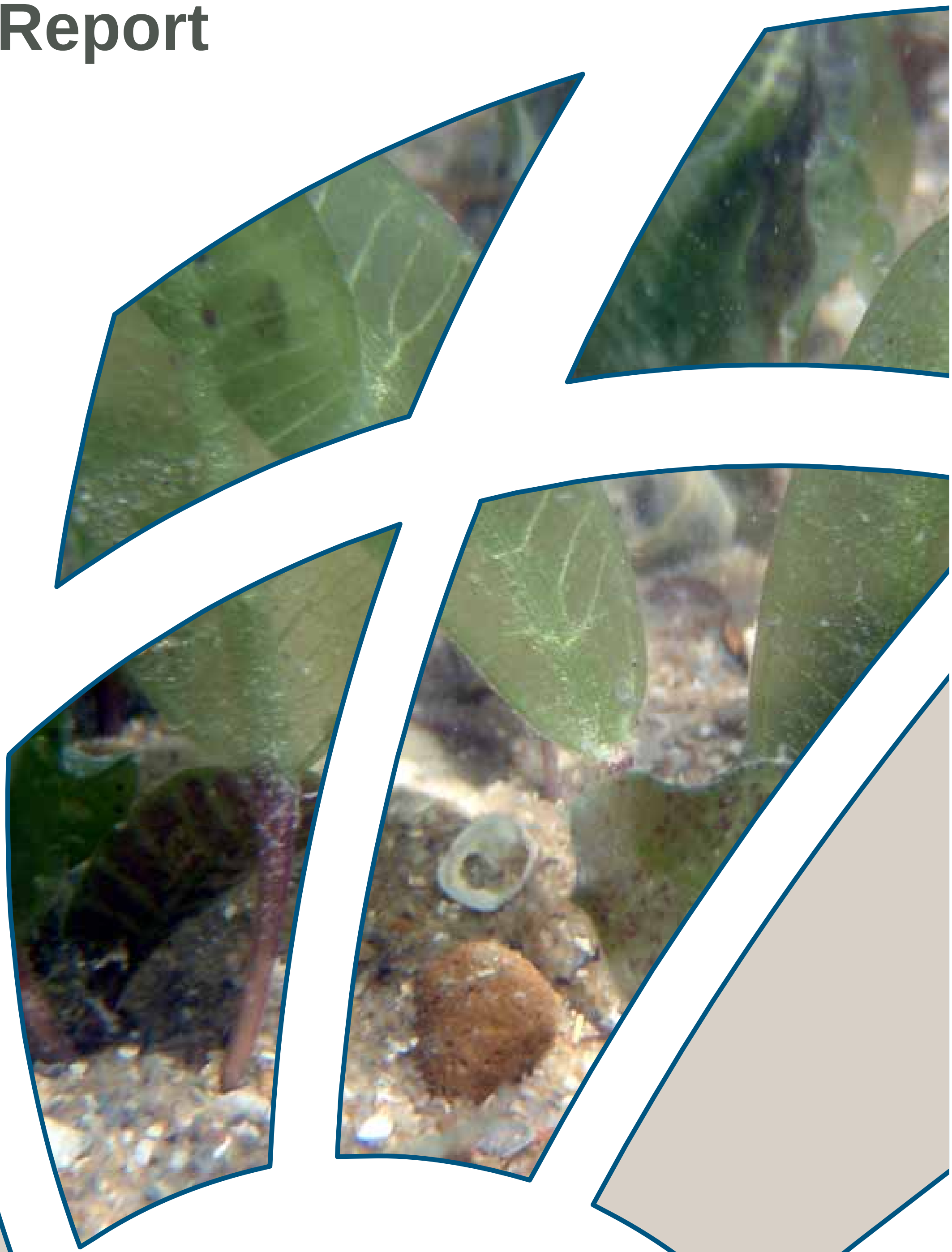
A part of BMT in Energy and Environment

Port of Brisbane Seagrass Monitoring 2010 Final Report

R.B17998.001.01.doc

November 2010



Port of Brisbane Seagrass Monitoring 2010 Final Report

Offices

Brisbane
Denver
Mackay
Melbourne
Newcastle
Perth
Sydney
Vancouver

Prepared For:	Port of Brisbane Pty Ltd
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

DOCUMENT CONTROL SHEET

BMT WBM Pty Ltd BMT WBM Pty Ltd Suite 206, 118 Great North Road PO Box 129 FIVE DOCK NSW 2046 Australia Tel: +61 2 9713 4836 Fax: +61 2 9713 4890 ABN 54 010 830 421 www.wbmpl.com.au	***Document :*** ***Project Manager :*** ***Client :*** ***Client Contact:*** ***Client Reference***	R.B17998.001.01.doc Chris Pietsch Port of Brisbane Pty Ltd Scott McKinnon

Title :	Port of Brisbane Seagrass Monitoring 2010
Authors :	Conor Jones, Chris Pietsch,
Synopsis :	A report detailing the findings of an ongoing seagrass monitoring program developed to identify any broad scale changes occurring within seagrass communities adjacent the Port of Brisbane. Results have been presented for seagrass depth profiles, edge of bed mapping, and broad scale mapping of meadows surrounding the Port of Brisbane.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0	28th September 2010	CMJ		CP	
1	10th November 2010	CMJ	Conor Jones	CP	C Pietsch

DISTRIBUTION

DESTINATION	REVISION			
	0	1	2	3
Port of Brisbane Corporation	PDF			
BMT WBM File	PDF			
BMT WBM Library	PDF			

BMT WBM

EXECUTIVE SUMMARY

The Port of Brisbane Pty Ltd (PBPL, formerly the Port of Brisbane Corporation) has been expanding through reclamation works since the late 1960's. Most recently, major port expansions have included the "Superbund" development resulting in the amalgamation of Bishop Island with Fisherman Islands and the Future Port Expansion (FPE), where a 4.6 kilometre seawall was built and ~230 ha of subtidal seabed were reclaimed. The seawall was completed in August 2005, and the area within sea wall is progressively being filled.

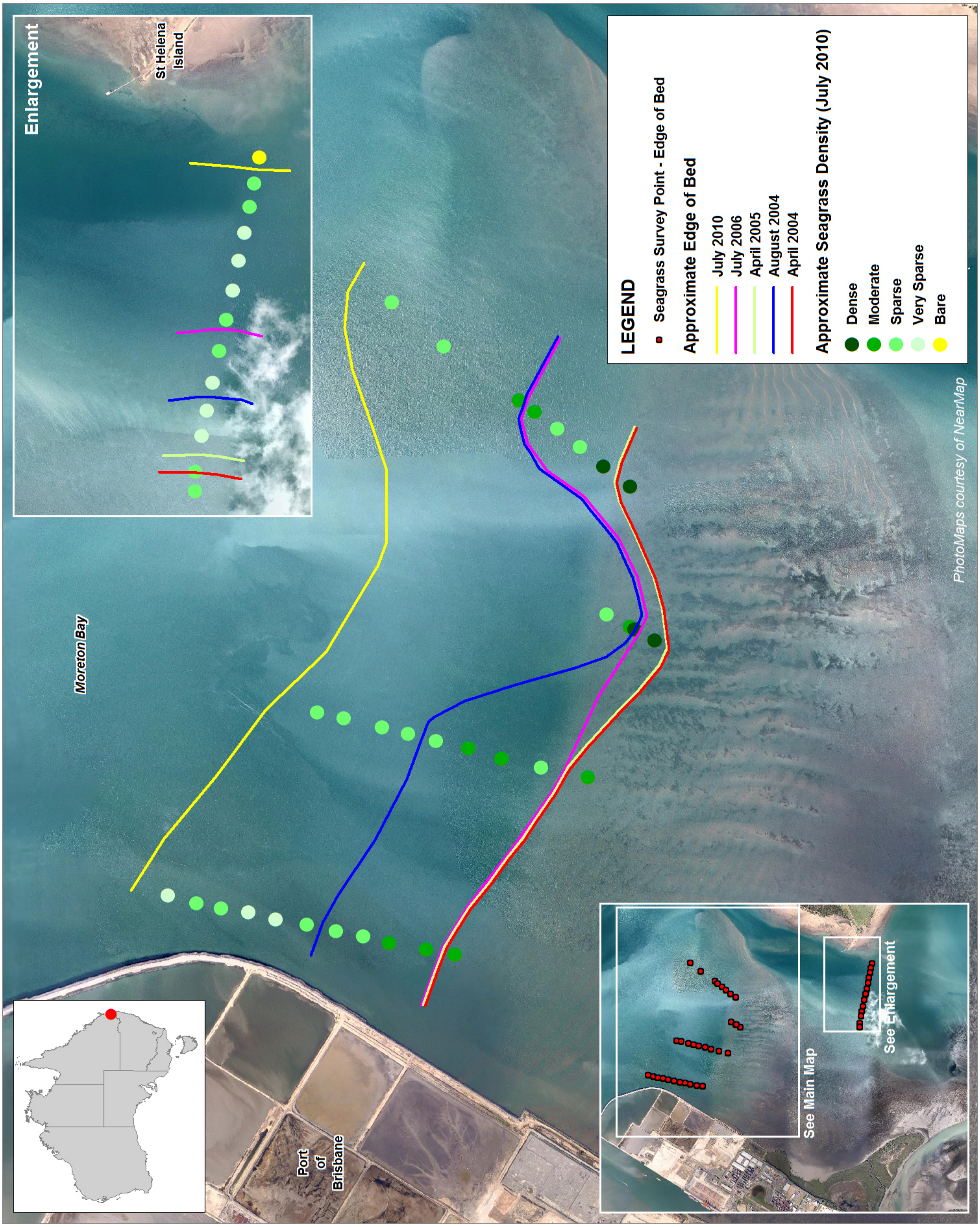
A pilot study in 2002 identified the depth profiling and edge of bed monitoring as the most suitable techniques to monitor adjacent seagrass. Seagrass monitoring has been undertaken by BMT WBM on behalf of PBPL since 2002; with the preceding event occurring in July 2006. The monitoring program utilised two sites (Manly and Cleveland) south of the Port of Brisbane (the Port) as broad-scale environmental controls and the Port itself as a putative impact site. Multiple transects were established at each of these sites. Due to seasonal variations in seagrass cover, namely summer contraction and winter expansion of distributions, recent monitoring events have been conducted at the same time in winter to estimate the maximal winter distribution and allow better detection of impacts by reducing seasonal variation.

These seasonal changes were well documented by the long term results of this monitoring program. Prolonged periods of poor water quality in western Moreton Bay are coincidental with the loss or landward retraction of seagrass species, particularly *Halophila* ovalis, to shallower water during summer months. During winter months when water clarity generally improves, there is a seaward expansion of *H. ovalis* into deeper subtidal waters. These changes are probably driven by variation in water clarity (particularly in response to wind speed and direction and rainfall) .

In the earlier part of the monitoring period, between 2003 and 2005, there was a significant reduction in the extent of *H. ovalis* and *H. spinulsoa* at Manly (control). Subsequent monitoring events showed no evidence of recovery to 2005, followed by increases in distributions in 2010. It was suggested that longer-term changes to localised water conditions may have altered the distribution at Manly between 2003 and 2005.

In the latter part of the monitoring period (including seawall completion) there have been no gross-scale changes in community structure. However, between survey events in 2005 and 2006, there was a reduction in the cover of the potentially invasive algae, *Caulerpa taxifolia,* as well as an increase in the cover of *H. ovalis.* The extent of seagrass beds at the Port (putative impact) and Cleveland (control) sites between 2005 and 2006 suggested that growing conditions overall had improved, and that there was little evidence of impacts related to seawall construction.

Between 2006 and 2010 seagrass cover continued to increase at all locations (see Figures E1-E3). The seaward expansion of seagrass at the Port of Brisbane was consistent with an increase in the maximum growing depth of approximately 1 m, to -5.7m AHD. At control locations such as Cleveland, maximum seagrass depths along transects either remained similar or increased by over 2.5m to -7.7m AHD. Because surveys took place at approximately the same time of year in 2006 and 2010, these differences do not reflect seasonal changes.



Title:

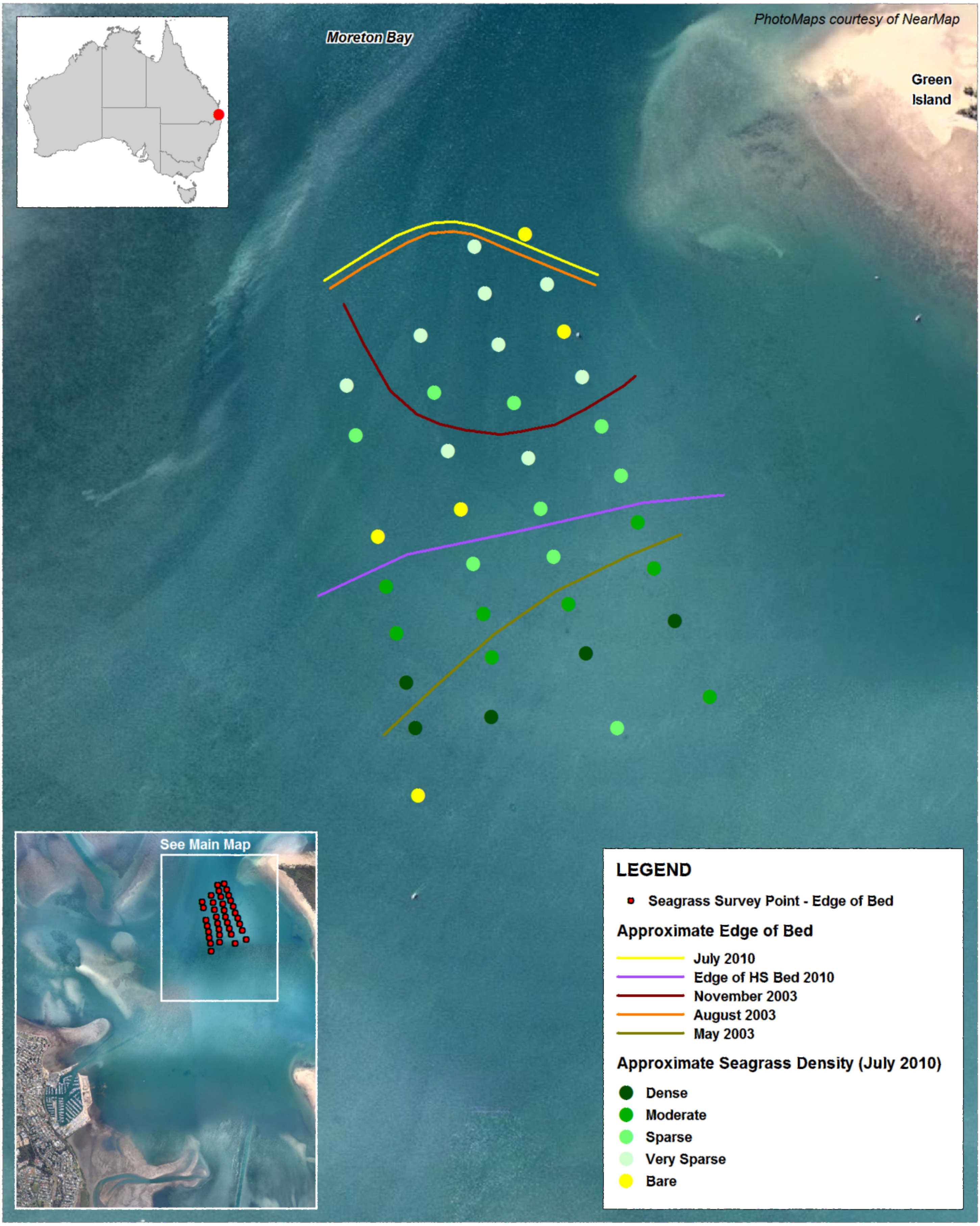
Temporal Variation in Seagrass Edge of Bed Adjacent to Port of Brisbane

Figure: **E1**

Rev: **A**

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_012_Port_EOB.wor



Title:

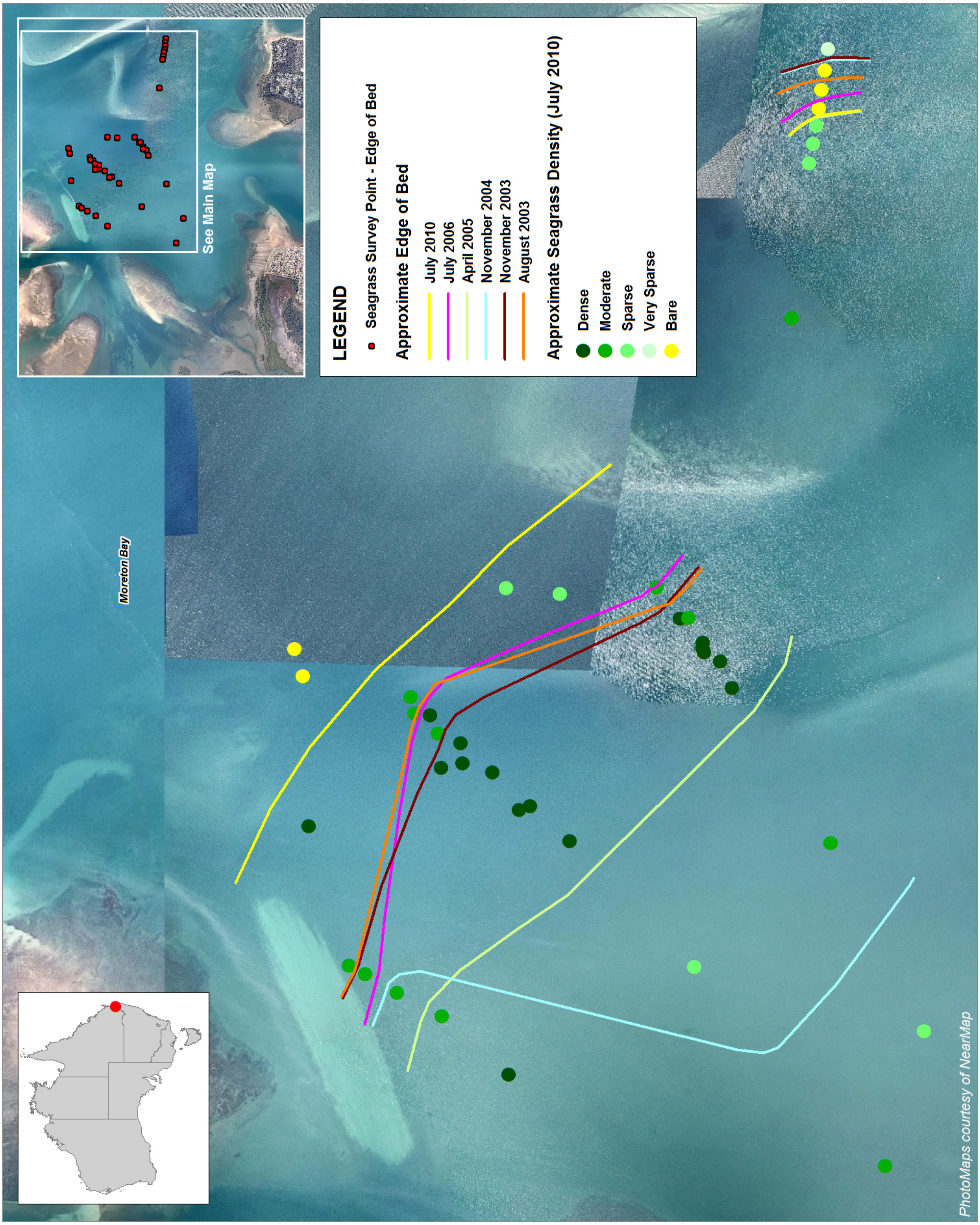
Temporal Variation in Seagrass Edge of Bed Adjacent to Manly

Figure: E2

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_011_Manly_EOB.wor



Title:

Temporal Variation in Seagrass Edge of Bed Adjacent to Cleveland

Figure: **E3**

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.

N

0m 300 600

Scale - Main Map

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_010_Cleveland_EOB.wor

After two successive seagrass expansion events in 2006 and 2010, it appears that the effects of the FPE seawall are either benign or they are enhancing the growth of seagrass surrounding the Port. Expansion may be driven by the provision of more protected conditions, enhanced sediment and nutrient entrapment (BMT WBM 2010), and/or greater separation from the negative influences of the Brisbane River. Because seagrass extent has also increased at control locations, this expansion may also be unrelated to the FPE seawall extension.

Several recommendations are made on the basis of the findings of the present study, as follows:

- Seagrass monitoring should continue, despite broad scale patterns in seagrass distribution and extent in space and time being well documented. Changes to broad scale patterns in seagrass distribution may manifest over longer periods of time than measured over the present study;
- Future monitoring surveys could be based on either of two options:
    - an annual winter survey (i.e. during greatest seagrass extent), and include all the components undertaken in this monitoring episode. This option would enable PBPL to detect inter-annual broad scale changes to the distribution and extent of seagrass beds; or
    - quarterly monitoring of edge of bed transects and an annual winter survey including all components undertaken in this monitoring episode. This option would enable PBPL to detect seasonal and inter-annual changes to the distribution and extent of seagrass beds, offering greater temporal resolution to the study.
- Edge of bed monitoring sites should be extended seaward beyond the new bed edges to incorporate observed range extensions.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Port of Brisbane Pty Limited (PBPL, formerly the Port of Brisbane Corporation) has its main port infrastructure at Fisherman Islands, situated at the mouth of the Brisbane River. Since the late 1960's strategic reclamation works have been undertaken within the area as a response to the growing demand for port land. Most recently, major port expansions include:

- The "Superbund" development initiated in 1992 that involved extensive reclamation of intertidal and shallow subtidal land to the east and southeast of Fisherman Islands, resulting in the amalgamation of Bishop Island with Fisherman Islands; and
- The Future Port Expansion (FPE) project commencing in 2002 resulted in the creation of a 4.6 kilometre seawall and the associated reclamation of ~230 ha of subtidal seabed. The seawall was completed in August 2005, and the area within the reclamation is progressively being in-filled with dredged material.

Previous seagrass monitoring has been undertaken by BMT WBM on behalf of PBPL between 2002 and 2006. A pilot study identified the depth profiling and edge of bed monitoring as the most suitable monitoring techniques. The monitoring program utilised two sites (Manly and Cleveland) south of the Port of Brisbane (the Port) as broad-scale environmental controls and the Port itself as a putative impact site. Multiple transects were established at each of these sites.

Monitoring between 2002 and 2006 found that no gross-scale changes in community structure occurred during the latter part of the monitoring period, which included the completion of the seawall construction (in 2005). However, between survey events in 2005 and 2006, there was a reduction in the cover of the potential invasive algae, *Caulerpa taxifolia,* as well as an increase in the cover of *Halophila ovalis.* The extent of seagrass beds at the Port (putative impact) and Cleveland (control) sites between 2005 and 2006 suggested that growing conditions overall had improved, and that there was little evidence of impacts related to seawall construction.

In the earlier part of the monitoring period, between 2003 and 2005, there was a significant reduction in the extent of *H. ovalis* and *H. spinulsoa* at Manly (control). Subsequent monitoring events showed no evidence of recovery to 2005. It was suggested that longer-term changes to localised water conditions may have altered the distribution at Manly.

Due to seasonal variations in seagrass cover, namely a summer contraction and winter expansion of distributions, recommendations were made to conduct subsequent monitoring events at the same time in winter. This would give an estimate of the maximal winter distribution and allow better detection of impacts by reducing seasonal variation.

1.1 Study 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

- any temporal trends in seagrass extent and species distribution at monitoring location.

The specific objectives of this study are to:

- 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 control areas remote from activities from the FPE;
- 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 the FPE on the distribution and extent of seagrass beds at the Port.

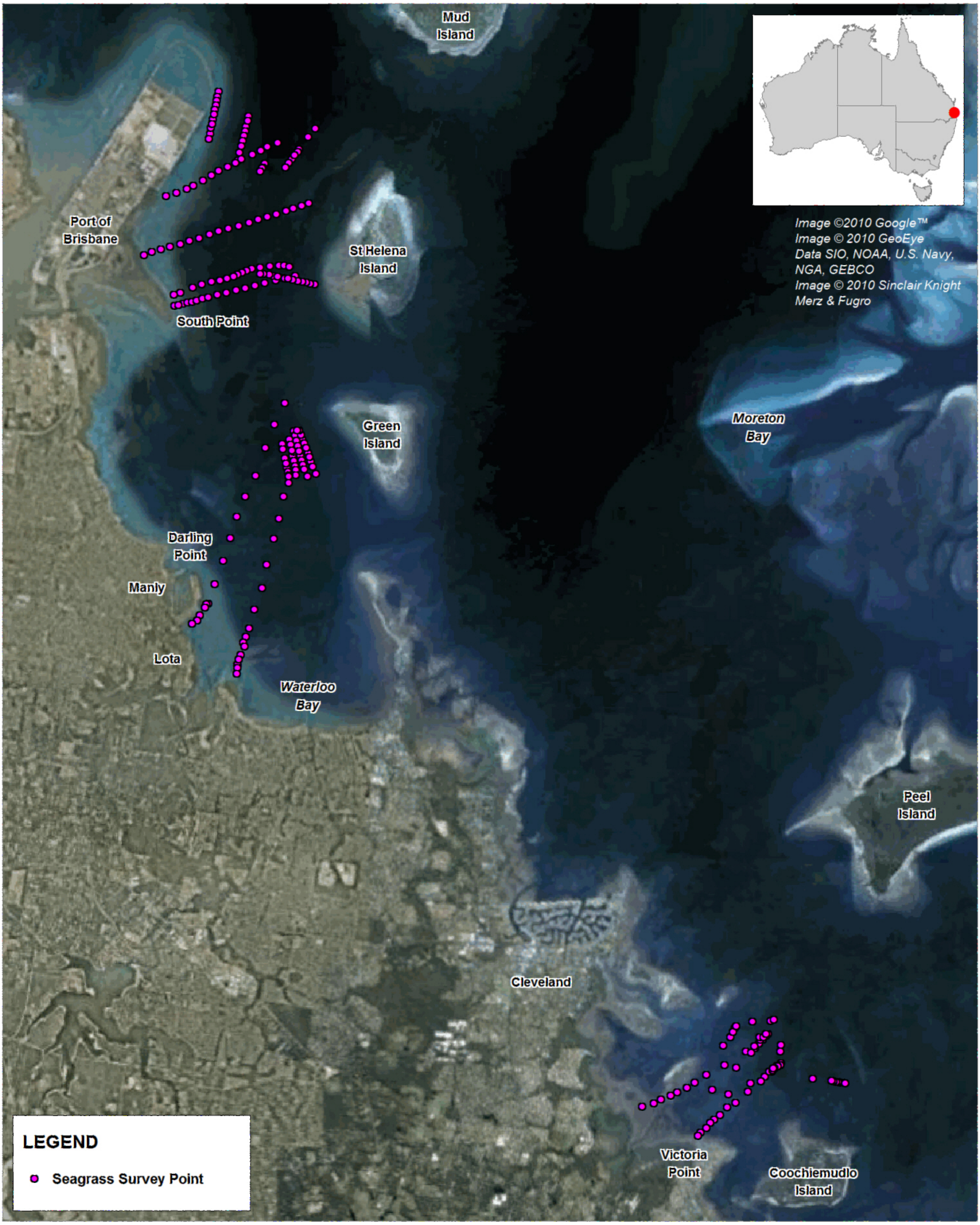
1.2 Description of the Study Area

The Port of Brisbane is located at Fisherman Islands (the study area), which is situated at the mouth of the Brisbane River on the western foreshore of Moreton Bay, Queensland (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 taken to re-locate port facilities from the city reaches in 1974. The Port of Brisbane is now Queensland’s largest container port facility (third largest capital city port in Australia) and exists as an area of approximately 975 hectares of reclaimed land either complete and in use, or under progressive filling within the existing perimeter bund (WBM Oceanics Australia 2000).

Construction of the present day port facilities over intertidal and sub tidal 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. Situated to the south and east of the FPE seawall lays Moreton Bay Marine Park, which 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).



Title:

Location of Monitoring Sites Within Moreton Bay

Figure: **1-1**

Rev: **A**

N

0km 2.5 5

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_019_100922_Locality Map.wor

2 METHODOLOGY

2.1 Edge of Seagrass Bed Monitoring

2.1.1 Background

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.

Light availability in seagrasses is influenced primarily by concentrations of suspended material (such as plankton and sediments) in the water column and by the growth of epiphytic or fouling organisms (e.g. algae). Changes in seagrass depth range can therefore reflect changes in water quality parameters, notably turbidity (suspended solids) and/or nutrient concentrations (which lead to a reduction in light availability by causing epiphytic algae or phytoplankton blooms).

Turbidity in Moreton Bay is generated mostly from two processes: (1) the resuspension of bed sediments from tidal currents, wind waves and ocean swell; and (2) catchment inputs of sediments associated with river/stream flow events (Dennison and Abal 1999). The shallow portions of western Moreton Bay are particularly influenced by wind waves generated by the prevailing winds. In late spring and summer months these are typically from the north, becoming more stronger and more northeasterly in afternoons. During autumn, winter, and early spring, winds are frequently from the south, becoming more southeasterly and freshening in afternoons. These stronger winds with an easterly aspect create wave-driven re-suspension in the western bay, whereas tidal currents also represent an important turbidity generator near river estuaries, such as the Brisbane River (Dennsion and Abal 1999). Episodic flow or flooding events from creeks and rivers within western Moreton Bay also generate high turbidity, particularly during summer months.

Seagrass on the outer edge of a bed under natural conditions can be assumed to be at the limits of its light requirements and is, therefore, the most sensitive to change (Kirkman, 1996). Small changes in water quality are capable of reducing light availability and result in shifts in seagrass distribution and depth penetration (Abal and Dennison, 1996).

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

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, the deep water edge of a seagrass bed, formed almost exclusively by *Halophila ovalis,* was used to examine seasonal fluctuations in the subtidal extent of seagrass in the Fisherman Islands precinct of western Moreton Bay.

The Department of Environmental Resource Management (DERM) undertakes regular seagrass depth range monitoring at a range of sites throughout Moreton Bay as part of the Environmental Health Monitoring Program. A surveyor's staff and level is used to monitor seagrass depth range by measuring the difference in height between the near-shore and deep edges of the bed of seagrass. This technique is not suitable for the deeper edge of sub-tidal beds of seagrass and so a new technique was developed for this study.

2.1.2 Monitoring Methods

The present edge of bed monitoring was conducted between 26 and 28 July 2010 and between August 17 and 18 2010. Hereafter this monitoring event is referred to as July 2010.

During the pilot study (WBM 2002), edge of seagrass bed monitoring sites were established at the Port (putative impact location), and two control locations unaffected by FPE activities (Manly and Cleveland) to monitor any variations in the maximum growing depths of seagrasses (Figure 2-1). This monitoring component has been termed the 'edge of seagrass bed' assessment methodology

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 metre intervals (Figure 2-1), and recorded using a differential GPS (accurate to ± 5m) to ensure repeatability between surveys.

At each point along these transects, the seabed was surveyed using one (or both) of the following techniques. During calm sea conditions and clearer water, a low light, high-resolution camera linked to and recorded by a surface laptop computer, which was used to observe and record seabed features in real time. All video was recorded in M-PEG2 format and stored on DVD by BMT WBM. At sites where poorer water quality was encountered, van Veen grabs were used to collect samples of the seabed to confirm the video image.

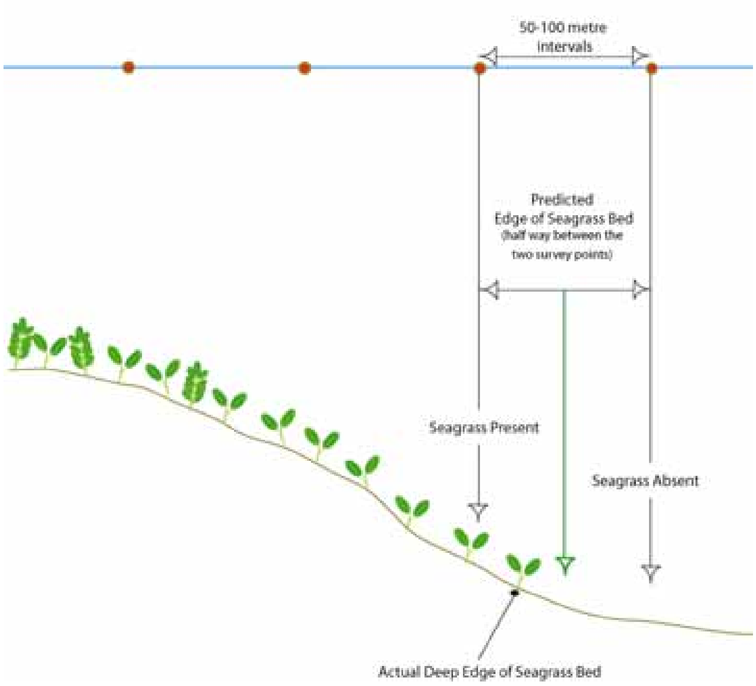


Figure 2-1 Permanent survey point method for identifying the edge of seagrass bed

The surveys 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.

2.2 Seagrass Depth Profiles

The present seagrass depth profiles were conducted between 26 and 28 July 2010 and between August 17 and 18 2010.

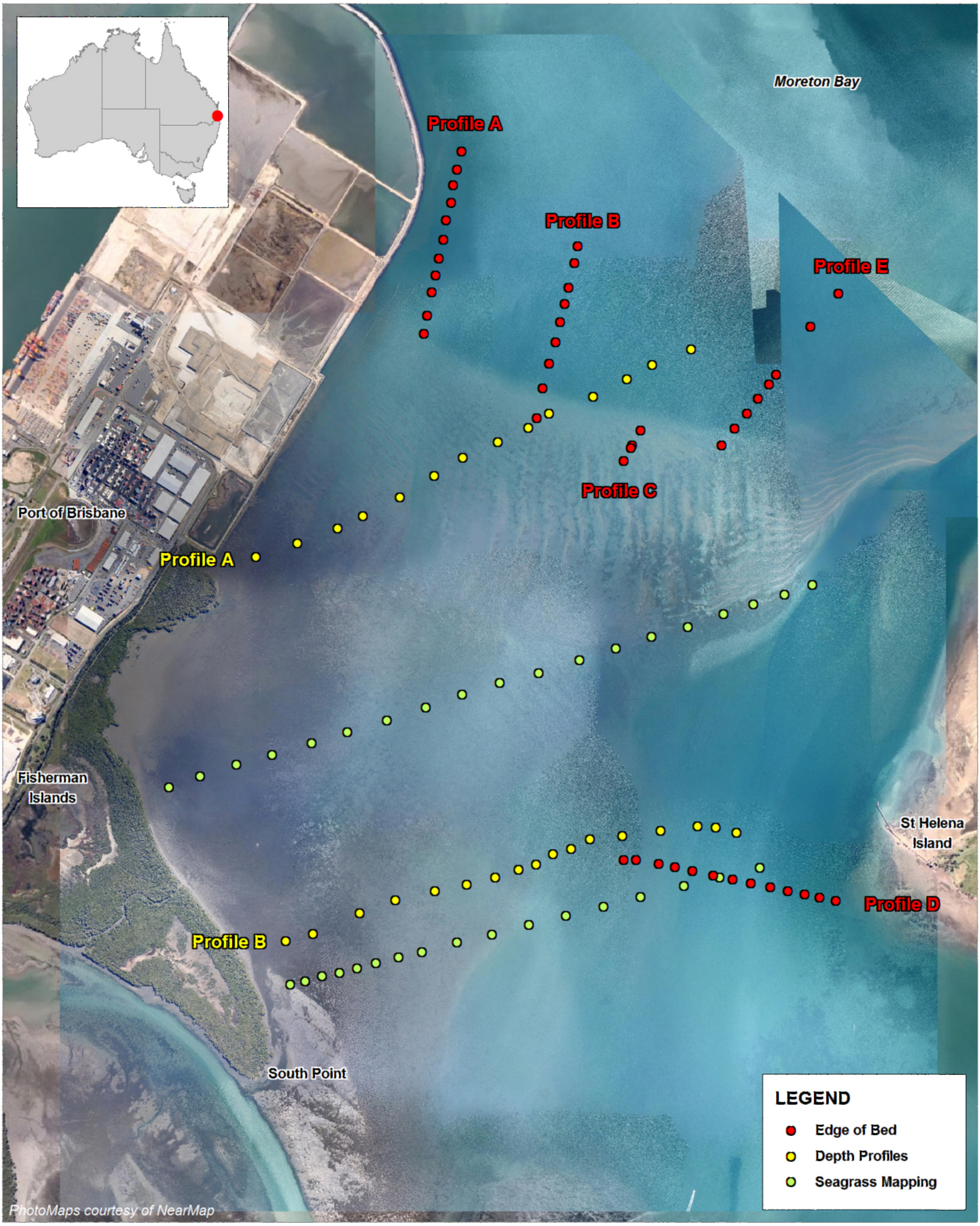
During the pilot study (WBM 2002), seagrass depth profile monitoring sites were established at the Port of Brisbane (putative impact location), and two control locations unaffected by FPE activities (Manly and Cleveland) to monitor any variations in seagrass depth distribution and extent of seagrass species (Figure 2-2). Depth profiles were monitored on a six monthly basis and began during Stage 2 (November 2002), continuing on in May 2003 (Monitoring Event 2) and November 2003 (Monitoring Event 3). Depth profiling was not completed during 2004 (two monitoring events missed) due to poor weather conditions at the time of these surveys (WBM 2004a; b).

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 (using differential Global Positioning System, 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 Seagrass Mapping in the Study Area

Information from two seagrass depth profile transect, edge of bed monitoring transects and seagrass mapping transects were also used each year to map the extent of seagrass beds at the Port, Manly and Cleveland (Figure 2-2 to Figure 2-4). 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 (using differential Global Positioning System, 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.



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

Figure: 2-2

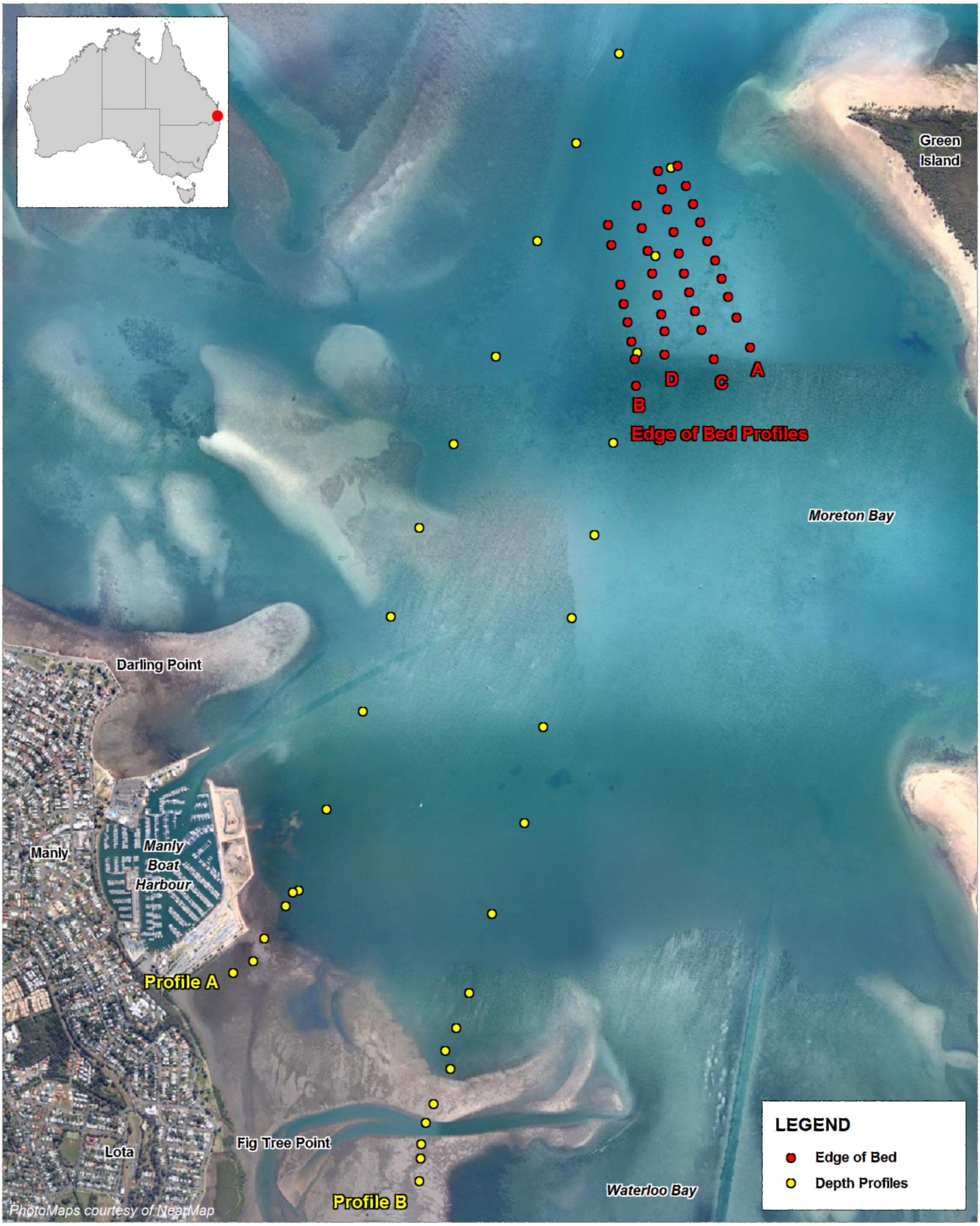
Rev: A

N

0km 0.5 1
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_013_Survey_Points_POB.wor



Title:

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

Figure: 2-3

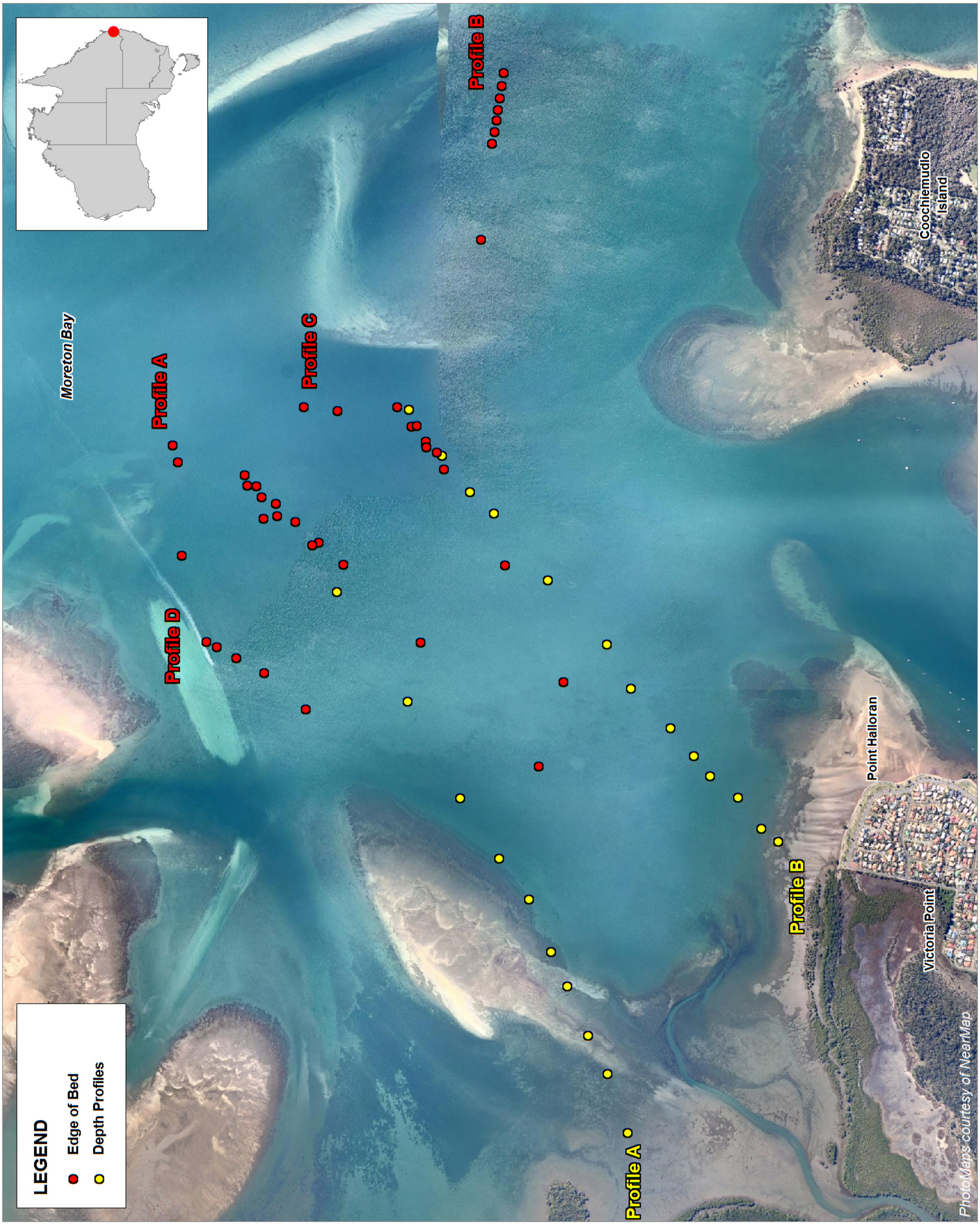
Rev: A

N

0km 0.5 1
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_014_Survey_Points_Manly.wor



Title:

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

Figure: **2-4**

Rev: **A**

N

0km 0.5 1

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_015_Survey_Points_Cleveland.wor

3 RESULTS

3.1 Seagrass Depth Profiles

Figure 3-1 to display a conceptual representation of seagrass assemblages along replicate depth profiles (A & B) at each monitoring location: Fisherman Islands (Port of Brisbane), Manly, and Cleveland. Each profile was compared to seagrass depth profiles conducted in July 2006, April 2005 and May 2003. Map views that show the composition of seagrass communities at each sample location are displayed in APPENDIX A:

Maximum recorded growing depths of seagrass species[2] during depth profiling at each monitoring location during both the July 2010 and the July 2006 survey are displayed in Table 3-1. With the exception of *H. spinulosa* at profile B at the Port and *Z. muelleri* at profile A at Cleveland, all other species/ location combinations grew to greater depths in July 2010 that they did in July 2006. *Halophila ovalis* had the deepest maximum depth of each of the species, followed by *H. spinulosa* and *Z. muelleri.* Between locations, the Port had the deepest beds of *Z. muelleri,* but the shallowest beds of *H. ovalis.* Maximum depths of *H. spinulosa* were too inconsistent for meaningful comparisons with Cleveland, but were similar between Manly and the Port.

Table 3-1 Comparison of maximum recorded growing depths of seagrass species during depth profiling at the Port of Brisbane, Manly and Cleveland during the 2006 and 2010 surveys. Maximum depths are shown in bold for *H. ovalis* (HO), *Z. muelleri* (ZM) and *H. spinulosa* (HS).

Location	Profile	Seagrass Species	Max. Growing Depths 2006	Max. Growing Depths 2010
Port of Brisbane	**A**	HO	-3.82	**-5.70**
		ZM	-1.96	**-2.53**
		HS	-3.82	**-4.35**
	B	HO	-2.57	**-4.56**
		ZM	-1.26	**-2.35**
		HS	**-2.47**	-2.35
Manly	**A**	HO	-2.23	**-4.86**
		ZM	-2.23	**-2.34**
		HS	-2.65	**-3.99**
	B	HO	-0.39	**-8.82**
		ZM	-2.08	**-2.23**
		HS	n.a	**-4.41**
Cleveland	**A**	HO	-5.89	**-6.39**
		ZM	**-1.30**	-0.77
		HS	n.a	**-3.38**
	B	HO	-5.73	**-6.17**
		ZM	-0.57	**-1.51**
		HS	-3.16	n.a

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

3.1.1 Species Patterns along Depth Profiles

Key patterns in the species distributions of marine vegetation in the depth profiles during the July 2010 monitoring episode area as follows:

- Consistent with previous monitoring episodes, three species of seagrass were recorded during the present episode, each one occurring at all three monitoring locations. These species included *Zostera muelleri* (*capricorni*), *Halophila ovalis*[3], and *Halophila spinulosa*.
- *Z. muelleri* was recorded on each depth profile, generally within the shallower part of transects. It was found within intertidal areas (i.e. occurring above LAT) and some shallow subtidal zones (at all profiles excluding those at Cleveland). Its maximum depth was -2.53 meters at the Port of Brisbane (Table 3-1). Within the shallow intertidal zone, *Z. muelleri* formed continuous cover and occurred in both monospecific beds (Port of Brisbane and Cleveland 'B' profiles, and Manly profile's 'A' & 'B'), and mixed communities with *H. ovalis* (Port of Brisbane and Cleveland 'A' profiles) and *H. spinulosa* and *Caulerpa taxifolia* (Port of Brisbane 'A' profile). In shallow sub-tidal zones, *Z. muelleri* occurred in consistent to patchy cover within mixed beds of *H. ovalis* and *H. spinulosa* (Port of Brisbane and Manly profiles 'A' & 'B').
- *H. ovalis* was the most commonly occurring seagrass species, recorded on all profiles and found within shallow intertidal areas to deeper subtidal zones to a maximum depth of -8.82 meters (recorded at Manly). At the Port of Brisbane and Cleveland, *H. ovalis* found more consistently than at profiles undertaken at Manly. *H. ovalis* was also the deepest recorded species on each profile most commonly in monospecific beds at Cleveland and the Port of Brisbane and with *H. spinulosa* at Manly.
- *H. spinulosa* occurred infrequently on all profiles with the exception of profile 'B' at Cleveland where it was absent.
- *Caulerpa taxifolia* (a potentially invasive algal species) was found at three southernmost transects, usually in association with mixed communities consisting of moderately dense, *Z. muelleri, H. ovalis* and *H. spinulosa* (see 6APPENDIX A: for more detail).
- Macro algae was found midway along transects 'A' and 'B' at the Port of Brisbane, sporadically at a range of distances from shore at Manly, and extensively at both transects at Cleveland. Macroalgal species included *Dasya naccroides, Chondria* spp. *Asparagopsis taxiformis, Hydroclathrus clathrus, Laurencia* spp., *Chnoospora minima* and filamentous algae probably comprised of *Hincksia (Giffordia) mitchellae* and possibly *Lyngbya majuscula* (Figure 3-7).

[3] It is noted that seagrass species *Halophila ovalis* and *H. decipens* form deeper subtidal communities in Western Moreton Bay. Given the similar morphology and ecology of these species, and the fact that video transects do not provide a sufficiently detailed imagery to discern the two species, they area collectively referred to as *H. ovalis* in the text.

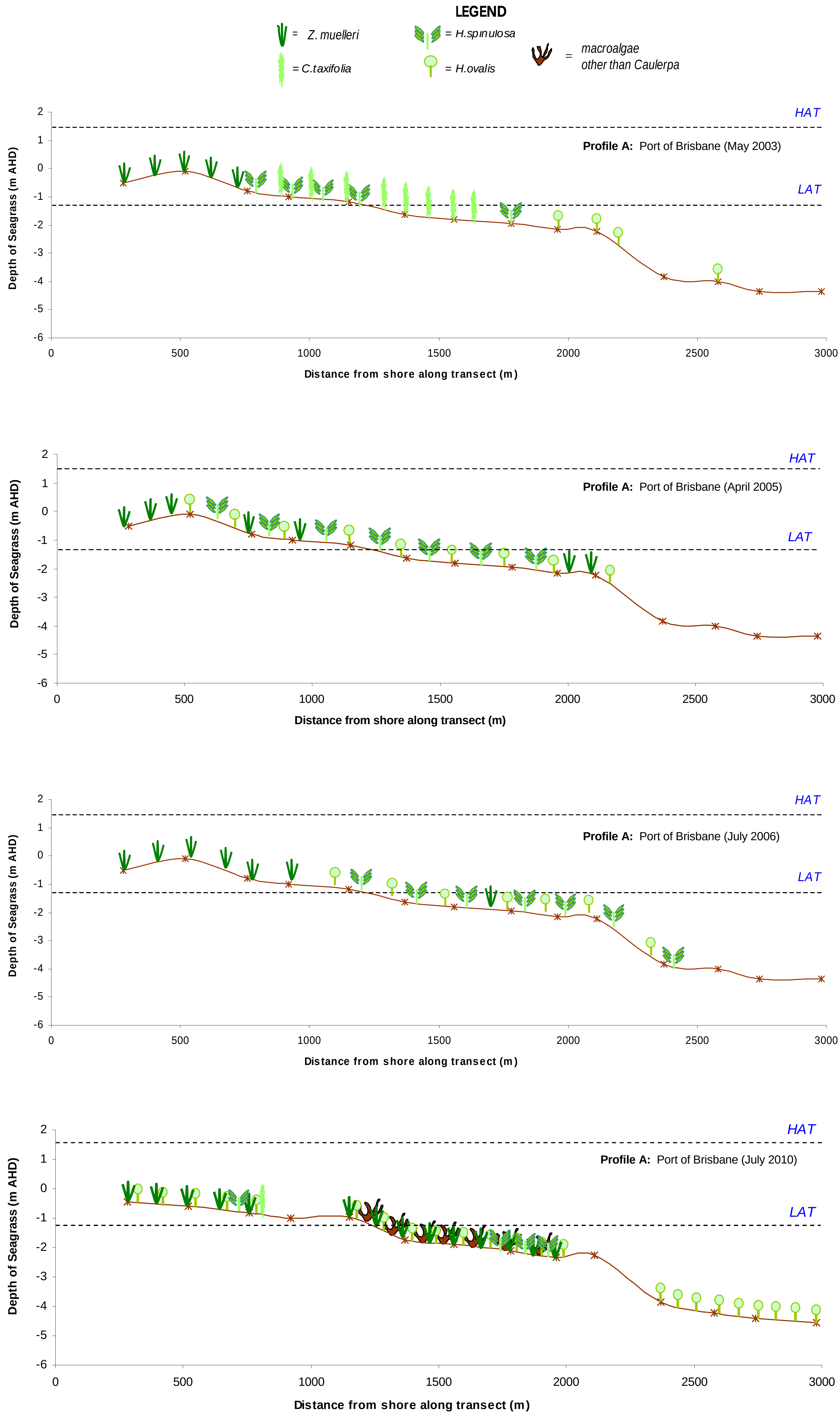


Figure 3-1 Seagrass depth profile 'A' – Port of Brisbane (July 2010 to May 2003). Note that macroalgae was not studied in detail prior to July 2010.

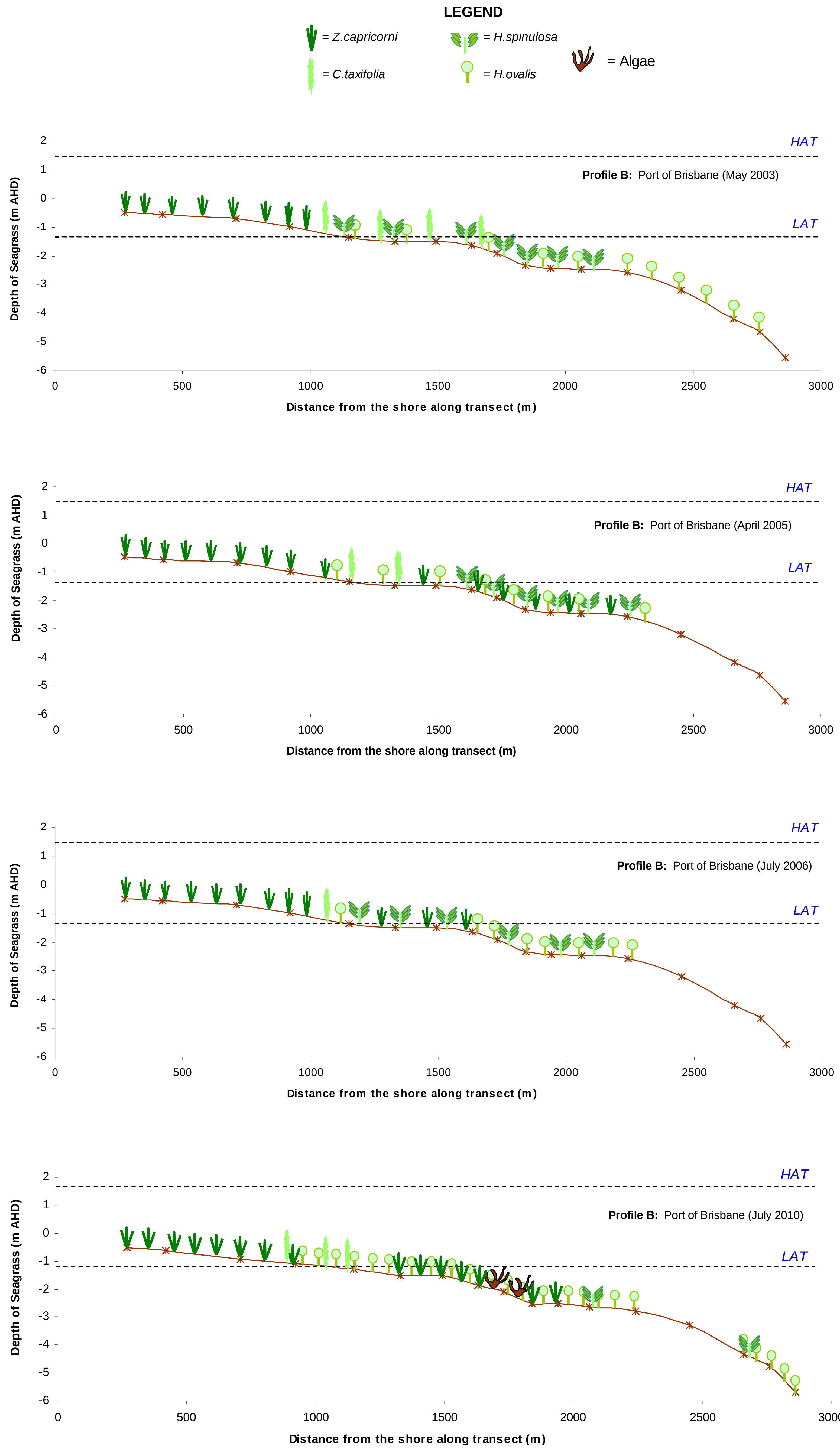


Figure 3-2 Seagrass depth profile 'B' – Port of Brisbane (July 2010 to May 2003). Note that macroalgae was not studied in detail prior to July 2010.

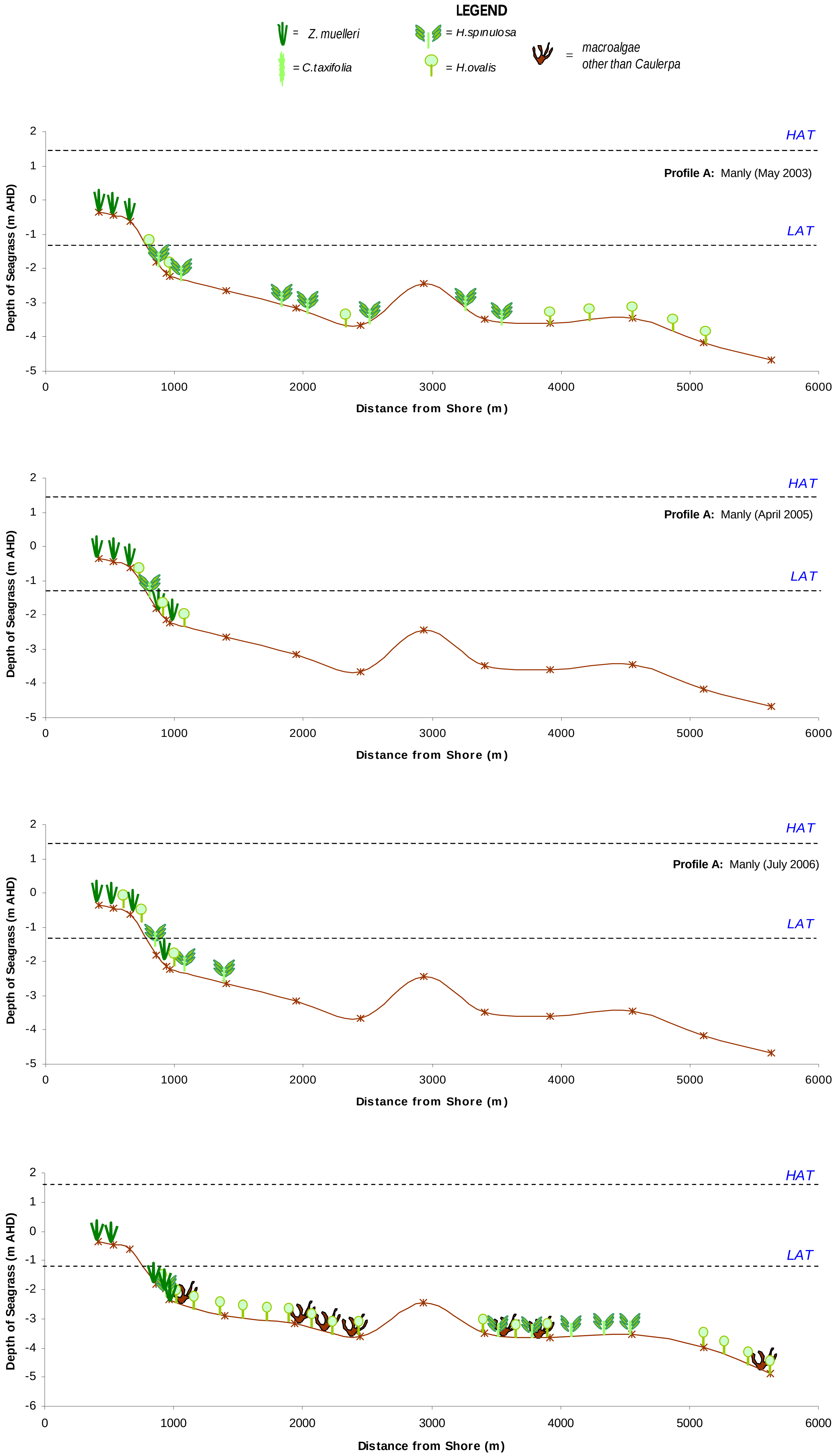


Figure 3-3 Seagrass depth profile 'A' – Manly (July 2010 to May 2003). Note that macroalgae was not studied in detail prior to July 2010.

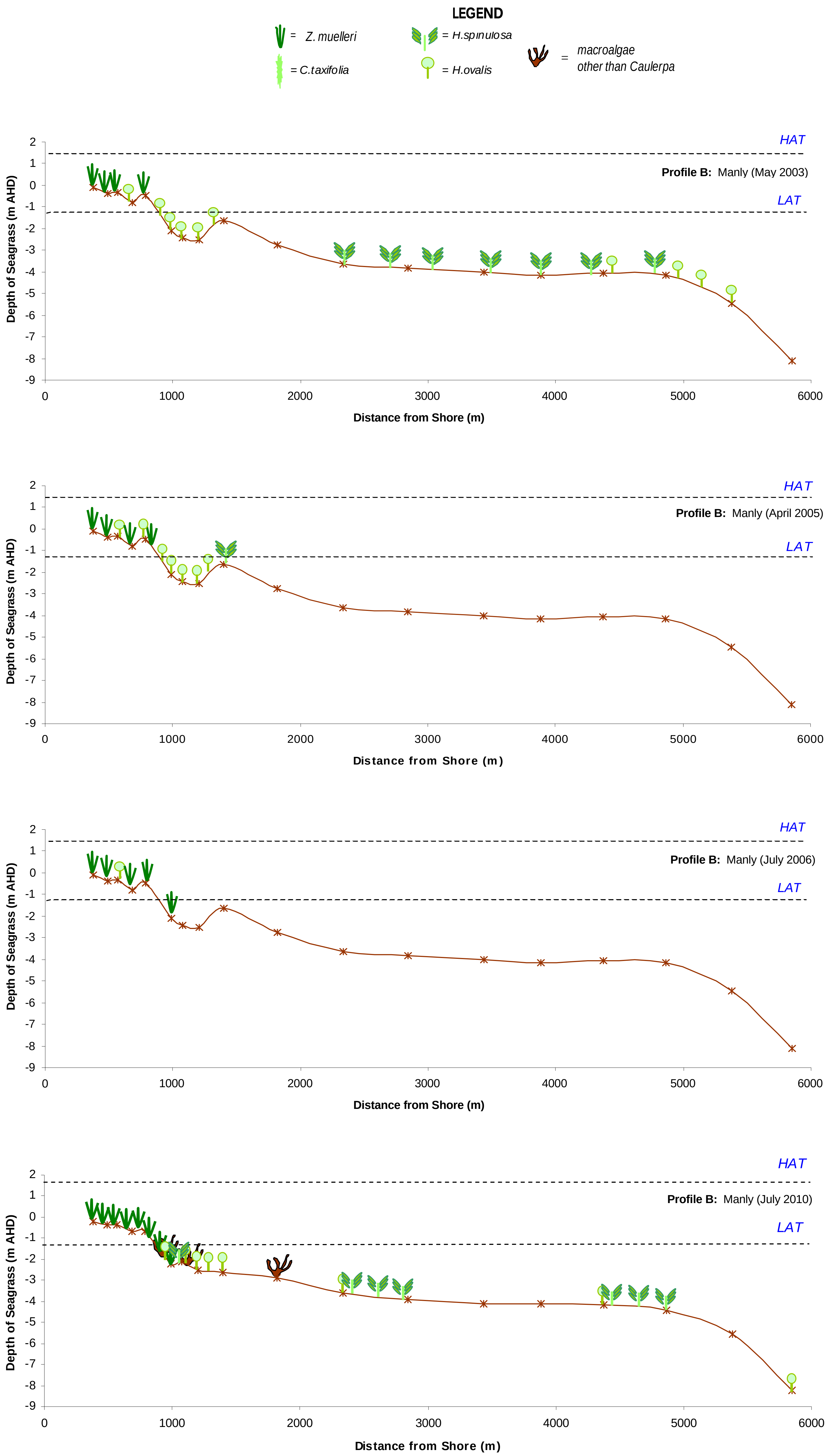


Figure 3-4 Seagrass depth profile 'B' – Manly (July 2010 to May 2003). Note that macroalgae was not studied in detail prior to July 2010

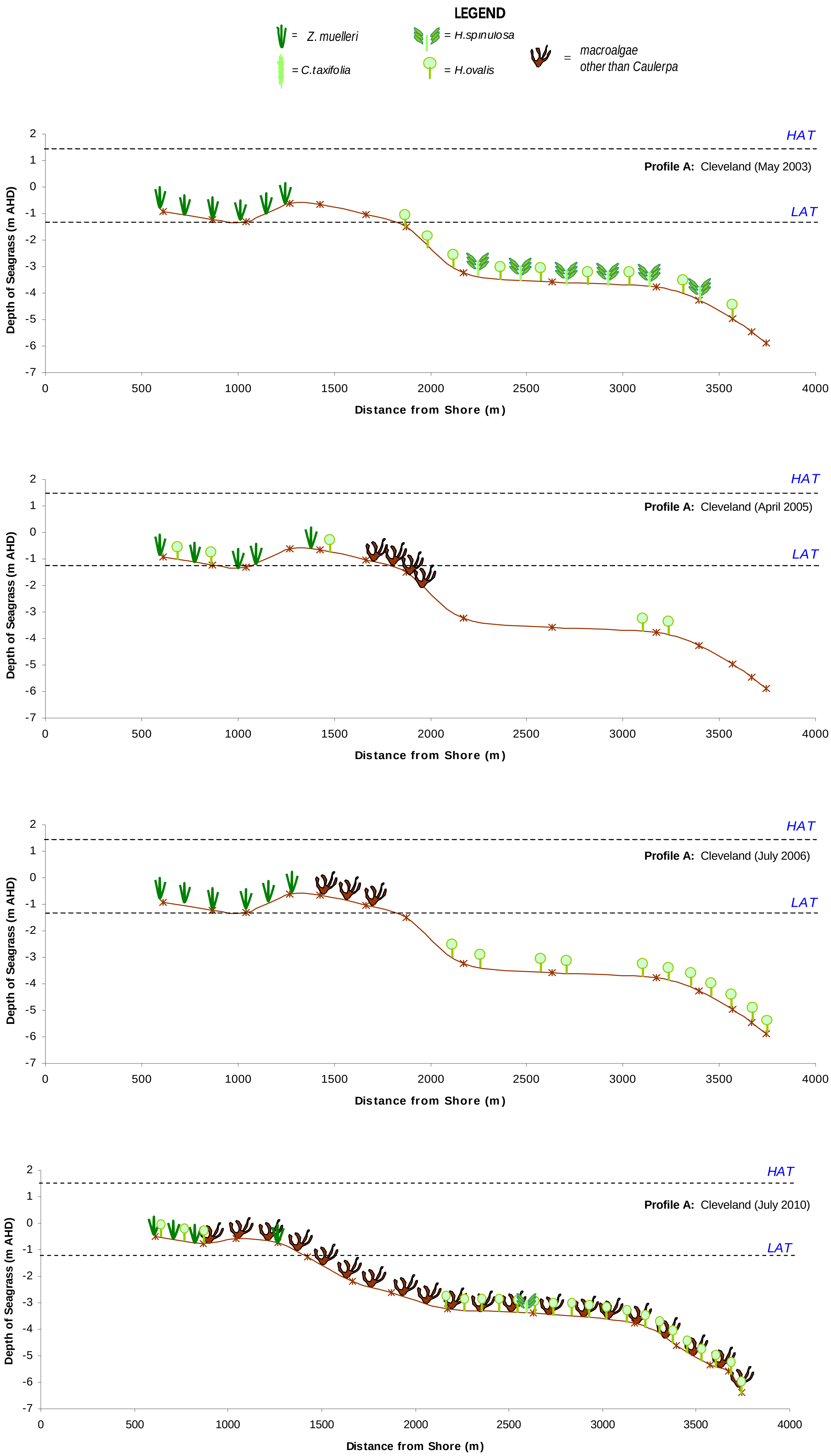


Figure 3-5 Seagrass depth profile 'A' – Cleveland (July 2010 to May 2003). Note that macroalgae was not studied in detail prior to July 2010

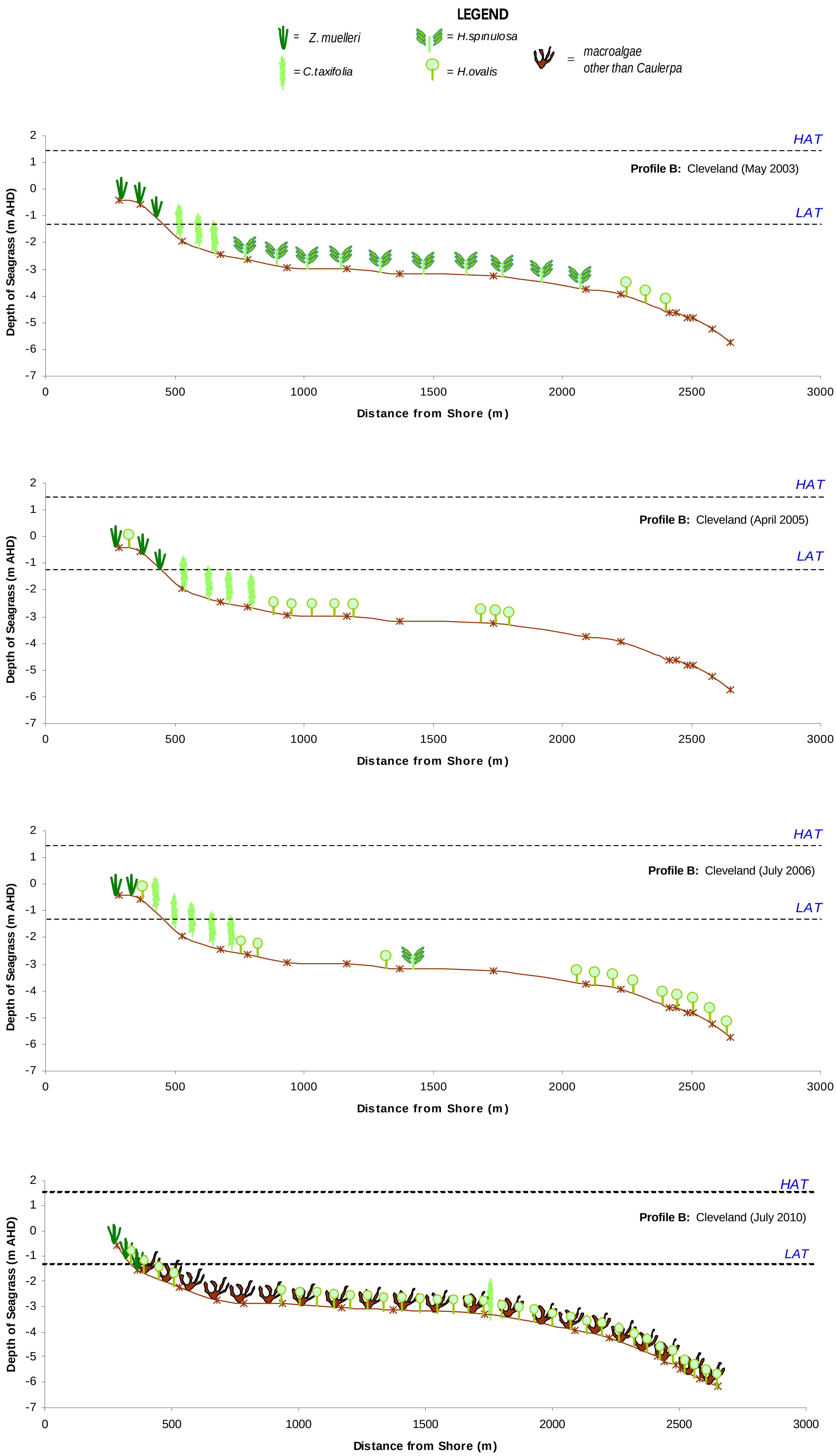


Figure 3-6 Seagrass depth profile 'B' – Cleveland (July 2010 to May 2003). Note that macroalgae was not studied in detail prior to July 2010.

3.1.2 Temporal Patterns within Depth Profiles

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

- At the Port of Brisbane, *H. ovalis* was more prevalent and had colonised to a greater depth along both profiles than it was in July 2006. The same pattern was observed for *Z. muelleri. Halophila spinulosa* was the only species at the Port that was recorded at fewer locations in July 2010 than previously. *Caulerpa taxifolia* was recorded at a similar number of sites between July 2006 and July 2010.
- At Manly, the prevalence of all three seagrass species had increased compared to April 2005 and July 2006, approaching the cover of May 2003. *Caulerpa taxifolia* was not recorded in either of the depth profiles between 2003 and 2010.
- At Cleveland, there was more *H. ovalis* in both of the depth profiles, particularly in the shallower parts of each profile, in 2010 than there was in 2006. Fewer recordings of *Halophila spinulosa* were made in 2010 than in 2006 in both profiles. The distribution of *Z. muelleri* was relatively unchanged between 2006 and 2010. *Caulerpa taxifolia* was recorded at a fewer sites in 2010 than it was in 2006. *Caulerpa taxifolia* was not recorded at profile A and was recorded once at profile B. The biggest change observed at Cleveland in 2010 was the increased prevalence of macroalgae.
- The cover of macroalgae (other than *Caulerpa* spp.) appears to have increased since 2006. However, macroalgae was mapped more comprehensively in 2010 than it was in 2006, so it is unlikely that the cover of macroalgae has actually changed as significantly it may appear in Figure 3-1 to Figure 3-6, after revision of selected video files from July 2006. Common forms of macroalgae observed in July 2010 are shown Figure 3-7.

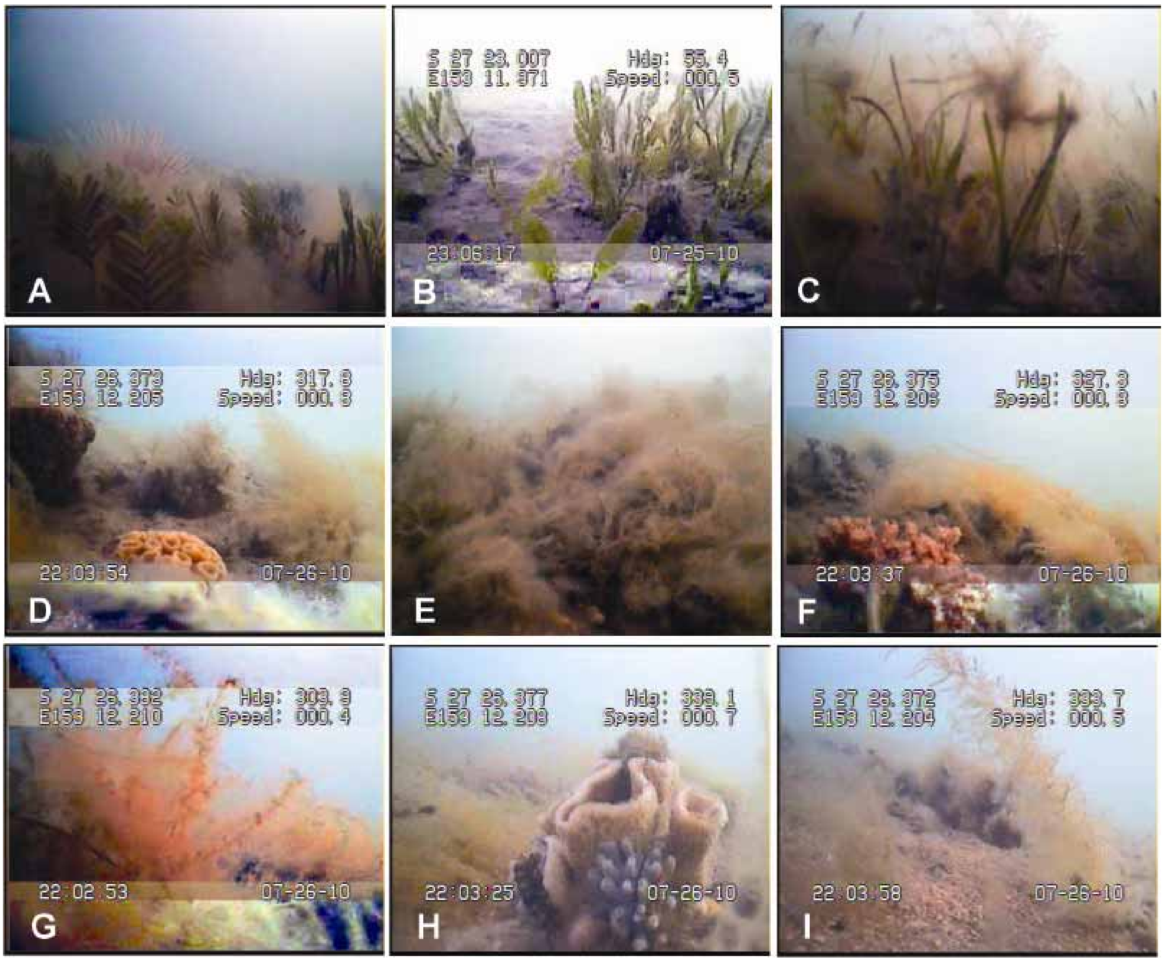


Figure 3-7 Screen grabs of macroalgae, seagrass, and fauna: *H. spinulosa* and filamentous algae (A); *H. ovalis* and *Caulerpa taxifolia* (B); *Z. muelleri* and epiphytic filamentous algae (C), faviid corals and *Laurencia* sp. (D); a mass of brown and filamentous algae (E); *Laurencia papillosa* (foreground) and *c.f. Hincksia mitchellae* (F); *Dasya* sp. (G); sponges (H); and *Hypnea* sp. and filamentous algae (I).

3.2 Edge of Seagrass Beds

Water depths (AHD) of the seaward (deep) edge of seagrass beds at the Port of Brisbane, Manly and Cleveland between May 2003 and July 2010 are shown in Figure 3-8 to Figure 3-10. These results[4] are displayed as maps (in plan view) in Figure 3-11 to Figure 3-13. Key findings of edge of bed monitoring for July 2010 and patterns over time are provided below:

- At the Port of Brisbane, Manly, and Cleveland there was a marked increase in the extent of seagrass beds. At each of these locations, the majority of transect points had seagrass, suggesting that the edge of bed was substantially further from the shore than it has been in previous events.

[4] Note that edge of bed monitoring provides only indicative information on the maximum depth of seagrass. Pronounced changes in depth over short distances limit the precision of estimates of maximum depth.

- Although the maximum depth was shallower in 2010 than it was in 2006 in some transects, the majority were deeper than they had been in 2006 (Figure 3-8 to Figure 3-10).
- The seaward expansion of seagrass at the Port of Brisbane was consistent with an increase in the maximum growing depth of approximately 1 m, to -5.7m AHD. At Cleveland, three out of four transects showed no increases in the maximum depth of seagrass growth, however, maximum depth along one transect increased by over 2.5m to -7.7m AHD.
- Because surveys took place at approximately the same time of year in 2006 and 2010, these differences do not reflect seasonal changes.
- Based on historical seasonal comparisons, seagrasses were recorded at greatest depths between the months of June and October, with reduction in seagrass edge of bed depth occurring between November and May;
- Edge of bed monitoring location 'C' at the Port of Brisbane has maintained a relatively constant depth over time. Monitoring site 'D' at Cleveland had also maintained a constant depth until the 2010 monitoring event. Site 'C' is located across a shallow sand spit subject to wave action, while Site 'D' traverses a boating channel.

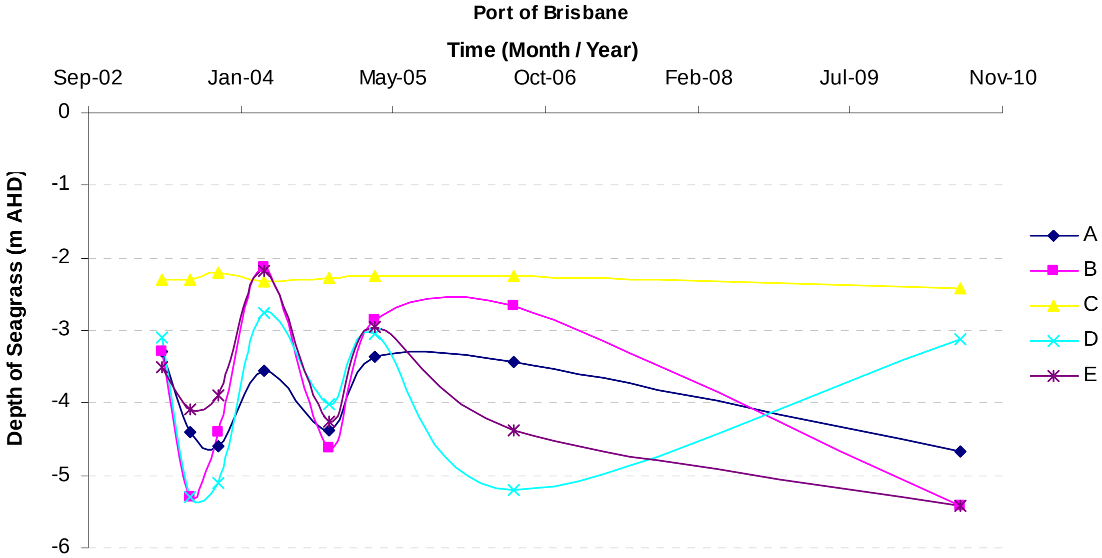


Figure 3-8 Maximum recorded depth of seagrass beds at the Port of Brisbane between May 2003 and July 2010 (depth in metres relative to AHD)

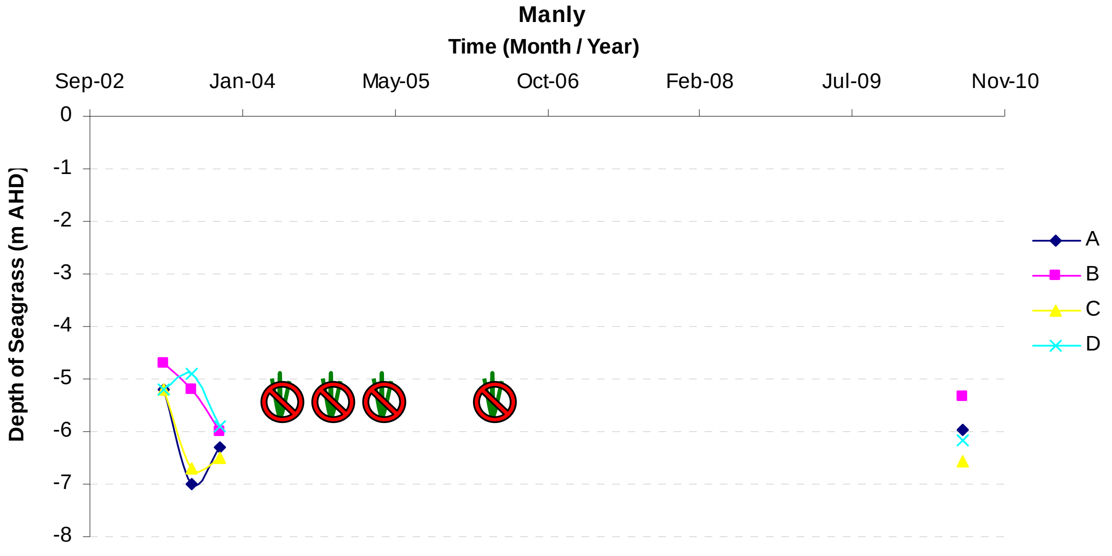


Figure 3-9 Maximum recorded depth of seagrass beds at Manly between May 2003 and July 2010 (depth in metres relative to AHD). Seagrass depth ranges were not collected at Manly between April 2004 and July 2006.

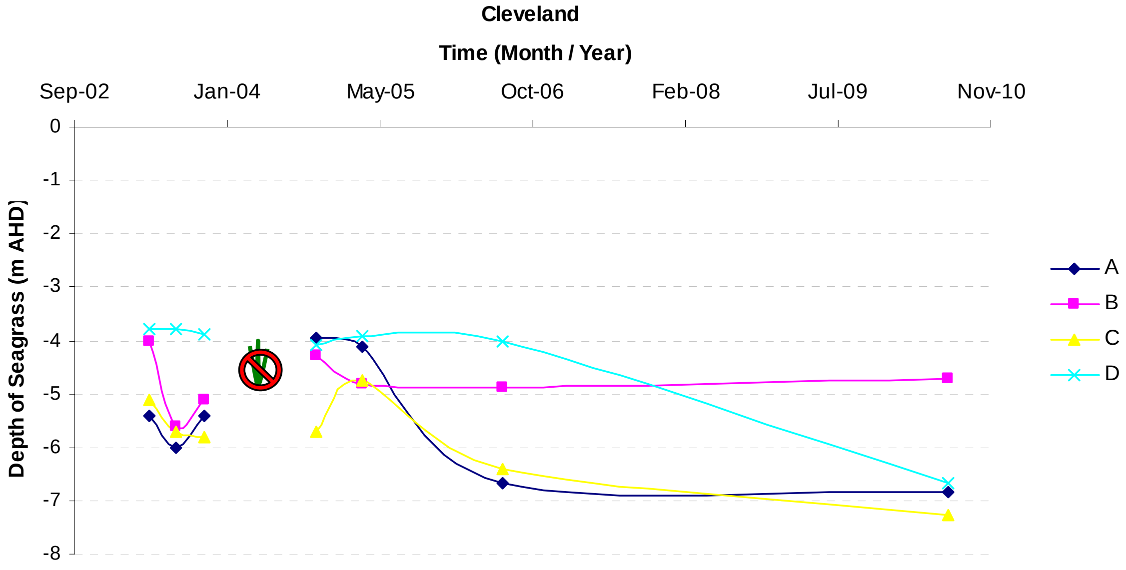
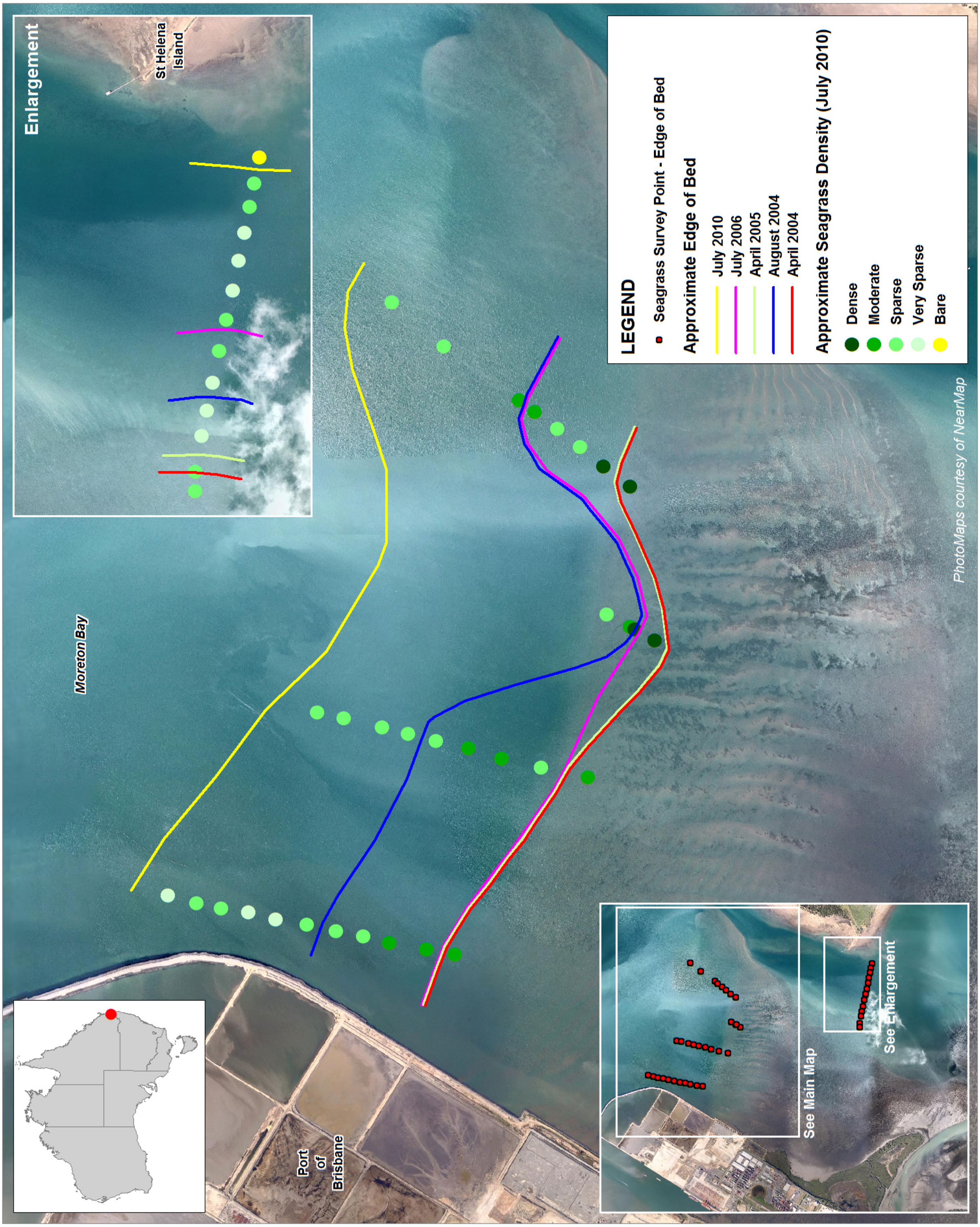


Figure 3-10 Maximum recorded depth of seagrass beds at Cleveland between May 2003 and July 2010 (depth in metres relative to AHD). Seagrass depth ranges were not collected at Cleveland in April 2004.



Title:

Temporal Variation in Seagrass Edge of Bed Adjacent to Port of Brisbane

Figure:

3-11

Rev:

A

N

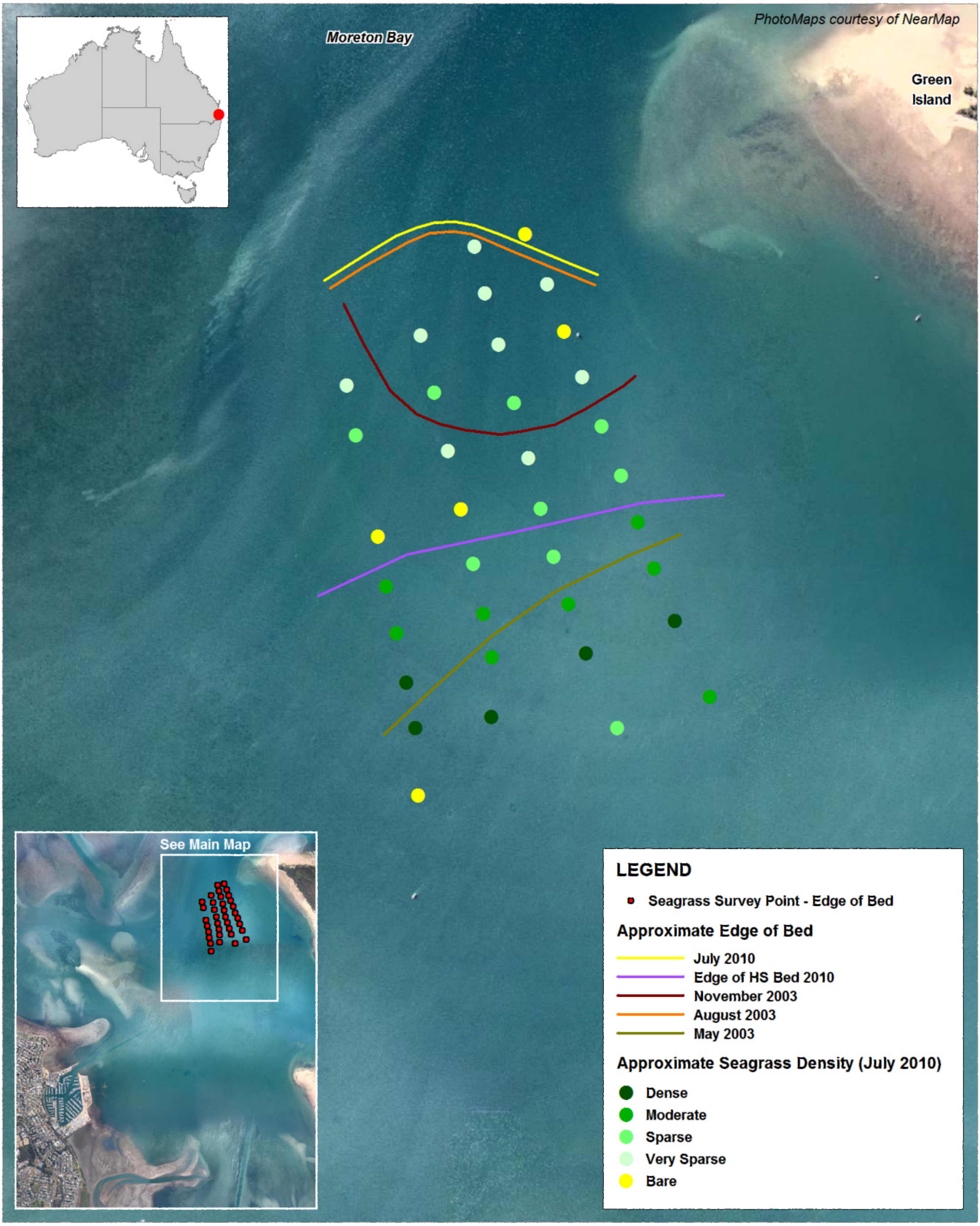
0m 400 800

Scale - Main Map and Enlargement

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_012_Port_EOB.wor



Title:

Temporal Variation in Seagrass Edge of Bed Adjacent to Manly

Figure: **3-12**

Rev: **A**

N

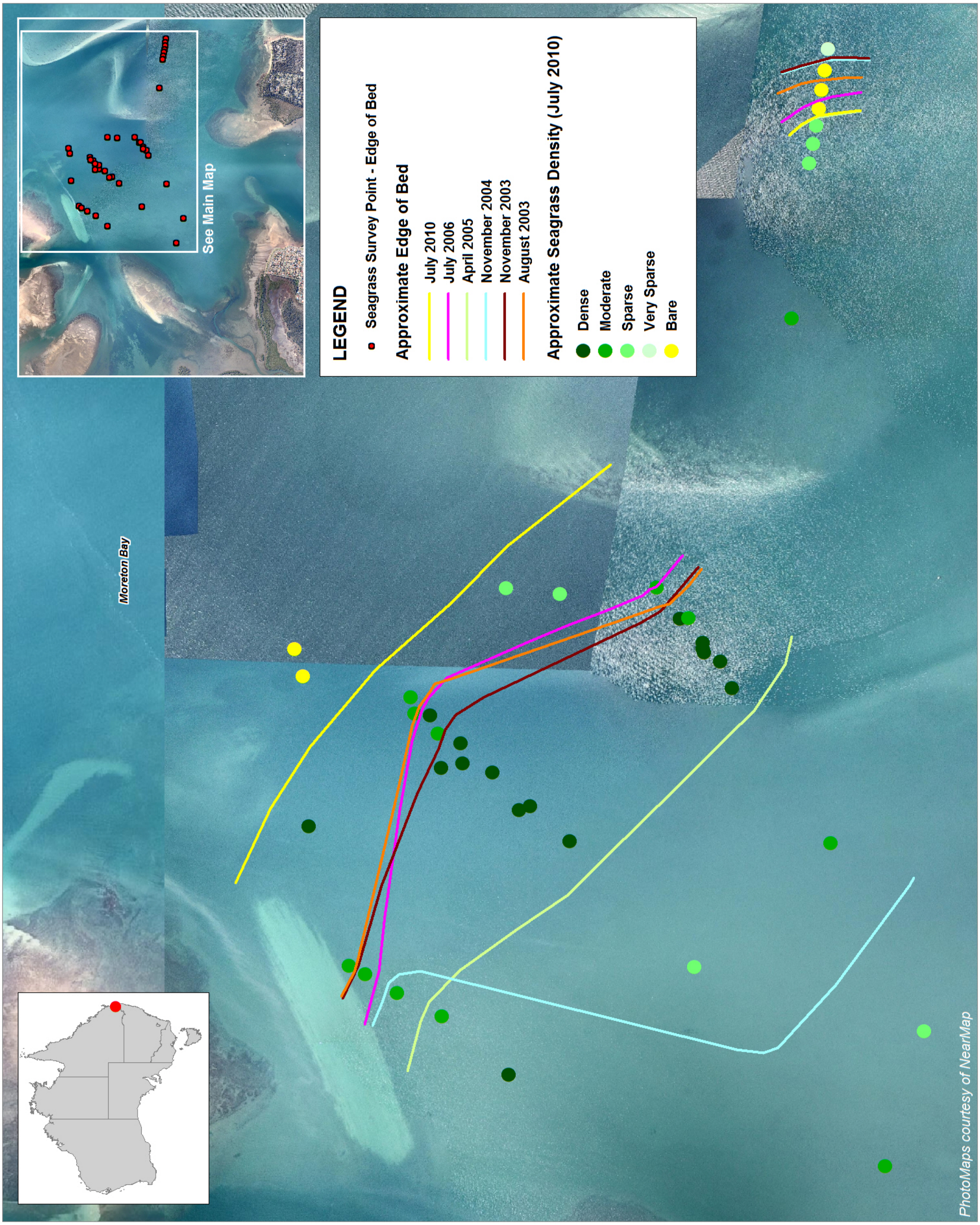
0m 250 500

Scale - Main Map

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_011_Manly_EOB.wor



Title:

Temporal Variation in Seagrass Edge of Bed Adjacent to Cleveland

Figure: 3-13

Rev: A

N

0m 300 600

Scale - Main Map

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_010_Cleveland_EOB.wor

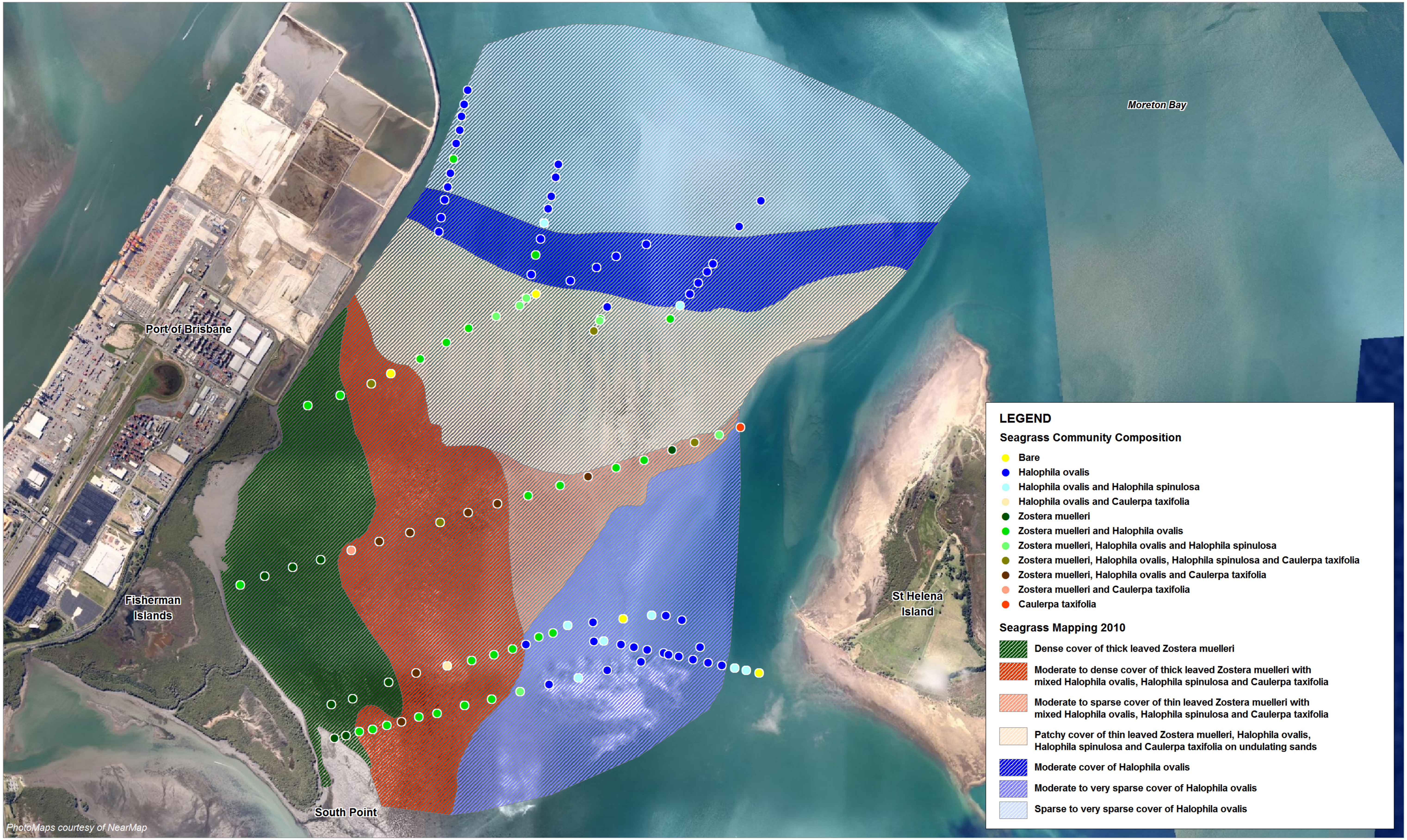
3.3 Seagrass Mapping Adjacent Port of Brisbane

Approximately 80 points were used to map seagrass at the Fisherman Islands tidal flats adjacent to the Port of Brisbane, where three seagrass species (*Z. muelleri, H. ovalis, H. spinulosa*) and macroalgae were observed (Figure 3-14). This mapping showed that:

- *Halophila ovalis* and *H. spinulosa* formed the seaward edge of the Port of Brisbane seagrass bed.
- *Zostera muelleri* formed the landward edge of the seagrass bed adjacent to the mangrove fringe of Fisherman Islands. This bed was comprised largely of a dense mono-specific bed, with occasional patches of *H. ovalis*. The bed was approximately 900 m at its widest point.
- Seaward of this zone was a mixed species community composed of moderate to dense, thick-leaved *Z. muelleri,* as well as *H. ovalis, H. spinulosa,* and *Caulerpa taxifolia.* Further east and north east of this zone were three other zones;

    1. Moderate to sparse *H. ovalis* to the southeast
    2. Moderate to sparse cover of thin-leaved *Z. muelleri* as well as *H. ovalis, H. spinulosa,* and *Caulerpa taxifolia* to the east
    3. Patchy cover of thin-leaved *Z. muelleri* as well as *H. ovalis, H. spinulosa,* and *Caulerpa taxifolia* on undulating sands to the north east

- Maximum growing depths of seagrasses across intertidal and sub-tidal areas of the Port were variable, ranging between -2.35 and -5.7 m AHD. *Halophila ovalis* was the deepest recorded seagrass species.
- The extent of seagrass in July 2010 was considerably larger than recorded any time previously. This was generally attributable to the greater maximum growing depth of seagrass species *H. ovalis*.



Title:

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

Figure: 3-14

Rev: A

N

0km 0.5 1

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_005_100714_Aerial_Analysis.wor

4 DISCUSSION

4.1 Spatial Patterns in Distribution

Patterns in the distribution of seagrasses have been broadly consistent among sampling locations and over time. Six species of seagrass have been recorded in Moreton Bay (Young and Kirkman, 1975), of which three have been recorded in the current monitoring program, namely: *Z. muelleri, H. ovalis* and *H. spinulosa*. In general, *Z. muelleri* occupied shallow intertidal areas, while *H. ovalis* inhabited deeper subtidal areas, and both of these species tended to form mixed seagrass assemblages with *H. spinulosa* in shallower subtidal water. In Moreton Bay, *Z. muelleri* is commonly found within the intertidal zone (Dennison and Abal, 1999; Young and Kirkman, 1975), which is consistent with the results of this study.

Since the onset of the monitoring program, *H. ovalis* has consistently formed the deepest edge of seagrass beds, growing in depths ranging between -7.0 and -0.5 m. In July 2006, *H. ovalis* was recorded in depths between -0.5 and -5.3 m. In 2010, *H. spinulosa* was recorded at depths between -0.8 and -4.4 m AHD. These results are contrary to the findings of Young and Kirkman (1975), which suggested that *H. spinulosa* was mostly found in areas too deep or turbid for other seagrasses in Moreton Bay.

A range of environmental conditions including light availability, sediment condition and type, nutrient availability, water motion and grazing are thought to control the extent, distribution and abundance of seagrasses in Moreton Bay (Longstaff and Dennison 1999). The distribution patterns of seagrass species can also be influenced by different growth strategies and tolerances to exposure.

The combination of factors that are responsible for determining the distribution and extent of seagrasses differ at each monitoring location (Port, Manly, Cleveland). Seagrass assemblages at the Port occur over broad intertidal and subtidal sand and mud banks, which have gradual bathymetric profiles and consistent gradients in sediment particle size with depth. There is a large shallow sand bank that extends to the north-east of Fisherman Islands, near St. Helena Island, which is exposed to wave action. This area has historically contained very little seagrass, but was vegetated in the July 2010 survey. Unlike the Port of Brisbane, Manly and Cleveland depth profile transects traversed various physical features, including coral rubble banks, mud and sand banks and often 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 light availability.

However, light availability is likely to be a major driver of seagrass depth distribution at the Port, due to the proximity of the site to the Brisbane River mouth. Seagrass had consistently grown at greater depths at Cleveland and Manly (prior to its disappearance in April 2005) than it has at the Port. In July 2006, *H. ovalis* was recorded at a depth of -6.2m at Cleveland, while the maximum recorded depth of seagrasses at Fisherman Islands was -5.29m. Similarly, in July 2010, *H. ovalis* was recorded at a depth of -6.2 m, -8.8 m and -5.7 m AHD at Cleveland, Manly, and the Port, respectively.

4.2 Long-term Variations in Seagrass

4.2.1 Community Structure

Seagrass assemblages at the Port, Manly and Cleveland monitoring sites have shown great variation in community structure since monitoring commenced in May 2003. This variation is mostly to do with changes in the distributions of *H. ovalis* and *H. spinulosa* in shallow subtidal areas, rather than the complete loss or substitution of a particular species.

Seagrass depth profiling has demonstrated that sub-tidal 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 sub-tidal seagrass beds have been demonstrated in the present study. These changes have occurred primarily in *H. ovalis* and *H. spinulosa* but also in some instances with *C. taxifolia*. While both *H. ovalis* and *H. spinulosa* are together considered 'pioneer' species, capable of rapidly colonising areas, *H. ovalis* is capable of more rapid growth rates, as measured by shoot production and rhizome extension. However, this does not explain why observed shifts in community structure occur in both directions (i.e. *H. spinulosa* dominating *H. ovalis*). It is suspected that these patterns 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). Sub-tidal seagrass beds at the Port are suspected to provide feeding habitat to a significant population of green turtles (*Chelonia mydas*), and also dugong (*Dugong dugon*), although these animals are suspected to be 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. Dugongs graze extensively on *Halodule* 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. The drivers of light availability and its effects on seagrasses will be discussed further in the following section 4.2.2.2.

Because seagrass depth distributions extend well into the subtidal zone, there has been no variation in the depth range of intertidal seagrass beds. In 2010, there was some seaward encroachment of *Z. muelleri,* and landward colonisation of *H. ovalis.* 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 have better tolerance to desiccation and thermal stress than other seagrasses in Moreton Bay.

4.2.2 Temporal Variation in Seagrass Extent

Between April 2005 and July 2006, the maximum growing depth of *H. ovalis* increased significantly (1-2 m) and corresponded to an increase in overall seagrass extent of between 100 and 600m at the Port and Cleveland. Similarly, cover and maximum growing depth increased between July 2006 and July 2010, such that the edge of bed had shifted seaward by at least a kilometre in some places at the Port, up to 350 m at Cleveland, and returning to the August 2003 extent at Manly.

Past monitoring has shown that seagrass grows deepest and is greatest in extent between the months of June and October, with a reduction in this growing depth and extent occurring between November and May. However, both the 2006 and 2010 events were conducted in winter (July and August), so the growth observed during this period is not related to seasonal variation.

Light has been cited as the most important driver of seagrass distribution and extent in nearshore or estuarine environments (Longstaff and Dennison 1999; Dennison *et al.* 1993; Abal and Dennison 1996). The following sections describe the primary drivers of light availability of western Moreton Bay.

4.2.2.1 Drivers of Light Availability for Seagrass

Attenuation of light in the water column can occur through an increase in concentration of suspended solids or phytoplankton (i.e. turbidity). These particles have the potential to completely or partially inhibit photosynthesis and hence affect the growth/viability of seagrass beds (Hopkins and White 1998). Turbidity in Moreton Bay is complex, and may be generated from the following processes:

- Resuspension of bed sediments from tidal currents, wind waves and ocean swell;
- Phytoplankton blooms in response to nutrient loading; and
- Catchment inputs of sediments associated with periodic river flows.

The shallow portions of western Moreton Bay are particularly influenced by wind waves generated by the prevailing north-east (typically summer months) and south-easterly winds, whereas tidal currents also represent an important turbidity generator near river estuaries, such as the Brisbane River (Dennsion and Abal 1999). Episodic flow events from the Brisbane River and smaller Tingalpa and Lota creeks (Manly) and Eprapah Creek (Cleveland) catchments also generate high turbidity, which typically occur during summer months. Extended periods of cloudy weather can also result in a significant period of low light availability (WBM 2001).

The Port is located in the central western bay, such that winds from the southeast and northeast blow over the largest uninterrupted body of water (fetch) generating the largest wind waves. Previous examination of study area sediment characteristics (WBM 2000), general water depth and predictive modelling of wave orbital velocity for a given wave size, indicates that waves of 0.3-0.5m are sufficient to remobilise a significant proportion of the bed sediments within the study area. Review of the fetch for predominant wind directions indicates that wind speeds of 12-15 knots would result in waves at the study area of this order (WBM 2000). Whilst this is a very simplistic review of the process, and does not take into account the factors such as tidal currents (which may significantly reduce wave orbital velocities required to cause remobilisation), bed roughness and sediment cohesion, it provides a guide to the remobilisation process (see below).

WBM (2000) demonstrated that, in general, winds from the south-east to north-east corresponded to the highest turbidities due to two factors: (1) fetch length, and (2) the dominance of these winds in the data record. Southeast to northeast winds dominate the record in summer, comprising over 70% of the total observations (December to February). A similar collection program undertaken in winter would record a dominance of south to west winds. Due to the fetch length of these winds at the study site, they are likely to generate significantly smaller waves and hence lower turbidities for a given wind strength.

Data collected by WBM (2001) also indicated that Photosynthetically Activate Radiation (PAR) levels characterised at seagrass beds (+1.0m LAT) adjacent to the Port of Brisbane were significantly attenuated by increased suspended sediment concentrations, reported as turbidity. When ambient turbidity levels increased above 10 - 20 NTU, PAR levels were attenuated by 50%, with all PAR attenuated above turbidity values of about 50NTU. During summer, turbidities within the Fisherman Islands precinct have been recorded often above 100 NTU, with maximum values exceeding 200 NTU in response to sustained wind events (WBM 2000).

It is also important to recognise that turbidity, and therefore light availability to seagrass is variable in space as well as time. Factors such as water depth, velocity of tidal currents, sediment cohesion, and particle size distribution may all influence turbidity, therefore, light levels experienced at the seabed can be highly variable over short distances (i.e. measured in 100's of metres). When turbidity was at, or below, about 10NTU, no consistent trend in PAR attenuation was evident. As turbidity levels increased above 10 - 20 NTU, PAR levels were attenuated by 50%, with all PAR attenuated above turbidity values of about 50NTU. During summer, turbidities around Fisherman Islands have been recorded often above 100 NTU, with maximum values exceeding 200 NTU in response to sustained wind events (WBM 2000).

4.2.2.2 Light Availability and Deep Water Seagrass Extent

Temporal changes in seagrass extent have been driven largely by changes in the distribution of *H. ovalis.* This study has recorded large retractions and expansions in the extent of this seagrass species at the Port. These patterns have been broadly consistent at Cleveland, while Manly saw a large period of dieback occurring between 2004 and the present 2010 survey.

Halophila ovalis is tolerant of only short term (2-3 day) reductions in light availability (Longstaff *et al.* 1999), 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.

Between November 2003 and April 2004 there was a significant landward retraction (2-4 km) of seagrass beds at Manly. This event is suspected to be linked to a period of elevated turbidity associated with a period of strong winds, heavy rainfall and catchment flows (low-level flooding).

Similar landward retractions occurred at all other monitoring locations, however, this period was not followed by a seaward expansion of seagrasses into deeper waters, until the most recent July 2010 monitoring period. Prolonged absence of seagrasses at Manly suggested there may have been a localised long-term change to water quality.

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, which saw large increases in seagrass cover at all locations.

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 impacted seagrasses at Fisherman Islands. The FPE Seawall structure has modified local tidal current dynamics at Fisherman Islands. The present study has shown that the extent of seagrass and the depth to which it grows has increased substantially since the 2006 monitoring event. These changes have occurred at the Port and the two control locations, suggesting that conditions aiding the growth of marine plants are widespread over the entire study area. Therefore, the FPE seawall either affected seagrass at the Port

1. negatively, well below the level of widespread positive environmental change witnessed since 2006, or

2. positively by enhancing growing conditions.

Under the scenario that the FPE seawall is enhancing the growth of seagrass surrounding the Port, mechanisms underpinning this may include:

1. 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.

2. 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.

3. 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.

4.4 *Lyngbya majuscula, Caulerpa taxifolia* and Other Macroalgae

Significant improvements in video capture technology occurred between the last two monitoring events, leading to greatly improved picture clarity in the current monitoring event. This allowed for better resolution of fine filamentous algae, which was mapped in more detail in July 2010. While it is also possible that there has been some expansion of macroalgae between July 2006 and July 2010, some of the apparent changes in extent may be due to improved reporting efficacy. It is also noted that past seagrass monitoring also considered in detail the macroalga *Caulerpa taxifolia*, primarily due to potential concerns of its impacts on seagrass beds, but also because it was often the dominant macroalga in the study area. In the July 2010 sampling episode, all visually distinct macroalgae species were examined noting that macroalgae, like seagrass, can also represent an indicator of ecosystem health. Macroalgae is often associated with anthropogenic eutrophication, and it can reduce the cover and rate of production in seagrasses (Hauxwell *et al.* 2001). Species of *Caulerpa* can have differential effects on seagrass growth, by inhibiting or promoting growth, depending on the seagrass species in question (Ceccherelli and Cinelli 1997; Ceccherelli and Campo 2002). Notwithstanding all of the above, there is no evidence that macroalgal cover changed at the Port relative to control locations, with all locations having greater macroalgal cover in the 2010 sampling episode.

Although there may have been more macroalgal cover over the entire study area between 2006 and 2010, the cover of *C. taxifolia* did not increase significantly over this period. This followed on from a reduction in the extent of *C. taxifolia* between April 2005 and July 2006.

Fine filamentous algae were commonly seen growing directly from the sea floor and epiphytically from other macroalgae and seagrass. This filamentous alga varied in colour from brown to light green to white, in places where it appeared to be senescing. The white senescent form was particularly common amongst beds of *H. spinulosa. Lyngbya majuscula, Rhizoclonium africanum* and *Hincksia (Giffordia) mitchellae* appear broadly similar to this filamentous alga and occupy similar habitats within Moreton Bay. *Lyngbya majuscula* is a toxic cyanobacteria, *R. africanum* is a green algae (Chlorophyta) often associated with mangroves, and *H. mitchellae* is a brown algae (Phaeophyta). Although microscopy is required to conclusively distinguish between these types, we suggest that the majority of the algae observed was not *L. majuscula,* based on its colour. *Lyngbya majuscula* in eastern Moreton Bay has previously been mapped using ground-truthed satellite imagery (Rolfsema *et al.* 2006). It is distinguishable from a range of other segrasses and algae by its relatively low levels of reflectance of infra-red and visible light (Rolfsema *et al.* 2006). It is optically dark and its reflectance is closest to that of *H. spinulosa* (Rolfsema *et al.* 2006). The filamentous algae observed in July 2010 was substantially lighter in colour than *H. spinulsoa* (Figure 3-7A). Therefore, it is likely that the majority of this algae was not *L. majuscula,* although it may have been present. *Lyngbya majuscula* has previously formed large blooms in the Fisherman Islands area.

5 CONCLUSIONS AND RECOMMENDATIONS

There has been a seaward expansion of seagrass at the Port and Cleveland since April 2005. This and the increased cover of macroalgae at all locations suggest that the conditions for marine plant growth have been favourable in recent times. The Manly site had displayed little evidence of longer term recovery until the July 2010 monitoring event, after its disappearance between the November 2003 and April 2004 monitoring episodes. It is possible that the loss of seagrass at Manly was a result of longer term changes to water quality (e.g. turbidity and/or nutrient loading), but it now appears to be in a state of recovery. Overall, the present seagrass monitoring program has reported large seasonal retractions and expansions to seagrass beds adjacent to the FPE Seawall. These patterns have been broadly consistent with results for sites distant (>5km) to the FPE Seawall and at control locations at Manly (prior to February 2004) and Cleveland. Consequently, it would appear that the observed gross scale changes in the extent of seagrass beds were due to natural processes operating at spatial scales measured in tens of kilometres, rather than any broad scale impacts resulting from the FPE Seawall.

The long term results produced by this monitoring program provide a basic understanding of seasonal patterns in seagrass community structure and extent in the western Moreton Bay region. Prolonged periods of poor water quality in western Moreton Bay are coincidental with the loss or landward retraction of seagrass species, particularly *Halophila* ovalis, to shallower water during summer months. During winter months when water clarity generally improves, there is a seaward expansion of *H. ovalis* into deeper subtidal waters. These changes are likely to be associated with various factors, primarily seasonal variation in climatic conditions (particularly wind speed and direction) and subsequent variation in water clarity (i.e. turbidity).

The results of the monitoring programme have now been collated to form one of the most intensive datasets available for seagrass beds in Western Moreton Bay, which is of value to stakeholders such as the Queensland Fisheries (DEEDI), Queensland Parks and Wildlife Services (QPWS). The monitoring data has provided a much better understanding of the seasonal patterns in distribution of seagrasses than previously existed, and actually challenges the long held belief that summer is the growth period for some species of seagrasses. The programme has recorded huge range extensions of deepwater seagrasses through winter, and a similar scale range reduction with the on-set of summer winds and associated increases in ambient turbidity

After two successive seagrass expansion events in 2006 and 2010, it appears that the effects of the FPE seawall are either benign or they are enhancing the growth of seagrass surrounding the Port. Expansion may be driven by the provision of more protected conditions, enhanced sediment and nutrient entrapment (BMT WBM 2010), and/or greater separation from the negative influences of the Brisbane River. Because seagrass extent has also increased at control locations, this expansion may also be unrelated to the FPE seawall extension.

Several recommendations are made on the basis of the findings of the present study, as follows:

- Seagrass monitoring should continue, despite broad scale patterns in seagrass distribution and extent in space and time being well documented. Changes to broad scale patterns in seagrass distribution may manifest over longer periods of time than measured over the present study;

- Future monitoring surveys could be based on either of two options:
    - an annual winter survey (i.e. during greatest seagrass extent), and include all the components undertaken in this monitoring episode. This option would enable PBPL to detect inter-annual broad scale changes to the distribution and extent of seagrass beds; or
    - quarterly monitoring of edge of bed transects and an annual winter survey including all components undertaken in this monitoring episode. This option would enable PBPL to detect seasonal and inter-annual changes to the distribution and extent of seagrass beds, offering greater temporal resolution to the study.
- Edge of bed monitoring sites should be extended seaward beyond the new bed edges to incorporate observed range extensions.

6 REFERENCES

Abal, E.G. and Dennison, W.C. (1996) Seagrass Depth Range and Water Quality in Southern Moreton Bay, Queensland, Australia. Marine and Freshwater Research. 47, 763-771

ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council/Agriculture and resource Management Council of Australia and New Zealand

BMT WBM (2006) Port of Brisbane Seagrass Monitoring – July 2006. Report prepared for the Port of Brisbane Corporation

BMT WBM (2008) Ecological character description for the Moreton Bay Ramsar Site. Report prepared for the Environmental Protection Agency

BMT WBM (2010) Assessments of marine sediments adjacent to Fisherman Island. Report Prepared for the Port of Brisbane Ptd Ltd.

Ceccherelli G., Cinelli, F. (1997) Short term effects of nutrient enrichment of the sediment and interactions between the seagrass *Cymodocea nodosa* and the introduced green alga *Caulerpa taxifolia* in a Mediterranean bay, Journal of Experimental Marine Biology and Ecology 217: 165-177

Ceccherelli G., Campo, D. (2002) Different effects of *Caulerpa racemosa* on two co-occurring seagrasses in the Mediterranean, Botanica Marina 45: 71-76

Conacher, C.A., Poiner, I.R., O'donohue, M. (1994) Morphology, Flowering and Seed Production of Zostera muelleri Aschers in Subtropical Australia. Aquatic Botany, 49: 33-46

Dennison, W.C. and Abal, E.G. (1999) Moreton Bay Study: A Scientific Basis for the Healthy Waterways Campaign. South-East Queensland Water Quality Management Strategy. Brisbane

EHMP (Ecosystem Health Monitoring Program) EPA, 2002 Kirkman H. (1996) Baseline and Monitoring Methods for Seagrass Meadows. Journal of Environmental Management. 47, 191-201

Hauxwell, J., Cebrián, J., Furlong, C., Valiela, I. (2001). Macroalgal canopies contribute to eelgrass (*Zostera marina*) decline in temperate estuarine systems. Ecology. 82:1007–1022]

Lanyon, J.M. and Marsh, H. (1995) Temporal Changes in the Abundance of Some Tropical Intertidal Seagrasses in North Queensland. Aquatic Botany. 49: 217-237

Lee Long, W.J., Mellors, J.E. and Coles, R.G. (1993) Seagrasses between Cape York and Hervey Bay, Queensland, Australia. Australian Journal of Marine and Freshwater Research, 44 (1): 19-31.

Longstaff, B.J. Loneragan, N.R., O'Donohue, M., Dennison, W.C. (1999) The effects of light deprivation on the survival and recovery of the seagrass *Halophila* ovalis. Journal of Experimental Marine Biology and Ecology. 234: 1-27

Marsh, H., Channells, P.W., Heinsohn, G.E., Janice Morrissey (1982) Analysis of stomach contents of dugongs from Queensland, Australian Wildlife Research. 9: 55-67

McKenzie, L.J. (1994) Seasonal Changes in Biomass and Shoot Characteristics of Zostera capricorni Aschers Dominant Meadow in Cairns Harbour, Northern Queensland. Australian Journal of Marine and Freshwater Research. 45: 1337-1352

Mellors, J.E., Marsh, H., Coles, R.G. (1993) Intra-annual Changes in Seagrass Standing Crop, Green Island Northern Queensland. Australian Journal of Marine and Freshwater Research , 44: 33-41

Moore, K.A., Wetzel, R.L., Orth, R.J. (1997) Seasonal pulses of turbidity and their relations to eelgrass (Zostera marina L.) survival in an estuary. Journal of Experimental and Marine Biology and Ecology. 215: 115-134.

Nakaoka, M. Aioi, K. (1999) Growth of seagrass *Halophila* ovalis at dugong trails compared to existing within-patch variation in a Thailand intertidal flat. Marine Ecology Progress Series. 184: 97-103

Ralph, P. (1998) Photosynthetic responses of *Halophila ovalis* (R. Br.) Hook. f. to osmotic stress, Journal of Experimental Marine Biology and Ecology. 227: 203-220

Rolfsema, C, Phinn, S.R., Dennison, W.C., Dekker, A.G., Brando, V.E. (2006) Monitoring toxic cyanobacteria *Lyngbya majuscula* (Gomont) in Moreton Bay, Australia by integrating satellite image data and field mapping. Harmful Algae, 5: 45-56

Preen, A. (1995) Impacts of dugong foraging on seagrass habitats: observational and experimental evidence for cultivation grazing. Marine Ecology Progress Series, 124: 201-213.

WBM Oceanics Australia (2000) Port of Brisbane – Port Expansion Impact Assessment Study. Report prepared for the Port of Brisbane Corporation.

WBM Oceanics Australia (2002) Port of Brisbane Seagrass Monitoring Pilot Study. Report prepared for the Port of Brisbane Corporation.

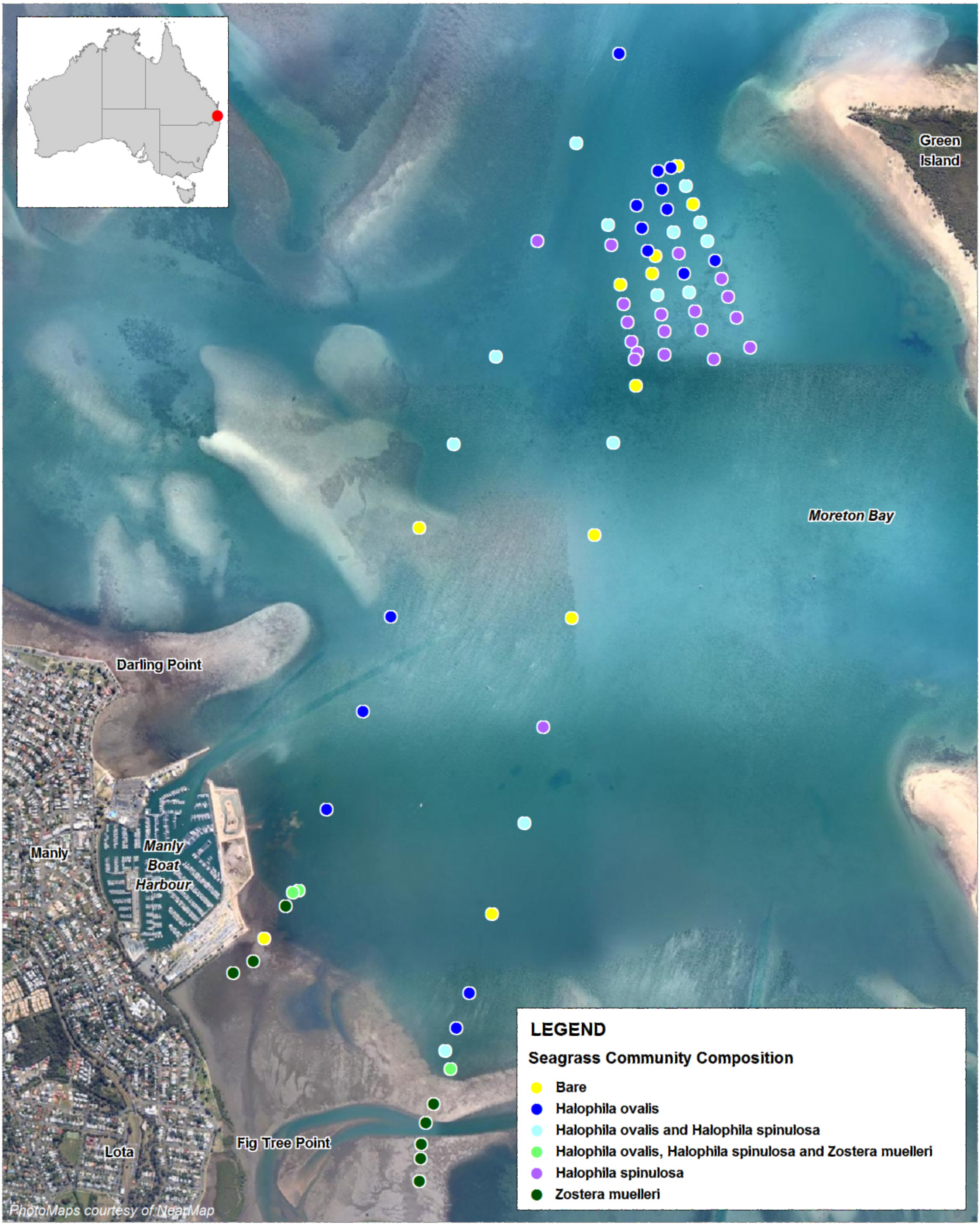
WBM Oceanics Australia (2003a) Port of Brisbane Seagrass Monitoring – Stages One and Two. Report prepared for the Port of Brisbane Corporation.

WBM Oceanics Australia (2003b) Port of Brisbane FPE Seagrass Monitoring Report May 2003. Report prepared for the Port of Brisbane Corporation.

WBM Oceanics Australia (2004a) Port of Brisbane Seagrass Monitoring – March 2004. Report prepared for the Port of Brisbane Corporation

WBM Oceanics Australia (2004b) Port of Brisbane Seagrass Monitoring – April 2005. Report prepared for the Port of Brisbane Corporation

APPENDIX A: SEAGRASS DEPTH PROFILES FOR MANLY AND CLEVELAND COMPLETED JULY 2010



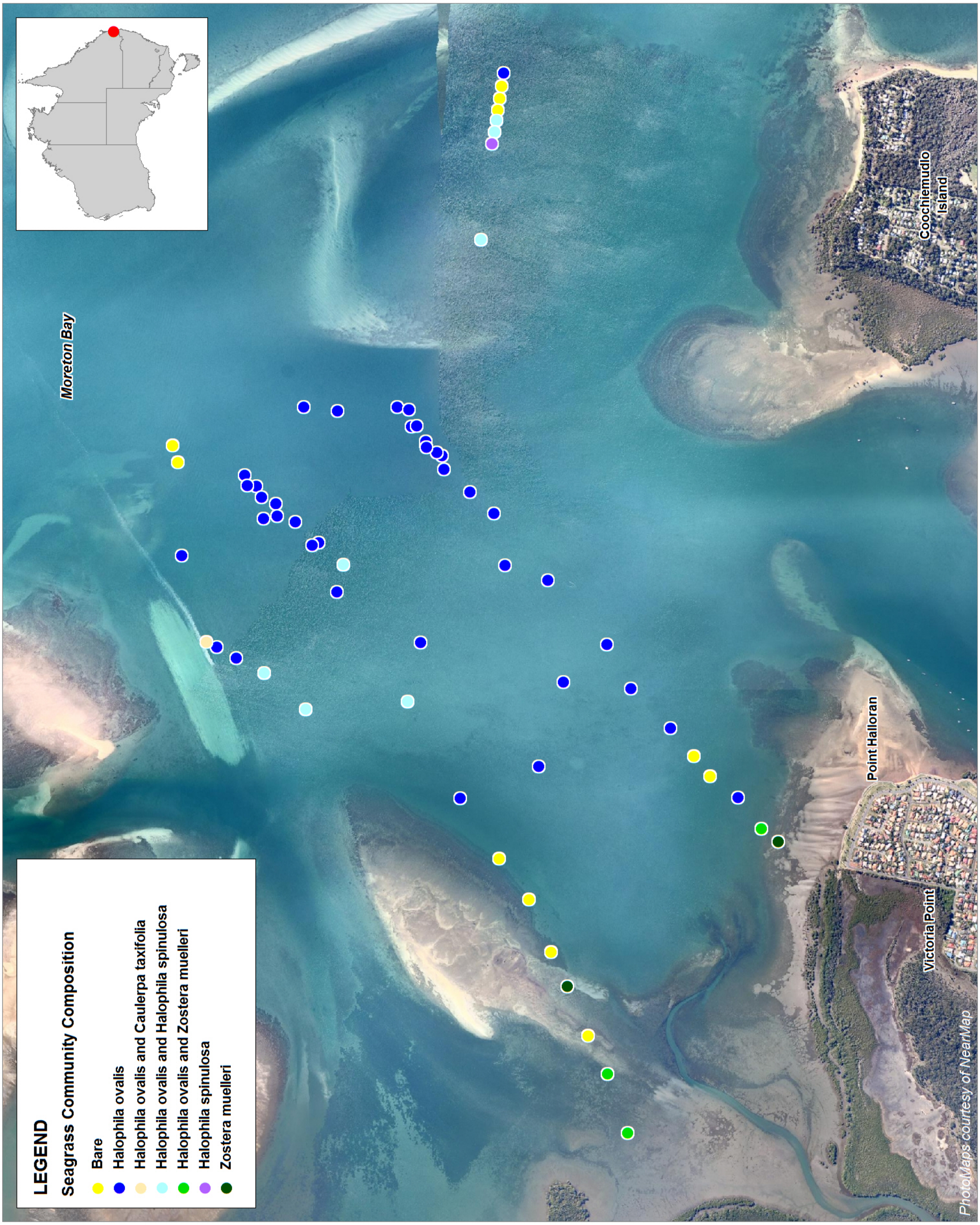
Title:
Broadscale Patterns in Seagrass Community Structure Adjacent to Manly

Figure: **A-1**

Rev: **A**

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_017_Seagrass_Composition_Manly.wor



Title:

Broadscale Patterns in Seagrass Community Structure Adjacent to Cleveland

Figure: A-2

Rev: A

N

0km 0.5 1

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17998_I_CP_PBC_Seagrass\DRW\ECO_016_Seagrass_Composition_Cleveland.wor

APPENDIX B: HISTORIC DISTRIBUTION AND COMMUNITY STRUCTURE OF SEAGRASS BEDS ADJACENT THE PORT OF BRISBANE

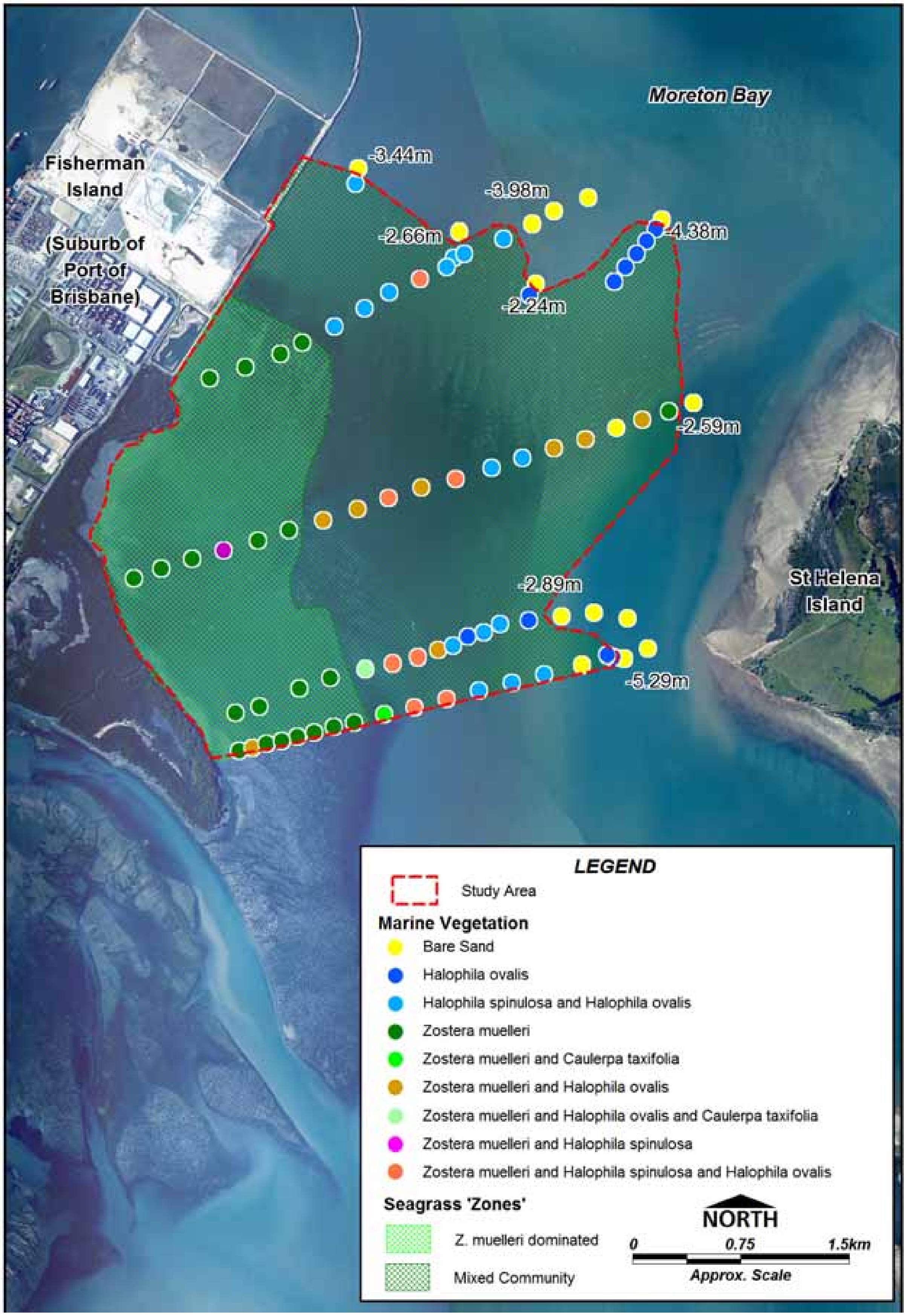


Figure B- 1 Distribution and community structure of seagrass adjacent the Port of Brisbane in July 2006

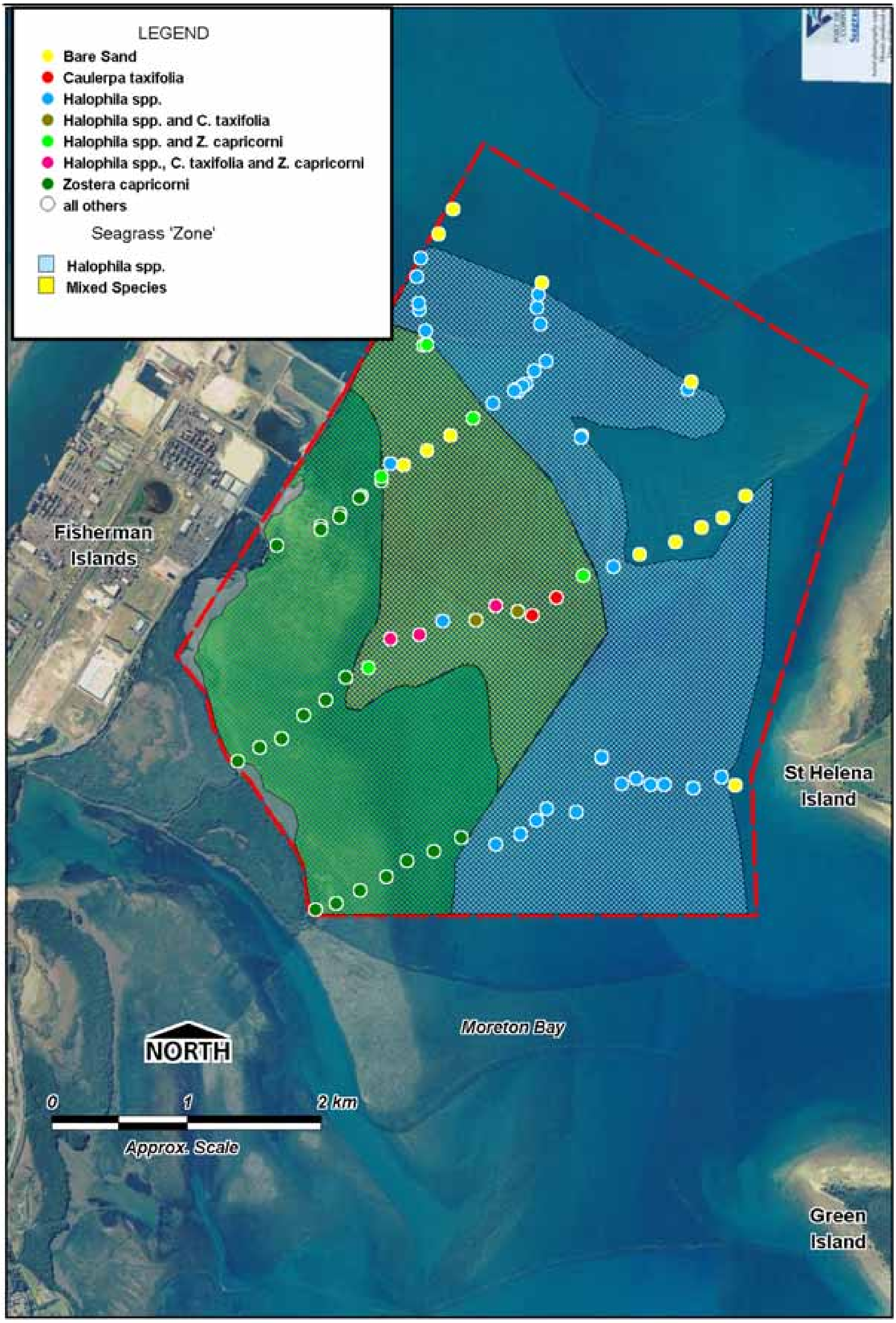
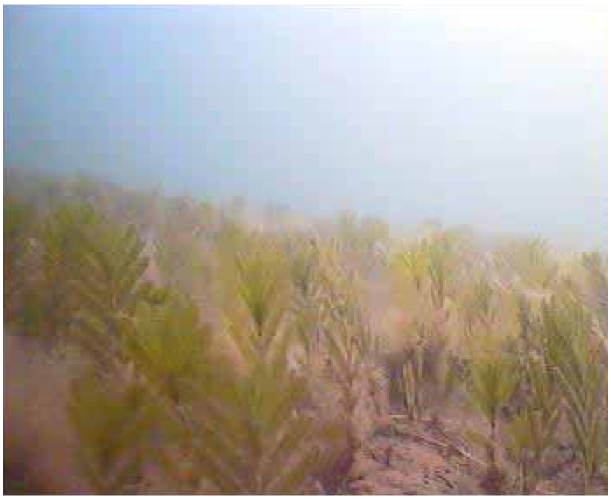


Figure B- 2 Distribution and community structure of seagrass adjacent the Port of Brisbane in August 2003

APPENDIX C: VIDEO IMAGERY SNAPSHOTS

mono-specific bed of *Zostera muelleri*

mono-specific bed of *Halophila ovalis*



mono-specific bed of *Halophila spinulosa*

mixed beds of *Z. muelleri* and *H. ovalis*

Z. muelleri mixed with *Caulerpa taxifolia*

mono-specific bed of *H. ovalis* on undulating sands

Figure C- 1 Seagrass assemblages recorded during July 2010

BMT WBM Brisbane	**Level 11, 490 Upper Edward Street Brisbane 4000** **PO Box 203 Spring Hill QLD 4004** **Tel +61 7 3831 6744 Fax +61 7 3832 3627** **Email wbm@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Denver	**14 Inverness Drive East, #B132** **Englewood Denver Colorado 80112 USA** **Tel +1 303 792 9814 Fax +1 303 792 9742** **Email wbmdenver@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Mackay	**Suite 1, 138 Wood Street Mackay 4740** **PO Box 4447 Mackay QLD 4740** **Tel +61 7 4953 5144 Fax +61 7 4953 5132** **Email wbmmackay@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Melbourne	**Level 5, 99 King Street Melbourne 3000** **PO Box 604 Collins Street West VIC 8007** **Tel +61 3 8620 6100 Fax +61 3 8620 6105** **Email wbmmelbourne@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Newcastle	**126 Belford Street Broadmeadow 2292** **PO Box 266 Broadmeadow NSW 2292** **Tel +61 2 4940 8882 Fax +61 2 4940 8887** **Email wbmnewcastle@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Perth	**1 Brodie Hall Drive Technology Park Bentley 6102** **Tel +61 8 9328 2029 Fax +61 8 9486 7588** **Email wbmperth@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Sydney	**Suite 206, 118 Great North Road Five Dock 2046** **PO Box 129 Five Dock NSW 2046** **Tel +61 2 9713 4836 Fax +61 2 9713 4890** **Email wbmsydney@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Vancouver	**1190 Melville Street #700 Vancouver** **British Columbia V6E 3W1 Canada** **Tel +1 604 683 5777 Fax +1 604 608 3232** **Email wbmvancouver@wbmpl.com.au** **Web www.wbmpl.com.au**