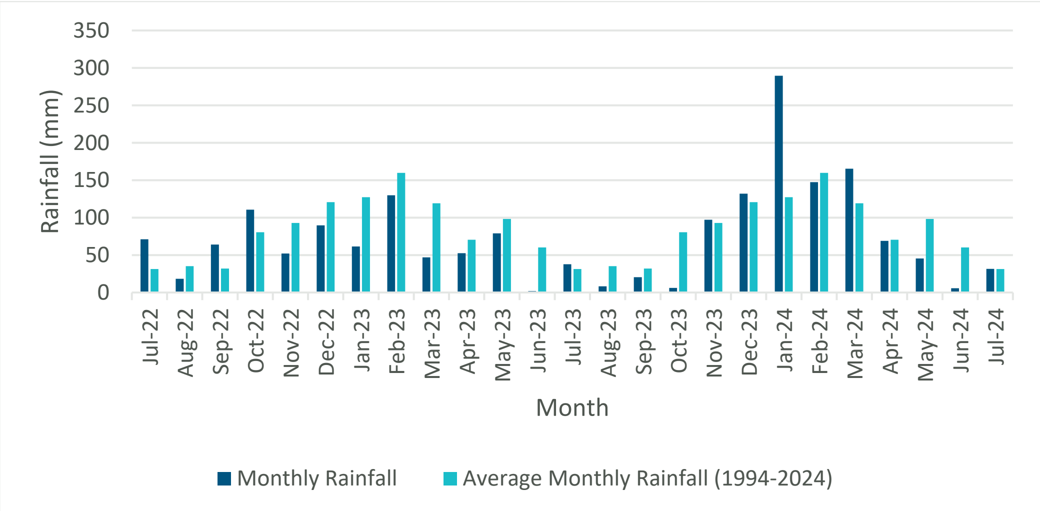


Figure 3.2 Monthly rainfall from July 2022 to July 2024 and average monthly rainfall (1994 to 2024) at Brisbane Aero Station 040842 (Data source: BOM 2024)

Figure 3.3 shows that mean maximum temperature from 1995 to 2024. The annual mean temperature in 2023 (26°C) was above the annual average value (25.4°C). Figure 3.4 shows the mean monthly maximum air temperature between 2022 to 2024 and the long-term average monthly maximum air temperature. In the period from July 2023-24, mean maximum temperature was in February 2024 (29.9 °C) exceeding the long-term average for February by +0.8 °C.

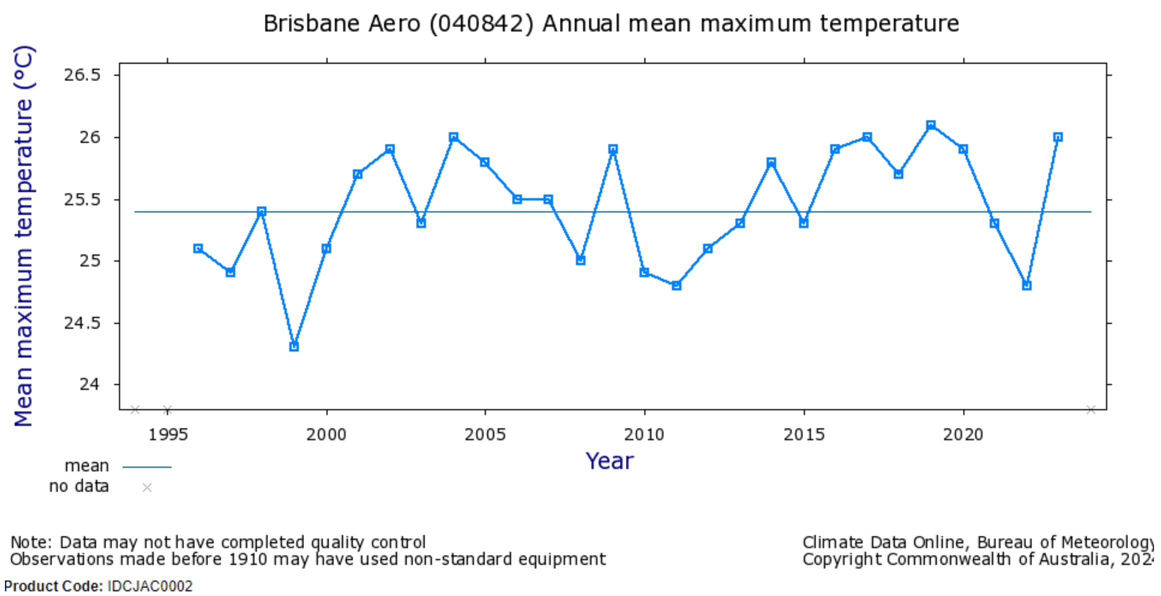


Figure 3.3 Annual mean maximum air temperature between 1995 and July 2024 at Brisbane Aero Station 040842 (Data source: BOM 2024)

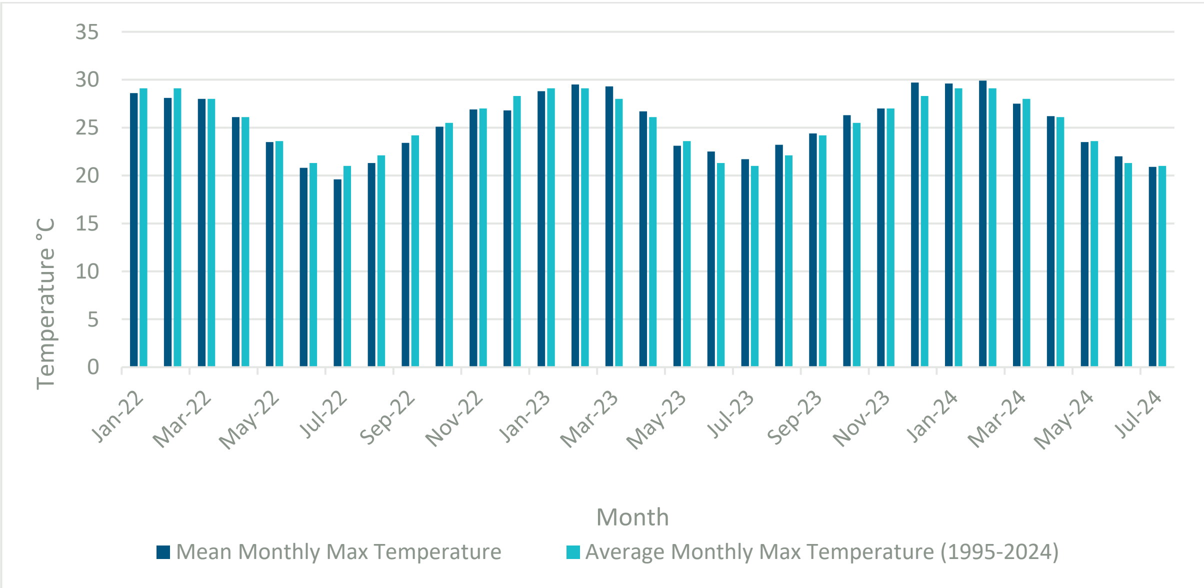


Figure 3.4 Mean monthly maximum air temperature from July 2022 to July 2024 and average monthly maximum air temperature between 1995 and July 2024 at Brisbane Aero Station 040842 (Data source: BOM 2024)

3.2 Seagrass Spatial Distribution and Percentage Cover

Species distribution

Five of the eight seagrass species known to occur in Moreton Bay were recorded in the 2024 survey: *Zostera muelleri* (*subsp. capricorni*), *Halophila ovalis*, *Halophila spinulosa*, *Halophila decipiens* and *Halodule uninervis*. *Cymodocea serrulata* was recorded in the 2021 survey but has not been observed in the SMP since then (see Table 3.1).

Maps showing the spatial distribution of each seagrass species in 2024 survey are shown in Figure 3.5 to Figure 3.8. The general pattern of assemblage structure across the depth zones at Fisherman Islands was as follows (Figure 3.9):

- *Halophila decipiens and H. ovalis* were numerically dominant or co-dominant in the subtidal zone
- *Halophila spinulosa* was numerically dominant in the intertidal/subtidal transitional zone
- *Halodule uninervis* was present in both intertidal and subtidal waters
- *Zostera muelleri* numerically dominated intertidal and shallow subtidal waters.

Frequency of seagrass detections

A total of 303 survey points were sampled in 2024. The frequency of seagrass detections varied among locations and over time as follows:

- 81% of the Fisherman Islands survey points (n = 110) in 2024 compared to 62% in 2023 (increase)
- 89% of Manly survey points (n = 75) in 2024 compared to 84% in 2023 (decrease)
- 78% of Cleveland survey points (n = 58) in 2024 compared to 79% in 2023 (same)
- 42% of Deception Bay survey points (n = 60) in 2024 compared to 54% in 2023 (decrease).

A chi square test was performed to examine the relation between seagrass detections at each location and year (2023 and 2024). There was a significant difference in the number of detections between years among locations ($\chi^2(3, N=602) = 45.623$, $p < 0.001$). Additionally, there was a significant interaction between years and areas ($\chi^2(3, N=602) = 11.125$, $p = 0.011$), suggesting that the change in seagrass presence between 2023 and 2024 varied by area. However, the main effect of year was marginally non-significant ($\chi^2(1, N=602) = 2.886$, $p = 0.089$), implying that there may not be a uniform change in seagrass presence across all areas from 2023 to 2024.

In summary:

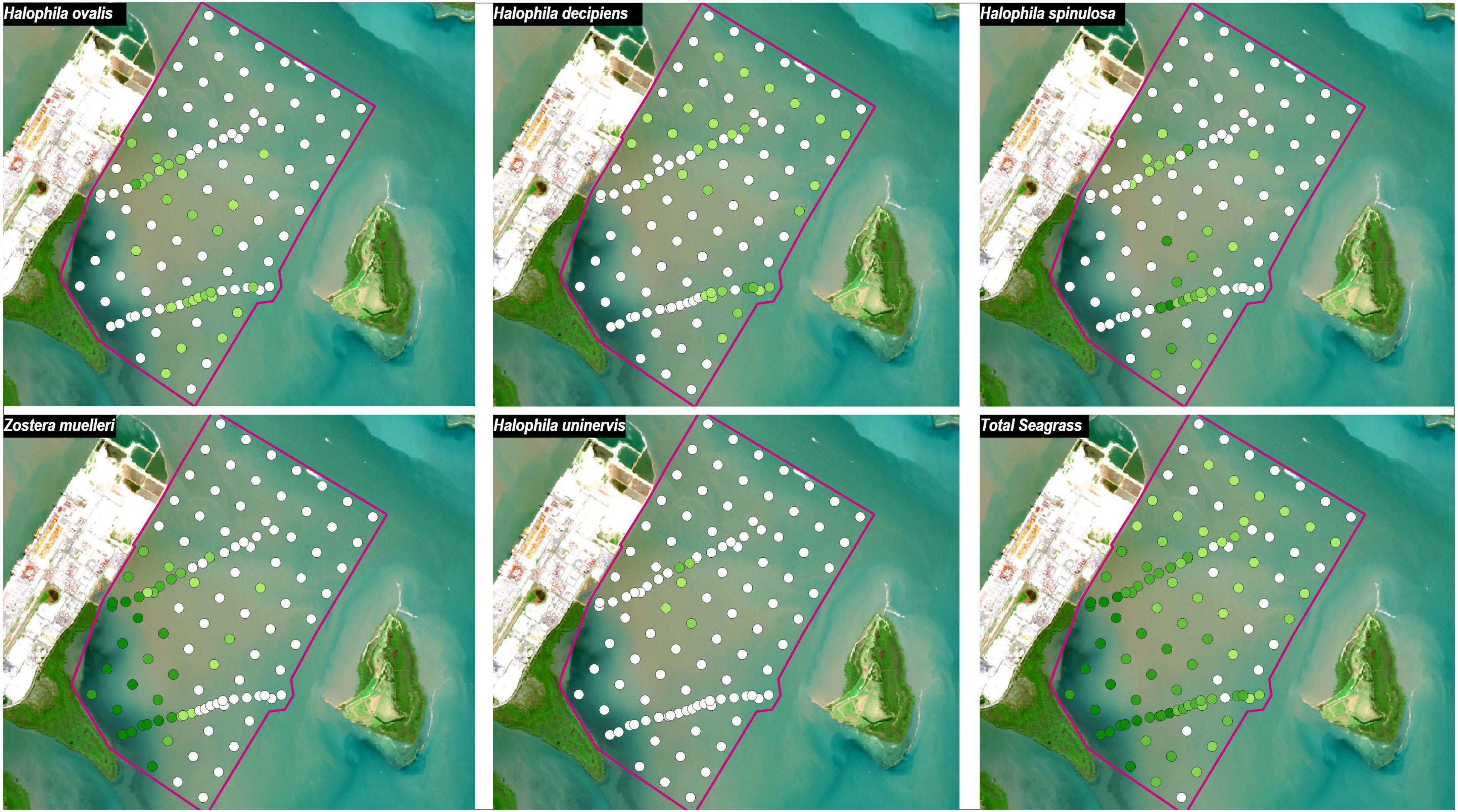
- *Halophila spinulosa* was the most frequently observed seagrass species at Fisherman Island, Manly and Cleveland but was infrequently observed at Deception Bay.
- *Halodule uninervis* was the least frequently observed seagrass species across all locations except Cleveland.
- The frequency of *Halophila ovalis* detections increased between 2023 and 2024 at all locations. An average increase of 9-10% was typically observed with a lower increase seen at Cleveland (4%).
- The frequency of *Zostera muelleri* decreased between 2023 and 2024 at Fisherman Islands by 9% and Deception Bay by 5% but remained stable at Cleveland. Manly location had an increase in frequency of 2%.

- Macroalgae detections were recorded at a total of 223 survey points at all locations in 2024 compared to 205 survey points in 2023. Detections varied at each location:
  - 81% of the Fisherman Islands survey points (n = 110) in 2024 compared to 52% in 2023 (increase)
  - 97% of Manly survey points (n = 75) in 2024 compared to 76% in 2023 (increase)
  - 75% of Cleveland survey points (n = 58) in 2024 compared to 61% in 2023 (increase)
  - 43% of Deception Bay survey points (n = 60) in 2024 compared to 98% in 2023 (decrease).

Table 3.1 Seagrass presence at survey points (%)

Site	Species	No. of survey point detections (%)						Trend 2023-24
		2019	2020	2021	2022	2023	2024	
Fisherman Islands	*H. decipiens*	24	13	6	6	15	35	↑↑
	H. ovalis	36	27	28	18	23	32	↑
	H. spinulosa	53	42	39	20	31	32	↑
	H. uninervis	20	0	7	18	3	5	↑
	Z. muelleri	40	46	38	38	47	38	↓
	C. serrulate	0	0	1	0	0	0	↔
Manly	H. decipiens	14	6	24	0	0	20	↑↑
	H. ovalis	34	11	23	11	11	20	↑
	H. spinulosa	51	49	56	39	61	71	↑
	Z. muelleri	17	16	20	18	21	23	↑
	H. uninervis	-	-	-	0	0	4	↑
Cleveland	*H. decipiens*	21	21	17	3	37	43	↑
	H. ovalis	23	-	2	10	12	16	↑
	H. spinulosa	29	30	51	34	39	55	↑↑
	Z. muelleri	14	9	12	19	16	16	↔
	H. uninervis	-	-	-	-	4	0	↓
Deception Bay	*H. decipiens*	**Not sampled**	0	8	0	22	20	↓
	H. ovalis	**Not sampled**	32	18	18	27	37	↑
	H. spinulosa	**Not sampled**	3	18	2	5	8	↑
	Z. muelleri	**Not sampled**	25	18	29	40	35	↓
	H. uninervis	**Not sampled**	10	30	14	0	8	↑

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 Island 2024

Figure: 3-5

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 2 km

BMT
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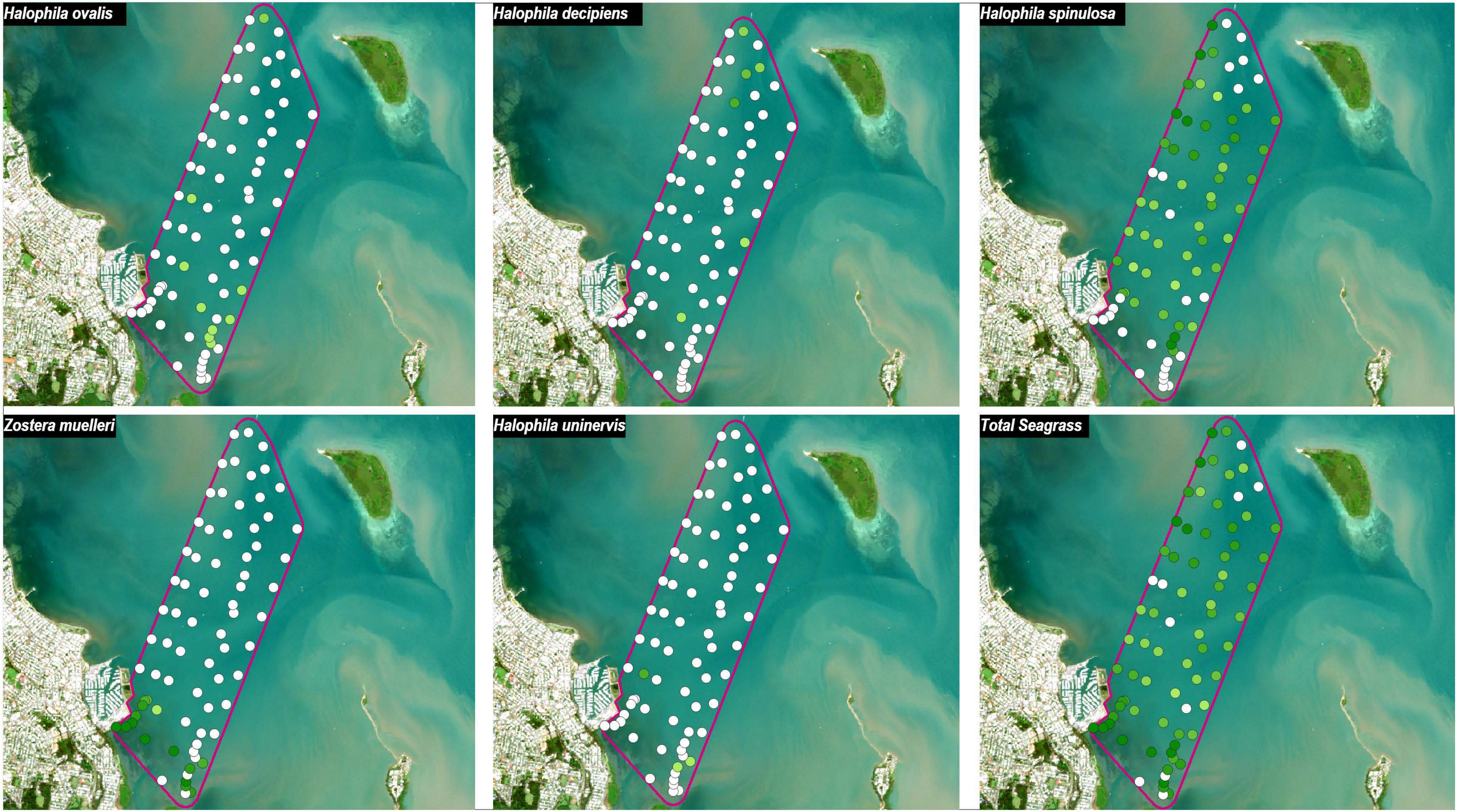
Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2024_Seagrass\Updated_PoBSeagrass_2024QGIS.qgz



LEGEND

Seagrass Cover (%)

Study Area

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

Title:

Species Distribution at Manly 2024

Figure: 3-6

Rev: A

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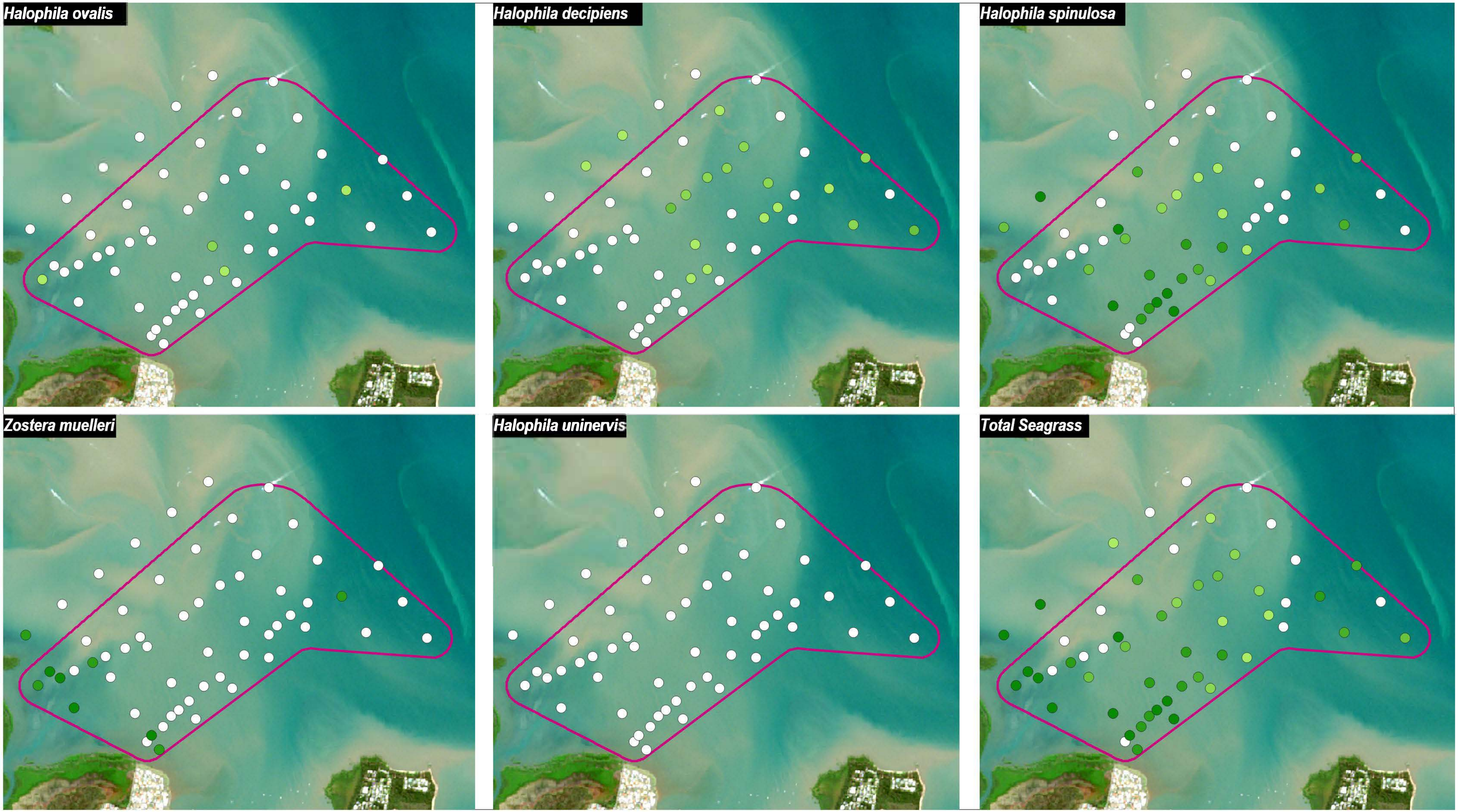

LEGEND

Seagrass Cover (%) — Study Area

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

Title:

Species Distribution at Cleveland, in Moreton Bay 2024

Figure: 3-7

Rev: A

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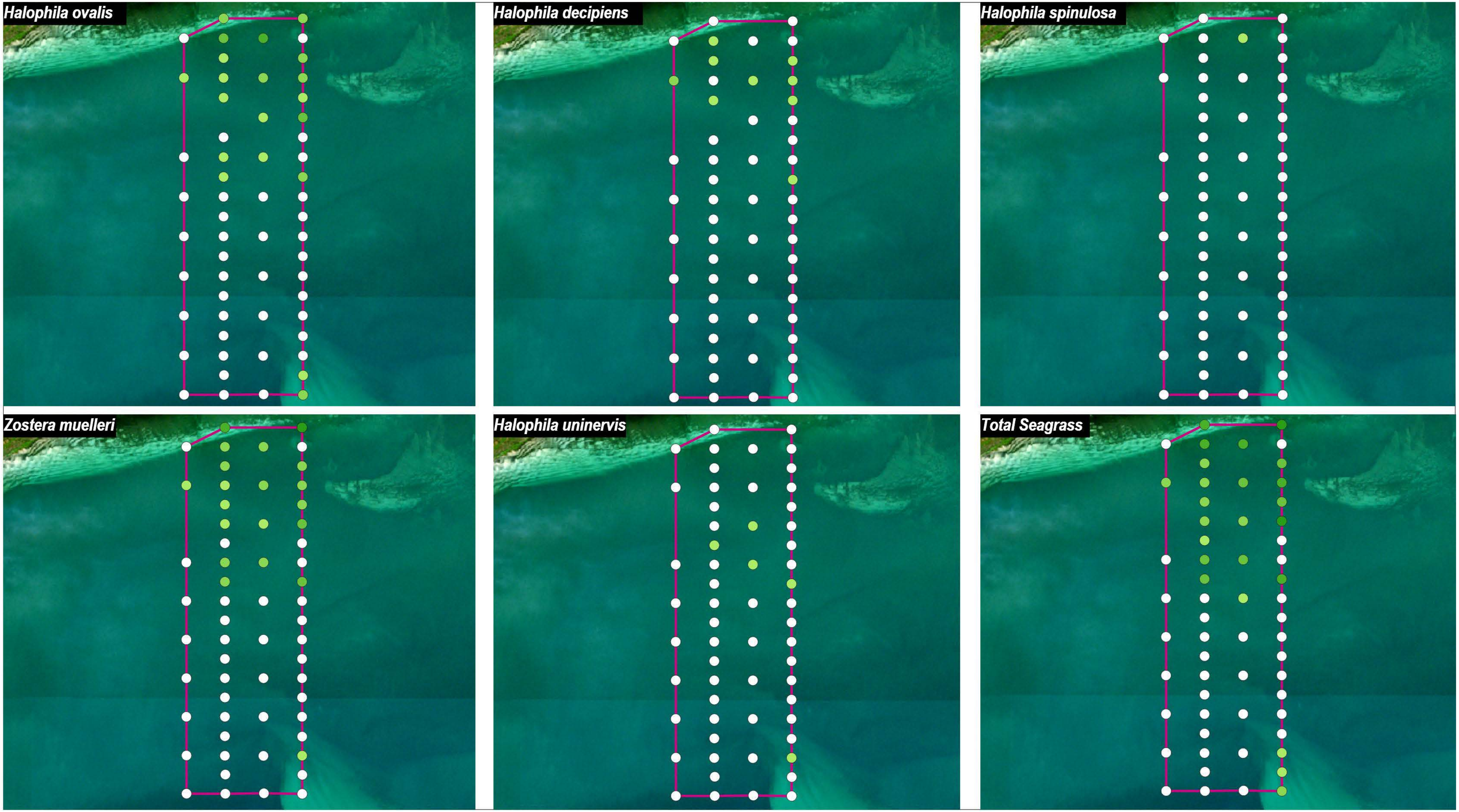

LEGEND

Seagrass Cover (%)

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

Study Area

Title:

Species Distribution at Deception Bay 2024

Figure: 3-8

Rev: A

N

0 1 2 km

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www.bmt.org

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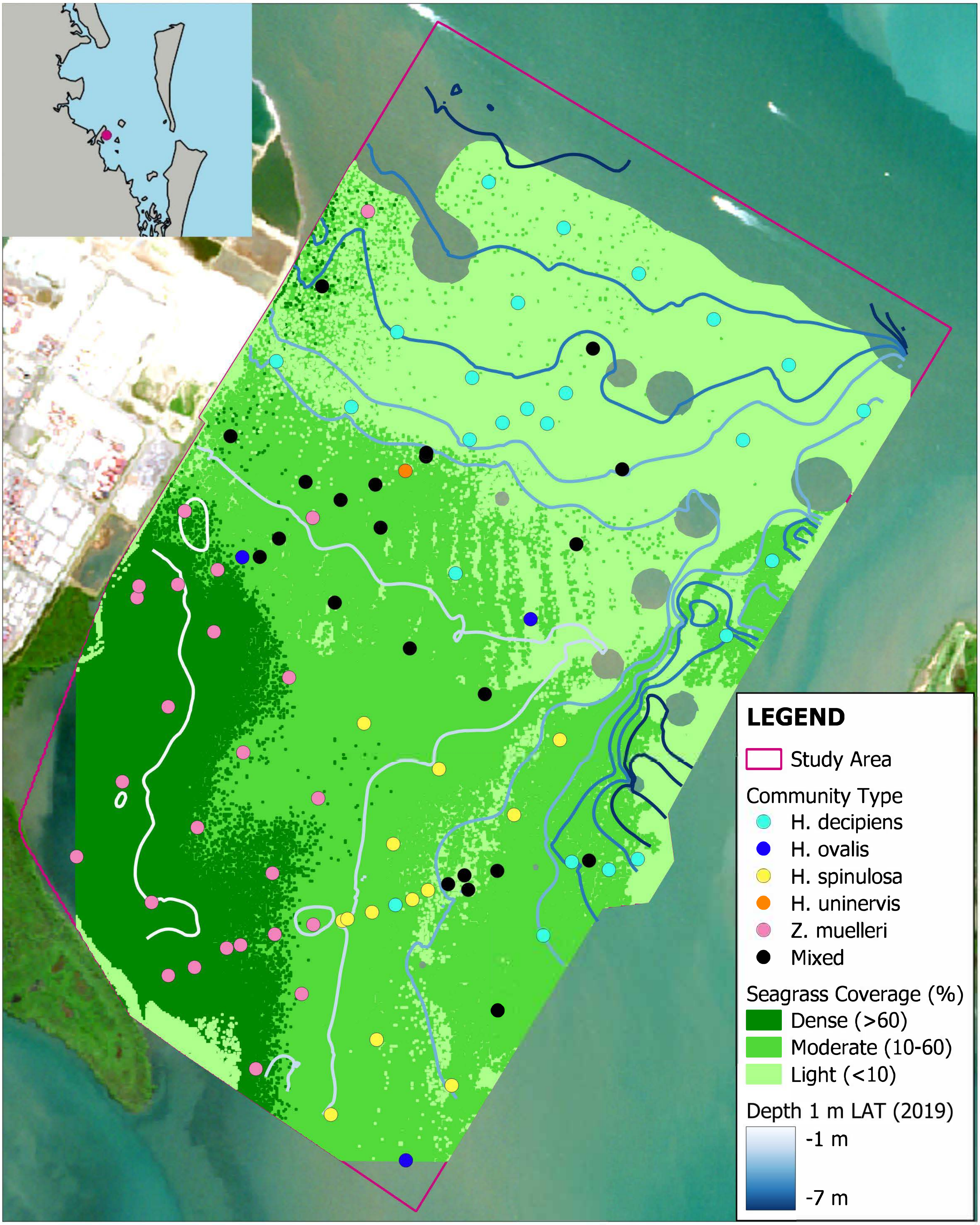

Title:

Satellite Imagery Classification for Fisherman Islands Study Area 2024, Showing Field Community Types

Figure: 4-9

Rev: A

N

0 500 1,000 m

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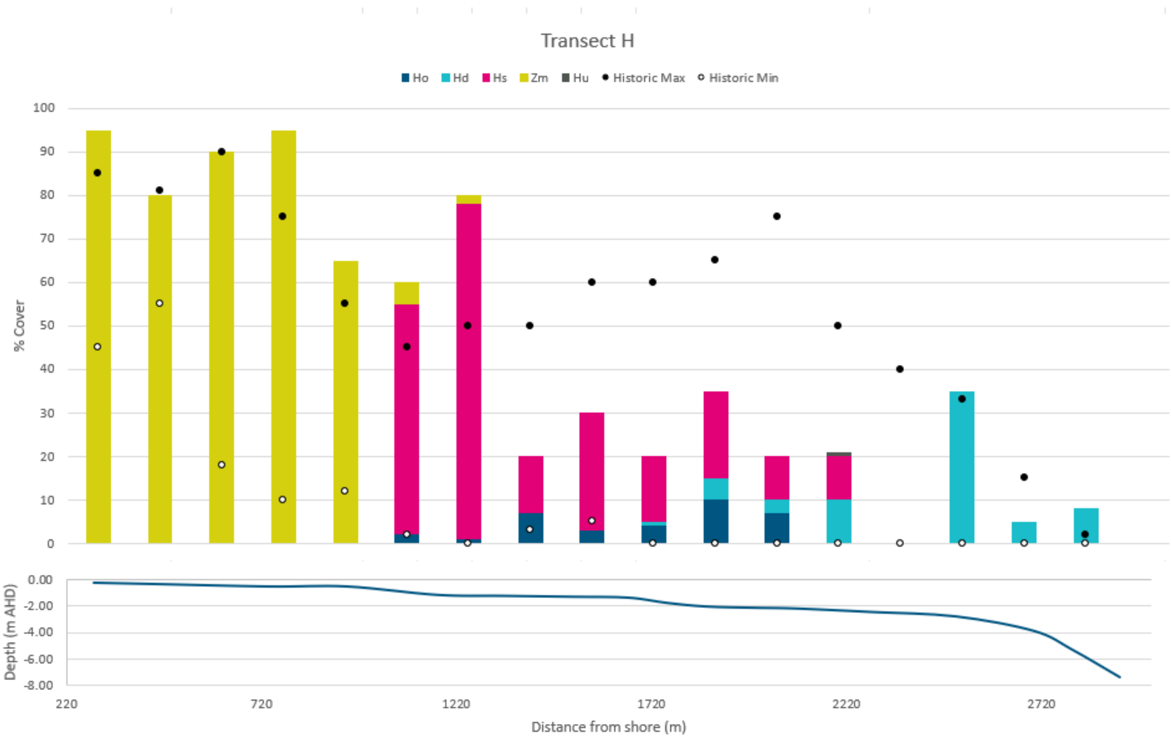
3.3 Seagrass Cover at Fisherman Island

Figure 3.10 presents percentage cover values of each seagrass species on permanent transects at Fisherman Islands, and the historical minimum and maximum total seagrass cover values. The percentage cover of intertidal *Zostera* dominated meadows in 2024 was generally in the upper range of historical values, whereas seagrass meadows in subtidal waters had total cover well below the histrorical maximum.

Figure 3.11 shows the difference in total seagrass coverage (%) between 2023 and 2024 at Fisherman Islands. Most sites had a positive difference in seagrass cover, with the largest differences in seagrass cover occurring in areas supporting dense seagrass meadows (*Z. muelleri*). There was an increase in percentage cover (0-5%) of seagrass in the northeastern seaward extent of Fisherman Islands seagrass meadows, specifically *H. decipiens.* There were large declines (-75% to -25%) in seagrass coverage in the southern and central sections of Fisherman Islands.



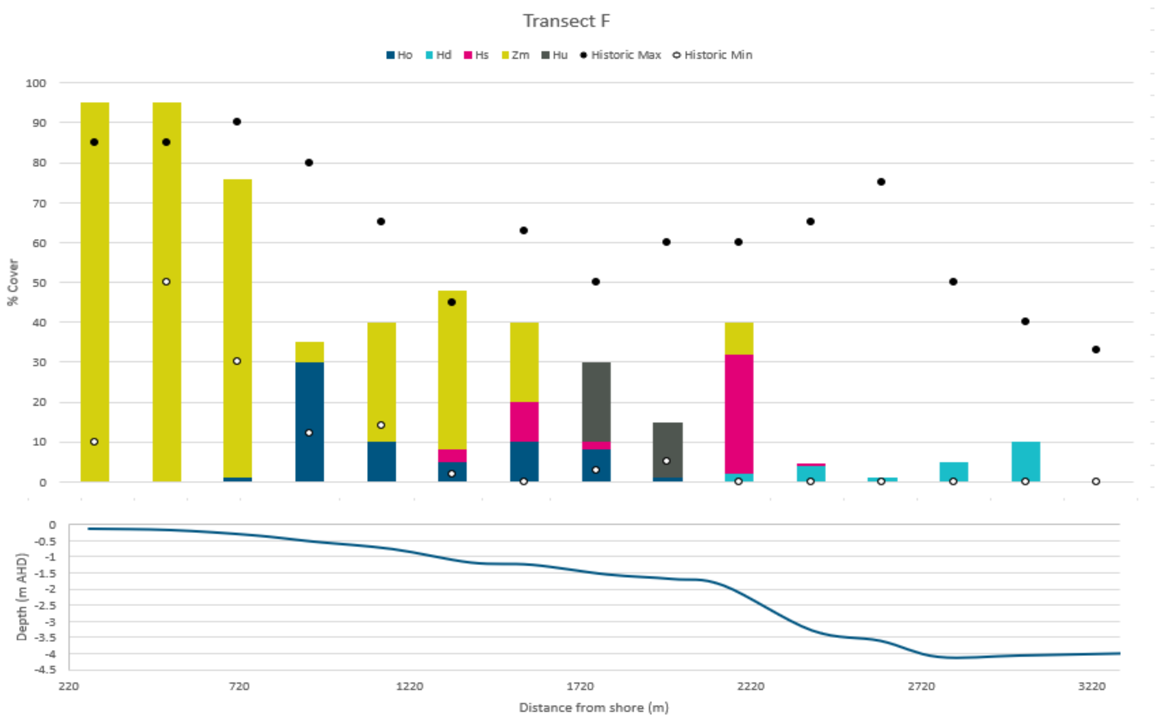
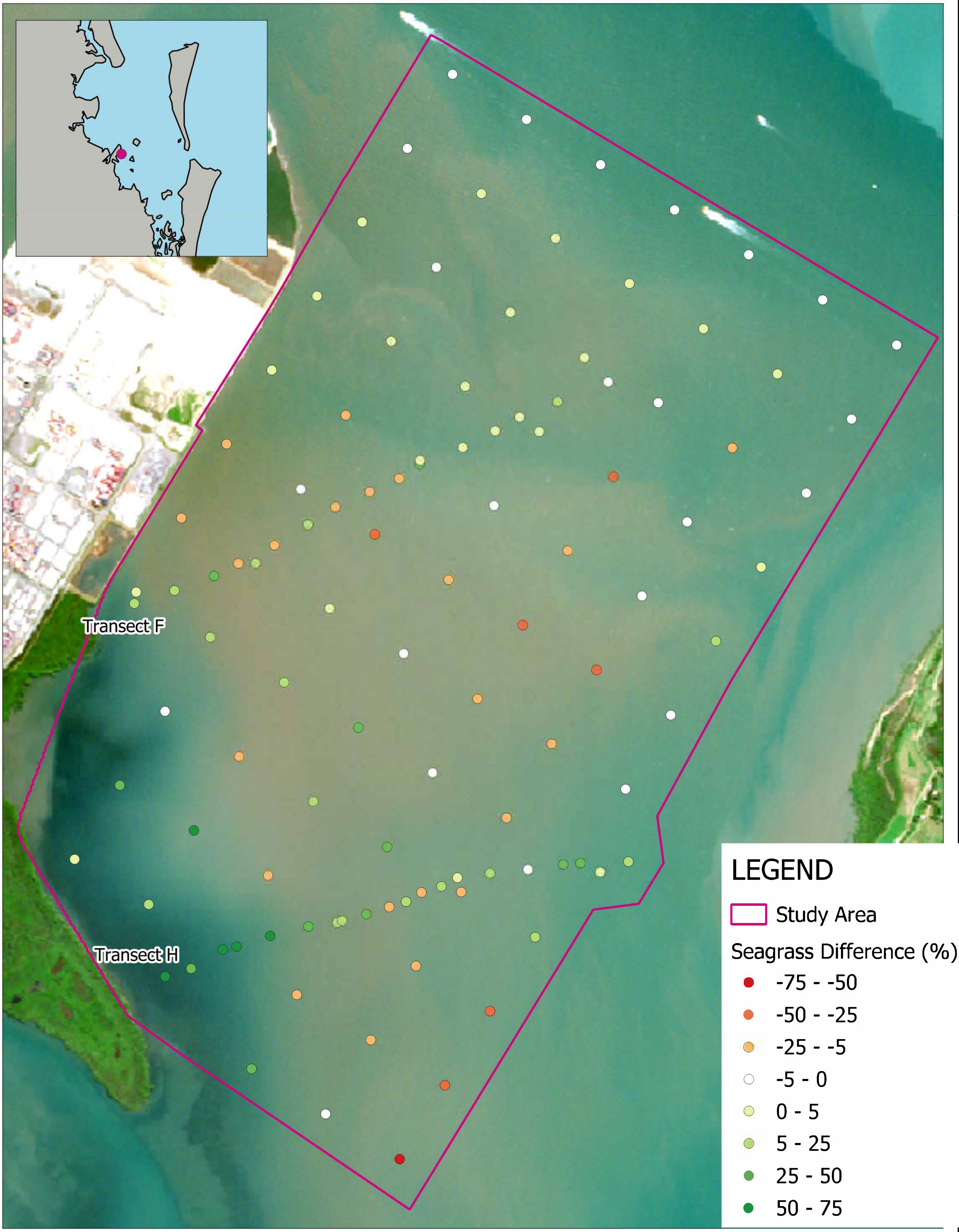


Figure 3.10 Percent cover of seagrass distribution across depth transects at Fisherman Islands (transects H & F). Ho = *Halophila ovalis*, Hd = *Halophila decipiens*, Hs = *Halophila spinulosa*, Zm = *Zostera muelleri*, Hu = *Halodule uninervis*



Title:

**Seagrass Cover Difference, Fisherman Island:
(2024 total % coverage) - (2023 total % coverage)**

Figure: **3-11**

Rev: **C**

N

0 500 1,000 m

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www.bmt.org

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3.4 Seagrass Depth Range (SDR) at Fisherman Island

Zostera muelleri

Figure 3.12 shows the *Zostera muelleri* SDR for permanent Transects F and H at Fisherman Islands and the average (±) for control sites. *Zostera muelleri* SDR on Fisherman Islands transect F (northern section of Fisherman Islands) was -2.0 m in 2024, which was an increase from 2022 and 2023 levels, and was at the 2020 (pre-2022 flood) SDR. By contrast, *Zostera* SDR at Fisherman Islands transect H (central section of Fisherman Islands) was -1.3 m, which was lower than 2023 levels (-1.7 m) and similar to the SDR recorded in 2022 (-1.4 m). *Zostera* SDR on transect H fell below levels recorded at control locations. The average *Zostera* SDR value at control locations remained stable between 2023 and 2024.

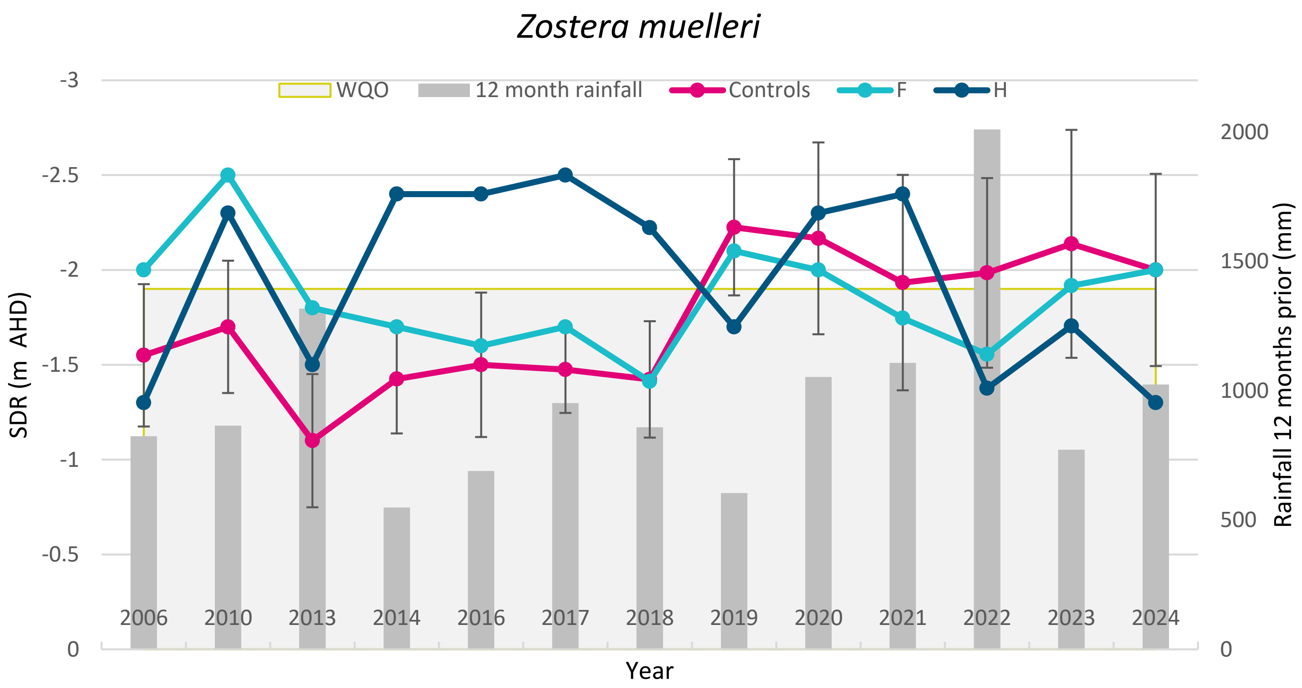


Figure 3.12 *Zostera muelleri* seagrass depth range (SDR) for Transect F and H at Fisherman Islands and the average (±SE) for control sites. Rainfall in the 12 months leading to the survey is also shown (BoM station number 040842 – Brisbane Aero)

Figure 3.13 shows the relationship between cumulative rainfall departure value rainfall (from long term annual average rainfall) and mean SDR for each year. There was a highly significant negative relationship between mean *Zostera* SDR and rainfall departure (d.f. = 11, $r^2 = 0.26$, $p < 0.01$), indicating that SDR was lower in and immediately following wet years.

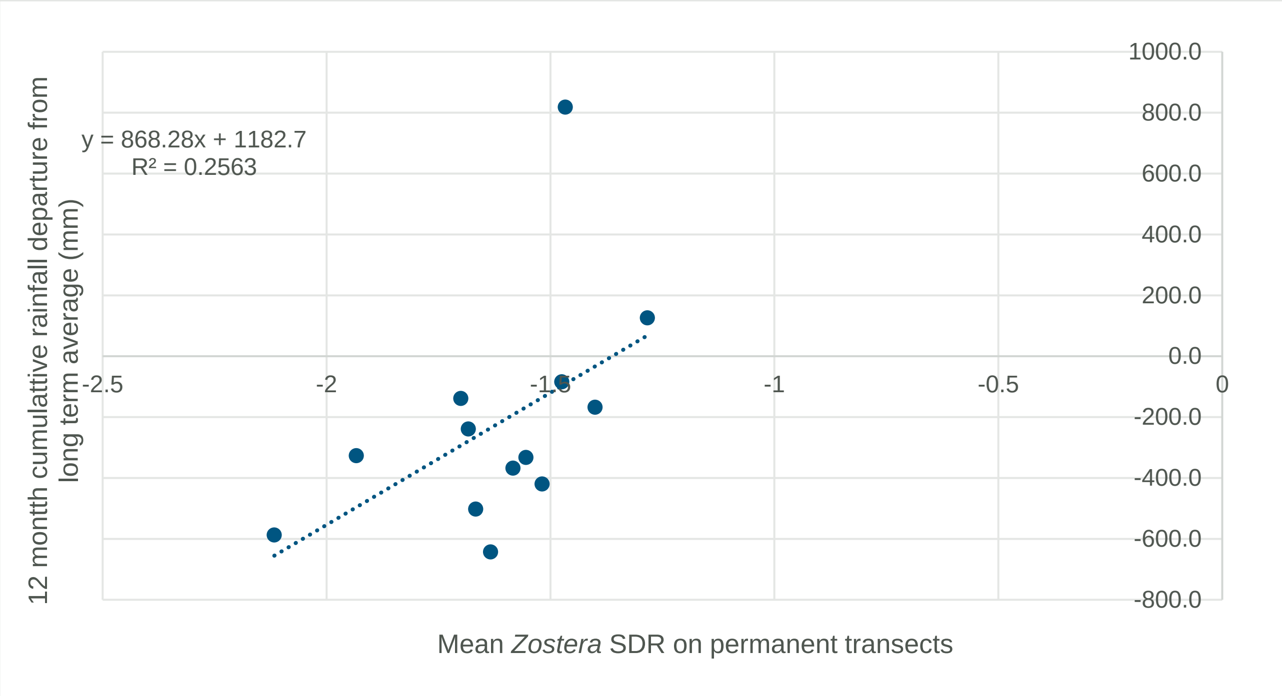


Figure 3.13 Relationship between average Zostera SDR value and rainfall departure from the long-term average value

The *Z. muelleri* SDR water quality objective (WQO) for Waterloo Bay is -1.9 m and was used as a benchmark[1]to assess seagrass condition. Transects that met the WQO (highlighted in Table 3.2) were:

- Fisherman Islands –Transect H (2010, 2014, 2016-18, 2020 and 2021) and Transect F (2006, 2010, 2019-21, 2023-2024)
- Manly—Transect J (2006, 2010, 2016, 2018, 2019-21, 2023, 2024) and Transect K (2006, 2010, 2014, 2016, 2017, 2019, 2020)
- Cleveland—Transect P (2019) and Transect Q (2023)
- Deception Bay—Transect R (2020-24) and Transect S (2020-24).

For 2024, only Transect F at Fisherman Islands and Transect R and S at Deception Bay met the WQO.

Other species

Table 3.2 presents the maximum recorded 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.

[1] 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

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

- ***Halophila spinulosa*** – SDR values on Fisherman Islands H and F transects in 2024 (-2.4 and -3.6 m) were in the third (75th percentile) and first (25th percentile) quartile of historical values respectively.
- ***Halophila ovalis*** – SDR values on Fisherman Islands H and F transects in 2024 (-2.2 and -1.8 m) were in the third (75th percentile) quartile of historical values.
- ***Halophila decipiens*** –SDR values on Fisherman Islands H and F transects in 2024 (-7.4 and -4.1 m) were in the first (25th percentile) and third (75th percentile) quartile of historical values respectively.
- ***Halodule uninervis***—SDR values on Fisherman Islands H and F transects in 2024 (-2.4 and -1.8 m) were in the first (25th percentile) and third (75th percentile) quartile of historical values respectively.

Seagrass assemblage composition and percent cover (%) for the depth transects at control locations is presented in Annex A.

Table 3.2 Comparison of SDRs (maximum recorded depth m AHD) of seagrass on permanent transects at each location from 2006 to 2024

Species	Location	Transect	2006	2010	2013	2014	2016	2017	2018	2019	2020	2021	2022	2023	2024	Mean	CoV
Zm	Fisherman Island	F	-2	-2.5	-1.8	-1.7	-1.6	-1.7	-1.4	-2.1	-2.0	-1.7	-1.6	-1.9	-2.0 (↔)	-1.8	-15
		H	-1.3	-2.3	-1.5	-2.4	-2.4	-2.5	-2.2	-1.7	-2.3	-2.4	-1.4	-1.7	-1.30 (↓)	-2.0	-24
	Manly	J	-2.2	-2.3	-1.6	-1.5	-2.1	-1.6	-2.1	-1.9	-2.1	-2.1	-3.2	-2.0	-2.0 (↔)	-2.0	-20
		K	-2.1	-2.2	-0.4	-2.1	-2.2	-2	-0.7	-3.3	-2.1	-0.8	-0.4	-0.3	-1.5 (↑)	-1.5	-60
	Cleveland	P	-1.3	-0.8	-0.6	-0.7	-0.7	-0.9	-1.7	-1.9	-0.5	-0.6	-0.9	-0.6	-0.4 (↓)	-0.9	-52
		Q	-0.6	-1.5	-1.8	-1.4	-1	-1.4	-1.2	-1.8	-1.2	-1.2	-1.4	-2.6	-1.2 (↓)	-1.4	-34
	Deception Bay	R	-	-	-	-	-	-	-	-	-3.8	-4.3	-3.1	-3.4	-3.6 (↑)	-3.6	-13
		S	-	-	-	-	-	-	-	-	-3.3	-2.6	-3.0	-4.0	-3.3 (↓)	-3.2	-16
Ho	Fisherman Island	F	-3.8	-5.7	-2.2	-2	-1.8	-4.7	-1.6	-5.1	-1.9	-3.8	-0.7	-1.6	-1.8 (↑)	-2.8	-57
		H	-2.6	-4.6	-2.5	-2.4	-2.4	-5.5	-2.2	-4.4	-1.2	-2.9	-1.6	-2.3	-2.2 (↔)	-2.8	-44
	Manly	J	-2.2	-4.9	-4.5	-2	-2.1	-2.9	-2.1	-3.3	-2.1	-2.6	-2.4	-2.0	-4.6 (↑)	-2.9	-37
		K	-0.4	-8.8	-5	-2.1	-2.2	-2.4	-1.8	-7.9	-2.5	-3.0	-2.0	-2.6	-2.1 (↓)	-3.3	-75
	Cleveland	P	-5.9	-6.4	-6.2	-4.8	-3.6	-3.3	-2.1	-3.6	Absent	Absent	-0.858	-2.0	-2.9 (↑)	-3.8	-49
		Q	-5.7	-6.2	-5.7	-2.7	-2.5	-5	-2.4	-2.8	-2.5	Absent	-1.4	-1.8	-3.8 (↑)	-3.5	-48
	Deception Bay	R	-	-	-	-	-	-	-	-	-4.2	-0.5	-0.5	-3.7	-3.6 (↔)	-2.5	-73
		S	-	-	-	-	-	-	-	-	-3.8	1.0	-1.3	-4.0	-3.3 (↓)	-2.3	-94
Hd	Fisherman Island	F	-3.8	-5.7	Absent	-4	-4.1	-4.3	-4.1	-4.2	-4	-4.2	Absent	-0.7	-4.1 (↑)	-3.9	-30
		H	Absent	Absent	-2.9	-5.1	-5	Absent	-7.2	Absent	-5.4	-4.0	-2.5	-2.1	-7.4 (↑)	-4.6	-42
	Manly	J	-2.2	-4.9	-4.5	-4.4	-3.5	-4.8	-4.5	Absent	Absent	-3.7	Absent	Absent	-2.3 (↑)	-3.9	-27
		K	-0.4	-8.8	-5	-3.7	-4	-5.3	-7.7	-4.1	-5	-5.1	Absent	Absent	-7.7 (↑)	-5.2	-45
	Cleveland	P	-5.9	-6.4	-5.1	-6.4	Absent	Absent	-4.4	Absent	-3.4	-3.5	Absent	-3.4	-3.9 (↑)	-4.7	-27
		Q	-5.7	-6.2	-4.6	-4.6	-5.9	Absent	-5.6	-5.8	-5.7	-4.6	-3.617	-4.0	-4.5 (↑)	-5.1	-17
	Deception Bay	R	-	-	-	-	-	-	-	-	Absent	Absent	Absent	-4.3	-3.6 (↓)	-3.9	-12
		S	-	-	-	-	-	-	-	-	Absent	Absent	Absent	-4.4	-3 (↓)	-3.7	-27
Hs	Fisherman Island	F	-3.8	-4.3	-2.2	-1.6	-1.8	-3.8	-2.0	-5.1	-2	-2.1	-1.8	-1.9	-3.6 (↑)	-2.8	-42
		H	-2.5	-2.3	-2.5	-2.4	-3	-2.5	-3.9	-4.7	-2.8	-2.9	-2.5	-2.3	-2.4 (↔)	-2.8	-25
	Manly	J	-2.6	-4	-3.4	-3.4	-4.1	-3.4	-4.5	-4.8	-2.1	-3.3	-3.9	-3.5	-4.6 (↑)	-3.7	-21
		K	Absent	-4.4	-4	-3.9	-2.2	-2.3	-3.9	-8	-3.8	-3.9	-3.8	-4.0	-3.9 (↔)	-4.0	-36
	Cleveland	P	Absent	-3.4	-3.5	-4.8	Absent	-0.9	Absent	-3.1	-3.4	-3.5	-3.0	-2.9	-3.9 (↑)	-3.2	-30
		Q	-3.2	Absent	-3.7	-4	-2.9	-3.3	-2.6	-3.1	-3.5	-3.6	-2.8	-2.7	-3.8 (↑)	-3.3	-14
	Deception Bay	R	-	-	-	-	-	-	-	-	Absent	-4.3	Absent	-4.0	-3.6 (↓)	-4.0	-9
		S	-	-	-	-	-	-	-	-	Absent	Absent	Absent	-4.0	-3.3 (↓)	-3.6	-13
Hu	Fisherman Island	F	Absent	Absent	Absent	Absent	Absent	Absent	-2.0	-1.6	Absent	-4.2	-1.8	Absent	-1.8 (↑)	-2.3	-48
		H	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-2.8	Absent	Absent	-2.1	Absent	-2.4 (↑)	-2.4	-14
	Manly	J	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-2.3 (↑)	-2.3	N/A
		K	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-0.2 (↑)	-0.2	N/A
	Cleveland	P	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	N/A	N/A
		Q	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	N/A	N/A
	Deception Bay	R	-	-	-	-	-	-	-	-	-3.2	-2.9	-3.3	Absent	-4.2 (↑)	-3.4	-17
		S	-	-	-	-	-	-	-	-	-3.6	-3.4	-3.6	-2.266	-3.1(↑)	-3.2	-17

Species	Location	Transect	2006	2010	2013	2014	2016	2017	2018	2019	2020	2021	2022	2023	2024	Mean	CoV
Rainfall			823.6	864.6	1317.5	548.4	689.5	952.2	858.8	604.2	1053	1107.6	2009.8	772	1024	**1192.0	

SDR relative to historical maximum:

Max	99-80% max	79-50% max	49-20% max	<20% max	Absent

Trend since 2023: ↑ improvement, ↔ stable (within 0.1 m of 2023), ↓ 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 – Average annual rainfall data sourced from BoM station 040913 (Brisbane Aero) for 2006-2024.

** Mean average annual rainfall data was collected from BoM station Fort Lytton (Station 040320) as it has the longest rainfaill record (1964-2024).

4 Discussion

4.1 Species Composition

A total of 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 previously been recorded in the Port of Brisbane SMP. *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 Islands in the 2021 survey but was not observed since. Moreton Bay is the southern-most distribution limit of *S. isoetifolium, H. uninervis, H. spinulosa C. serrulata* and *H. minor* (Kirkman 1997).

4.2 Inter-annual Patterns 2020-2024

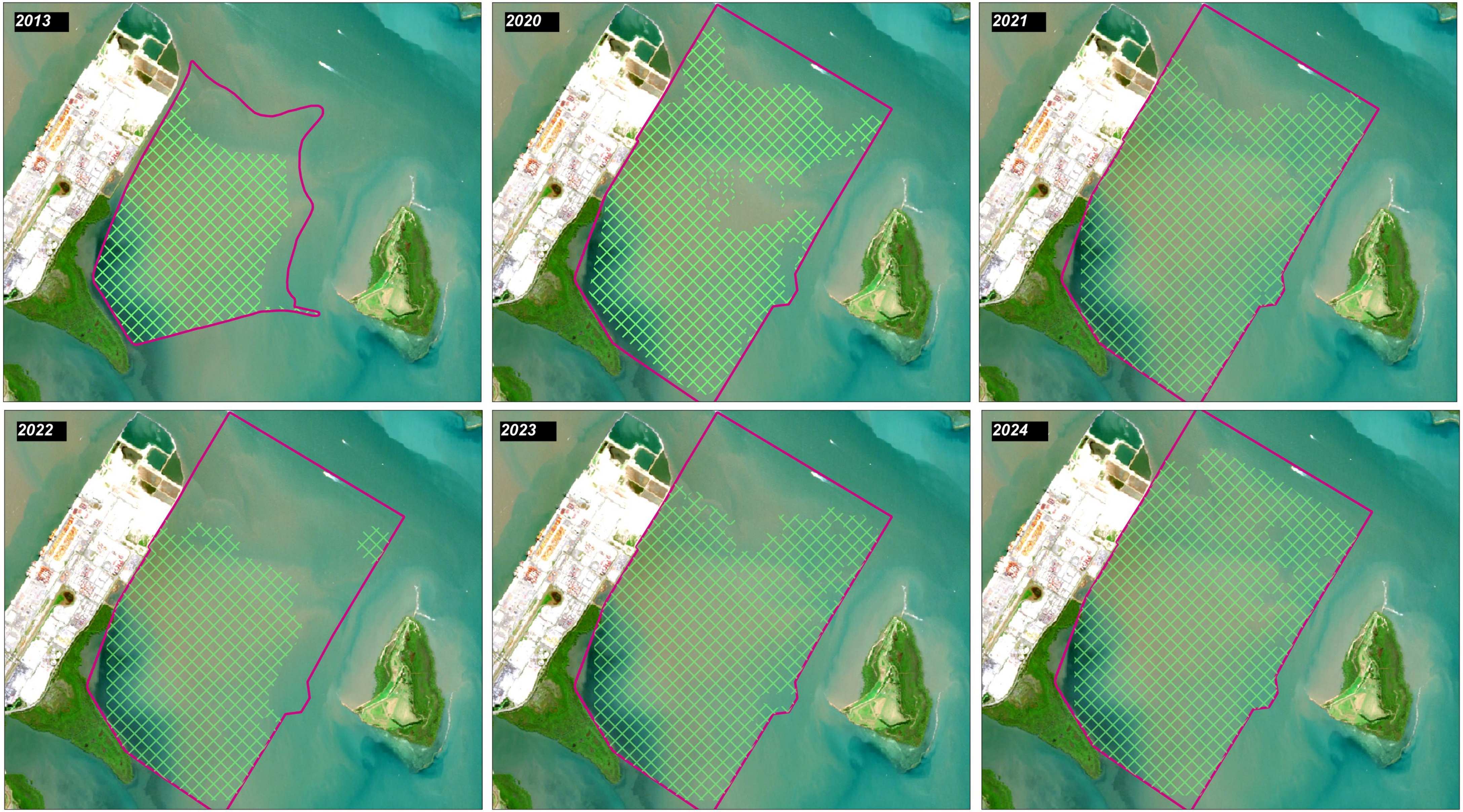
The results of the SMP indicate that seagrass meadows of western Moreton Bay show cyclic changes in extent in response to flood-drought cycles. Flooding reduces seagrass by limiting light availability and physical disturbance. Reductions in seagrass meadow extent were observed at Fisherman Islands and control sites following major flood events in 2010, 2013 and 2022. A major decline in seagrass meadow extent occurred between 2021 (12.8 km^2) and 2022 (11.15km^2), coincident with the 2022 Brisbane River flood event (Figure 4.1). The magnitude of change in seagrass meadow extent and seagrass depth range in 2022 was similar to that observed in 2013 (BMT 2022). Seagrass losses were reported elsewhere in the region between 2021-22, including Hervey Bay (TropWATER 2022).

Between survey events 2023 and 2024, meadow extent expanded approximately by 1.90 km^2, from 14.8 km^2 to 16.7 km^2. The 2024 seagrass meadow extent was 3.9 km^2 more than recorded in 2021 (12.8 km^2), indicating that seagrass meadow extent had recovered to pre-2022 flood levels. The period 2023 -24 had lower than average rainfall conditions. As shown in Figure 3.13, drier periods on average tended to have the most extensive seagrass meadows. There were complex temporal patterns among seagrass species, as described below.

Halophila species

Seagrass meadow expansion in the period 2023-2024 was predominantly driven by re-colonisation of deepwater *Halophila* dominated meadows in the northern section of the Fisherman Islands survey area (Figure 4.1). *Halophila ovalis* extent and percentage cover increased across all sites between 2023 and 2024. These extent increases typically took the form of seaward expansions previously seen in 2023, with Fisherman Islands experiencing a large expansion seaward with an overall light percentage coverage. *Halophila decipiens* also expanded and increased in percentage cover (predominantly within the subtidal zone) across all sites except Deception Bay, which experienced a small change in percentage cover from 2024. *Halophila spinulosa* had the largest distribution increase at Cleveland (from 39% in 2023 to 55% in 2024) with smaller increases in distribution at remaining sites.

Halophila species are considered colonising species, known for their ability to recover quickly following disturbance but among the least tolerant seagrass species to reductions in light availability (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 dimmish following flooding events (as seen in 2022) or other disturbance events (Longstaff *et al.*1999).



LEGEND

Study Area

Seagrass Extent

Title:

Seagrass meadow extent between 2013-2024

Figure: 4-1

Rev: D

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

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There was considerable small-scale heterogeneity in the distribution of different *Halophila* species (i.e. differences among transects within locations). Various processes can interact to control small-scale heterogeneity in seagrass meadows, including biological interactions such as competition for space with other seagrass species and macroalgae, and grazing by marine fauna (Hearne *et al.* 2018). 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

Temporal patterns in the distribution of *H. uninervis* varied among sites. Fisherman Islands and Deception Bay had an increase in total extent and percentage cover, whereas Cleveland control sites observed a decrease in extent and percentage cover. More notably, a small percentage cover (4%) was observed at Manly control sites, where in previous years (2022 and 2023) the species was not observed.

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.

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.

Temporal patterns in *Z. muelleri* condition (percentage cover, frequency of detections, and *Zostera* SDR) varied among sites as follows:

- Fisherman Islands -: there were complex spatial patterns in Zostera at this location. Between 2023 and 2024 there was:
  - a reduction in the frequency of *Zostera* detections;
  - a decline in *Zostera* SDR at Transect H. *Zostera* SDR at Transect H was near the historical minima and below levels recorded at control sites in 2024 ;
  - stable *Zostera* SDR levels at Transect F. *Zostera* SDR at Transect F was near the historical maxima (-2.5 m) in 2024.
- Control sites – there was great temporal variability in *Zostera* indicators among sites. On average, control site SDR value remained stable between 2023 and 2024.

These results suggest that *Zostera* meadow condition at Fisherman Islands showed great spatial variability. *Zostera* meadows in subtidal waters in the central sector of Fisherman Islands (around transect H) were in poor condition, whereas *Zostera* meadows in subtidal waters in the north and southern sectors, and intertidal areas, were in excellent condition.

Potential drivers of *Zostera* losses include reduced light availability (higher turbidity, smothering by epiphytic algae), reduced salinity, physical disturbance (scour and sediment mobilisation), disease and competition with other benthic species (Table 4.1).

There have been no flood events since 2022, and rainfall in the period 2023-24 was less than average. *Halophila* and *Halodule*, which are more sensitive to light reductions than *Zostera*, typically expanded between 2023 and 2024, which also does not suggest turbidity was a key driver of *Zostera* losses.

Grazing and other physical disturbances can impact seagrass meadows, however: (i) these disturbances typically operate at spatial scales measured in metres to 10's of metres, whereas the *Zostera* losses were recorded at spatial scales of 10s to 100s of metres; and (ii) there was no evidence of physical disturbance to seagrass (e.g. sand burial) in video footage; (iii) no floods or major storms occurred during the period.

Increased epiphytic algae cover is a potential driver of *Zostera* losses. Epiphytic algae were detected at 81% of Fishermen Island survey points, representing an increase of 31% from 2023 (50% of survey locations). In addition to an increase in the extent of filamentous algae presence, the mean cover also increased by 21% (mean cover of 2% in 2023, and 23% in 2024). Epiphytic algae can proliferate under nutrient enriched conditions, leading to reductions in available light and loss of seagrass (Han and Liu 2014). Sediments in western Moreton Bay are nutrient enriched (especially ammonia), which can be resuspended through wind driven waves and tidal action to result in periods of elevated ammonia flux (Grinham *et al*. 2024). The elevated nitrogen in the terrestrial mud deposits can lead to algal blooms and smoothing of seagrass by algae (Grinham *et al.* 2024; Han and Liu 2014). Further work is required to determine potential linkages between *Zostera* losses and epiphytic algae loading at Fisherman Islands.

Other macroalgae species were not abundant in the study area and were unlikely to be a driver of *Zostera* losses. *Lyngbya* is a species of cyanobacteria that occurs in Moreton Bay attached to seagrass beds. A small patch of Lyngbya was observed in the 2022 survey, however none was observed in 2023 or 2024. The green alga *Caulerpa taxifolia*, which can out-compete and replace seagrass during extended dry periods (West and West, 2007), has not been an abundant component since the early 2000s (BMT 2023).

Table 4.1 Potential drivers of Zostera losses

Potential drivers	Assessment
Reduced light availability due to turbidity	Unlikely: • light sensitive seagrass species increased • no flood events in the period
Reduced light availability due to epiphytic algae cover	Probable – higher frequency of epiphytic algae detections at Fisherman Islands in 2024 (81%) c.f. 2023 (52%)
Reduced salinity due to flooding	Unlikely – no flood events in the period
Physical disturbance (bed erosion, sediment deposition)	Unlikely – no flood events in the period, *Zostera* meadows located in area
Disturbance by bait wormer diggers	Unlikely – disturbance of seagrass by bait worm digging typically occurs at smaller spatial scales than the broad scale changes observed at Fisherman Islands
Disease	Unknown
Out-competition by macroalgae and other seagrass species	Unlikely – *Caulerpa* and other macroalgae species were not abundant in *Zostera* meadows. Areas previously occupied by *Zostera* in 2023 were colonised by *Halophila* species, which due to their smaller size, are unlikely to outcompete *Zostera*.
Over-grazing	Unlikely – disturbance by dugongs and sea turtles typically occurs at fine spatial scales (10s of metres). *Zostera* is not a preferred food resource for dugongs. No major infestations of sea urchins or other grazing invertebrate species were observed.

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 was 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 be related to exposure during hot days, and possibly other environmental drivers such as rainfall. However, in 2022, BMT observed a landward expansion of Z. muelleri at Fisherman Islands between July 2021 and July 2022.

Inspections of aerial photography suggest that between July 2023 and July 2024, the landward boundary of the Fisherman Islands seagrass meadows expanded landward (see example images in Figure 4.2). While the 2023 mean maximum temperature (26°C) was slightly higher than the annual average (25.4°C) (see Figure 3.3) it remained within the range of optimal growing conditions of 27°C for *Z. muelleri* (York et al., 2013).

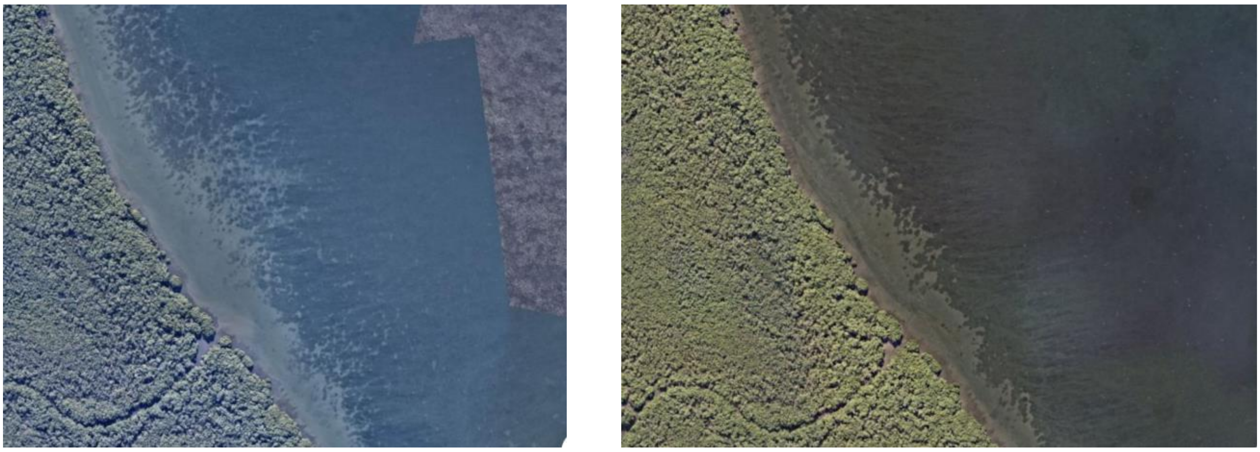

Figure 4.2 Change in Nearshore *Zostera* between July 2023 (left) and July 2024 (right)

4.3 Decadal Scale Changes

A consistent overall long-term increase in the seagrass meadow extent at the Fisherman Islands has been observed since the FPE seawall construction (see BMT WBM 2016 for details), with the exception of the 2022 flood anomaly which resulted in a major contraction of seagrass extent. Specifically, the meadow has begun to colonise sediment directly adjacent to the seawall bund replicating meadow extents observed in 2020 and community composition (BMT WBM, 2020). Communities have increased their connectivity with cover becoming less patchy and more consistent across the study area. Seagrass extents in other monitoring sites have also recovered, with increases in extent and percentage cover of most seagrass types observed across all other sites.

Observations made in 2024 are consistent with the predictions of the FPE IAS (WBM 2000), with the results of the Port of Brisbane SMP suggesting 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; 201; 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 Conclusions

In summary, the key findings of the 2024 seagrass field campaign are as follows:

- Seagrass meadow extent and connectivity surrounding the Fisherman Islands has increased in comparison to previous surveys across the entire study area.
- *Zostera muelleri* meadows were in poor condition in the central sector of Fisherman Islands, which continues a long term trend in this area. *Zostera muelleri* meadows were in excellent condition in intertidal areas and the northern and southern section of Fisherman Islands, indicating that the processes causing to *Zostera* losses in the central area were not operating across broad scales.
- There was an increase in epiphytic algae coverage at Fisherman Islands. Further work would be required to assess potential linkages between *Zostera* losses and epiphytic algae loading. Other algae species were not abundant.
- 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, contracted in 2022 due to flooding and then began to recover in 2023 due to lack of major disturbances. 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 Seagrass assemblage composition and percent cover for other species

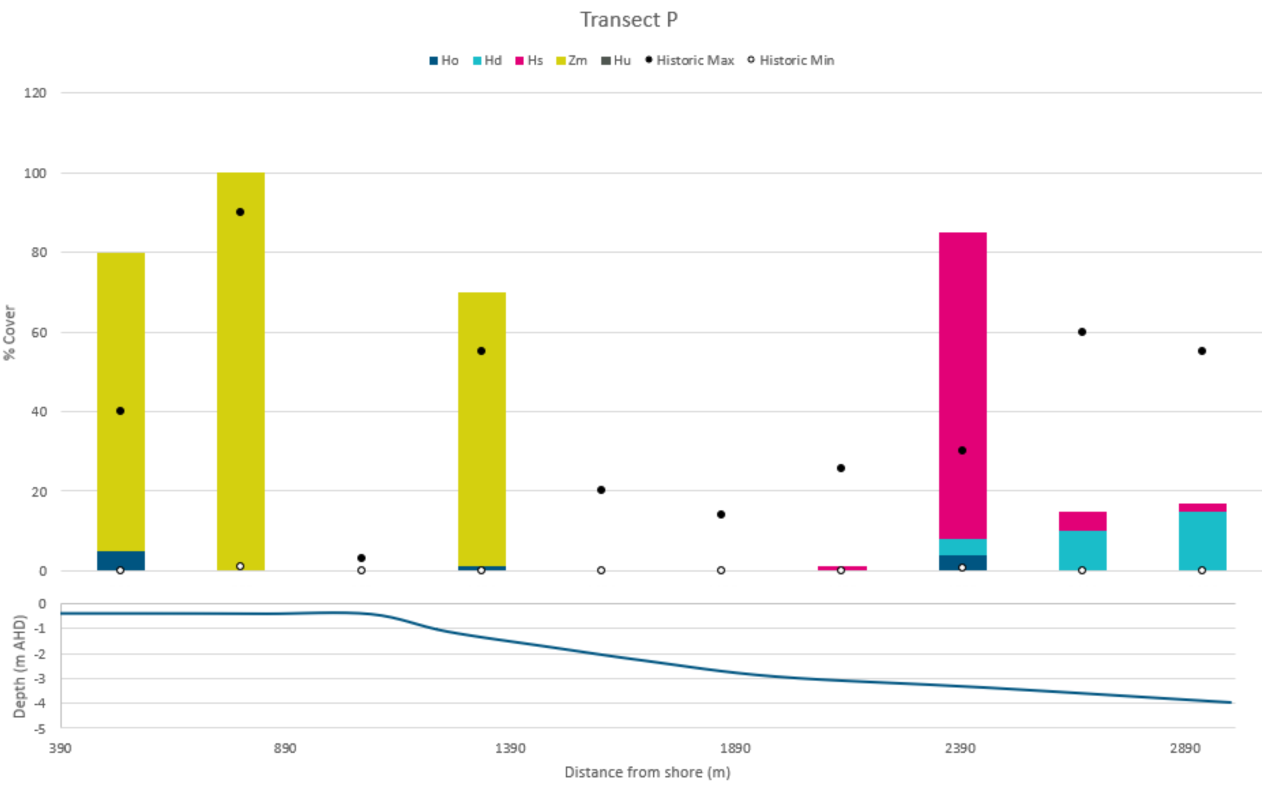
Seagrass assemblage composition and percent cover (%) for the depth transects at Manly, Cleveland and Deception Bay are illustrated in Figure A.1—Figure A.2 Most sites have a percent cover between the historical minimum and maximum:

- Halophila ovalis was present at all sites in a range of depths forming meadows at predominately mixed communities with Z. muelleri, H. spinulosa with light coverages with H.decipiens. The depths that had H. ovalis present were: -1.5 m to -3.1 m, -1.42 m, -0.3 m to -3.1 m AHD at Manly and Deception Bay respectively. Only light coverage (1%) of H.ovalis was observed at a depth of -3.8 m at Cleveland Bay.

- Halophila decipiens was observed at all sites at greater depths at Cleveland and Manly with the maximum depth at –7.7 m AHD at Manly site. The coverage was predominately light to moderate and was generally either in monospecific stands or mixed communities with H. spinulosa, Z. muelleri, H. ovalis.

- Halodule uninervis was recorded at a small number at Manly (-2.3 m AHD) and at Deception Bay (-4.2 m AHD) sites compared to 2023 where the species was at Manly.

Figure A.1 Percent cover of seagrass distribution across depth transects at Manly (transects J & K). Ho = *Halophila ovalis*, Hd = *Halophila decipiens*, Hs = *Halophila spinulosa*, Zm = *Zostera muelleri*, Hu = *Halodule uninervis*



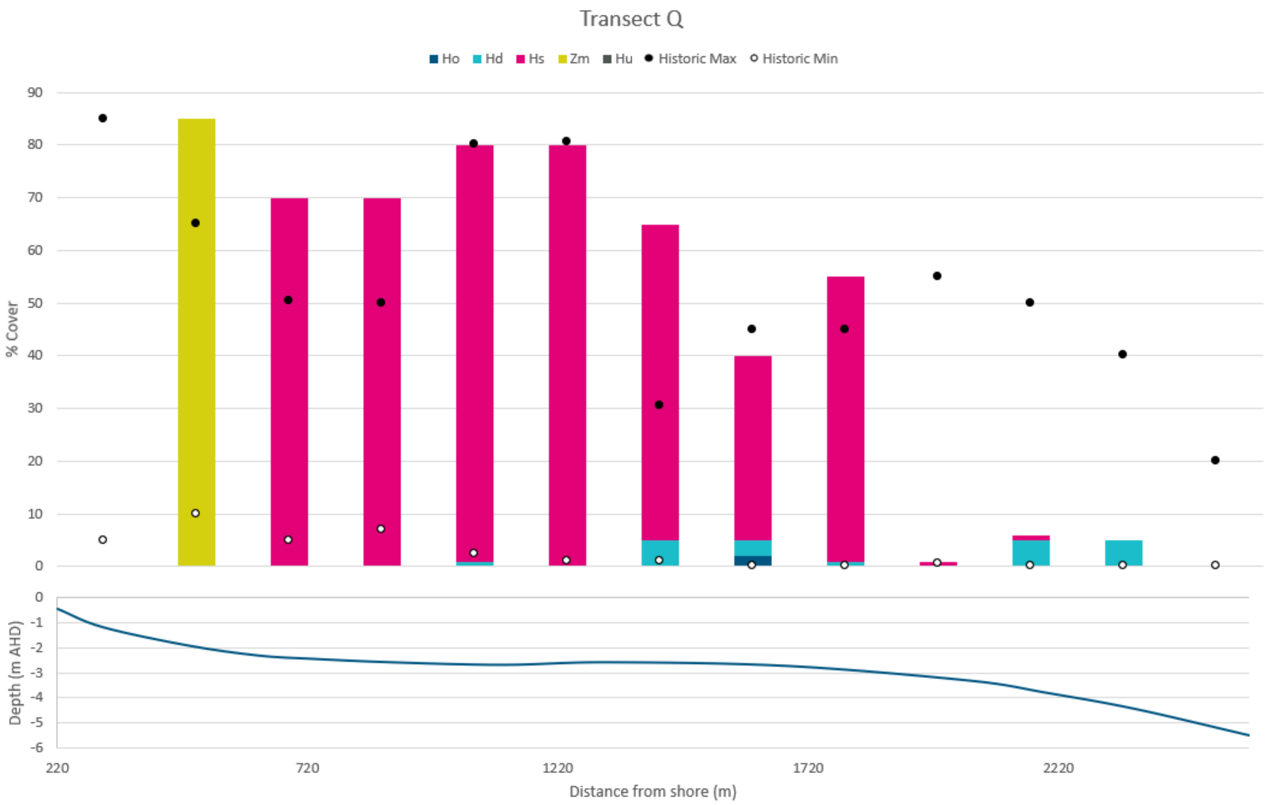
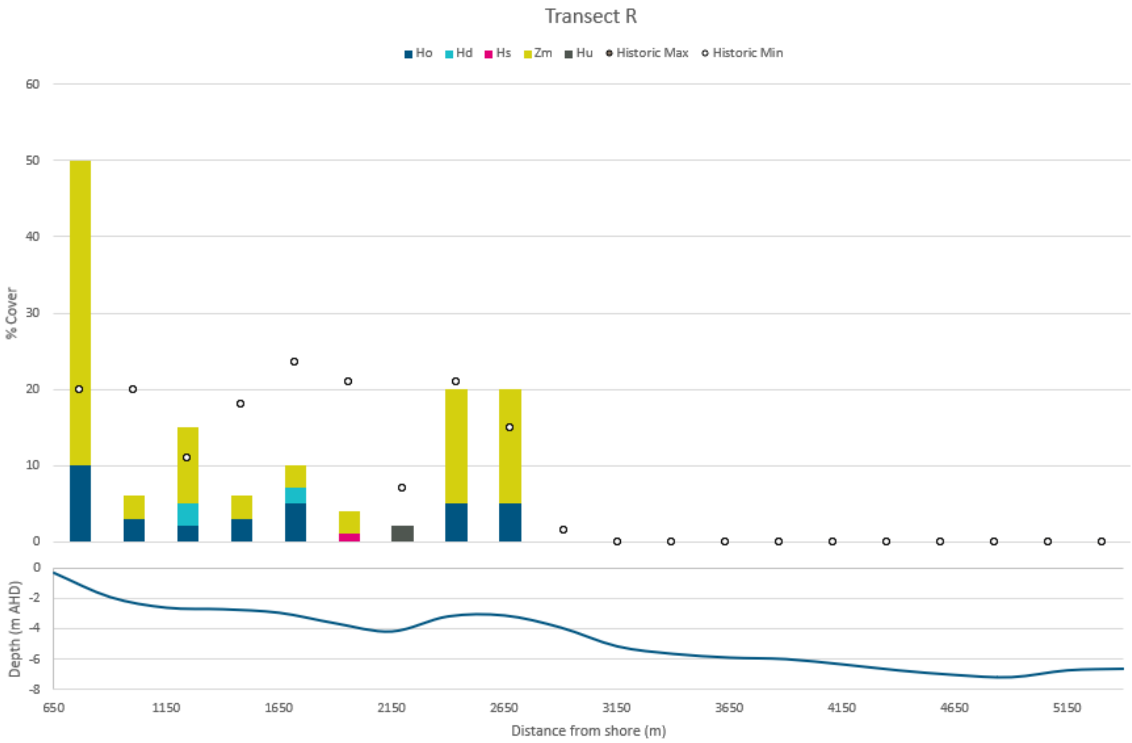


Figure A.2 Percent cover distribution across depth transects at Cleveland (P & Q).Ho = *Halophila ovalis*, Hd = *Halophila decipiens*, Hs = *Halophila spinulosa*, Zm = *Zostera muelleri*, Hu = *Halodule uninervis*.



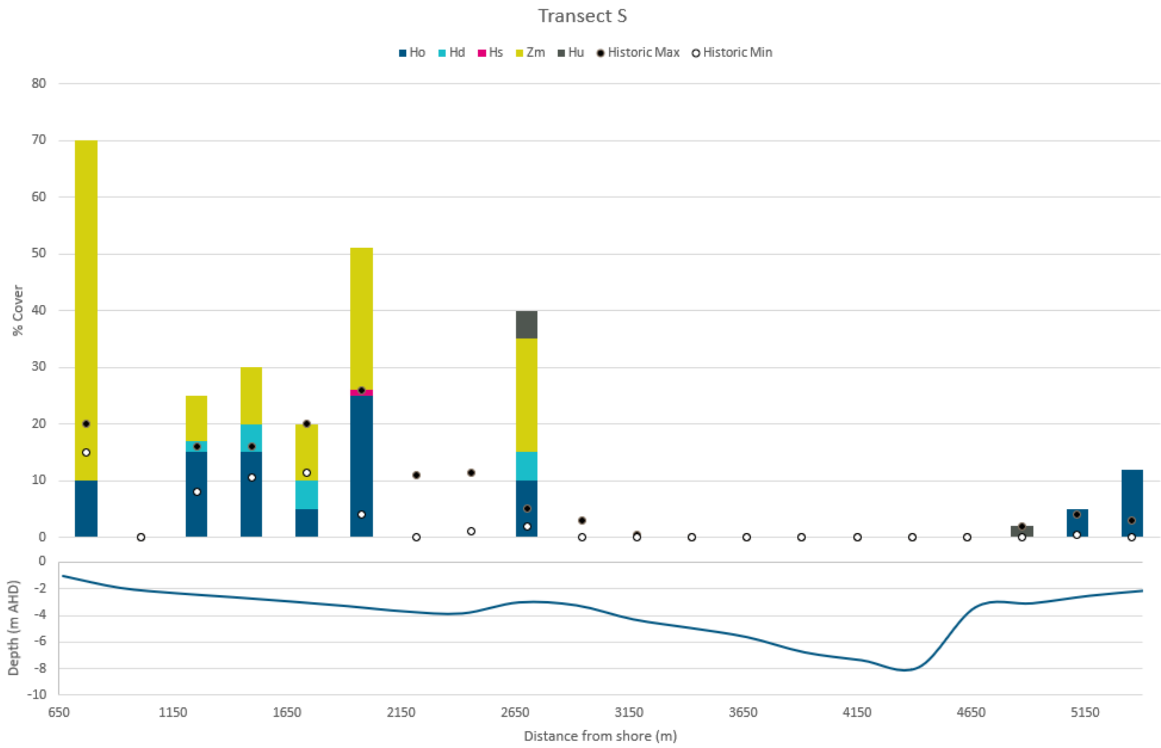


Figure A.3 Percent cover distribution across depth transects at Deception Bay (R & S). Ho = *Halophila ovalis*, Hd = *Halophila decipiens*, Hs = *Halophila spinulosa*, Zm = *Zostera muelleri*, Hu = *Halodule uninervis*

Annex B Photo Plate

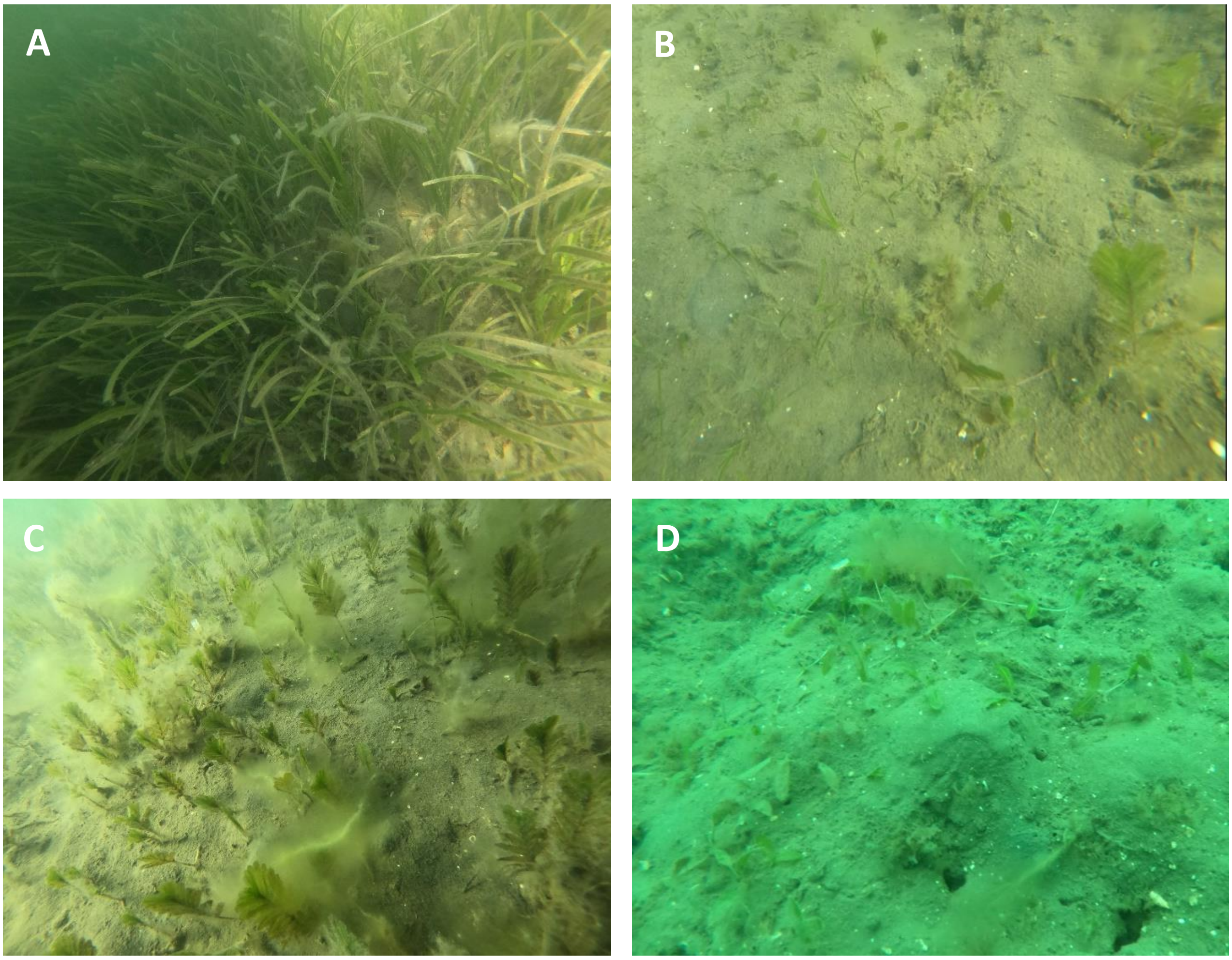


Figure B.1 Dense *Zostera muelleri* at Fisherman Islands (A) Sparse mixed community of *Halophila ovalis, Halophila spinulosa* and *Zostera Muelleri* at Fisherman Islands (B) Moderate *Halophila spinulosa* at Fisherman Islands (C) Sparse *Halophila decipiens* at Manly (D)

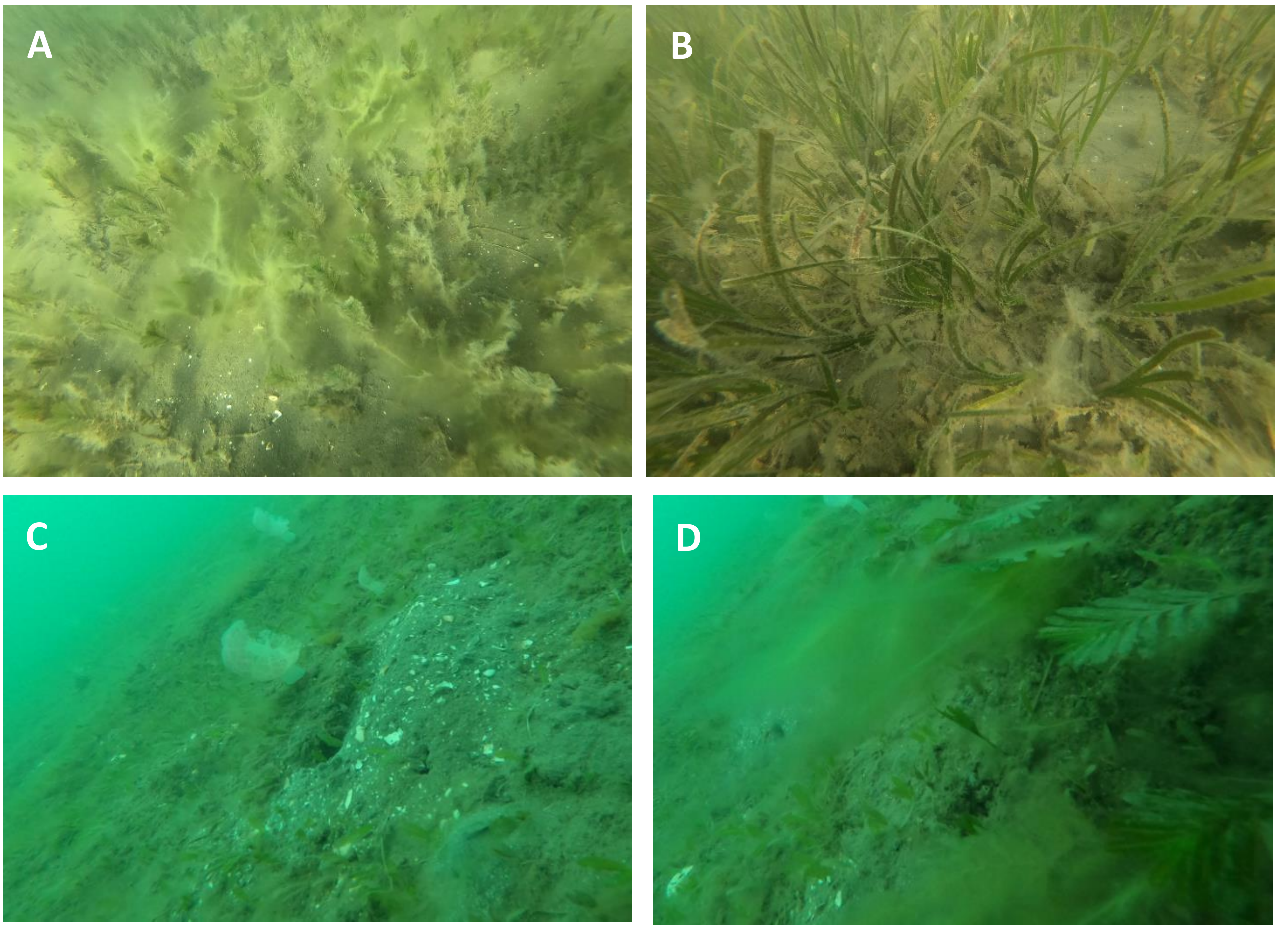


Figure B.2 Fisherman Islands: Prominent filamentous algae and epiphytic algal cover on *Halophila spinulosa* (A) Epiphytic algae on *Zostera Muelleri* (B) *Halophila decipiens* with Dendronepthya (soft coral) (C) Mixed community of *Halophila spinulosa* and *Halophila decipiens* with filamentous algae (D)

Annex C Broad Scale patterns in seagrass species distribution at the Port of Brisbane 2010, 2013-2023

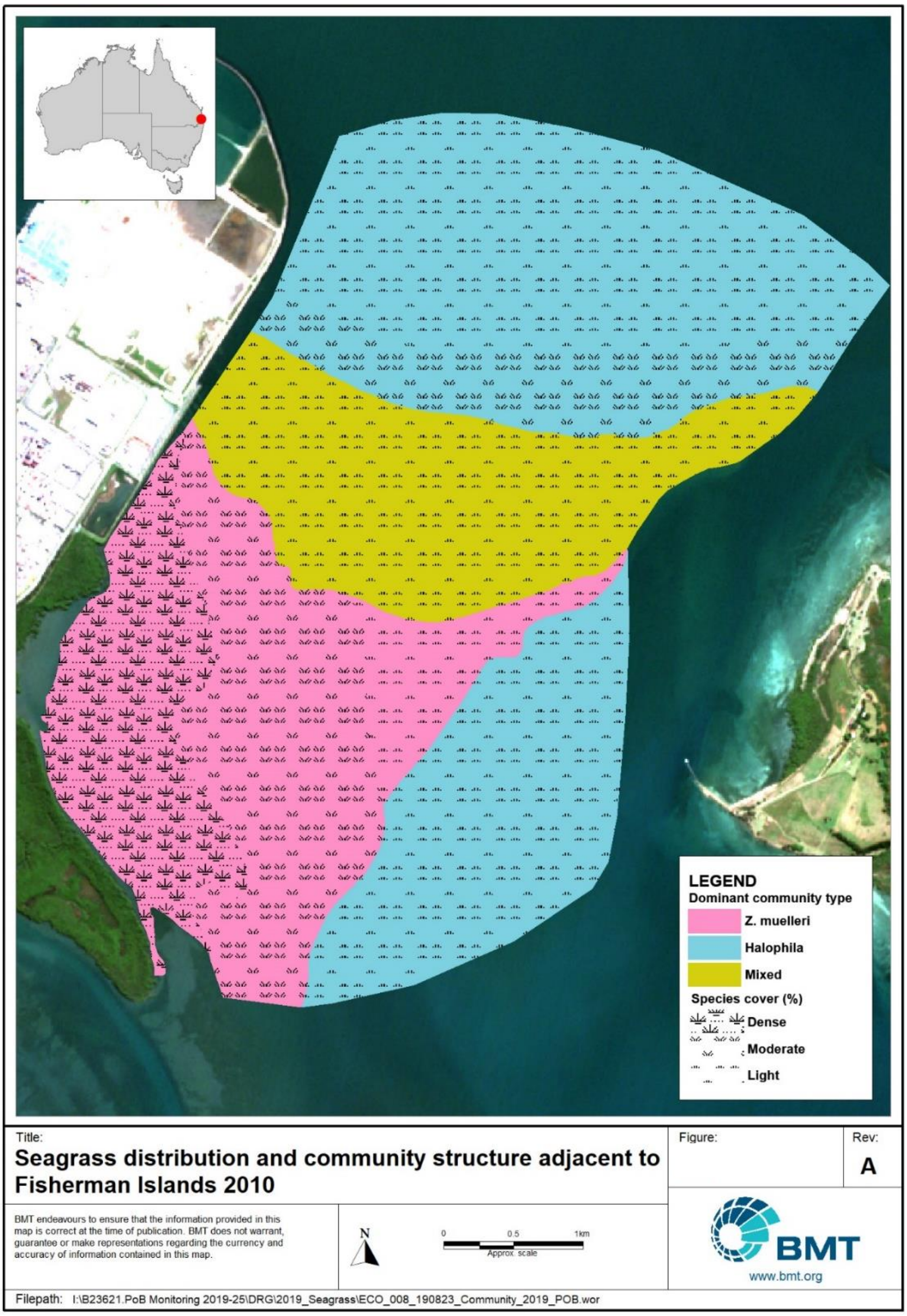


Figure C.1 Broadscale Patterns in Seagrass Distribution and Community Structure Adjacent to Fisherman Islands in 2010

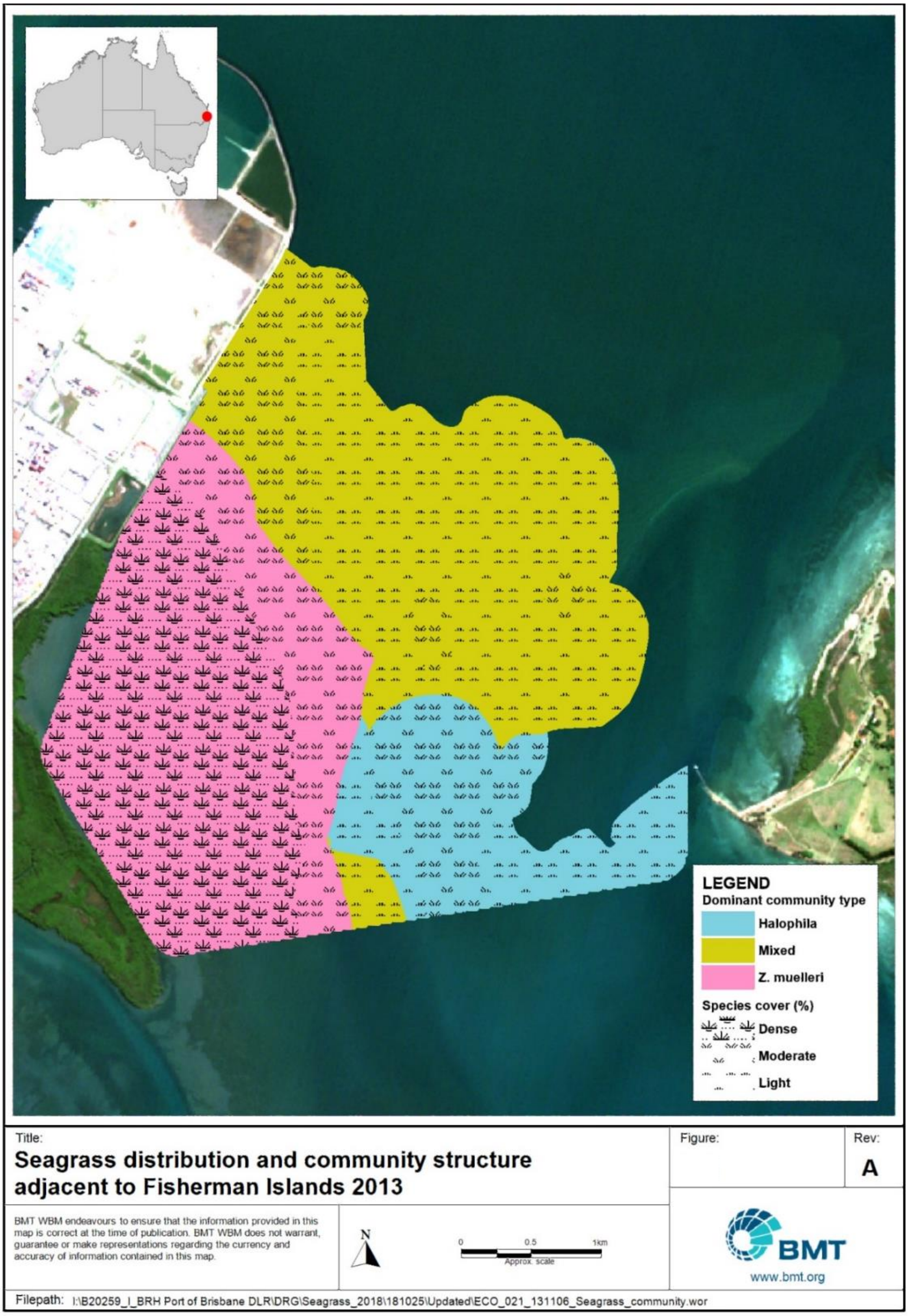


Figure C.2 Broadscale Patterns in Seagrass Distribution and Community Structure Adjacent to Fisherman Islands in 2010

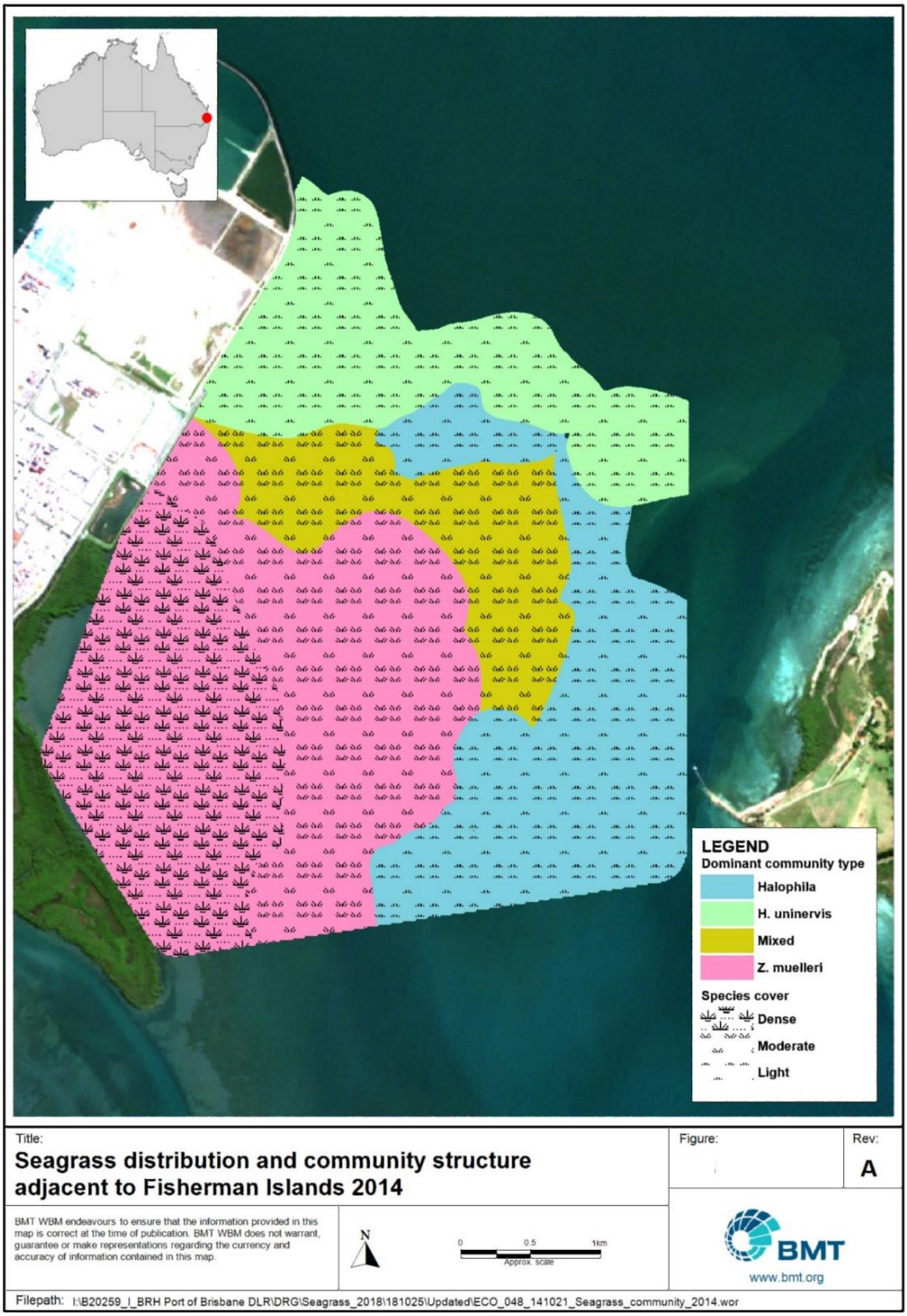


Figure C.3 Broadscale Patterns in Seagrass Distribution and Community Structure Adjacent to Fisherman Islands in 2014

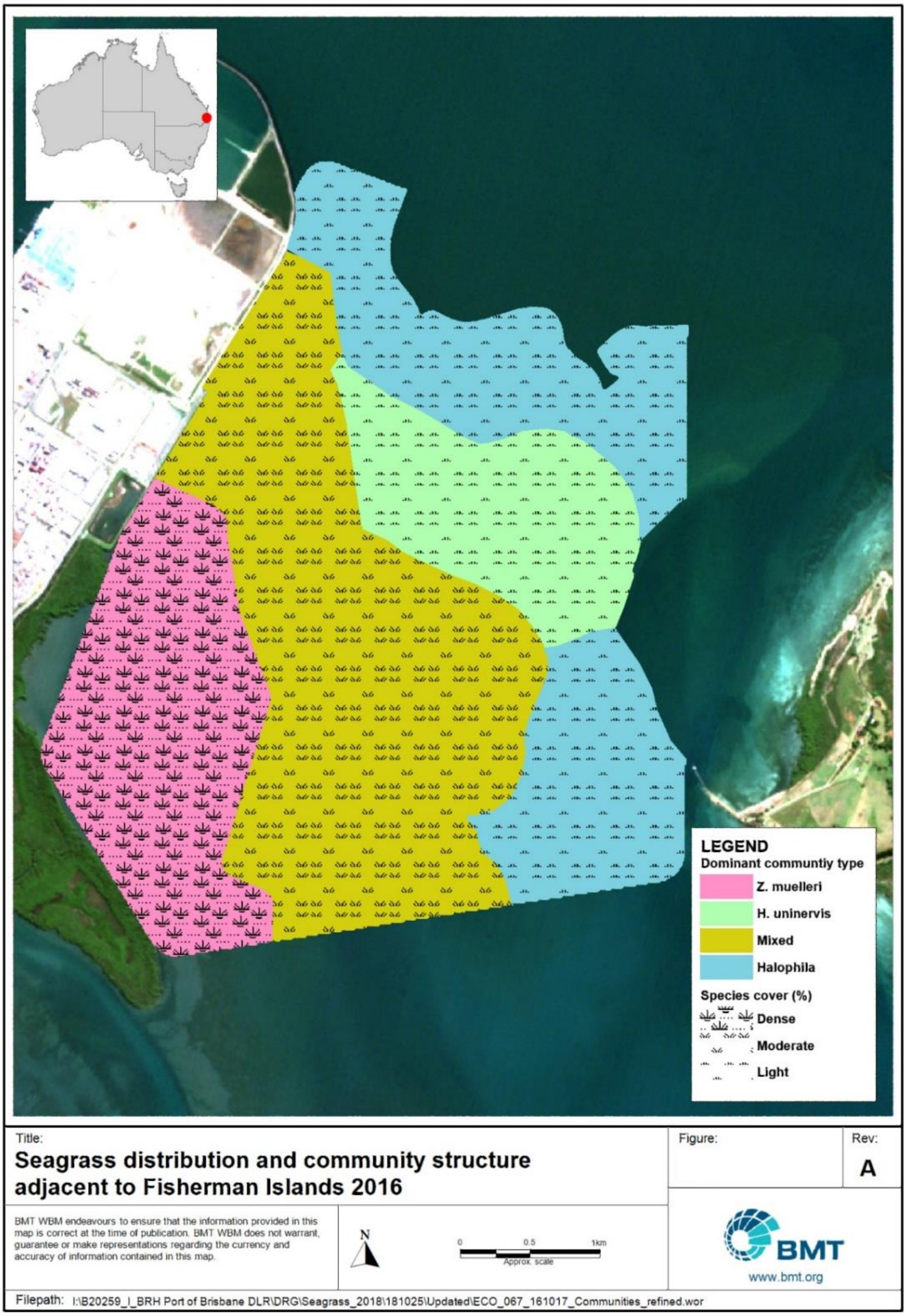


Figure C.4 Broadscale Patterns in Seagrass Distribution and Community Structure Adjacent to Fisherman Islands in 2016

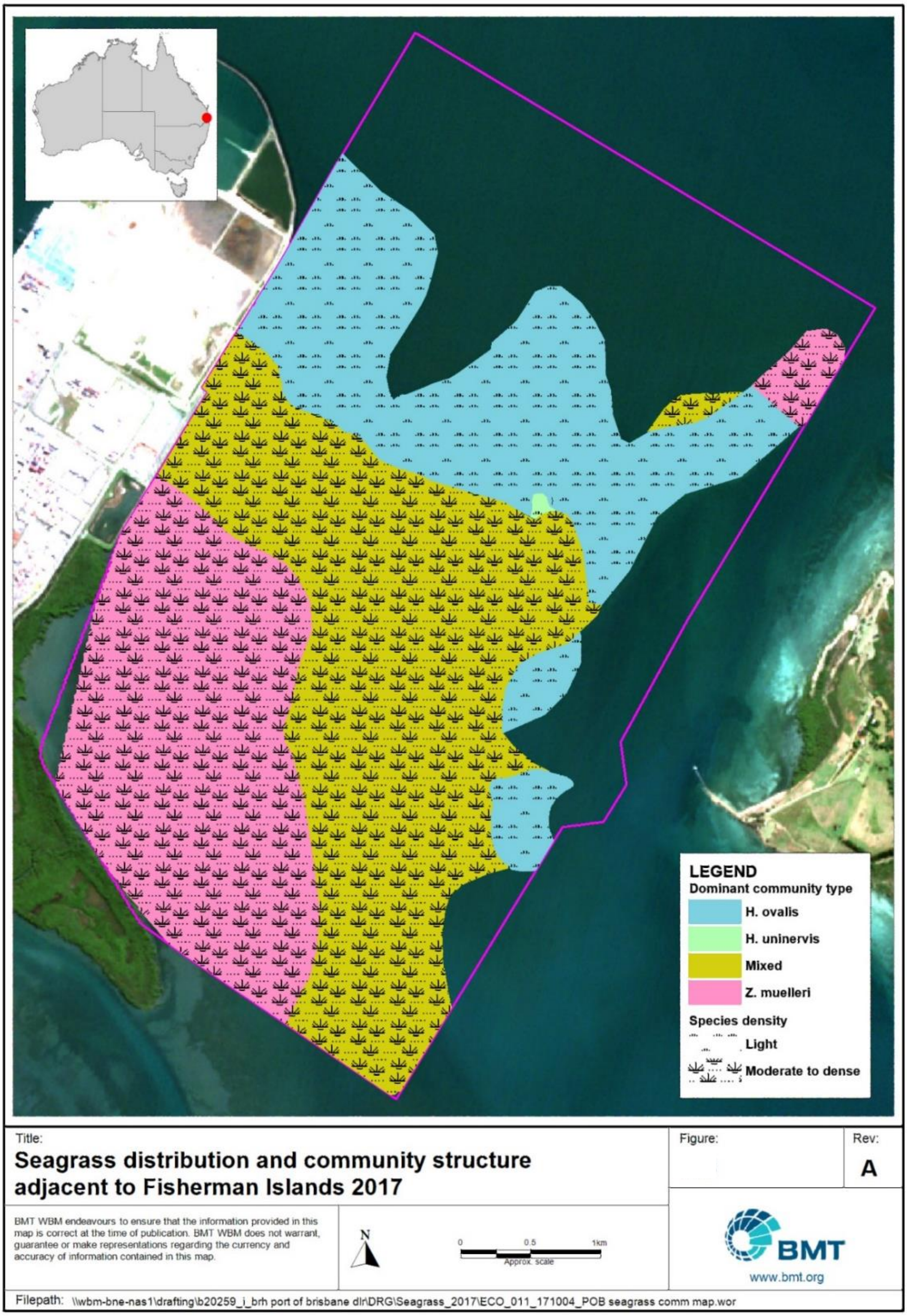


Figure C.5 Seagrass Distribution and Community Structure Adjacent to Fisherman Island, 2017

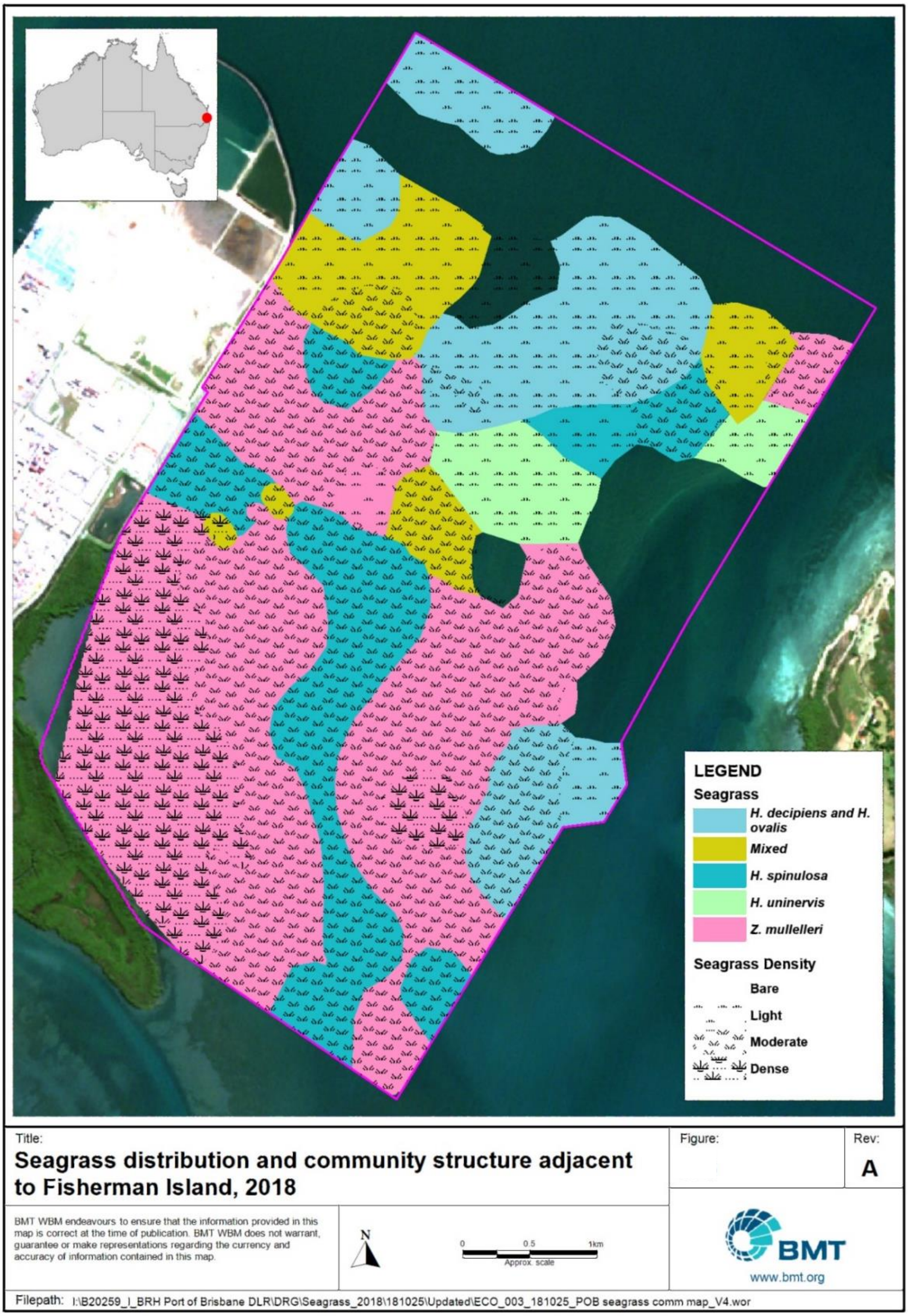


Figure C.6 Seagrass Distribution and Community Structure Adjacent to Fisherman Island, 2018

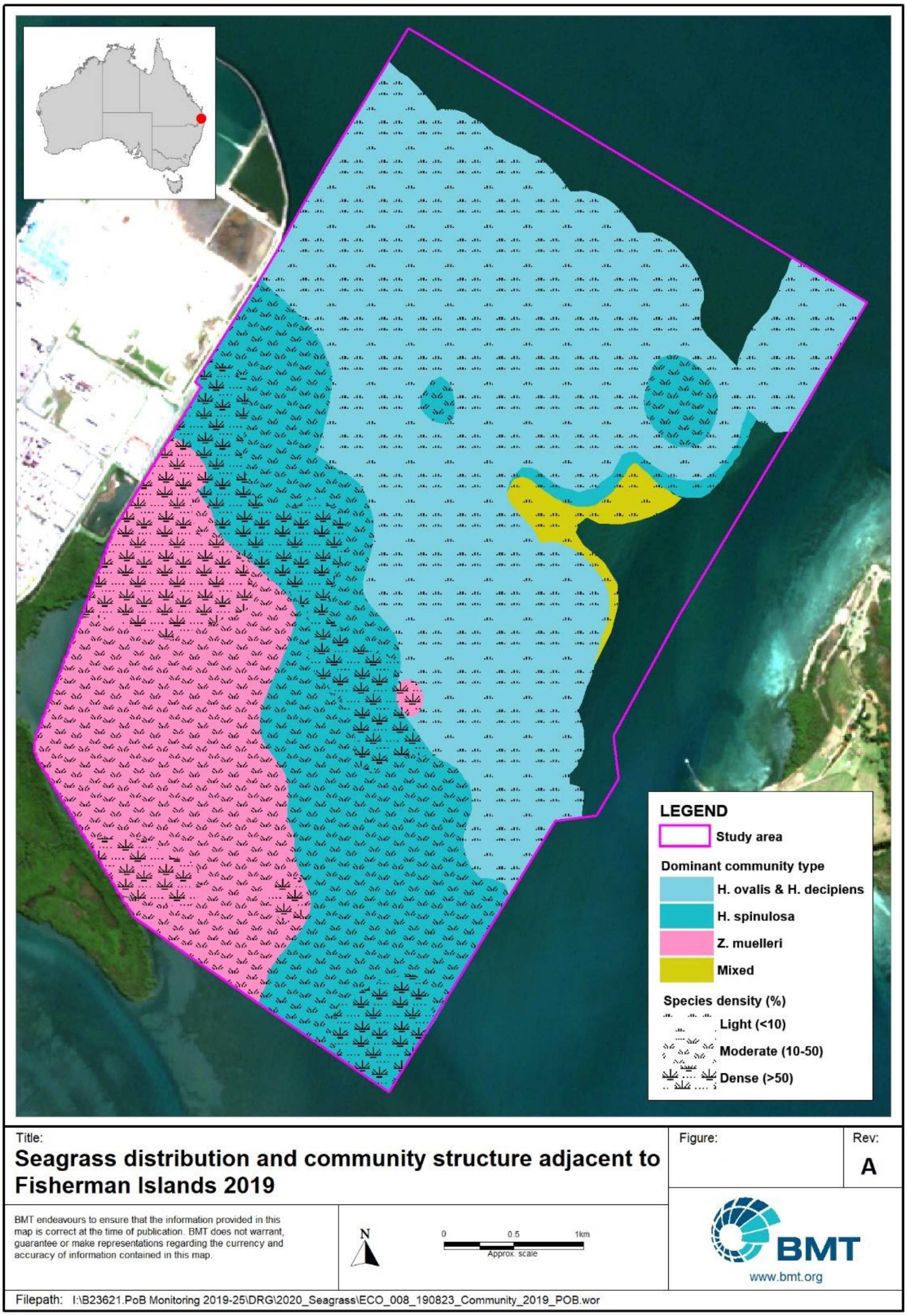


Figure C.7 Seagrass distribution and community structure adjacent to Fisherman Islands 2019

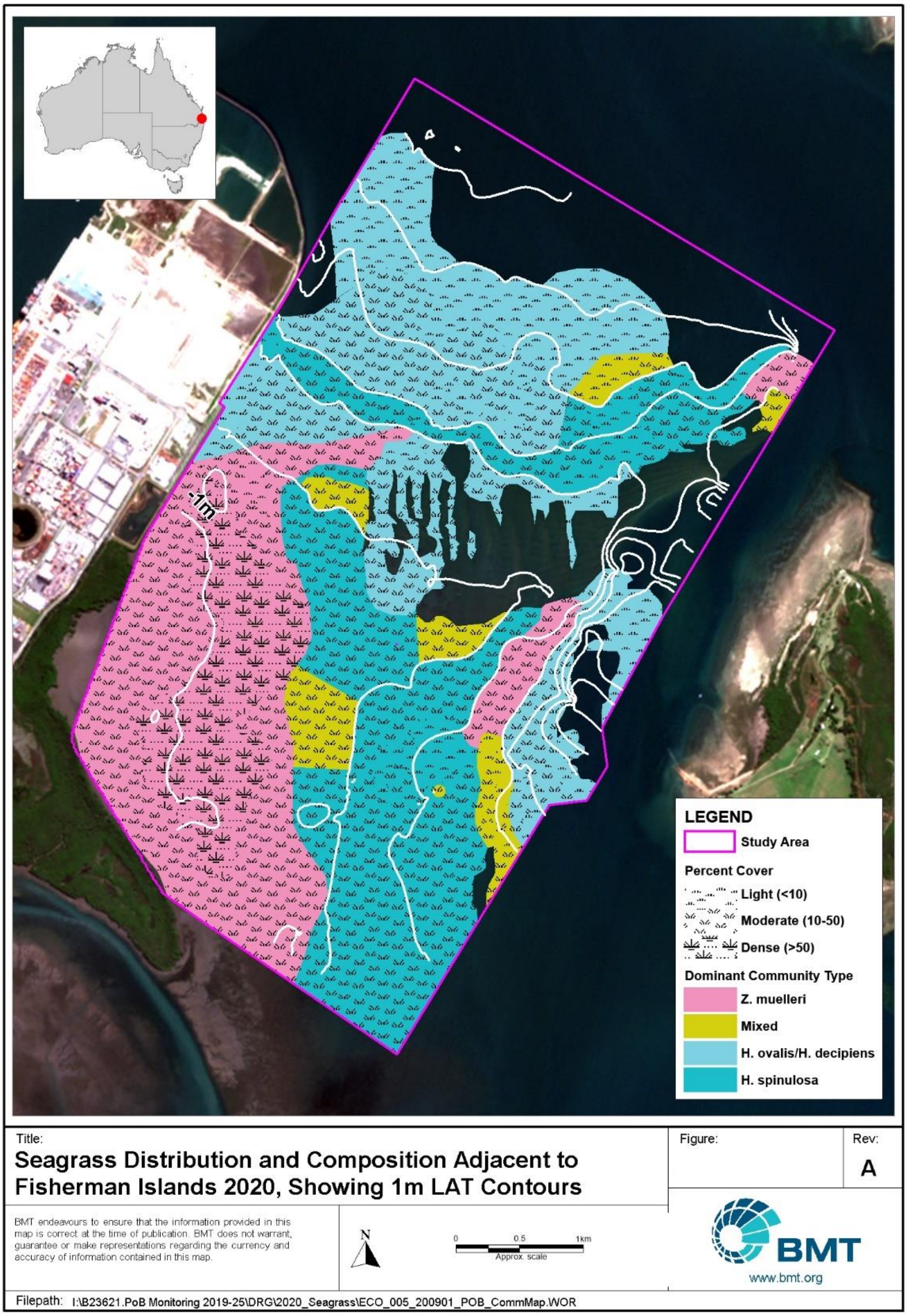


Figure C.8 Seagrass distribution and community structure adjacent to Fisherman Islands 2020

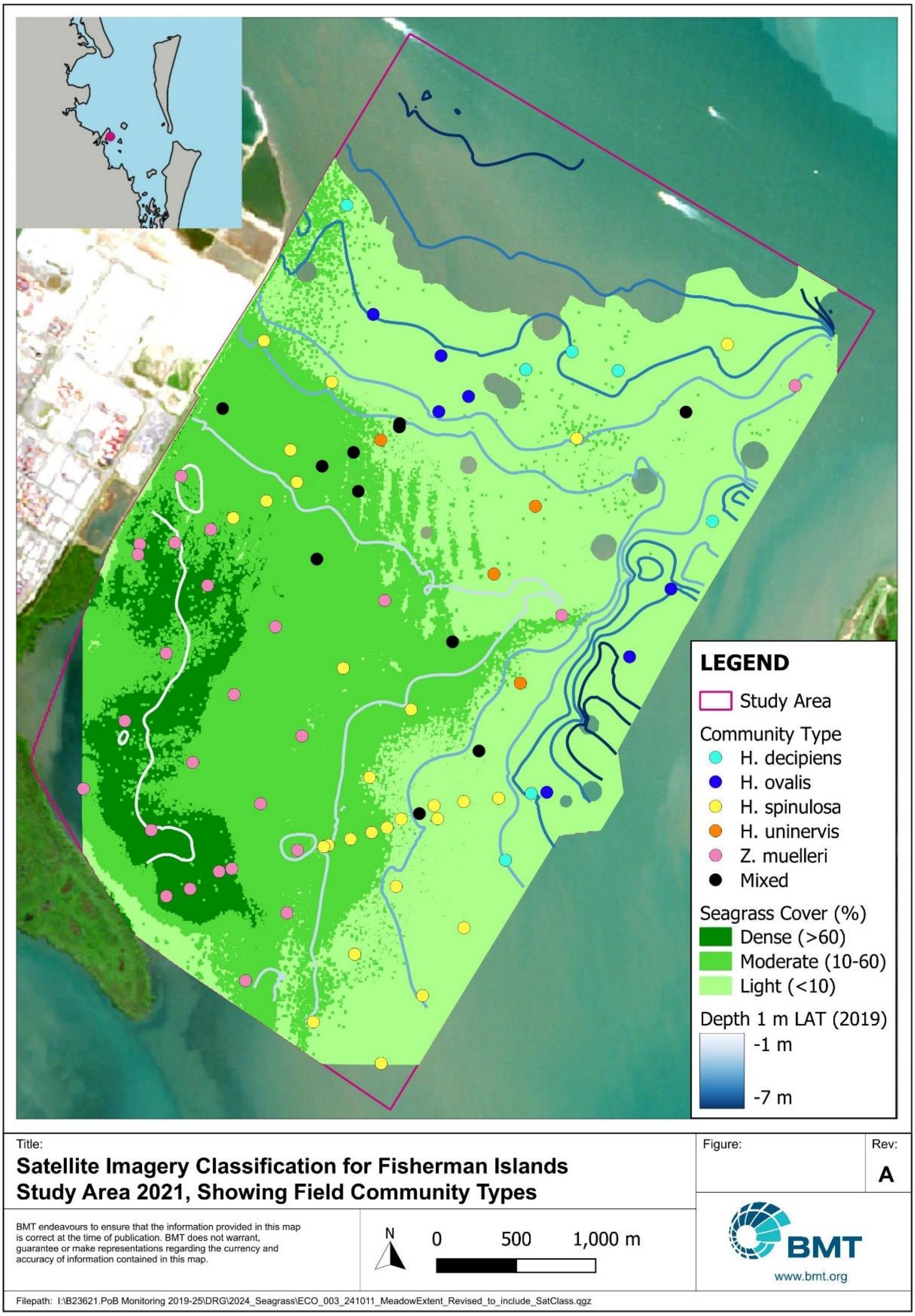


Figure C.9 Seagrass Distribution and Composition Adjacent to Fisherman Islands 2021, Showing 1m LAT Contours

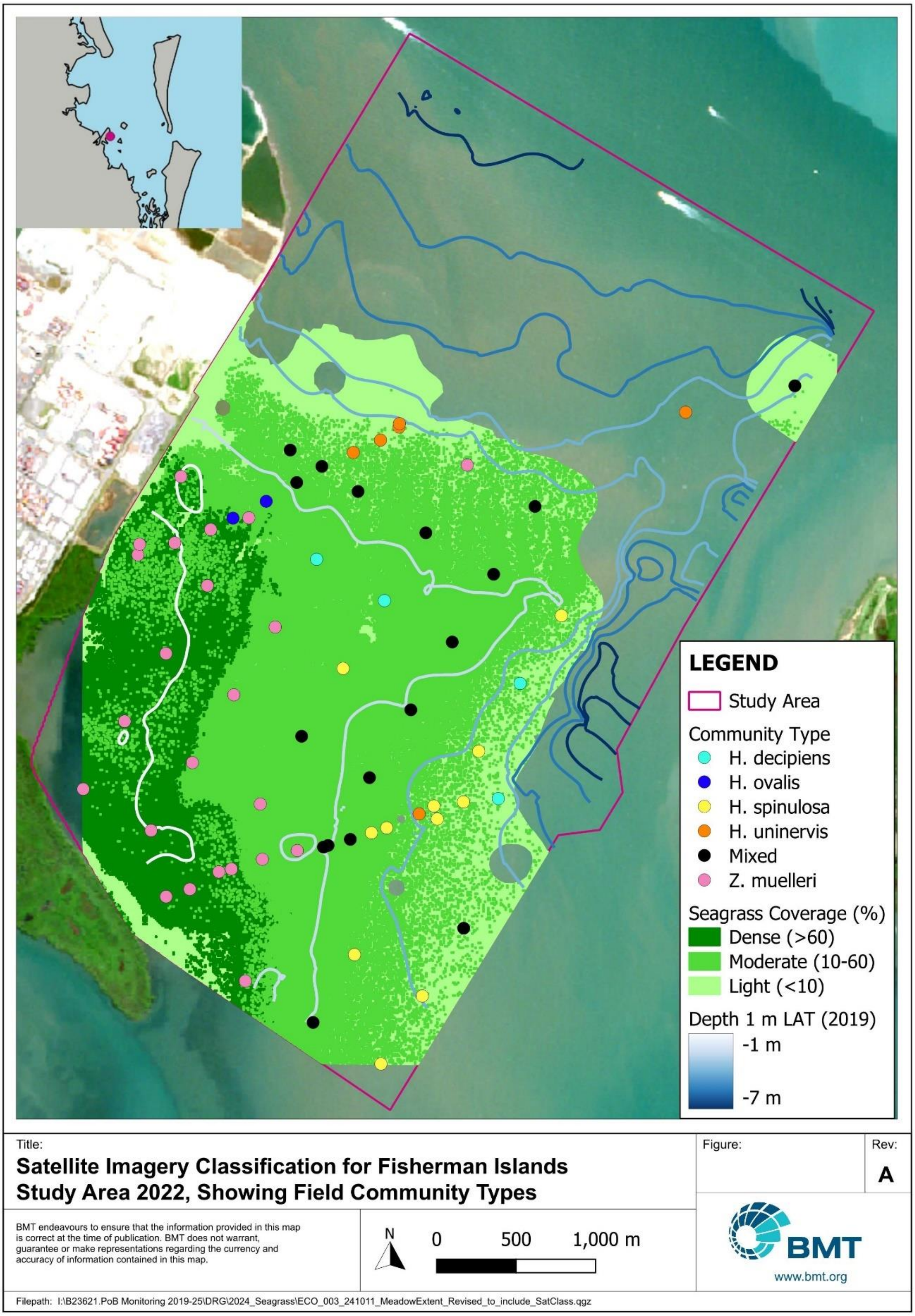


Figure C.10 Seagrass Distribution and Composition Adjacent to Fisherman Islands 2022, Showing 1m LAT Contours

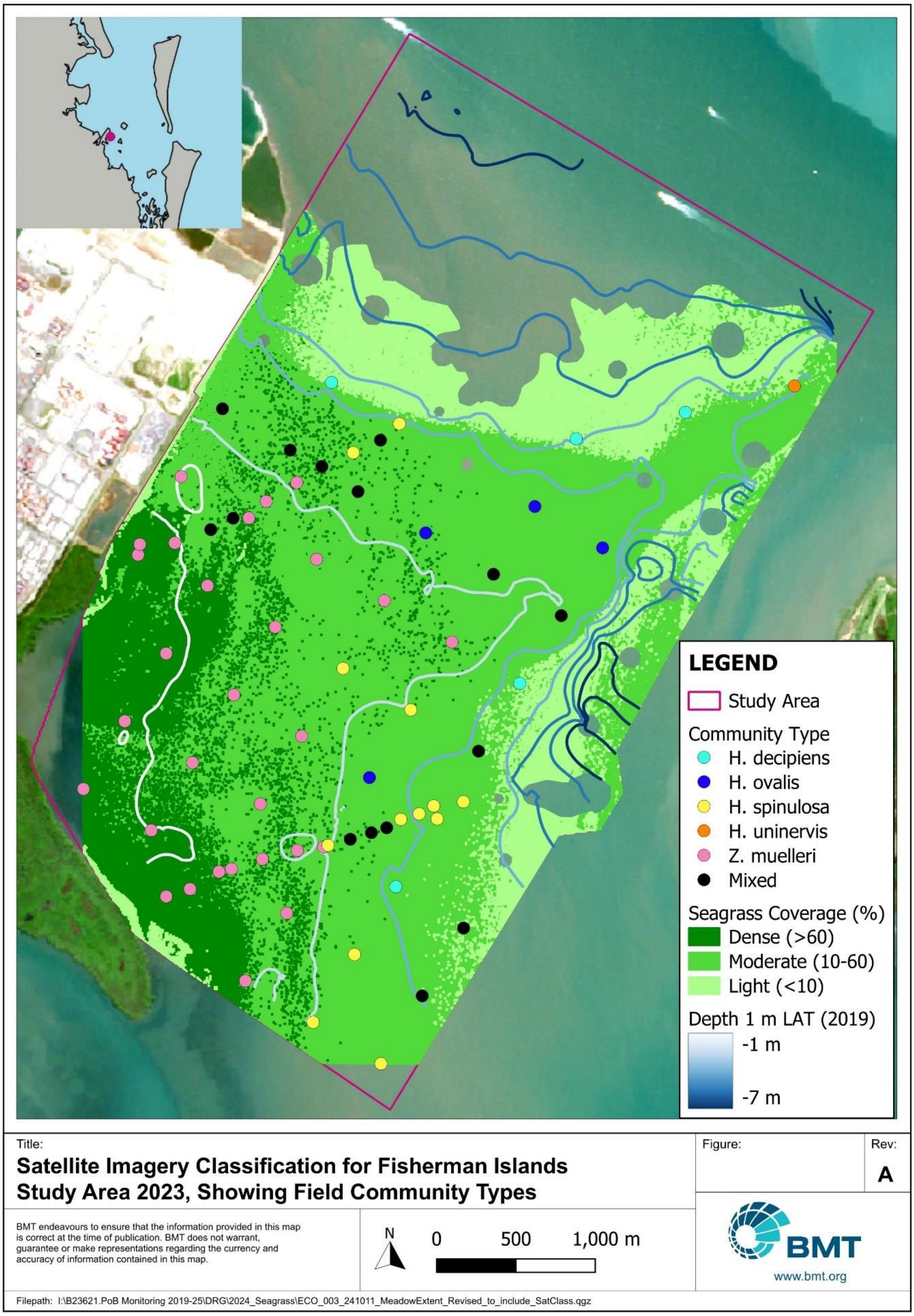
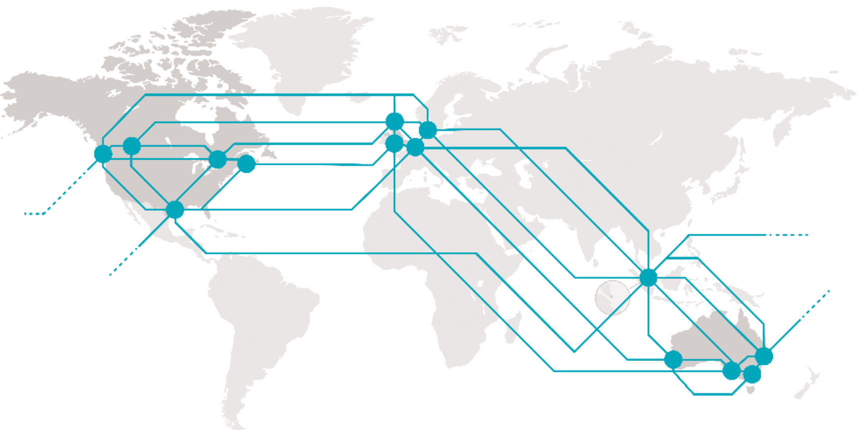


Figure C.11 Seagrass Distribution and Composition Adjacent to Fisherman Islands 2023, Showing 1m LAT Contours



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