Port of Brisbane - Seagrass Monitoring Report 2013

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Port of Brisbane - Seagrass Monitoring Report 2013

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Executive Summary

Extensive seagrass meadows occur in Waterloo Bay, adjacent to the Port of Brisbane. The Port of Brisbane Pty Ltd (PBPL) undertakes routine monitoring of the extent and condition of seagrass meadows. The monitoring program is intended to identify any broad-scale changes in seagrass meadow condition near the port, and through comparisons with trends at adjacent control locations, to determine whether such changes are indicative of port-related impacts.

The monitoring design and indicators adopted has been developed and refined since routine monitoring commenced in 2002. The three assessment methods adopted were: (i) broad-scale mapping based on aerial photography interpretation; (ii) video-based assessments of seagrass distribution along permanent transects; and (iii) video-based assessments of the maximum depth of seagrass meadows (edge of bed monitoring). Sampling was carried out at Fisherman Islands (putative impact location), and two ‘control’ locations (Manly and Cleveland) south of the Port of Brisbane (the Port).

In 2013, seagrass meadows at Fisherman Islands were structurally similar to those recorded between 2002 and the most recent survey in 2010. In this regard, dense *Zostera muelleri* meadows continue to dominate in shallow waters (maximum depth -1.84 m AHD), whereas mixed assemblages of *Halophila ovalis, H. decipiens, H. spinulosa* and several macroalgae species were found in deeper waters. The small-leafed seagrass species *Halodule uninervis* was also recorded in the study area but at low densities.

The 2013 monitoring episode demonstrates that while seagrass meadows at Fisherman Islands were generally in good condition, there was evidence of a decline since the previous (2010) survey. In this regard, the maximum depth of seagrass meadows, an indicator of ambient water quality (turbidity) conditions, was lower in 2013 than in 2010. Seagrass cover (*Zostera muelleri* and *Halophila* species) at Fisherman Islands was also lower than recorded previously.

Temporal trends in seagrass condition since the beginning of monitoring in 1992 have been relatively consistent between Fisherman Islands and the control locations at Manly and Cleveland. This indicates that the processes controlling temporal changes in seagrass meadows were operating across broad scales (i.e. across Waterloo Bay and elsewhere in western Moreton Bay), rather than a local scale change.

Based on generalised seagrass models, climatic processes are considered to be the key driver of changes in seagrass communities at broad (>10 km) spatial scales. In recent years there have been several major disturbance events, including flooding in 2011 and 2013. These events represent pulsed disturbance on a large scale, resulting in medium to long-term changes to the light regimes and nutrient loads across western Moreton Bay over a time period of weeks to months. Flooding events are probably the primary causes of reduced seagrass distributions across all locations, particularly the more pronounced declines at Fisherman Islands and Cleveland, where the increase in mud deposition from flood plumes was greatest (O’Brien *et al*. 2012).

Changes in seagrass distribution and edge of bed depth occurring between 2010 and 2013 do not suggest that seagrass at Fisherman Islands has been negatively affected by the Port. Changes are more consistent with broad-scale processes affecting the seagrasses at control locations and the Port similarly. This variation may appear to be more extreme at the port because of the very

gradual depth gradient that occurs here compared with Manly and Cleveland but evidence of these broad-scale changes can be seen in widespread expansion to 2010 and widespread contraction between 2010 and 2013, where there was an almost universal reduction in growing depths across all sites.

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1 Introduction

1.1 Background

The Fisherman Islands area contains one of the largest seagrass meadows in western Moreton Bay (Dennison and Abal 1999). These seagrass meadows have inherent biodiversity and fisheries habitat values, and are located within conservation areas, namely the Moreton Bay Ramsar site and Moreton Bay Marine Park.

The Port of Brisbane is located directly adjacent to the Fisherman Island seagrass meadows. In recognition of the values of local seagrass meadows, the Port of Brisbane Pty Ltd (PBPL) undertakes routine monitoring of seagrass meadows adjacent to the port and more broadly at Manly and Cleveland. This monitoring is intended to provide port management with information on the condition and status of seagrass meadows, and to identify whether there is any evidence that port operations are having an impact on these seagrass meadows.

Seagrass assemblages are widely demonstrated as sensitive indicators of natural and human (anthropogenic) processes in the marine environment, particularly reflecting changes in water quality/clarity (e.g. Abal and Dennison 1996). Seagrass depth range has been identified as a useful bioindicator of water quality degradation because it can "*integrate changes in aquatic light climate caused by various factors, and because seagrasses themselves are important and highly-valued elements of marine and estuarine environments*." (ANZECC/ARMCANZ 2000, p A3-79). The maximum depth at which seagrass grows is thought to mainly be a function of the availability of certain wavelengths of light[1] (Abal and Dennison, 1996). A reduction in light availability below the requirements of a particular seagrass species can reduce seagrass energy production (through the process of photosynthesis), typically resulting in the death of that seagrass. A reduction in light availability and associated loss of seagrass can therefore be manifested as a reduction in the vertical, and associated horizontal, distribution of seagrass.

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

1.2 Aims and Objectives

This study describes:

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

The specific objectives of this study were to:

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

- Identify and describe broad-scale (accuracy measured in tens of metres) spatial and temporal patterns in the vertical (depth) and horizontal distribution of seagrass beds 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;
- On the basis of the above, identify possible broad-scale operational impacts of PBPL activities on the distribution and extent of seagrass beds.

1.3 Study Area Context

The Port of Brisbane is located at Fisherman Islands (the study area), which is situated at the mouth of the Brisbane River on the western foreshore of Moreton Bay, Queensland (Figure 1-1).

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 1974. The Port of Brisbane is now Queensland's largest container port facility and continues to expand by progressive filling within the existing perimeter bund.

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

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

Control sites for the study are located adjacent to Manly and Cleveland on the western foreshore of Moreton Bay and to the south of the Fisherman Islands monitoring location (see Figure 1-1). At Manly, seagrass habitat extends from the intertidal areas adjacent to the Manly Boat Harbour and Fig Tree Point to the subtidal area close to Green Island. At Cleveland the seagrass habitat extends throughout the bay which is formed between Toondah Harbour and Coochiemudlo Island. Growing conditions at Manly and Cleveland are similar to those experienced at the Fisherman Islands site and in western Moreton Bay more generally.

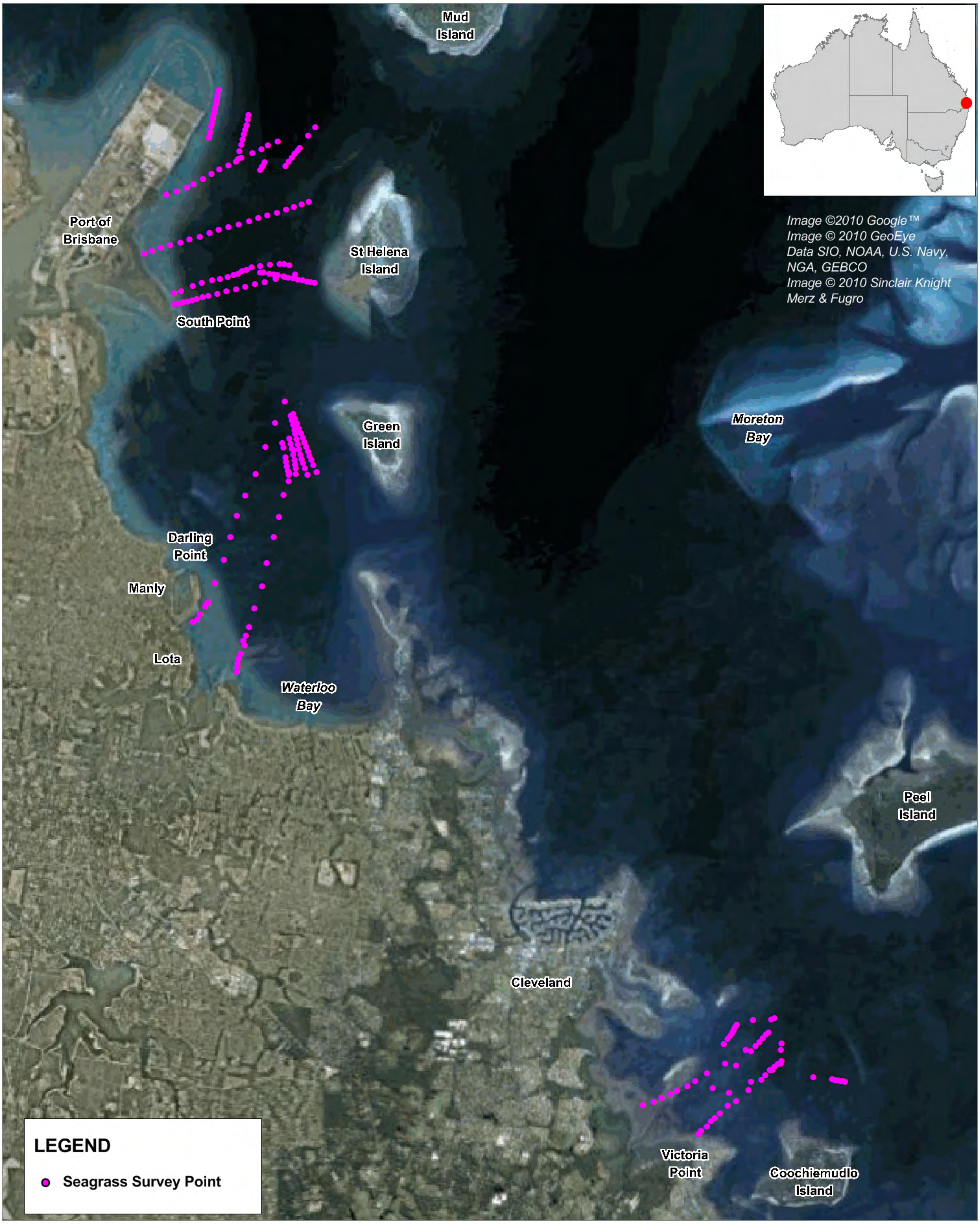
1.4 Previous Monitoring

The Port of Brisbane seagrass health monitoring program commenced in 2002. This seagrass habitat is adjacent to one of the major operational areas of the Port and forms a putative impact site, providing information on previous and current impacts of PBPL activities on seagrass health. The PBPL seagrass monitoring program also utilises two sites (Manly and Cleveland) south of the Port as broad-scale environmental controls. Multiple transect lines have been established at each of these sites. BMT WBM has completed all of the previous seagrass monitoring for PBPL at these sites since 2002 (see WBM Oceanics Australia 2002; 2003a; 2003b; 2004; 2005; BMT WBM 2006, 2010b).

Monitoring throughout the PBPL survey area between 2002 and 2006 found consistency in the size and composition of most meadows. This period included the completion of seawall construction for the Future Port Expansion (FPE) project in 2005. The 2010 monitoring event saw an expansion in the range of *Halophila ovalis* at all three survey locations.

Seagrass meadows naturally expand and contract over the course of each year, throughout Queensland (Mellors *et al*. 1993; Lanyon and Marsh 1995; McKenzie 1994) and surrounding the Port. These fluctuations are a result of changes in growing conditions due to seasonal variation in conditions. Expansions in seagrass distribution usually occur during the winter while meadows typically contract in summer. In the early 2000’s seagrass monitoring over both winter and summer documented this seasonal variation in seagrass extent (WBM Oceanics Australia 2002, 2003a, 2003b). More recent monitoring events in 2004, 2006, and 2010 have been conducted in the winter months; this year monitoring was conducted in August for consistency with these previous sampling campaigns. Consistently sampling during the winter allows estimates of the maximal winter distribution of seagrass to be made and improves the likelihood of detecting real impacts by reducing the potential influence of seasonal variation.

The present study is the first assessment of the study locations since the flooding events in 2011 and 2013. The 2011 flood event resulted in the loss of approximately half of the seagrass area within parts of Moreton Bay. While the CSIRO estimated that seagrass cover had recovered within a year of the floods, this estimate was based on LandSat imagery which has difficulty discerning deepwater seagrass distributions.



Title:

Location of Monitoring Sites Within Moreton Bay

Figure: 1-1

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Approx. Scale

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2 Methodology

2.1 Timing

The field program for the 2013 seagrass monitoring event was undertaken from the 12th to the 14th of August. Tidal data from the Tidal Unit, Maritime Safety Queensland was obtained for the Brisbane Bar throughout this study period (Figure 2-1) and was used to correct depth soundings to Australian Height Datum (AHD).

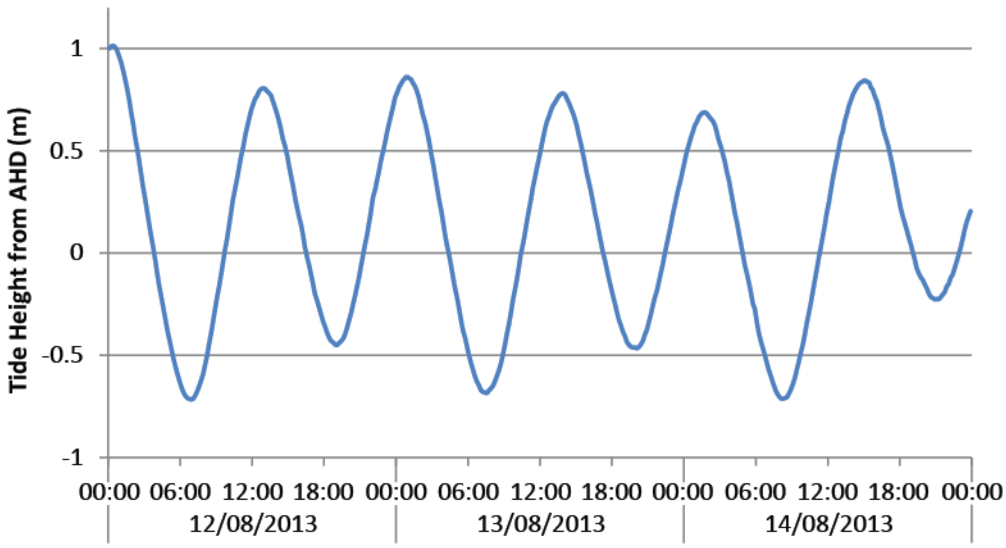


Figure 2-1 Tidal heights at Brisbane River Bar during the study period

2.2 Survey Vessel and Positioning

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

2.3 Monitoring Sites and Approach

Monitoring sites for this survey were based on those previously used for the Port of Brisbane seagrass monitoring program which was developed in 2002 (WBM Oceanics Australia 2002). During the pilot study for this monitoring program depth profiling and edge of bed monitoring was determined as the most suitable monitoring techniques. Putative impact and control locations were chosen at the Port of Brisbane (impact), Manly (control) and Cleveland (control) and monitoring sites for edge of bed, depth profiling and general mapping were established at these locations (see (Figures 2-3 to 2-5).

2.3.1 Edge of Seagrass Bed Monitoring

Sites were established at intervals along a number of transects, which traverse the known seasonal fluctuations in the deep-water edge of the seagrass bed at each location. The approximate edge of each seagrass bed was identified during the ground truthing of the mapping exercise undertaken during the pilot study. The general distribution and extent of seagrass beds was initially established by depth profiling (see WBM 2003a; b), which was used as guidance for positioning sites for this assessment method.

Along each transect, a number of permanent survey points were positioned at roughly 50-100 m intervals (Figure 2-2), and recorded using a dGPS to ensure repeatability between surveys.

At each point along these transects, the seabed was surveyed using one (or both) of the following techniques. Low light and high-resolution cameras with direct connection to a surface laptop were used to observe and record seabed features in real time. All video was recorded and stored on an external hard drive by BMT WBM. At sites where poorer water quality was encountered, van Veen grabs were used to collect samples of the seabed to confirm identifications made from the video imagery.

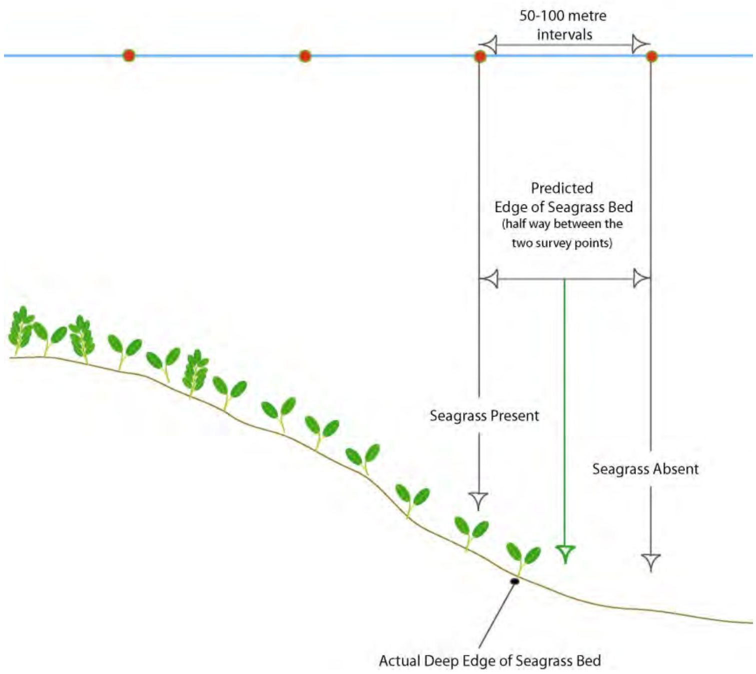


Figure 2-2 Permanent survey point method for identifying the edge of seagrass bed

The surveys initially began at a shallow survey point where seagrass was thought to be present. The survey vessel then moved to the next point along the transect until seagrass could no longer be found on the seabed. The deep water edge of the seagrass bed was assumed to be located mid-way between these two points. At each site, the depth of the seagrass and the time of survey were noted. Using this information and Brisbane Bar tidal data (Maritime Safety Queensland; 10 min interval), the depth of the seagrass bed relative to the Australian Height Datum was calculated, enabling standardised depth comparisons to occur between sites, locations and survey times.

2.3.2 Seagrass Depth Profiles

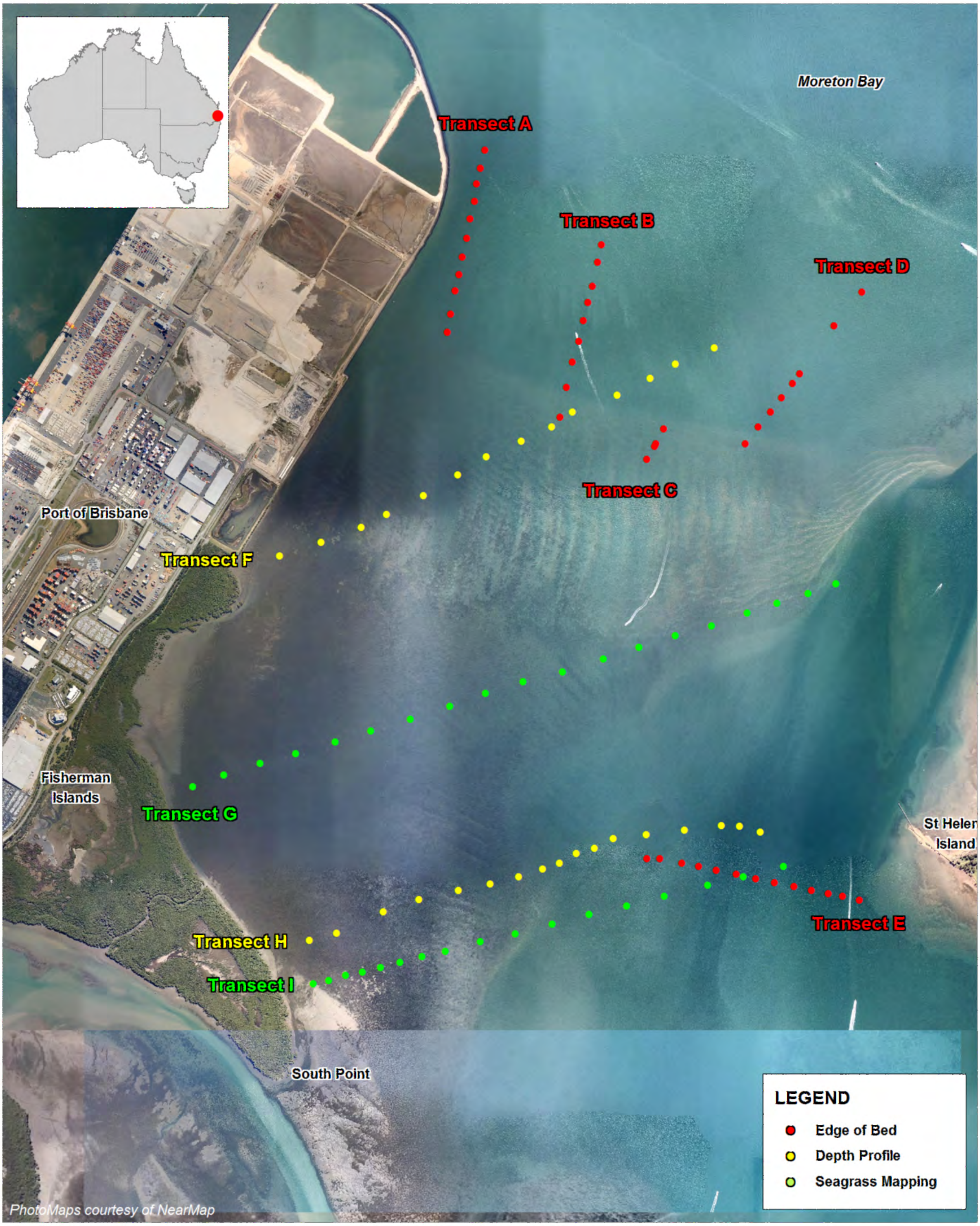
Seagrass depth profiles are used to monitor any variations in seagrass depth distribution and extent of seagrass species at each of the study locations. Depth profiles were originally monitored on a six monthly basis throughout the FPE project but were unable to be completed in 2004 due to adverse weather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

Two depth profile transects occur at each survey location, and run approximately perpendicular to the shoreline (Figure 2-3). At each point along the profile transect, the following parameters were recorded: time, water depth (using the survey vessel's sounder), position (dGPS) and seagrass species (a video image was recorded at each point). The depth at each point was reduced to Australian Height Datum to enable comparisons between locations.

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

2.3.3 Additional Seagrass Mapping in the Study Area

Information from two seagrass mapping transects at the Port, in conjunction with depth profile transects and edge of bed monitoring transects were also used to map the extent of seagrass beds at the Port, Manly and Cleveland (Figures 2-3 to 2-5). Consistent with depth profiling, at each point along the seagrass mapping transects the following parameters were recorded: time, water depth (using the survey vessel's sounder), position (dGPS) and seagrass species (a video image was also recorded at each point). The depth at each point was reduced to Australian Height Datum to enable comparisons between locations.



Title:

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

Figure: 2-3

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Approx. Scale

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Title:

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

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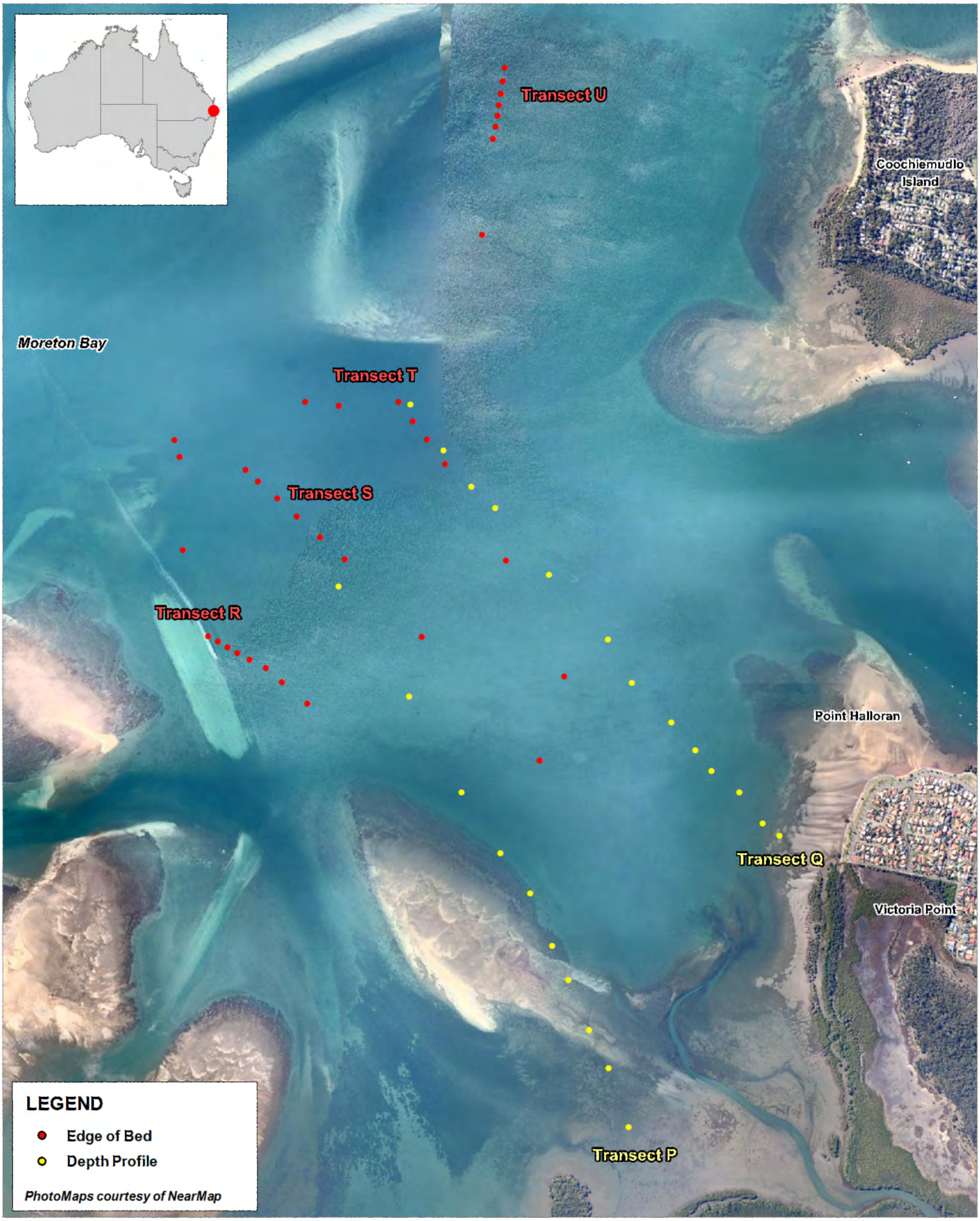

Title:

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

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3 Results

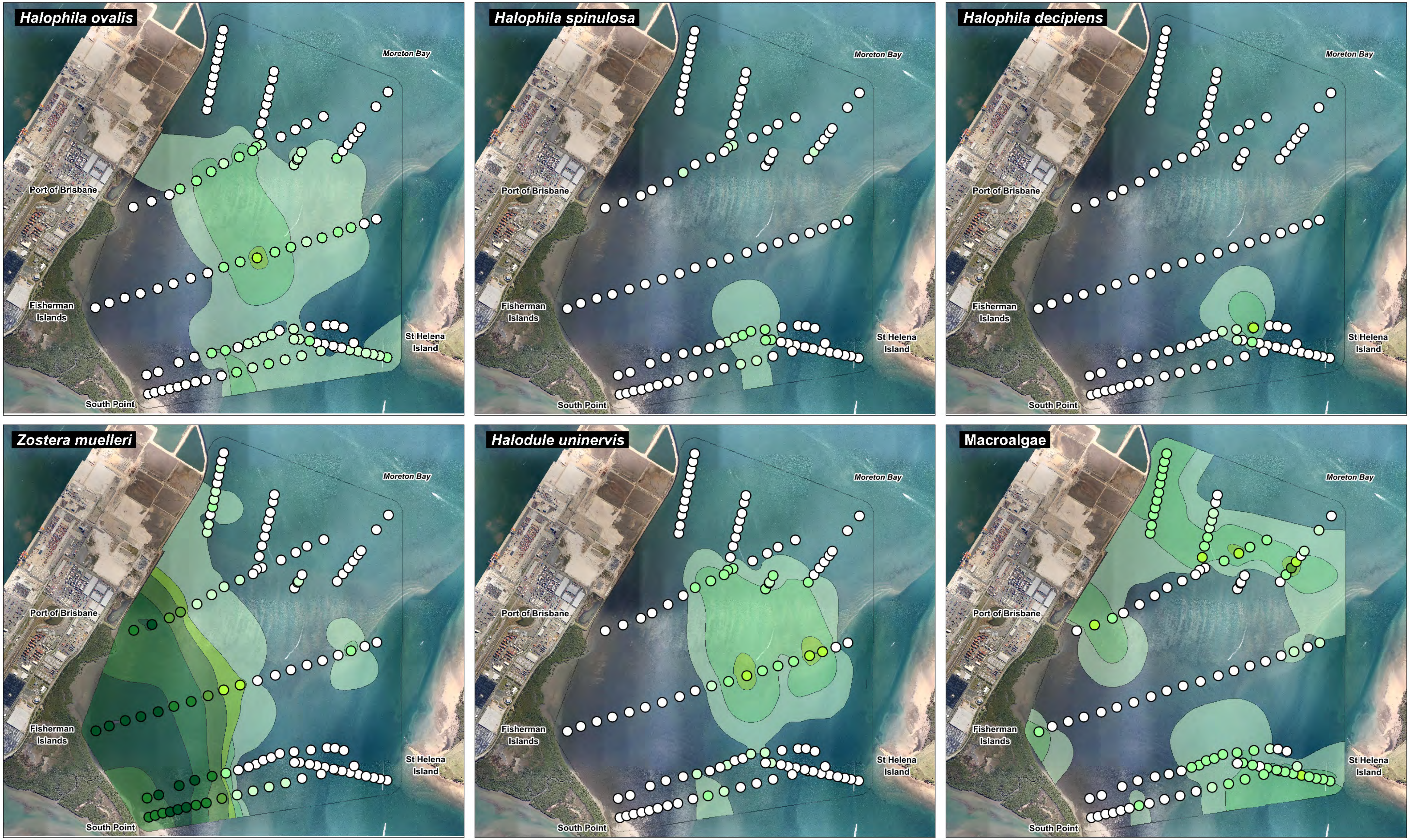
3.1 Seagrass Species Distribution Mapping

Five species of seagrass were recorded in the present survey episode, two more than were recorded in previous years. *Zostera muelleri, Halophila ovalis,* and *Halophila spinulosa* have been recorded at all sampling locations, past and present. Two species that have not been recorded at these monitoring sites previously include *Halophila decipiens* and *Halodule uninervis. Halophila. decipiens* was recorded at all three survey sites in 2013 and *H. uninervis* was recorded at the Port of Brisbane and Manly sites in this year. In previous surveys, video transects did not provide sufficiently detailed imagery to discern *H. ovalis* from *H. decipiens* and, given the similar morphology and ecology of these species, they were collectively referred to as *H. ovalis* for reporting purposes (BMT WBM 2010). During the present study, conditions permitted discrepancy between these two species. *Halophila uninervis* may also have been present in previous surveys but classified collectively with *Z. muelleri* or as a “thin leaved” variety of *Z. muelleri* for similar reasons to those described above. Photographs of seagrass species are displayed in Figure A-1.

Data from all survey sites at the Port of Brisbane, Manly and Cleveland were used to map the spatial distribution of seagrass species and macroalgae at each location. Maps showing the spatial distribution of *H. ovalis, H. spinulosa, H. decipiens, Z. muelleri, H. uninervis* and total macroalgae are shown in Figure 3-1 to Figure 3-3. Combined community structure at the Port of Brisbane is shown in Figure 3-4.

General findings from this mapping show that:

- Species of the genus *Halophila* tend to form deeper subtidal communities at the seaward edge of seagrass beds at each of the survey locations. *Halophila ovalis* has a wider distribution, ranging from shallow intertidal (mixed with *Z. muelleri*) to deeper subtidal. *Halophila decipiens* and *H. spinulosa* tend to occur predominantly in the deeper subtidal zones.
- *Zostera muelleri* formed dense beds in the intertidal zone at the landward edge at each location and often extended slightly into the shallow subtidal. Intertidal beds were comprised largely of dense mono-specific stands of *Z. muelleri* with occasional patches of *H. ovalis*. Subtidal beds were usually mixed with other species, including *H. ovalis, H. spinulosa* and *H. uninervis.*
- There was mixed cover of *H. uninervis* in subtidal meadows, typically more inshore and more widely spread at the Port of Brisbane than at Manly. *Halodule uninervis* was not observed at Cleveland.



LEGEND

Coverage %

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

Survey Site

PhotoMaps courtesy of NearMap

Title:

Species Distributions at Fisherman Islands, Adjacent to the Port of Brisbane

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Figure: 3-1

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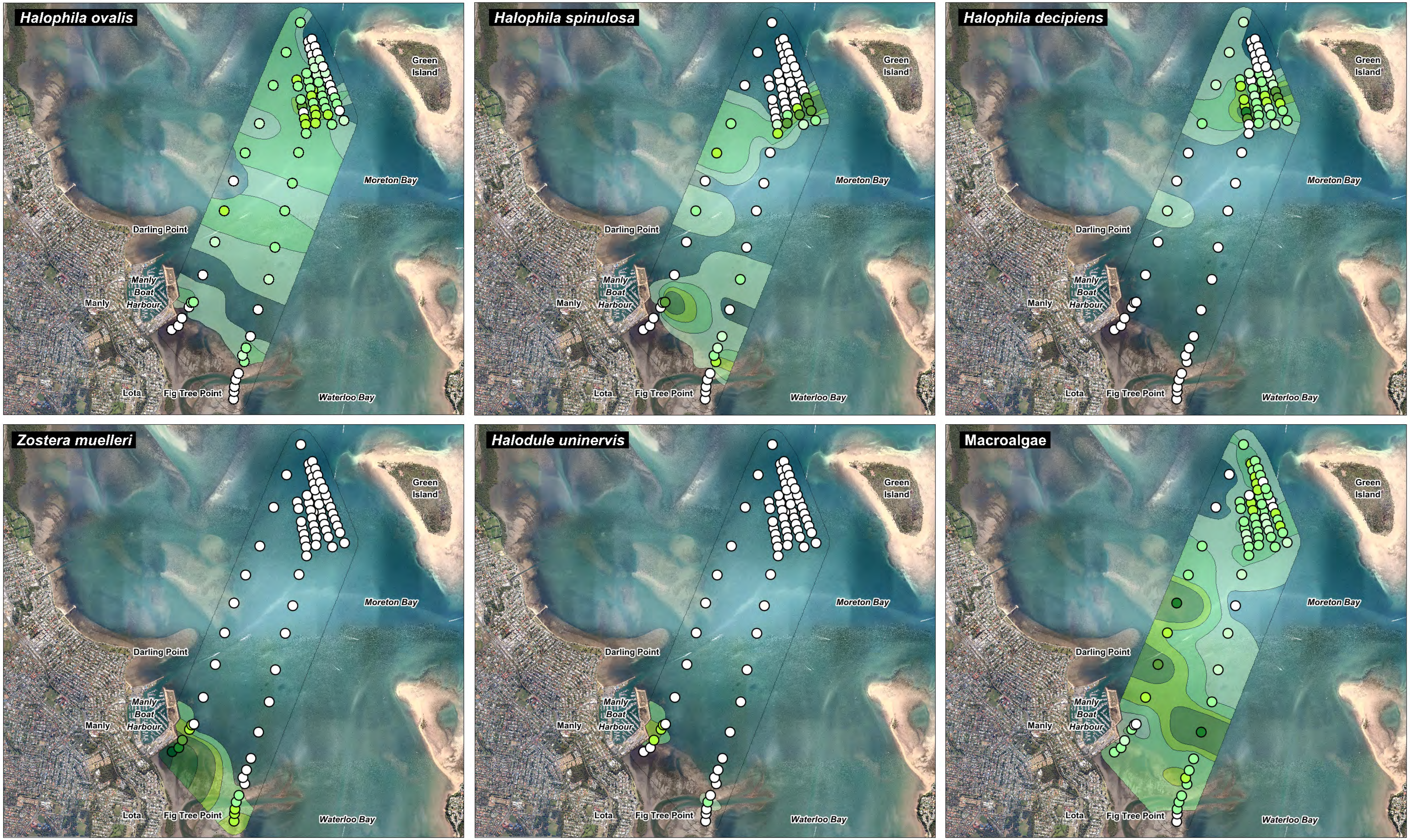

LEGEND

Coverage %

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

Survey Site

PhotoMaps courtesy of NearMap

Title:

Species Distributions at Manly

Figure: **3-2**

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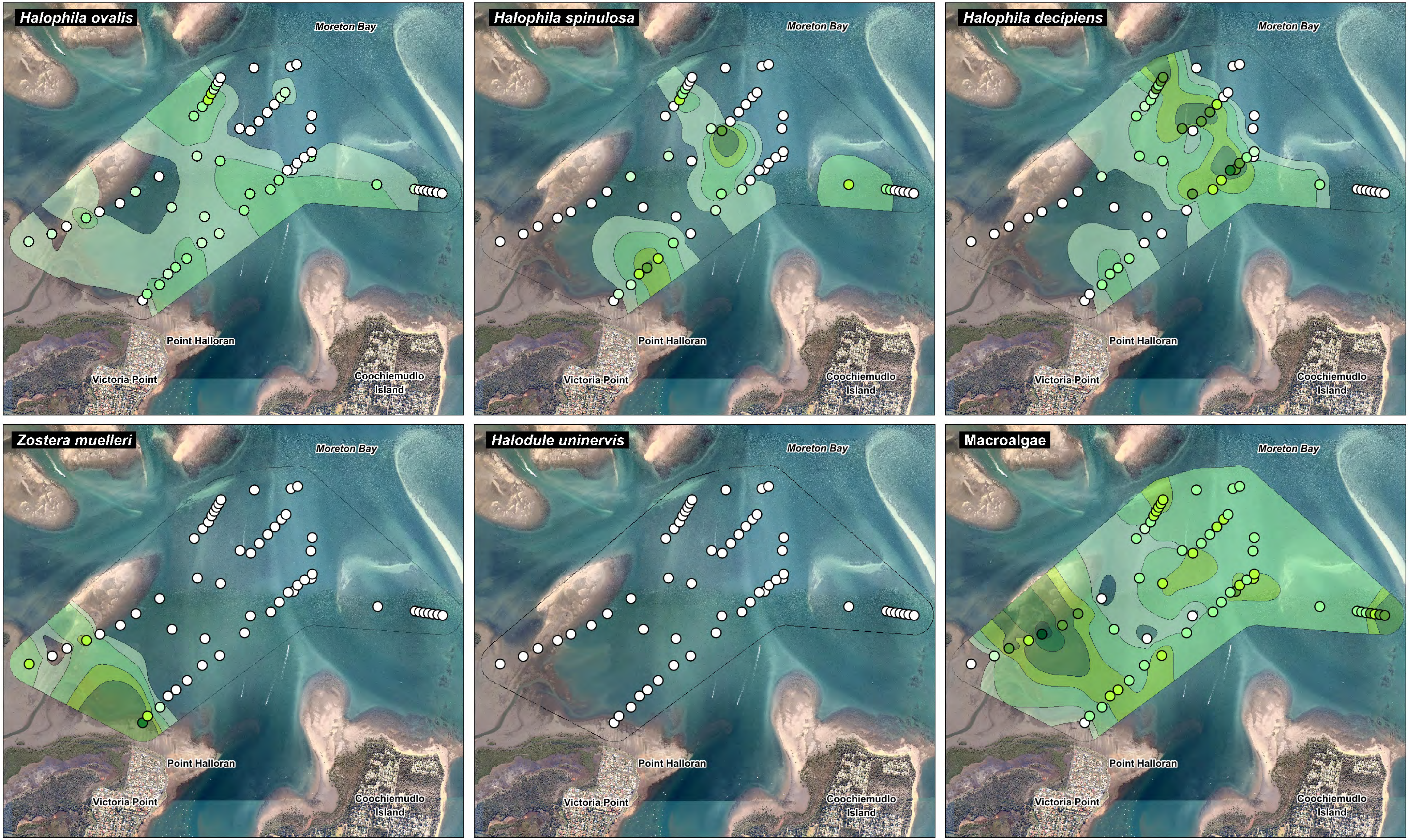

LEGEND

Coverage %

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

Survey Site

PhotoMaps courtesy of NearMap

Title:

Species Distributions at Cleveland

Figure: **3-3**

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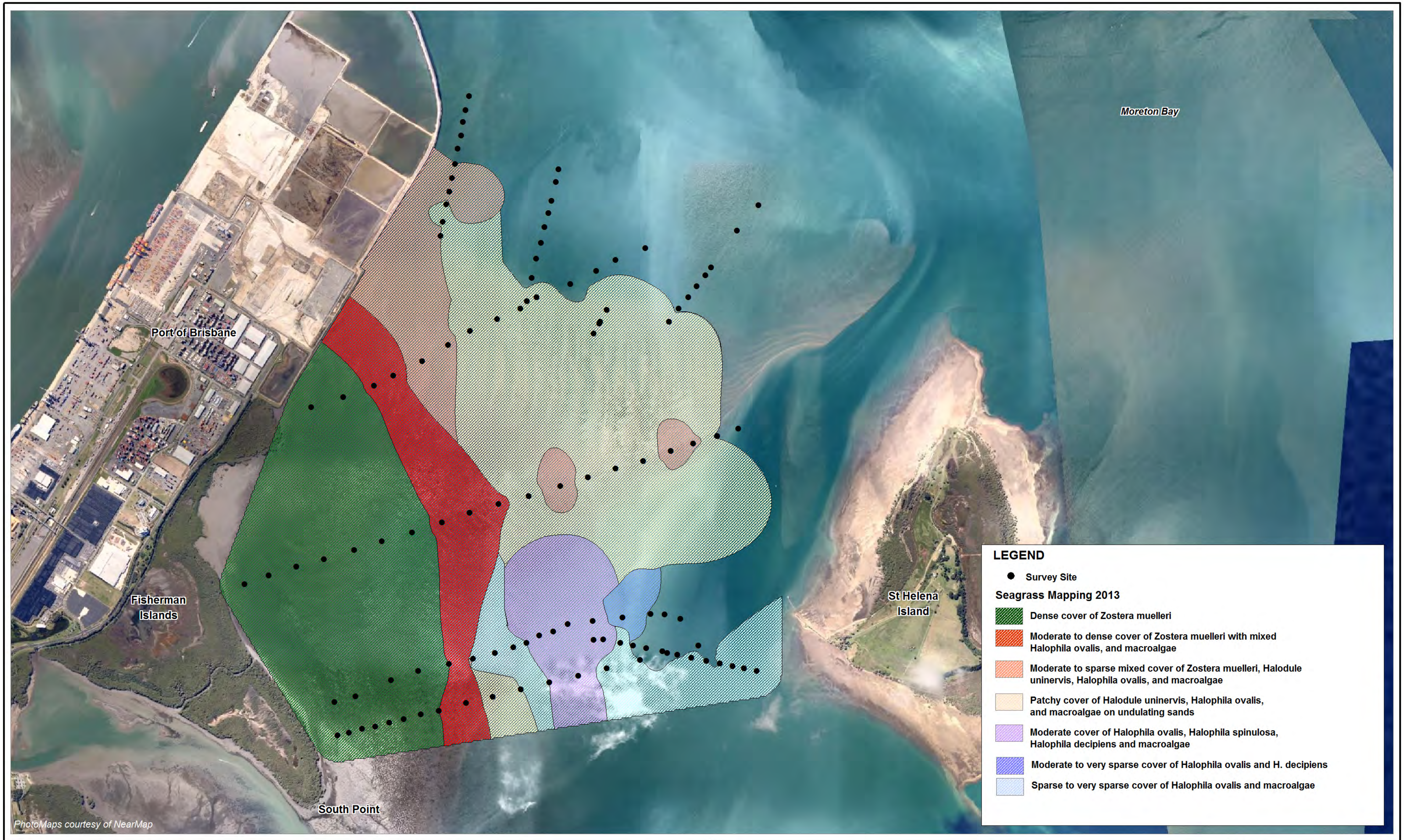

Title:
Seagrass Distribution and Community Structure Adjacent to Port of Brisbane

Figure: **3-4**

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3.2 Seagrass Depth Profiles

Figure 3-5 to Figure 3-10 display conceptual representations of seagrass assemblages along transects used to analyse seagrass depth profiles at each monitoring location (Fisherman Islands [Port of Brisbane], Manly, and Cleveland). Each profile is compared to seagrass depth profiles conducted in May 2003, July 2006, and July 2010. Maps showing the composition of seagrass communities at each sample location for 2013 are also displayed in Figure 3-1 to Figure 3-3.

Maximum recorded growing depths of seagrass species[2] from depth profiling at each monitoring location during both the August 2013 and July 2010 surveys are displayed in Table 3-1. The growing depths for most species that were seen in both 2010 and 2013 were greater in 2010, with the exception of *H. spinulosa* at Transects P and Q (Cleveland) and at Transect H (Port of Brisbane) and *Z. muelleri* at Transect Q (Cleveland).

H. ovalis was present at greater depths in 2010 than it was in 2013 on all depth profile transects; in 2010 it was present at more than twice the maximum depth of 2013 at Transect F (Port of Brisbane) and almost twice the 2013 max depth at Transects H (Port of Brisbane) and K (Manly). Overall, *H. ovalis* was the deepest occurring species, but in 2013, maximum growing depths were generally similar amongst all species from the genus *Halophila*.

The maximum growing depth of *Z. muelleri* was deeper at the Port of Brisbane and Manly in 2010 than in 2013 but was similar in both years at Cleveland. In 2010 the shallowest maximum depths for *Z. muelleri* were at Cleveland but in 2013, shallowest maximum depth was at Transect K (Manly). In fact, the overall deepest *Z. muelleri* beds were seen at Transect Q (Cleveland).

Between 2010 and 2013 the Port and Manly had substantially shallower maximum depths for meadows of *Z. muelleri* and *H. ovalis*, while at Cleveland, *Z. muelleri* remained relatively consistent between the two years.

[2] All depths in this document are in meters relative to Australian Height Datum (AHD)

Table 3-1 Comparison of maximum recorded growing depths of seagrass species from depth profiles at each location in 2010 and 2013. Maximum depths are shaded for *H. ovalis* (Ho), *H. spinulosa* (Hs) and *Z. muelleri* (Zm). *Halophila decipiens* (Hd) was not differentiated from *H. ovalis* in previous surveys[3] and so maximum growing depth for this species is only show for 2013.

Location	Transect	Seagrass Species	Max. growing depth 2010	Max. growing depth 2013
Cleveland	P	Ho	-6.39	-6.18
		Hd		-5.13
		Hs	-3.38	-3.54
		Zm	-0.77	-0.59
	Q	Ho	-6.17	-5.71
		Hd		-4.61
		Hs	N/A	-3.67
		Zm	-1.51	-1.84
Manly	J	Ho	-4.86	-4.46
		Hd		-4.46
		Hs	-3.99	-3.37
		Zm	-2.34	-1.63
	K	Ho	-8.82	-5.03
		Hd		-5.03
		Hs	-4.41	-4.03
		Zm	-2.23	-0.39
Port of Brisbane	F	Ho	-5.70	-2.24
		Hs	-4.35	-2.24
		Zm	-2.53	-1.80
	H	Ho	-4.56	-2.49
		Hd		-2.90
		Hs	-2.35	-2.49
		Zm	-2.35	-1.46

[3] In previous surveys, video transects did not provide sufficiently detailed imagery to discern *H. ovalis* and *H. decipiens.* Given the similar ecology and morphology of these species, they were collectively referred to as *H. ovalis* in previous reports.

3.2.1 Species Patterns along Depth Profiles

Key patterns in the species distributions of marine vegetation along the depth profiles during the August 2013 monitoring episode are as follows:

- *Zostera muelleri* was present on all depth profiles but was confined to intertidal and shallow subtidal parts of these transects. The maximum depth that this species was seen was -1.84m AHD at Cleveland, closely followed by the Port of Brisbane where it was observed at 1.80m (Table 3-1). The most dense cover of *Z. muelleri* was in the intertidal regions where this species often formed mono-specific stands (especially at the Port of Brisbane, Figure 3-5 and Figure 3-6) but it was also observed in mixed beds with *H. ovalis* (Figure 3-9); *H. uninervis* (Figure 3-7) and various macroalgae species, including *Hincksia mitchelliae*, *Ectocarpus fasciculatus*, and *Sporochnus comosus* (Figure 3-7 and Figure 3-8). In the shallow subtidal zone, *Z. muelleri* occurred in consistent to patchy cover in mixed beds with *H. ovalis, H. spinulosa, H. mitchelliae* and *S. comosus* (Figure 3-5 and Figure 3-6).
- *Halophila ovalis* was the most common and widespread species, spanning from shallow intertidal to deeper subtidal zones. *H. decipiens* and *H. spinulosa* often occurred in mixed beds with *H. ovalis* but were less widespread, coverage of these two species tended to be higher at sites further from shore. The maximum depth at which *H. ovalis* was recorded was -6.18m AHD at Cleveland, the maximum depth for *H. decipiens* was -5.13m AHD at Cleveland and the maximum depth for *H. spinulosa* was -4.03m AHD at Manly. The shallowest maximum depth for all of the *Halophila* species was at the Port of Brisbane.
- There was sparse cover of *H. uninervis* in mixed beds with *Z. muelleri*, *H. ovalis* and *H. spinulosa* in the shallow subtidal zone at Manly (Figure 3-7). *H. uninervis* was also seen at some subtidal sites along depth profiling and seagrass mapping transects at the Port of Brisbane (Figure 3-5).
- There was limited cover of the invasive macroalgae *Caulerpa taxifolia* in mixed beds with *H. ovalis* and *H. spinulosa* at deeper sites at Manly (Figure 3-8). *Caulerpa taxifolia* was also seen at some edge of bed monitoring locations at Manly and Cleveland but it was not observed at all at the Port of Brisbane.
- Various other species of macroalgae were seen across all locations at various depths. Macroalgae was more widely distributed at Cleveland and Manly and was less dense at the Port of Brisbane. The most common species of macroalgae identified in 2013 include *Sporochnus comosus, Hypnea spinella, Spyridia filamentosa* and other filamentous algae's comprising *Hincksia (Giffordia) mitchellae, Ectocarpus fasciculatus* and possibly *Lyngbya majuscula* (see Figure A-2).

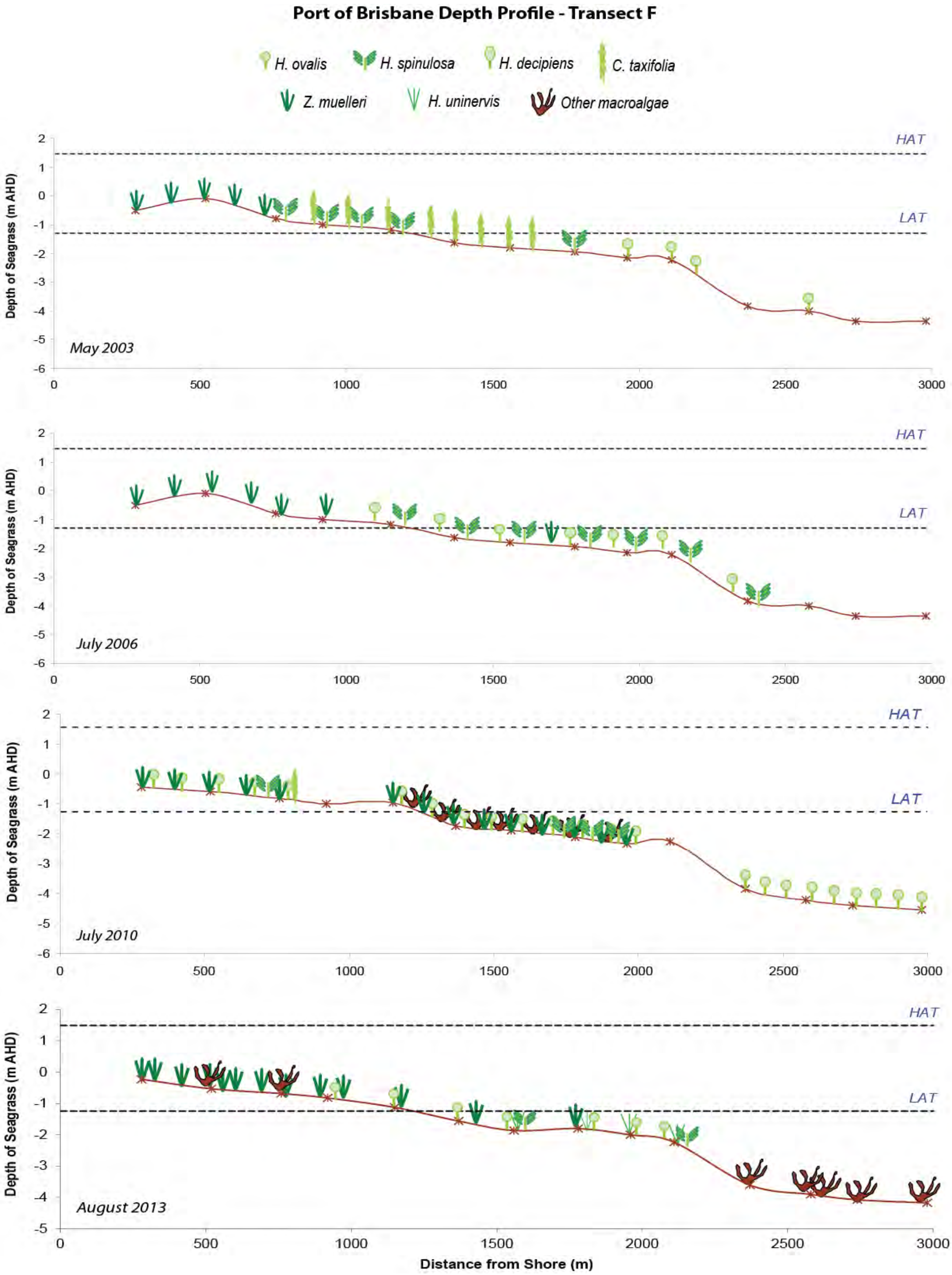


Figure 3-5 Schematic representation of seagrass species distributions for 2003, 2006, 2010 and 2013 from depth profiling at Transect F at the Port of Brisbane. Note that macroalgae was not studied in detail prior to July 2010.

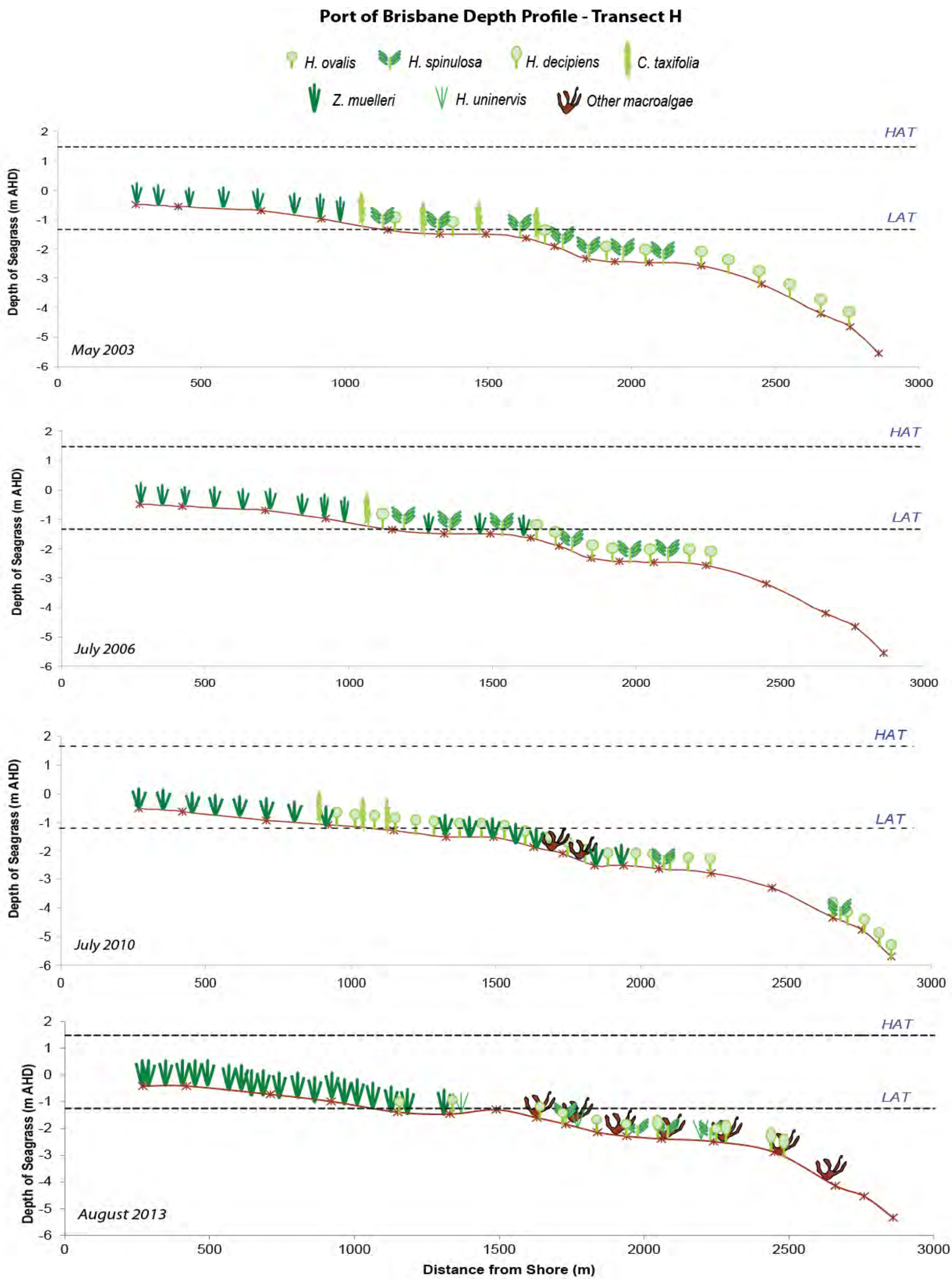


Figure 3-6 Schematic representation of seagrass species distributions for 2003, 2006, 2010 and 2013 from depth profiling at Transect H at the Port of Brisbane. Note that macroalgae was not studied in detail prior to July 2010.

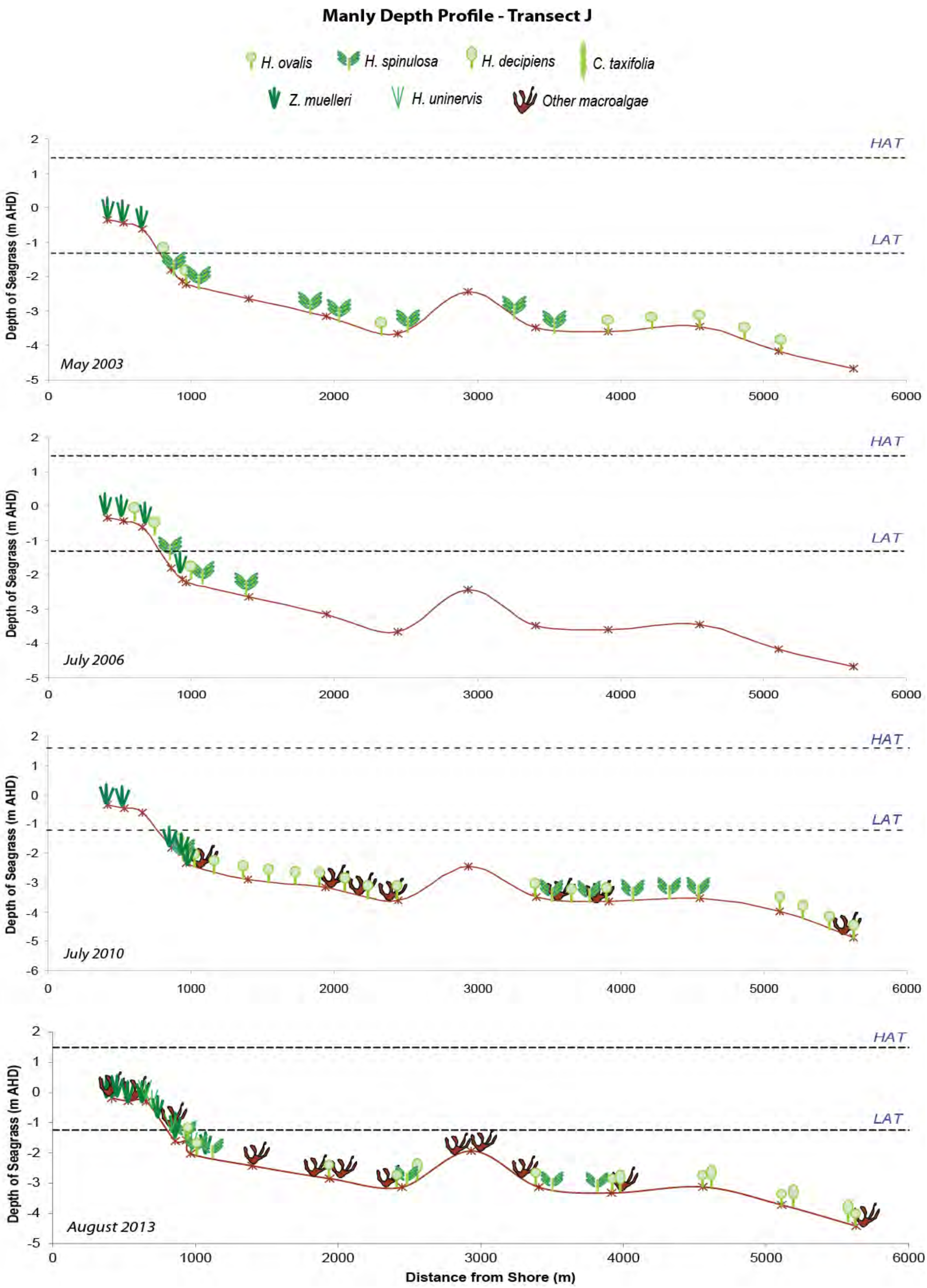


Figure 3-7 Schematic representation of seagrass species distributions for 2003, 2006, 2010 and 2013 from depth profiling at Transect J at Manly. Note that macroalgae was not studied in detail prior to July 2010

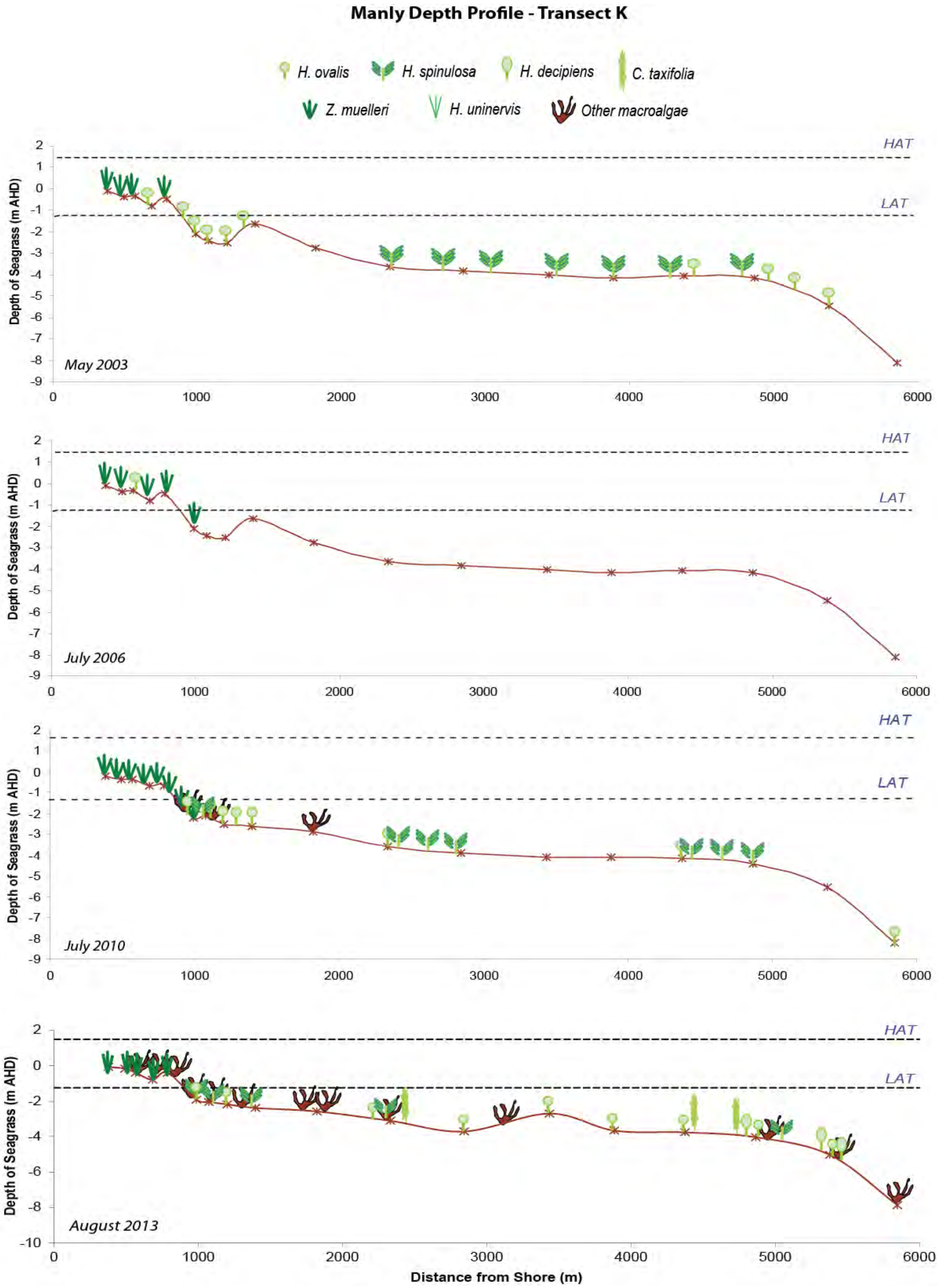


Figure 3-8 Schematic representation of seagrass species distributions for 2003, 2006, 2010 and 2013 from depth profiling at Transect K at Manly. Note that macroalgae was not studied in detail prior to July 2010.

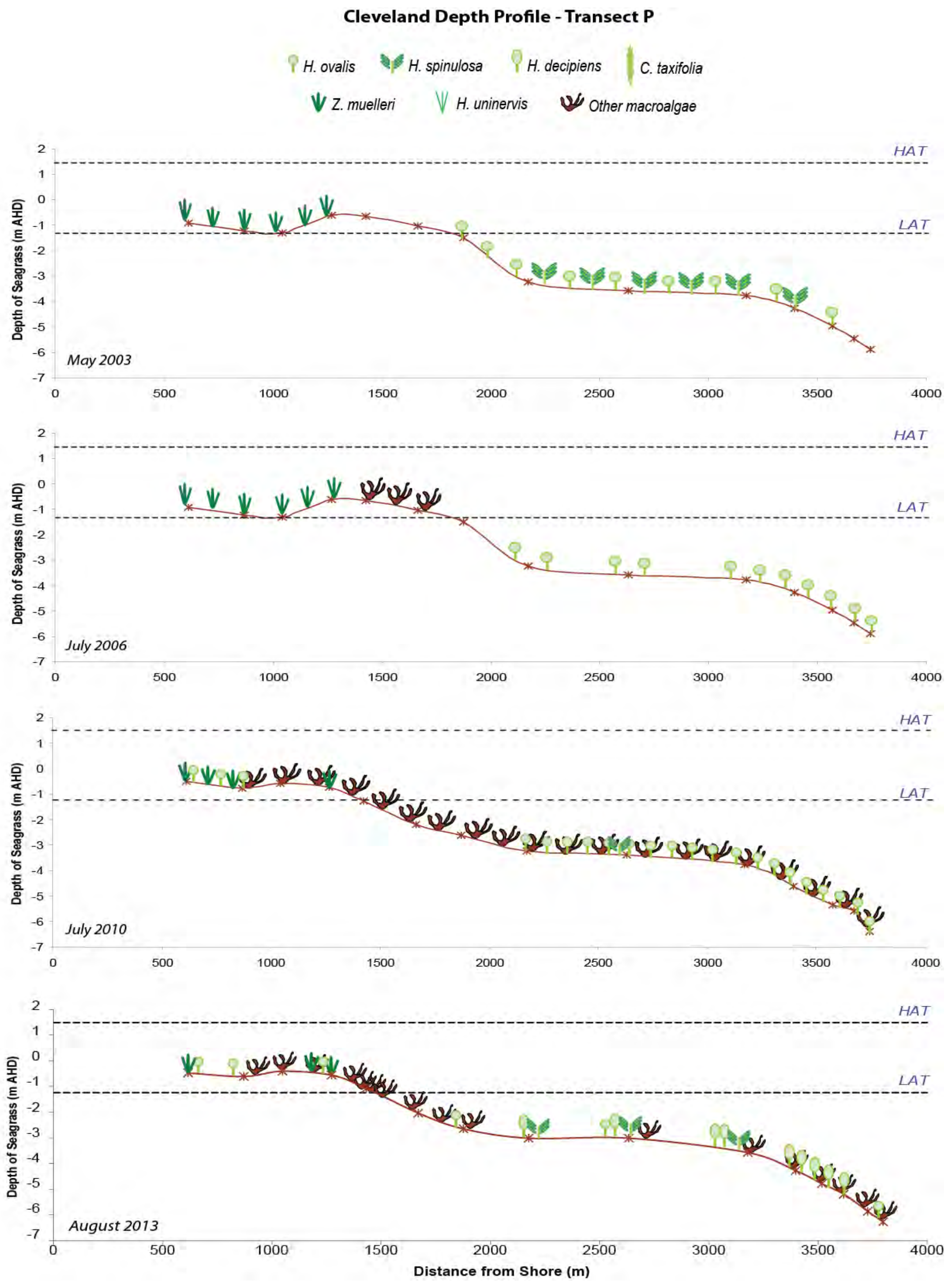


Figure 3-9 Schematic representation of seagrass species distributions for 2003, 2006, 2010 and 2013 from depth profiling at Transect P at Cleveland. Note that macroalgae was not studied in detail prior to July 2010.

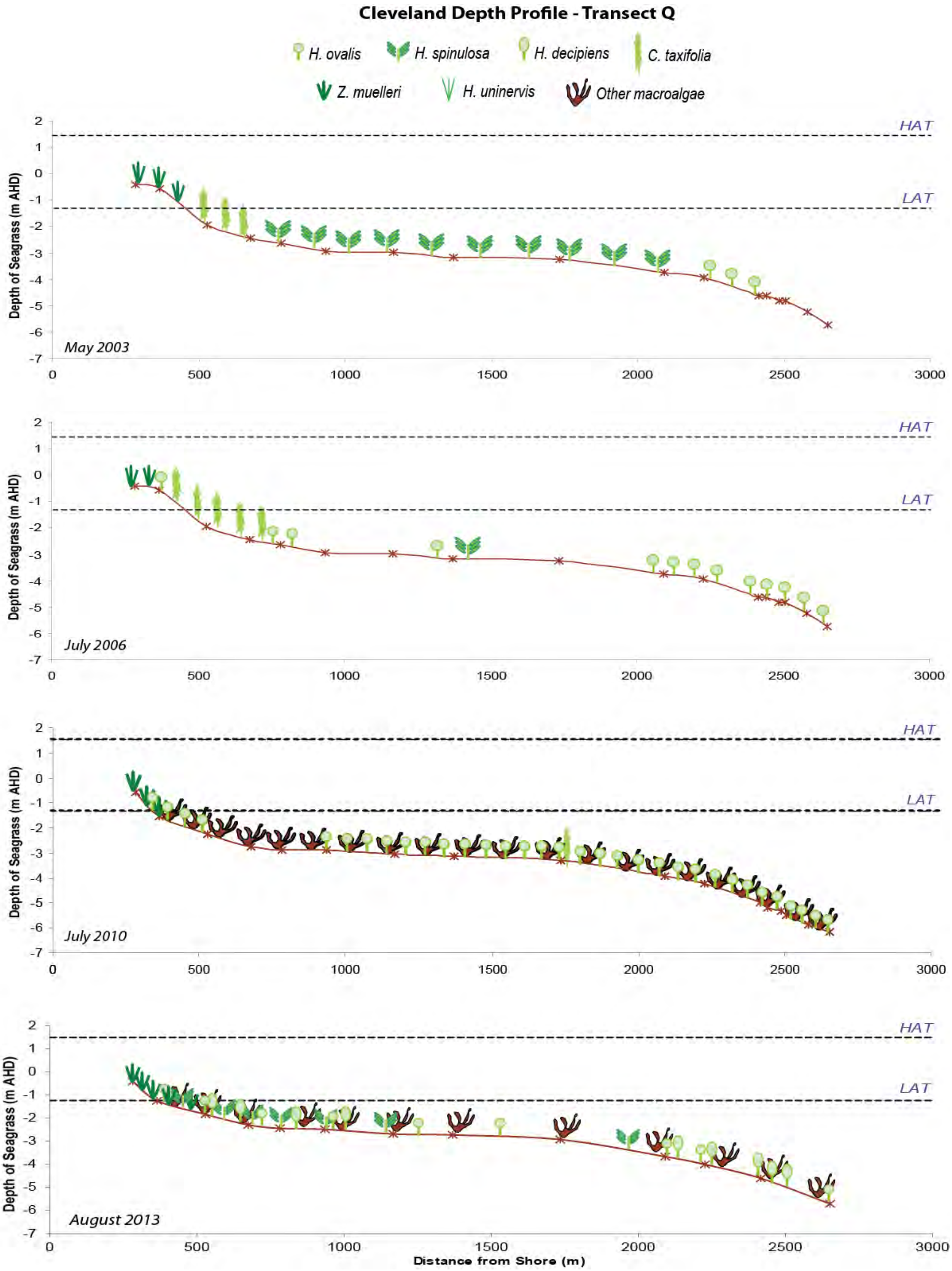


Figure 3-10 Schematic representation of seagrass species distributions for 2003, 2006, 2010 and 2013 from depth profiling at Transect Q at Cleveland. Note that macroalgae was not studied in detail prior to July 2010.

3.2.2 Temporal Patterns within Depth Profiles

Key changes in the distributions of marine vegetation in the depth profiles over time included:

- At the Port of Brisbane, *Z. muelleri and H. ovalis* were less extensive in 2013 than they were in 2010. In 2013, *Z. muelleri* had established to a similar depth at Transect F but was less dense at this depth and had retracted in its distribution at Transect H. *Halophila ovalis* and *H. decipiens* were distributed more widely in both directions (shallower and deeper) at both transects in 2010 when compared to 2013. The distribution of *H. spinulosa* was similar to that in 2010.
- There was a decline in seagrass at Manly in 2004 through to 2006 followed by recovery in 2010. Recovery of *H. ovalis and H. spinulosa* was better at Transect J in 2010 than at Transect K. In 2013, cover of *Halophila* species was stable at Transect J and there was an improvement in the extent of *Halophila* species at Transect K. In previous years coverage of *Z. muelleri* extended into the shallow subtidal at both transects at Manly but in 2013 there was a slight retraction in the range of this species. *C. taxifolia* has not been observed at Manly in previous surveys but was present at Transect K this year. *Caulerpa taxifolia* is a potentially invasive algal species that competes with seagrasses, its presence at Manly this year may be related to the dramatic declines in coverage that were observed here in 2005 or may potentially be the result of disturbance from recent flooding events in south east Queensland.
- Cover by various macroalgae species was high at Cleveland in 2010 and macroalgae was present at most sites here in 2013 but at slightly lower densities. *Caulerpa taxifolia* was not present this year, which follows a trend of gradual decline that has been seen for this species at Cleveland over time. The combined extent of *H. ovalis* and *H. decipiens* was similar to previous years but patchier between sites. Coverage of *H. decipiens* tended to be higher at sites further from shore and there was an increase in cover of *H. spinulosa* from previous years, especially at Transect Q. There was a slight decline in the cover of *Z. muelleri* at Transect P this year compared to 2010, but this species has remained stable at Transect Q between the years.
- There has been a shift in the distribution of macroalgae at the Port of Brisbane compared to 2010. This year macroalgae was more prevalent in the deeper subtidal region than in shallow subtidal (where it was most prevalent in 2010). At Manly, macroalgae cover was higher and has extended further into the intertidal while at Cleveland there appears to have been a decline in macroalgae cover.

3.3 Edge of Seagrass Beds

The extent of the seaward (deep) edge of seagrass beds at the Port of Brisbane, Manly, and Cleveland between May 2003 and August 2013 are shown in Figure 3-12 to Figure 3-14. Key findings of edge of bed monitoring for August 2013 and patterns over time are provided below:

- At Cleveland the edge of bed for 2013 lies between previously observed edges from winter monitoring in 2010 and 2006. Consistent observations over time for this site suggest that the level of natural variability in edge of bed position is relatively low.
- The edge of bed at Manly was similar this year to the extent observed from previous winter monitoring episodes in 2010 and 2003 (Figure 3-13). There was a dramatic decline in the extent of seagrass at Manly in 2005 and 2006 and the recovery at this site which was observed in 2010 appears to have now stabilised to pre-2005 levels.
- The edge of bed at the Port of Brisbane monitoring location this year has retracted from that which was observed in 2010. In 2010 there was a dramatic increase in the extent of seagrass at the Port and the decline observed this year shows the edge returning to within the range seen before the 2010 expansion.
- Transect E at the Port of Brisbane traverses a boating channel. Seagrass distribution at this site does not extend below 5.0m AHD in the channel but there is coverage above 5.0m AHD on either side of this channel.

In looking at longer-term changes in maximum growing depth of seagrasses (see Figure 3-11), there are several key points to consider.

- Cyclical changes in seagrass maximum depth are not visible after 2005 due the abandonment of seasonal sampling.
- The Fisherman Islands (Port of Brisbane) maximum growing depth has been consistently shallower than the other two environmental control sites.
- Temporal trends in maximum depth between Cleveland and Fisherman Islands have been very similar, suggesting that changes in maximum growing depth have been affected more by broad-scale environmental changes occurring in Moreton Bay than from the activities of the Port.
- There was a significant decline in seagrass cover at Manly between the 2003 and the 2005 monitoring events which is thought to have been due to changes in local hydrological patterns at this site (BMT WBM 2010), independent of conditions at Fisherman Islands and Cleveland. Recovery at Manly was not noted until 2010. Seagrass at Manly now appears to have stabilised following the 2013 survey results.
- A reduction in maximum seagrass depth distributions observed at Fisherman Islands and Cleveland, compared to relatively consistent maximum depths at Manly between 2010 and 2013 may be due to the differential effects of flood waters and sediment deposition (see section 4.2).

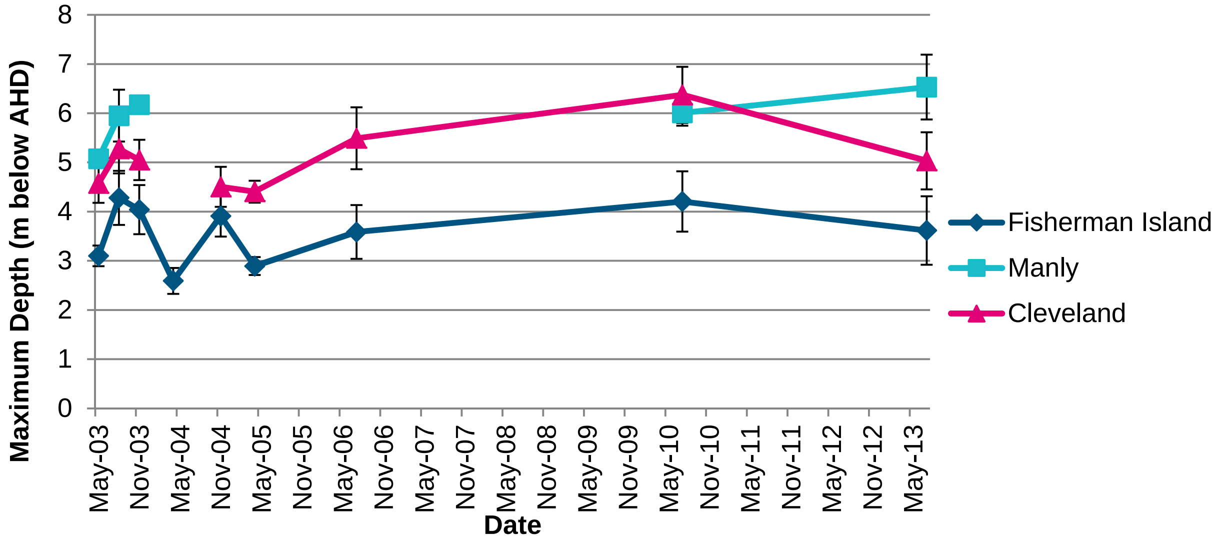
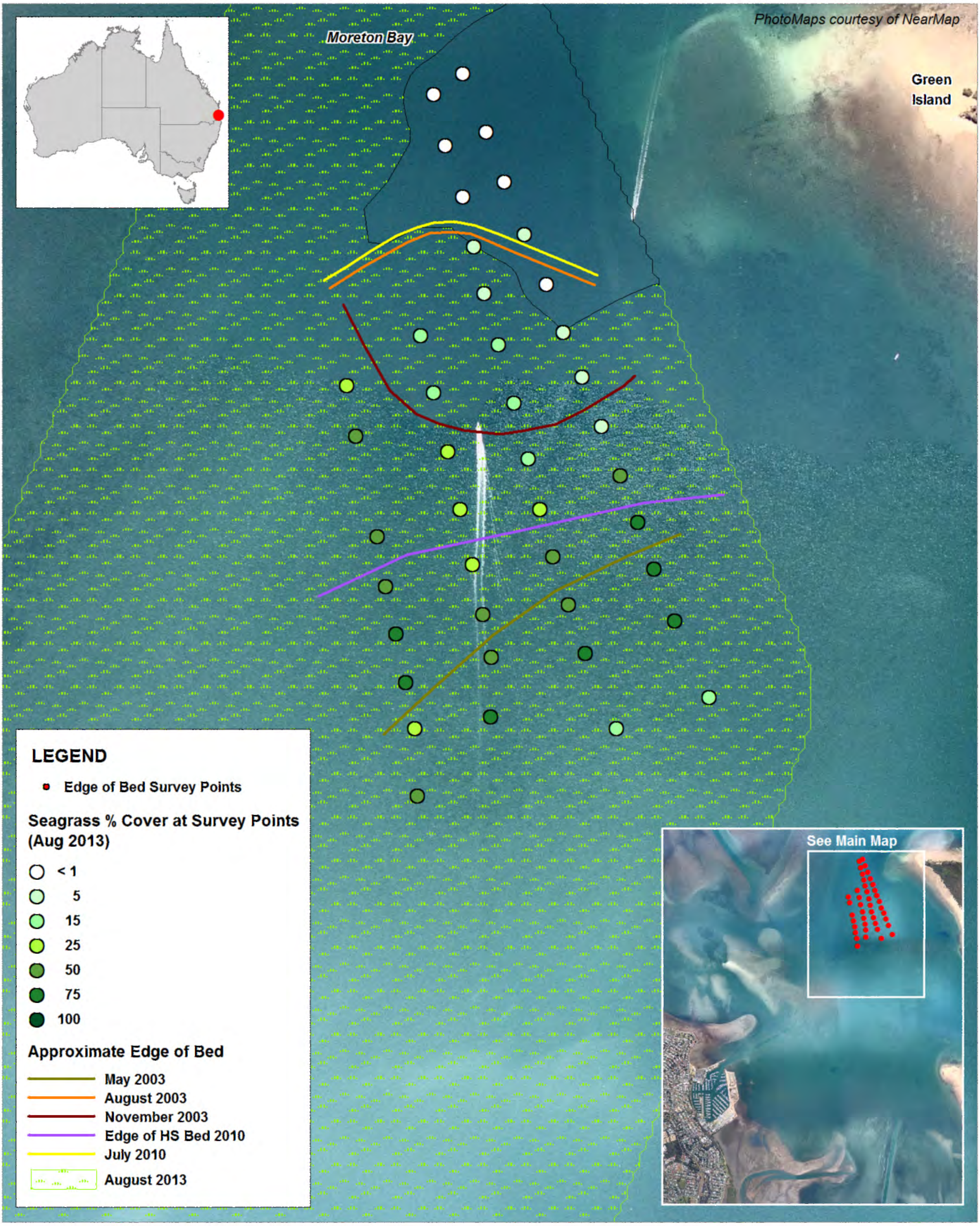


Figure 3-11 Mean (± SE) maximum depth at each location, where edge of bed transects are replicates.



Title:

Temporal Variation in Seagrass Edge of Bed Adjacent to Manly

Figure: **3-12**

Rev: **A**

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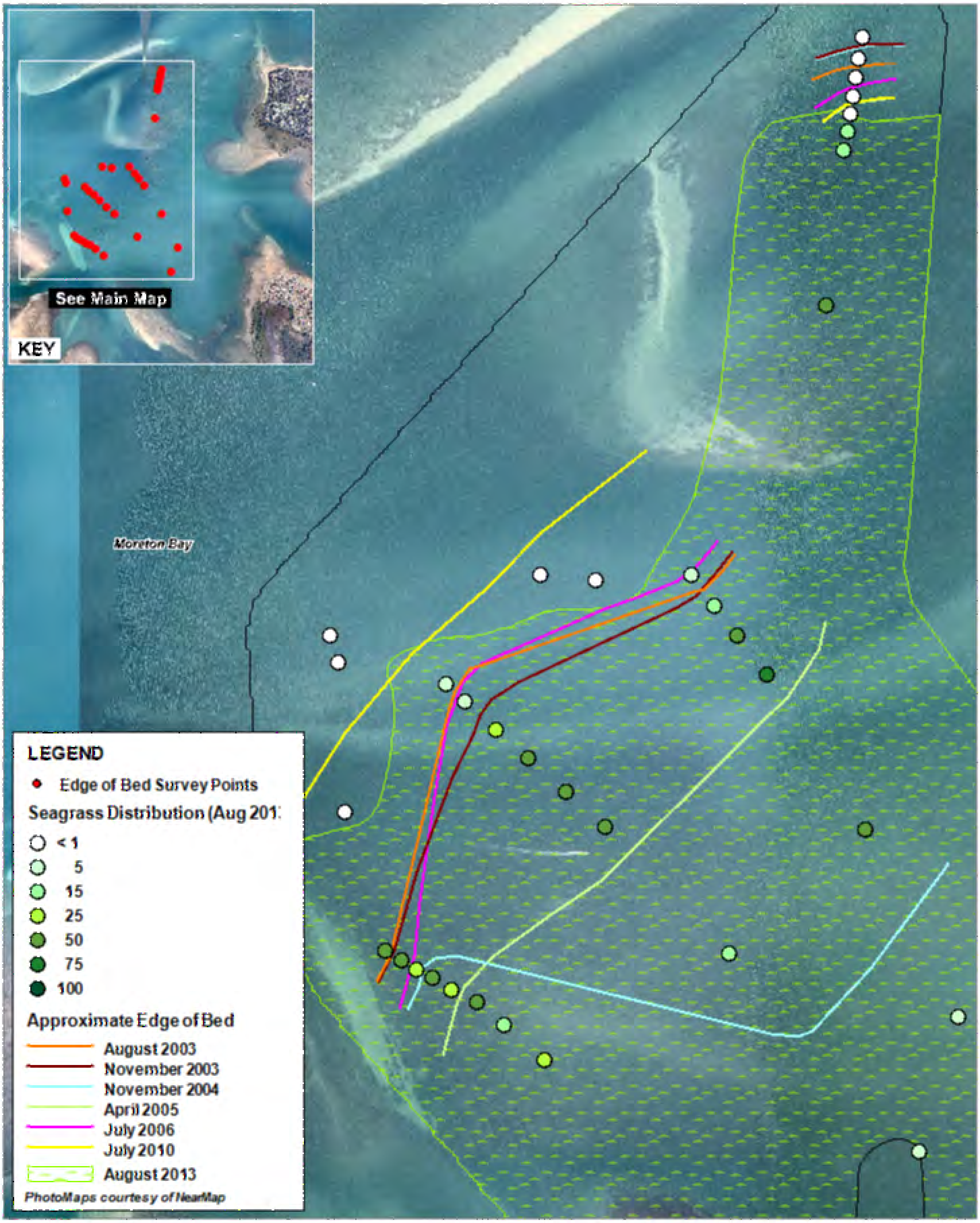

Title:

Temporal Variation in Seagrass Edge of Bed Adjacent to Cleveland

Figure: 3-13

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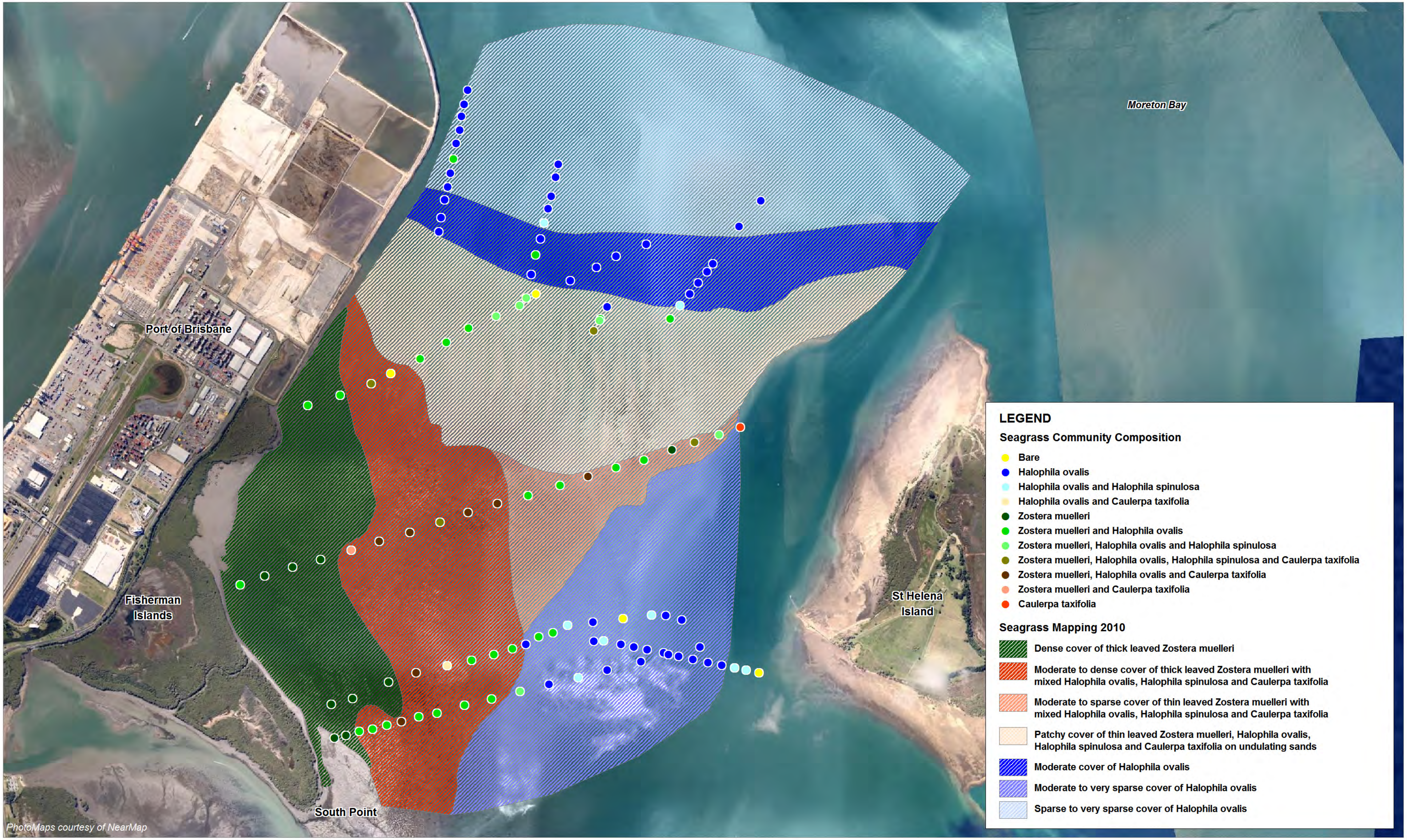

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Broadscale Patterns in Seagrass Distribution and Community Structure Adjacent to Port of Brisbane

Figure: 3-14

Rev: A

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

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4 Discussion

4.1 Spatial Patterns in Distribution

The distribution of seagrasses throughout the Port of Brisbane seagrass monitoring area has been broadly consistent among sampling locations and over time. Six species of seagrass are known in Moreton Bay (Young and Kirkman 1975) and in previous years, three of these species have been identified at the Port of Brisbane, Manly and Cleveland. In 2013, two additional species were observed (*H. uninervis* and *H. decipiens*). The ability to discern *H. decipiens* from *H. ovalis* was due to better image capture technology since 2010, very good visibility conditions at the time of survey, and the relatively large leaf size observed in 2013 compared to 2010. With regard to *H. uninervis,* it is possible that some of the “thin leaved” form of *Z. muelleri* which was previously reported at the Port (Figure B-1) was in fact *H. uninervis*. While confirmation grabs were taken to identify species in 2010, it is not possible to correctly identify every digital seagrass observation, when species differentiation often relies on micro morphology.

Since the onset of the monitoring program, *H. ovalis* and *H. decipiens* have consistently formed the deepest edge of seagrass beds, growing in depths ranging between -0.5 m and -7.0m AHD. In 2013, *H. ovalis* was again the most widely distributed species, spanning from shallow intertidal to deeper subtidal zones to a maximum depth of -5.71m AHD (at Cleveland). *Halophila decipiens* and *H. spinulosa* often occurred in mixed beds with *H. ovalis* but were less widespread, being more confined to deeper water. These two species reached respective maximum depths of -5.03m and -4.03m AHD, respectively. *Halophila decipiens* tended to occur at similar depths to *H. ovalis* while *H. spinulosa* occurred at slightly shallower depths to *H. ovalis* at Manly and Cleveland and at the same depth as *H. ovalis* at the Port of Brisbane. Previous work in Moreton Bay suggests that *H. spinulosa* was mostly found in areas too deep or turbid for other seagrasses (Young and Kirkman 1975) but this is not consistent with our observations from this year or from previous years. Consistent with previous years, the shallowest maximum growing depths for all of the *Halophila* species was at the Port of Brisbane.

A range of environmental conditions control the extent, distribution and abundance of seagrasses in Moreton Bay (Longstaff and Dennison 1999). These factors include light availability, sediment condition and type, nutrient availability, water motion, and grazing, as well as different growth strategies and tolerances to exposure of the seagrasses themselves. Different combinations of these factors are responsible for the different distributions that are seen throughout the Port of Brisbane seagrass monitoring area. Seagrass assemblages at the Port itself occur over broad intertidal and subtidal sand and mud banks, which have gradual bathymetric profiles and consistent gradients in sediment particle size with depth. These features are most likely responsible for the broad distribution of *Z. muelleri* at the Port of Brisbane, compared with other sites with steeper initial shore profiles and coarser sediments. Other physical factors restrict light availability at deeper sites at the Port, resulting in the shallower maximum growing depths at this location. These factors include the proximity of the Port to the mouth of the Brisbane River and the action of wind, waves and currents on the outer banks to the north east of Fisherman Islands, near St Helena Island.

Unlike the Port of Brisbane, Manly, and Cleveland depth profile transects traverse various physical features, including coral rubble banks, mud and sand banks and steep sided boating channels. A consequence of this has been that the depth distributions among locations may reflect changes in sediment quality and other factors (e.g. exposure to wave re-suspension/ boat wash and channels) as well as being driven by the availability of light in deeper waters.

4.2 Long-term Variations in Seagrass

4.2.1 Community Structure

Seagrass depth profiling has demonstrated that subtidal seagrass beds at the Port of Brisbane, Cleveland and Manly form communities that can show considerable change in composition measured over months to years. Mono-specific beds of *H. ovalis* can be replaced by mono-specific beds of *H. spinulosa*, and then form mixed assemblages with the two species combined months later. Changes of this nature have been documented elsewhere in Moreton Bay. Small subtidal seagrass beds composed primarily of *H. spinulosa* with some *H. ovalis* changed within one year to be dominated by *H. ovalis* with only a few remaining shoots of *H. spinulosa* (Young and Kirkman 1975). Dieback of H. *spinulosa* and concurrent expansion of *H. ovalis* has been observed at several Port of Brisbane seagrass depth profile sites previously.

Intra-annual changes to the composition of shallow subtidal seagrass beds have been demonstrated in the present study, prior to 2005. These changes have occurred primarily between *H. ovalis, H. decipiens* and *H. spinulosa* but also in some instances with *C. taxifolia* and H. *uninervis*. Bi-directional changes in community structure, (i.e. *H. spinulosa* dominating *H. ovalis* and vice versa) could be explained by the following key processes:

- Tolerance among seagrass species to seasonal nutrient loading, i.e. as a result of periodic catchment flows (e.g. Abal and Dennison 1996).
- The partial or complete removal of seagrass by marine megafauna (including dugong and turtle grazing) (e.g. Preen 1995). Subtidal seagrass beds at the Port are suspected to provide feeding habitat to a significant population of green turtles and also dugong, although these animals are present in far fewer numbers than populations in eastern Moreton Bay (Lanyon and Morris 1997). Dugongs can remove a large proportion (up to 95%) of above and below ground seagrass biomass (Preen 1995), leaving distinctive feeding trails. These were observed from the surface at Fisherman Islands in previous survey events. Dugongs graze extensively on *H. uninervis* and *H. ovalis* (Marsh *et al*. 1982). High growth rates may enable *H. ovalis* to persist under dugong grazing pressure.
- Periodic or seasonal light deprivation (e.g. Abal and Dennison 1996). The community response of seagrass beds to light deprivation may vary depending on the nature of the event (i.e. is it a pulsed or seasonal occurrence or longer-term changes to water quality) and the species of seagrass and its light requirements for growth.

Because seagrass depth distributions extend well into the subtidal zone, there has been no variation in the depth range of intertidal seagrass beds but there has been inter-annual variation in the extent to which these beds encroach into the subtidal zone. In 2013 and in previous years there have been fluctuations in the seaward encroachment of *Z. muelleri*, and the landward colonisation of *H. ovalis* and to a lesser extent, *H. spinulosa*. Lee Long *et al*. (1993) suggested that *Z. muelleri* colonised intertidal areas due to its competitive advantage over other species with lesser tolerance to varying salinity. In Deception Bay, this species has been found growing in salinities of three parts per thousand (Young and Kirkman, 1975), while exposure to fresh water can cause considerable stress in *H. ovalis* (Ralph 1998). *Zostera muelleri* may also be more tolerant to desiccation and thermal stress than other seagrasses in Moreton Bay.

Replacement of *H. ovalis* with sparse red macroalgae at the former (2010) Fisherman Island edge of bed is consistent with a possible reduction in light and increased nutrient availability. Red algae have photosynthetic pigments (phycobilins) which allow photosynthesis in low-light environments where seagrasses relying on chlorophyll a and b alone cannot survive. This change is probably reversible and the restoration of seagrass in these areas is expected once consistent light levels return.

4.2.2 Temporal Variations in Seagrass Extent

Despite temporal variation in seagrass composition, the overall spatial range of seagrasses at the Port, Manly and Cleveland has been relatively stable through time. This result has been consistent with long-term LandSat comparisons of seagrass over the last 30 years (Lyons *et al*. 2012.) These comparisons show that there has been minimal change in overall seagrass extent throughout Moreton Bay, but that seagrass cover is extremely dynamic; there have been large scale migrations of higher seagrass cover and several sudden and significant changes in cover (Lyons *et al*. 2012).

There have been two major variations in seagrass extent observed throughout the monitoring period, one in 2004 which saw a major decline in seagrass at Manly and to a lesser extent Cleveland; and another in 2010 which saw an increase in seagrass extent across all sites. The decline observed at Manly in 2004 is thought to be due to local scale variation in water quality and growing conditions while an extended period of drought leading up to the 2010 monitoring event, along with improvements in water quality due to catchment improvement works, are likely to have resulted in a positive growing conditions leading up to the monitoring event in 2010. Apart from these fluctuations the edge of bed positions have remained relatively stable, particularly at Manly and Cleveland where constant positioning has been maintained in 2003, 2004, 2006 (not including Manly) and now in 2013.

There has been slightly greater variability in edge of bed position at the Port than at Manly and Cleveland; this is probably due to the cumulative effects of the various factors affecting this location. Potential improvements to growing conditions as a result of the FPE Seawall construction (see Section 4.3) as well as proximity to the Brisbane River mouth and associated turbidity and nutrient input are probably the main drivers of this variability. Light has been cited as the most important driver of seagrass distribution and extent in nearshore or estuarine environments (Abal and Dennison 1996; Collier *et al*. 2012; Chartrand *et al*. 2012; Dennison *et al*. 1993; Longstaff and Dennison 1999) and may also explain this patchiness.

In recent years there have been several major disturbance events, including flooding in early 2011 and 2013. These events represent pulsed disturbance on a large scale, resulting in medium to long-term changes to the light regimes and nutrient loads at these sites over a time period of weeks to months. O'Brien *et al*. (2012) show that there was an increase in mud concentration (Figure 4-1) and a decrease in light penetration in Moreton Bay following the 2011 floods, particularly surrounding the mouth of the Brisbane River and in the southern part of the Bay.

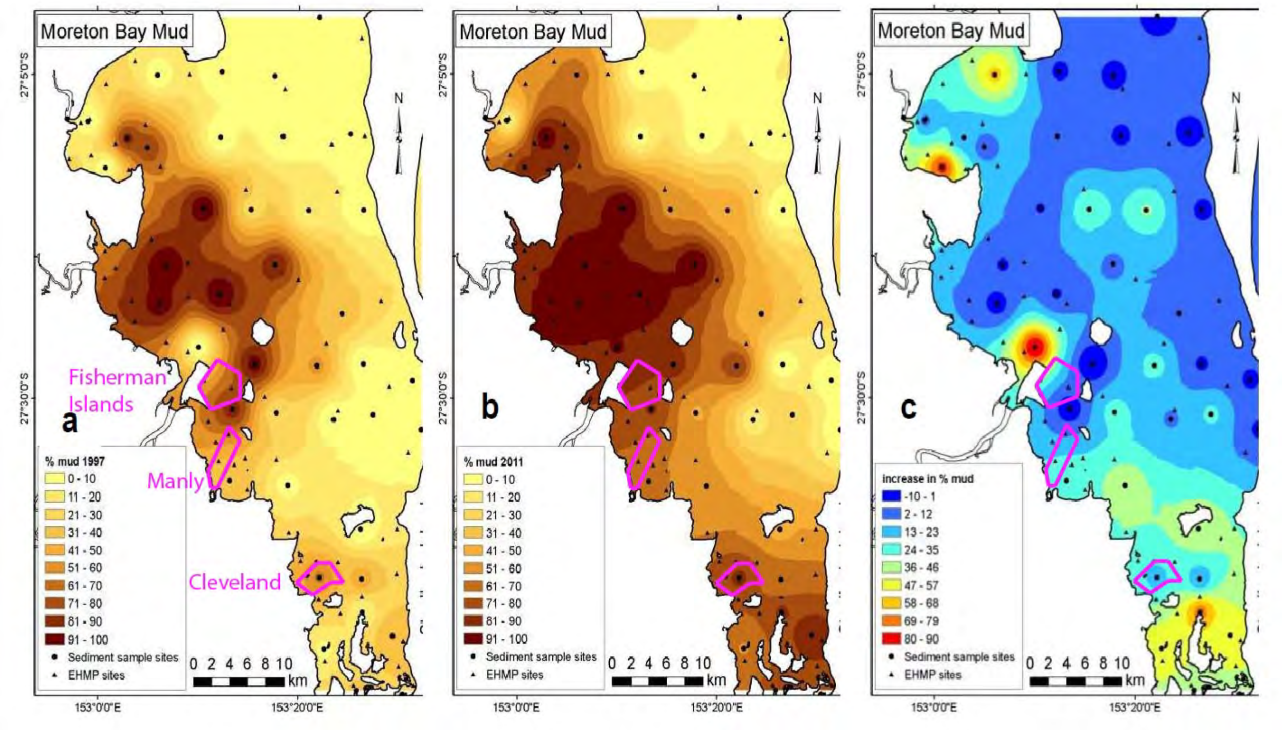

Figure 4-1 Percentage mud in Moreton Bay in 1997 (a); following the 2011 flood (b); and changes in percentage mud between 1997 and 2011 (c) (O'Brien *et al*. 2012). Seagrass monitoring sites are shown in pink

Unpublished data from CSIRO suggested that seagrass extent halved after the 2011 floods, but had recovered within 12 months. The present study showed that edges of beds had retracted at all locations and that the Port and Cleveland locations were most affected. Flooding events are likely to have influenced seagrass distributions at the Port, Manly and Cleveland, and are probably the biggest contributors to the reductions in edge of bed depth since 2010. The high concentrations of mud observed at Fisherman Islands and Cleveland relative to Manly (Figure 4-1b) may explain why maximum growing depths had reduced more at these locations compared to Manly.

Also it should be noted that sea bed profiles at the port tend to be more gradual and consistent than those seen at Manly and Cleveland, making small changes in vertical distribution manifest over a much larger horizontal distance. The unprecedented growth seen in 2010 (attributable to a number of variables, possibly including effects of the FPE seawall) may have also caused the current decline to appear dramatic when it in fact represents only a return to pre-2010 levels. At Cleveland, the current decline appears less dramatic but it is consistent with observations from the port (retraction back to pre-2010 distributions in 2013).

4.2.3 Light Availability and Deep Water Seagrass Extent

Halophila ovalis is one of the least tolerant species of seagrass to reductions in light availability (Longstaff *et al.* 1999), but it frequently colonises deep water areas during extended periods of clear water, or high light availability. As such, it is the most dynamic species in terms of its distribution as would be expected during sustained wind events and sediment re-suspension in western Moreton Bay. Extended periods of light deprivation (i.e. greater than 1 month) can cause death, which probably explained some of the dieback periods witnessed earlier in the monitoring program and also changes in patchiness, density of cover and meadow composition that have been seen in this year’s monitoring event.

Between November 2003 and April 2005 there was a significant landward retraction (2-4 km) of seagrass beds at Manly. This event is suspected to be linked to elevated turbidity associated with a period of strong winds, heavy rainfall and high catchment flows (low-level flooding). Similar landward retractions occurred at Cleveland but not as severely as that seen at Manly. This period was not followed by a seaward expansion of seagrasses into deeper waters until July 2010. Prolonged absence of seagrasses at Manly suggested there may have been a localised long-term change to water quality and other growth factors which were isolated to this location..

Although seasonal light deprivation is likely to explain cyclical variations observed earlier in the monitoring program, it cannot explain differences between 2006 and 2010 winter monitoring events and between the 2010 and 2013 winter monitoring events. Monitoring between 2006 and 2010 saw large increases in seagrass cover at all locations, with a retraction back to pre-2010 levels observed in 2013.

4.3 Impacts of the FPE Seawall

The purpose of seagrass monitoring was to identify whether changes to the physical environment created by the FPE seawall construction have affected seagrasses adjacent to the Port at Fisherman Islands. The FPE seawall is likely to have influenced hydrology around the Fisherman Islands through the provision of:

- More protected conditions. Observations would suggest that seagrasses immediately to the south of FPE Seawall structure are now more protected from wind generated waves and waves from the northwest and westerly directions than they were prior to construction.
- Greater deposition. The extension of the seawall may be enhancing the deposition of fine sediments (BMT WBM 2010), leading to the creation of new habitats (more shallow banks) and settlement of entrained nutrients.
- Separation from the Brisbane River. The seawall extension has effectively moved the mouth of the Brisbane River further from seagrass Beds at the Port, possibly enhancing water clarity and reducing the impacts of low salinity. This is not necessarily

Since the completion of the seawall in 2005 there was a period of high growth over the entire study area. The extent of seagrass and the depth to which it grew increased substantially between 2006 and 2010. Due to its effects on tidal dynamics and sediment deposition, it is probable that the FPE seawall played a role in the extent of seagrass growth that was observed at Fisherman Islands during this period; however, seawall construction is unlikely to have triggered this growth period, given widespread growth observed across all monitoring locations. .

Changes in seagrass distribution and edge of bed depth occurring between 2010 and 2013 do not suggest that seagrass at Fisherman Islands has been negatively affected by the Port. Changes are more consistent with further broad-scale processes affecting the seagrasses at control locations and the Port similarly. These broad scale processes are likely the result of adverse growing conditions associated with the 2011 and 2013 flood events. These flood events are likely to have negatively influenced seagrass at the port despite the provision of various benefits from the seawall, as discussed above.

We suggest that the FPE seawall may have extended the potential growth area for seagrass at Fisherman Islands but that the area continues to respond to broad scale variation in growing conditions. Positive growing conditions following the completion of the seawall saw unprecedented growth into the extended habitat zone and negative growing conditions following the 2011 and 2013 flooding events saw subsequent declines in seagrass extent.

5 Conclusions and Recommendations

The key findings of this study are:

- In 2013, seagrass meadows at Fisherman Islands were structurally similar to those recorded between 2002 and the most recent survey in 2010.
- The 2013 monitoring episode demonstrates that while seagrass meadows at Fisherman Islands were generally in good condition, there was evidence of a decline since the previous (2010) survey.
- The maximum depth of seagrass meadows, an indicator of ambient water quality (turbidity) conditions, was lower in 2013 than in 2010. Seagrass cover (*Zostera muelleri* and *Halophila* species) at Fisherman Islands was also lower than recorded previously.
- The seagrass monitoring program has detected changes to seagrass meadows at Fisherman Islands over time. These temporal patterns have been broadly consistent with results for sites distant (>5km) to the port and at control locations at Manly (prior to February 2004) and Cleveland.
- These observations suggest that the gross-scale changes in the extent of seagrass beds at the Port are due to natural processes operating at spatial scales measured in tens of kilometres, rather than any localised impacts resulting from PBPL activities.
- In recent years there have been several major disturbance events, including flooding in 2011-12 and 2013. Flooding events are likely to have influenced seagrass distributions at the Port, Manly and Cleveland, and are likely to have resulted in the reduction in edge of bed depth since 2010.
- It appears that the effects of the FPE seawall and PBPL activities more generally have had a benign influence on seagrass growth within the Port of Brisbane seagrass monitoring area. It is possible that the FPE seawall may have played a role in the expansion of seagrass through the provision of more protected conditions, enhanced sediment and nutrient entrapment, and/or greater separation from the negative influences of the Brisbane River. However, because seagrass extent has also increased at control locations, this expansion may also be unrelated to the FPE seawall extension and PBPL activities. Monitoring of environmental processes in conjunct with seagrass meadow monitoring will allow further conclusions regarding the influence of the seawall on seagrass growth to be drawn.

6 References

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Appendix A Photo Plates

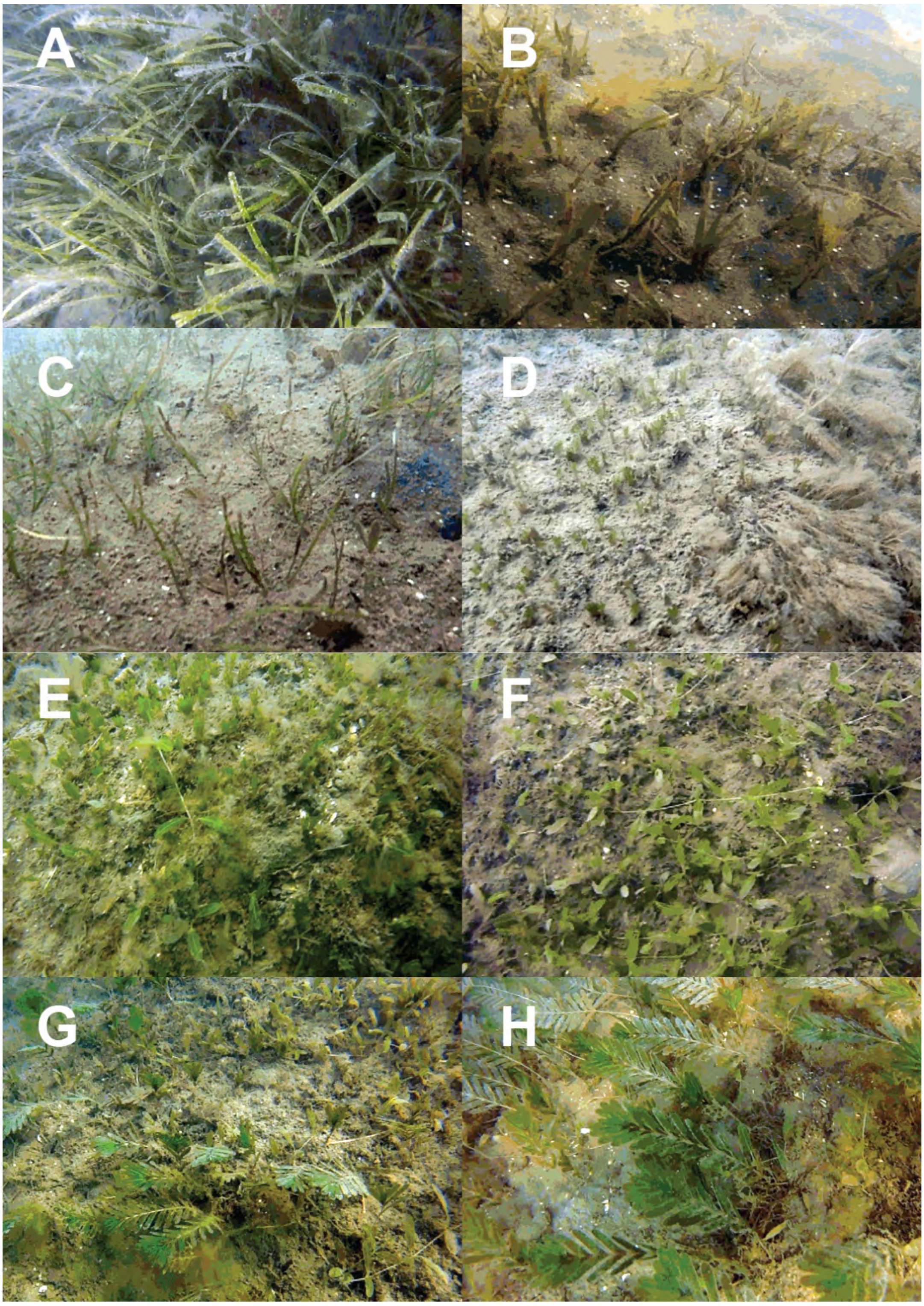


Figure A-1 Seagrass species: *Zostera muelleri* (A); *Z. muelleri* and filamentous algae (B); *Halodule uninervis* (C); *Halophila ovalis* with *Sporochnus comosus, Hypnea spinella* (D); *H. ovalis* and *Halophila decipiens* (E); *H. decipiens* (F); *H. decipiens* and *Halophila spinulosa* (G); *H. spinulosa* (H).

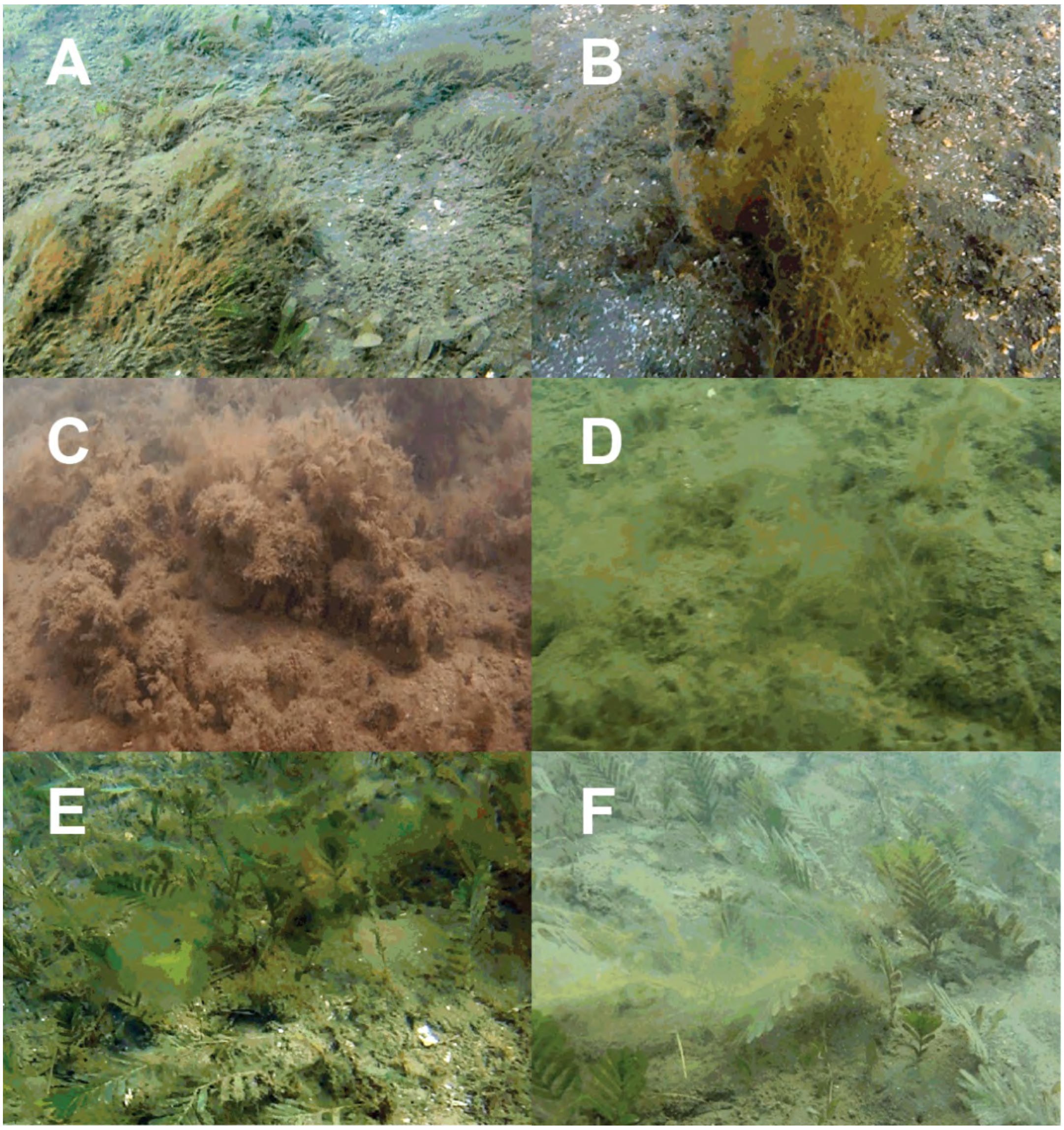
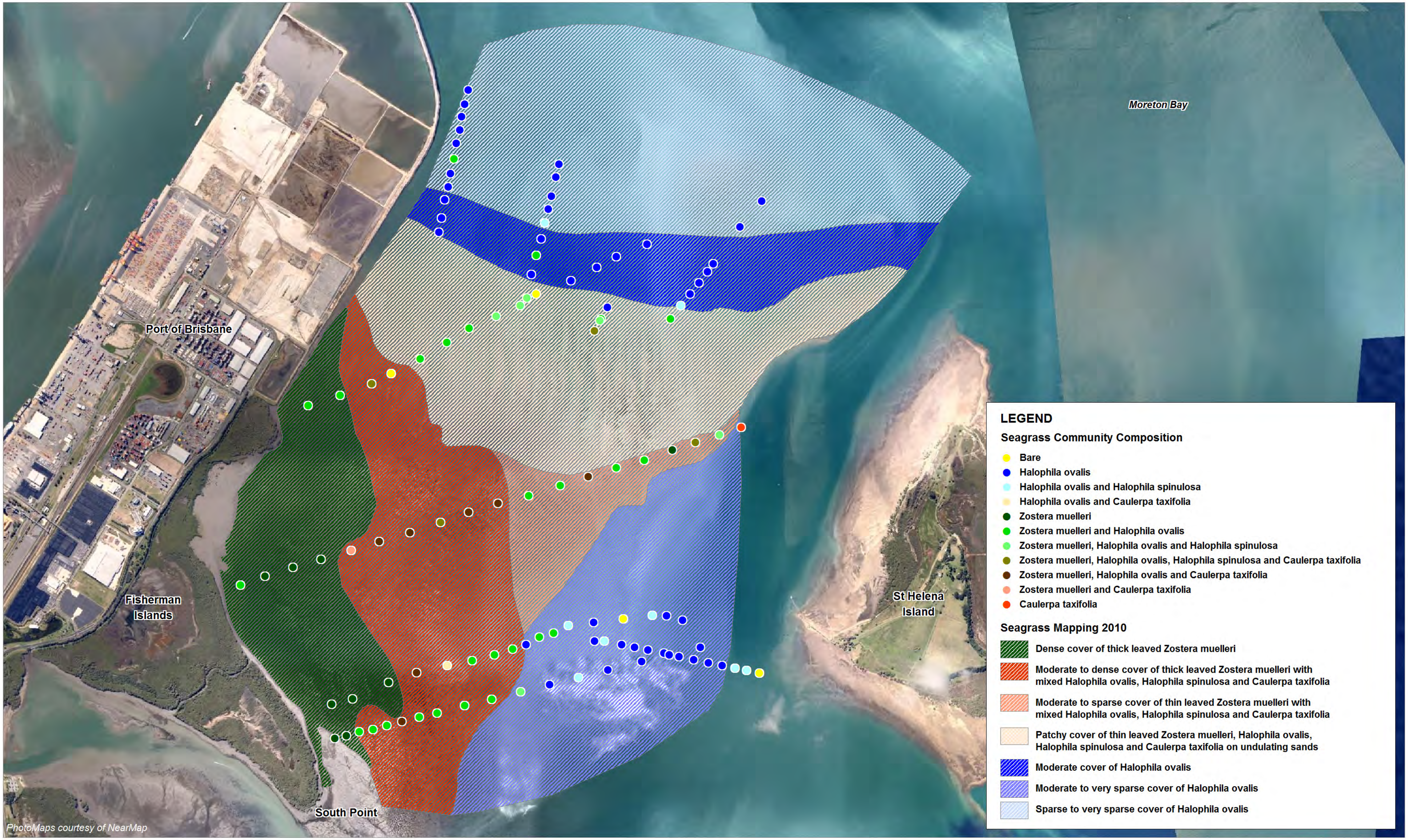


Figure A-2 Macroalgae: Brown algae *cf Hypnea spinella* with *Halophila decipiens* (A); *Sporochnus comosus* (B); high cover of mixed turfing algae (C); Filamentous algae c-f *Ectocarpus fasciculatus* (D); Filamentous algae *cf Ectocarpus fasciculatus* with *Halophila spinulosa* (E); Filamentous algae *cf Hincksia (Giffordia) mitchellae* with *H. spinulosa* (F).

Appendix B Broad scale patterns in seagrass species distribution at the Port of Brisbane from 2010



Title:

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

Figure: B-1

Rev: A

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Approx. Scale

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