Annual Port of Brisbane Corporation Seagrass Monitoring Episode

July 2006

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Title :	Annual Port of Brisbane Corporation Seagrass Monitoring Episode
Author :	Dan Pedersen, Darren Richardson, Chris Pietsch
Synopsis :	This report presents findings from an ongoing annual seagrass monitoring since completion of the construction of the FPE Seawall at the Port of Brisbane. Results are presented for edge of seagrass bed monitoring, seagrass depth profiles and seagrass mapping at Fisherman Islands, undertaken during July 2006.

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EXECUTIVE SUMMARY

Introduction

The Port of Brisbane Corporation (PBC) has its main port infrastructure at Fisherman Islands, located at the mouth of the Brisbane River. The expansion of the Port involves the extension of the existing reclamation to provide additional quayline length of 1800 metres and an additional 230 hectares of reclaimed land. An Impact Assessment Statement (IAS) identified that turbid plumes could potentially be generated by the works resulting in impacts to sensitive marine ecological resources, in particular, seagrasses within the adjacent Moreton Bay Marine Park.

A seagrass monitoring program was implemented by the PBC to examine the effects of Future Port Expansion (FPE) during and following construction on adjacent seagrass communities. A pilot study identified the following techniques as suitable for ongoing monitoring of gross-scale changes to seagrass distribution in the Fisherman Islands area: (1) Biannual depth profile monitoring; (2) Quarterly edge of bed monitoring and (3) An annual mapping exercise at the Port of Brisbane. This report presents the findings of the first seagrass survey following completion of the FPE Seawall construction, using a combination of all methods described above. This report is next in a series of seagrass monitoring reports describing trends in seagrass extent and distribution at three locations in western Moreton Bay since 2002. Survey works for the present study were undertaken in July 2006.

Study Methods

Light is a major limiting factor of the maximum depth inhabited by seagrasses. Seagrass depth range was therefore selected as a key indicator of potential changes in water quality resulting from activities during FPE construction and subsequent operation.

Seagrass surveys for the Corporation have been undertaken since 2002. Seagrass surveys for this report were done between and inclusive of the 24 and 26 July 2006. Three locations were sampled: Fisherman Islands (hereafter referred to as the Port), which was designated a putative impacted location, and two control locations (Manly and Cleveland). Seagrasses adjacent to the Port of Brisbane, Manly and Cleveland Point all occur on broad intertidal and subtidal sand banks. During seagrass profiling two transects were sampled at each location, however, edge of seagrass bed monitoring utilised 4 transects at each of the control locations, and 5 transects at the Port.

At a number of points along each seagrass profile, edge of bed monitoring transect and seagrass mapping transect, the following parameters were recorded: time, water depth (using the survey vessel's sounder corrected for stage of the tide), position (using differential Global Positioning System, dGPS) and seagrass species. This data was used to generate plots of the broad-scale distribution and maximum depths inhabited by each seagrass species. A series of permanent edge of bed sampling points were also re-sampled and compared to results from previous surveys to track changes in the maximum depth range of seagrass.

Study Findings

The present study demonstrated that there have been no gross scale changes to the community structure of seagrass beds at Fisherman Islands since the FPE Seawall construction was completed in April 2005. Furthermore, seagrass species *Halophila ovalis*[1] appeared to have recolonised deeper subtidal areas of seabed that were unvegetated in April 2005, resulting in an expansion to the overall extent of seagrasses at Fisherman Islands since this time. It is also interesting to note that there was a reduction to the extent of potentially invasive green alga *Caulerpa taxifolia* since April 2005.

There was an increase to the extent of seagrass beds at the Port and Cleveland between April 2005 and July 2006. The seaward expansion of seagrass at these locations was consistent with a 1-2 metre increase in the maximum growing depth of the edge of deeper water seagrass beds comprised of *Halophila ovalis* and *H. spinulosa*. Patterns in seasonal seagrass expansion and retraction at the Port, Manly and Cleveland were generally consistent with the results of previous monitoring surveys in western Moreton Bay. The observed changes are likely to primarily reflect seasonal changes in turbidity associated with sediment re-suspension from prevailing fetch driven waves and/or rainfall/catchment flow. Prolonged periods of low water clarity during summer typically result in the loss or landward retraction of deeper water seagrass during summer (i.e. *Halophila* species), with delays in seagrass re-establishment until water quality improves during winter months.

Consistent broad-scale zonation patterns of seagrass species were observed among locations and time. *Halophila ovalis* typically formed the deepest beds of seagrass, while *Zostera muelleri*, a large, slow growing species that is tolerant of exposure, was typically found within the intertidal zone. Species zonation patterns are thought to be a function of different growth strategies, and tolerances to exposure and other environmental variables. Broad scale distribution patterns in seagrass at the Port of Brisbane monitoring location also remained stable over the long-term (measured in years), however, dramatic short-term (seasonal) changes in *H. ovalis* and *H. spinulosa* were observed in the sub-tidal zone.

Beds of the green marine algae *Caulerpa taxifolia* formed both mono-specific (e.g. Cleveland) and multi-species beds (the Port) during the present survey. *Caulerpa taxifolia* and seagrass mixed assemblages have been highly dynamic since the outset of the monitoring program, although there has been no net increase or decrease in either taxon. This is in contrast to studies of introduced populations of *C. taxifolia* in New South Wales and the Mediterranean, which have been shown to out-compete seagrasses, resulting in large-scale reductions to the extent of seagrasses.

It is notable that no floating or submerged beds of *Lyngbya majuscula* were recorded during the present study.

Conclusions and Recommendations

There has been a seaward expansion of seagrass at Fisherman Islands and Cleveland since April 2005. Interestingly, the Manly edge of bed monitoring location has displayed little evidence of longer-term recovery since the disappearance of the seagrass between the November 2003 and April 2004 monitoring episodes. It is possible that the loss of seagrass at Manly is a result of longer term changes to localised water quality conditions.

Overall, the present seagrass monitoring program has reported large retractions and expansions to the area of seagrass beds adjacent to the FPE Seawall, both during and following construction.

[1] It is recognised that seagrass species *Halophila ovalis* and *H. decipiens* both form deeper subtidal communities in western Moreton Bay. Given the very similar morphology and ecology of these species, and the fact that video transects do not provide a sufficiently detailed image to discern the two species, they are collectively referred to as *H. ovalis* in the text.

However, these patterns have been broadly consistent with results for sites distant (>5km) to the FPE Seawall and at control locations at Manly 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.

Several recommendations are made on the basis of the findings of this study. Four key recommendations are outlined below:

- 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 PBC 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 PBC to detect seasonal and inter-annual changes to the distribution and extent of seagrass beds, offering greater temporal resolution to the study.
- Manly edge of bed monitoring sites should be moved to a shallower location, given that no seagrass has been recorded at edge of bed transects at this location since November 2004.

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1 INTRODUCTION

1.1 Background

The Port of Brisbane Corporation (PBC) has its main port infrastructure at Fisherman Islands situated at the mouth of the Brisbane River. The Future Port Expansion (FPE) Seawall Alliance, (comprising Port of Brisbane Corporation (PBC), Leighton Contractors Pty Ltd (LCPL), Coffey Geosciences Pty Ltd (Coffey), Parsons Brinckerhoff Australia Pty Ltd (PB) and WBM Oceanics Australia), was created in 2002 to construct a rock seawall that would extend seaward on the existing Port of Brisbane reclamation area, providing an additional 1.8 kilometres of quay line and an additional 230 hectares of reclaimed land.

An Impact Assessment Study (IAS) and supplementary IAS (WBM Oceanics Australia 2000a; b) for the expansion of the Fisherman Islands port facilities was approved in June 2001 prior to the formation of the FPE Seawall Alliance.

Although the reclamation area itself is located outside the Moreton Bay Marine Park, the IAS identified that the proposed works may have effects on sensitive marine ecological resources within the Marine Park. Of most concern was the potential effect of plumes of turbid water on seagrasses. The Fisherman Islands seagrass beds have high fisheries habitat values as they are thought to represent the largest semi-contiguous seagrass meadow on the western side of Moreton Bay (Hyland, *et al.* 1989).

While no regulatory agency required monitoring of seagrass to be conducted as a condition of development approvals, the Port of Brisbane Corporation (PBC) implemented a seagrass monitoring program in line with overall Best Practice Environmental Management. Stages 1 and 2 of the FPE seagrass monitoring program were combined as a Pilot Study to develop and refine monitoring methods for the assessment of potential effects on seagrasses in the Fisherman Islands area and to collect baseline data prior to the commencement of construction.

The pilot study (WBM Oceanics Australia 2003) identified the following techniques as suitable for ongoing monitoring of gross-scale changes to seagrass distribution in the Fisherman Islands area:

- **Depth profiles**: biannual monitoring of species composition of seagrasses along transects extending approximately perpendicular to the shore, starting from the shallow edge of the bed of seagrass and extending beyond its outer limit.
- **Edge of bed assessments**: quarterly monitoring of the position of the outer edge of the bed of seagrass.
- **Mapping**: annual mapping of distribution of the seagrass using the latest available aerial photography provided by PBC and ground truthed during other components of the monitoring program.

The FPE seawall was completed in August 2005, and a final seawall construction phase seagrass monitoring episode was conducted by WBM Oceanics Australia in April 2005. Port of Brisbane Corporation plans to infill the reclamation area bounded by the constructed FPE seawall over the next 10-15 years.

The FPE Seawall has the potential to modify tidal current dynamics within a localised area at Fisherman Islands, and the direction of freshwater flows from the Brisbane River. These changes could result in localised changes to the extent and distribution of seagrasses within the Fisherman Islands area. PBC has therefore decided to undertake a seagrass monitoring programme to monitor changes in seagrass distribution, extent and abundance.

This report presents the findings of the July 2006 survey works and builds on information collected to date. This survey is the first annual monitoring episode following completion of construction of the FPE seawall. The study was comprised of: (i) an edge of bed assessment; (ii) seagrass depth profiling; and (iii) a mapping exercise at the Fisherman Islands seagrass area.

1.2 Study Aims and Objectives

The broad aim of this study is to identify potential impacts of the Future Port Expansion (FPE) seawall development during construction and infilling phases on the distribution and extent of nearby seagrass beds. The specific objectives of this study are to:

1. 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 Fisherman Islands and control areas remote from activities from the FPE;
2. Determine whether broad-scale spatial and/or temporal patterns in seagrass extent are consistent among Fisherman Islands and control areas remote from activities at the FPE;
3. On the basis of the above, identify possible broad-scale operational impacts of the FPE on the distribution and extent of seagrass beds at Fisherman Islands.

1.3 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). The port facilities at the 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 (3rd largest capital city port in Australia) and exists as an area of approximately 975 hectares of reclamation either complete and in use, or under progressive filling within the existing perimeter bund (WBM Oceanics Australia 2000; 2005).

Construction of the present day port facilities over of 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 southern 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. Currently, there are 1,137 wetland sites included in the Ramsar list of Wetlands of International Importance, which recognises those areas extremely important to biodiversity conservation and in general of significance to the "well being of human communities".

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).

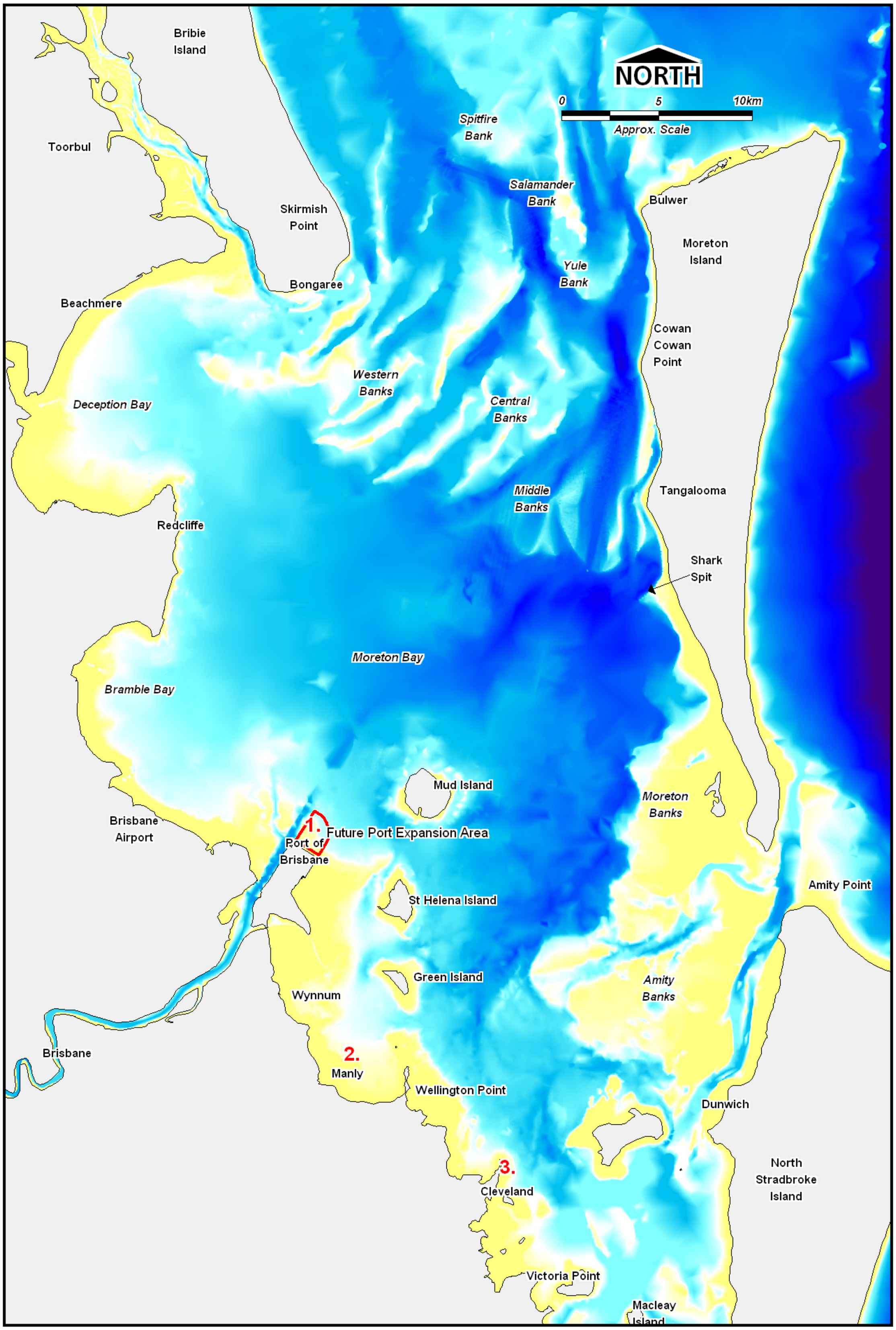


Figure 1-1 Location of the Port of Brisbane within Moreton Bay

2 STUDY 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 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[2] (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 north-easterly (typically summer months) and south-easterly winds (typically winter months), 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.

Seagrasses 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).

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

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

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 Queensland Environmental Protection Agency 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

Edge of bed monitoring sites was surveyed between 24 and 26 July 2006.

During the pilot study (WBM 2002), edge of seagrass bed monitoring sites were established at Fisherman Islands (putatively impacted 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 2003), 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 2-2), 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 WBM. At sites where poorer water quality was encountered, it was necessary to assess the seabed directly, so a number of van Veen grabs were used to collect samples of the seabed to confirm the video image.

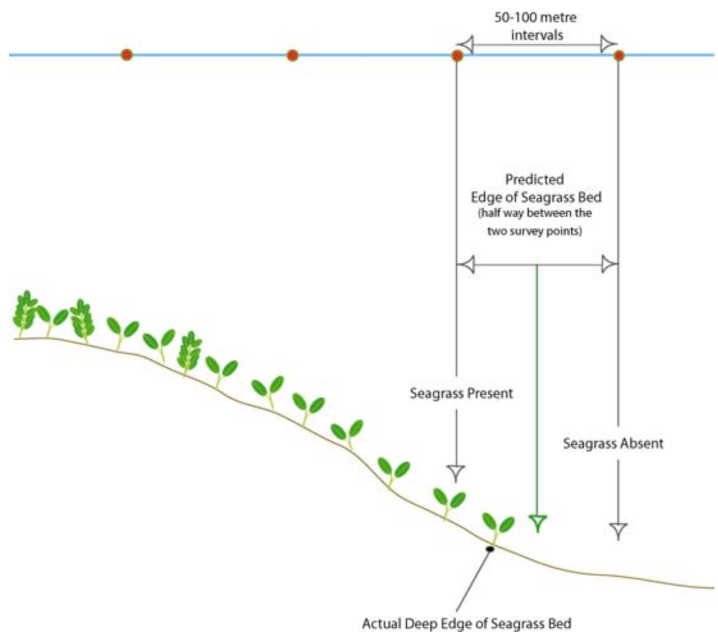


Figure 2-1 Permanent survey point method for identifying the edge of seagrass bed

The survey would begin at a shallow survey point where seagrass was thought to be present. The survey vessel then moved to the next deeper 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

Seagrass depth profiles were surveyed between 24 and 26 July 2006.

During the pilot study (WBM 2002), seagrass depth profile monitoring sites were established at Fisherman Islands (putatively impacted 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.

Two depth profile transects occur at each survey locations, 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 at Fisherman Islands

The seagrass mapping exercise at Fisherman Islands was conducted on 25 July 2006.

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 Fisherman Islands (Figure 2-3). 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.

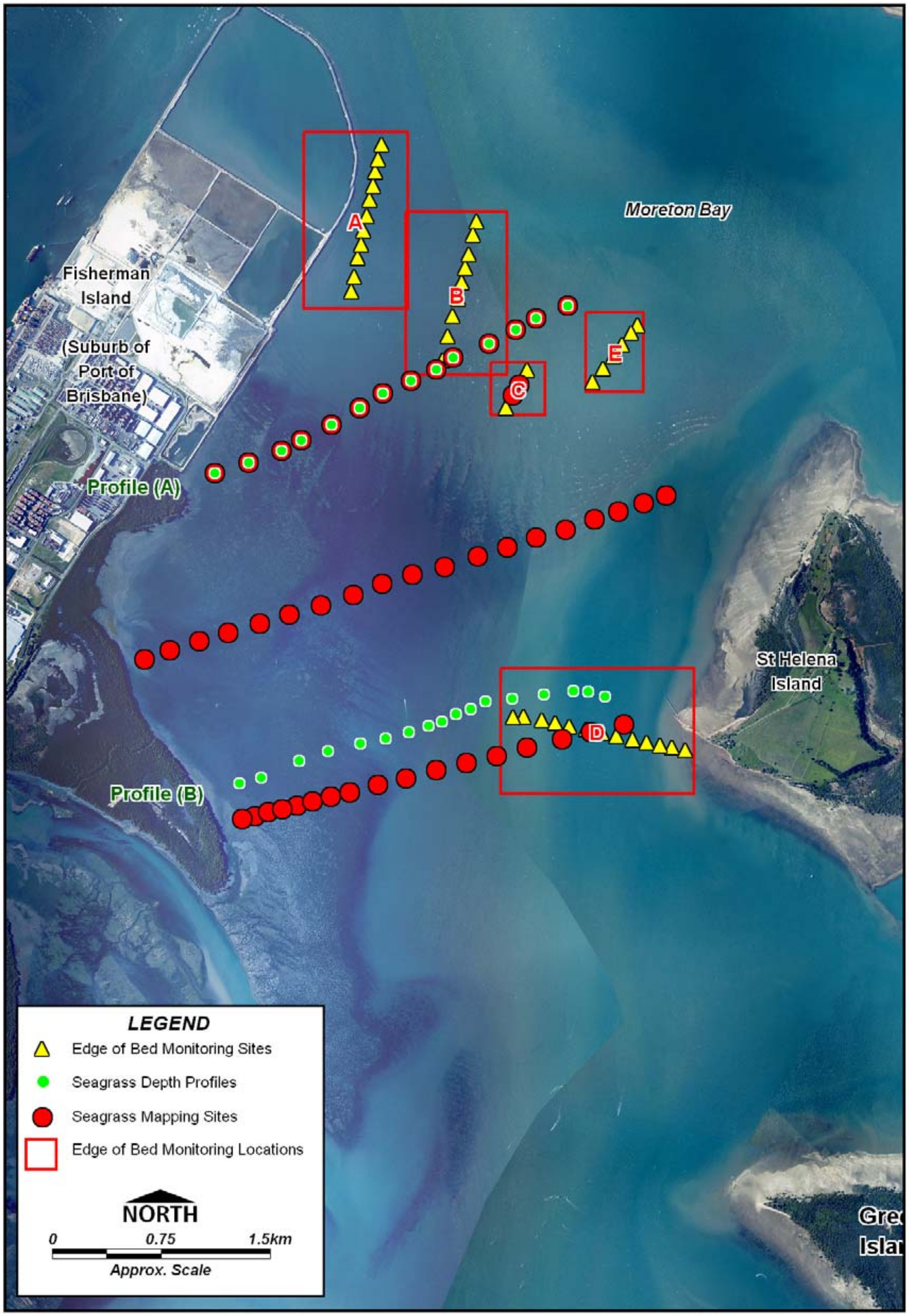


Figure 2-2 Seagrass survey points (edge of bed; depth profiles; seagrass mapping) used to map the distribution and extent of seagrass beds at Fisherman Islands.

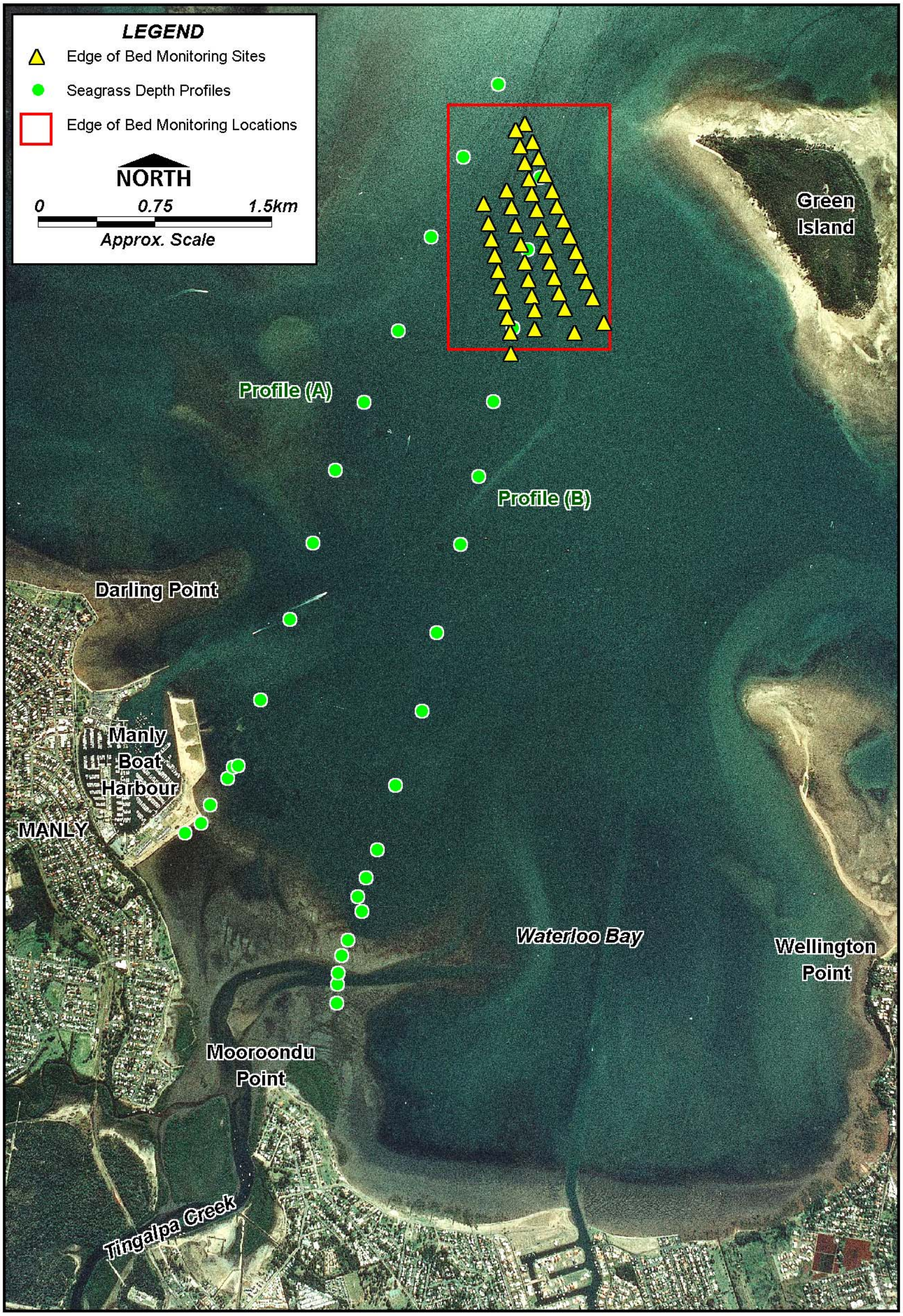


Figure 2-3 Seagrass depth profile and edge of bed monitoring locations at Manly, Waterloo Bay.

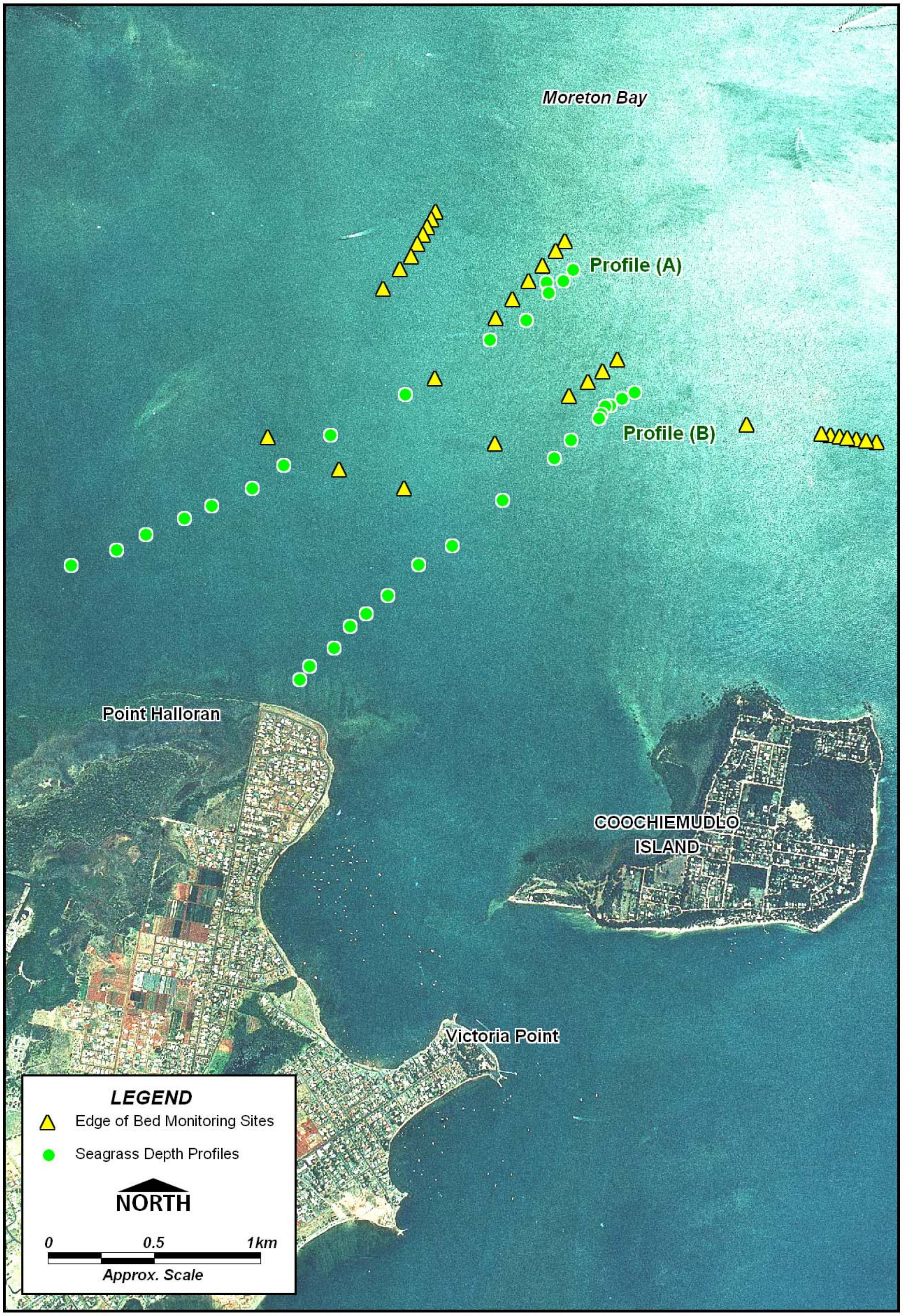


Figure 2-4 Seagrass depth profile and edge of bed monitoring locations at Cleveland

2.4 Calculating the Depth of Seagrasses

In order to compare the depth of seagrass beds between survey points within and among locations, recorded depths required to be referenced to a fixed point in time and space. The Australian Height Datum (AHD) was selected as the most suitable reference point to standardise all depth information collected during the monitoring study.

Tidal heights recorded at the Brisbane River Bar for each survey period were required to reference depths to AHD. This information was obtained from Maritime Safety Queensland on 14 August 2006 for the period extending between the 23 and 26 July 2006. The depth of each survey point at Fisherman Islands was calculated according to methods shown in Figure 2-5.

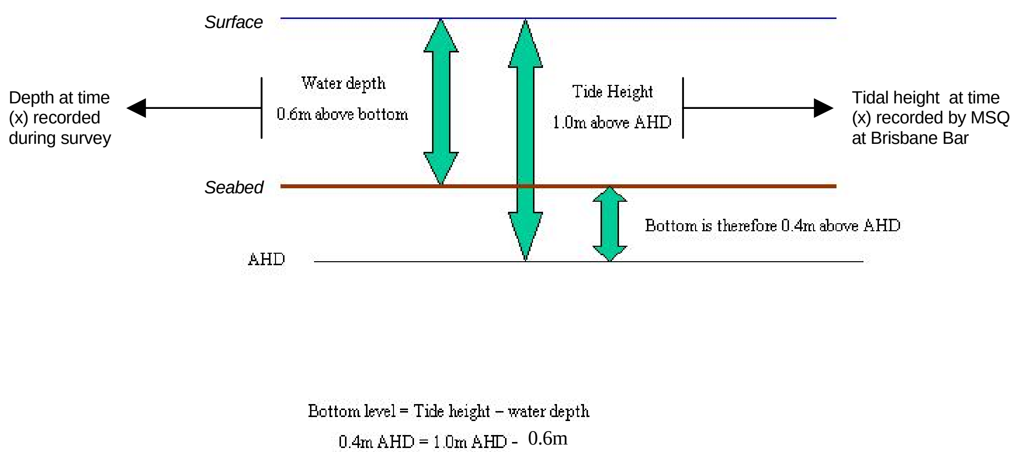


Figure 2-5 Example of method for calculating seabed depths at Fisherman Islands from tidal heights recorded by Maritime Safety Queensland at the Brisbane Bar

2.5 Data Limitations

The intent of the present monitoring study since its inception in May 2003 has been to identify and describe broad patterns in seagrass distribution and deeper water seagrass extent over time at Fisherman Islands, and to compare these patterns with those at two control locations distant from the Port of Brisbane. This study was not designed nor intended to provide quantitative information on changes in seagrass distribution and does not consider changes to seagrass bed characteristics (e.g. seagrass biomass and density). The current study therefore provides information on whether there has been a gross scale change in seagrass communities that may have occurred as a result of the FPE Seawall construction and operation.

3 RESULTS

3.1 Seagrass Depth Profiles

Figure 3-1 to Figure 3-6 show a conceptual representation of seagrass along replicate depth profiles (A & B) at each study location: Port of Brisbane, Manly and Cleveland. Map views of each seagrass profile are shown in Appendix A. Maximum recorded growing depths of seagrass species during depth profiling at Port of Brisbane, Manly and Cleveland during the July 2006 survey are displayed in (Table 3-1).

Key patterns in the distribution of seagrass species at seagrass depth profiles during the July 2006 sampling occasion are as follows:

- The maximum growing depths[3] of seagrasses was greatest at Cleveland (-5.89m), followed by Port of Brisbane (-3.82m) and Manly (2.65m) seagrass depth profiles respectively.
- *Halophila ovalis*[4] was generally the deepest recorded seagrass species at all seagrass profiles in July 2006, growing to a maximum recorded depth of 5.89m at Cleveland (Profile A);
- *Zostera muelleri* consistently comprised the shallowest growing seagrass species, typically forming a mono-specific bed at the seaward edge of mangroves, and extending down to - -2.22 metres.
- *Caulerpa taxifolia* was recorded at multiple sites at Cleveland (Profile B) and one site at the Port of Brisbane (Profile B) in July 2006, growing to a maximum depth of -2.46m and -1.35m at these locations respectively. At Cleveland, this alga was recorded as a mono-specific bed but also amongst other seagrass species towards the upper and lower depth limits of its distribution. At the Port of Brisbane, this alga formed a mixed species community with seagrass species *H. ovalis, H. spinulosa and Z muelleri*.

The most notable changes in seagrass community structure and extent over time amongst May 2003, April 2005 and July 2006 sampling episodes, are summarised as follows:

- Overall, the most notable change to the extent of seagrasses occurred at Manly where a large area (>2km in linear extent) of subtidal seagrass disappeared between November 2003 and February 2004. This large subtidal area of seagrass was also absent during both April 2005 and July 2006 surveys;
- Between April 2005 and July 2006, there was a small increase to the extent of seagrass beds at Manly (A), while there was small reductions to the extent of seagrasses at Profile B;

[3] All depths referred to in this document are in metres relative to Australian Height Datum (AHD)

[4] [4] It is recognised that seagrass species *Halophila ovalis* and *H. decipiens* form deeper subtidal communities in western Moreton Bay. Given the very similar morphology and ecology of these species, and the fact that video transects do not provide a sufficiently detailed image to discern the two species, they are collectively referred to as *H. ovalis* in the text.

- Shifts in the distribution and extent of *C. taxifolia* have occurred at the Port of Brisbane depth profile 'A', where a shallow subtidal community dominated by *C. taxifolia* in May 2003 was replaced by a community comprised of *H. ovalis* and *H. spinulosa* in April 2005 and July 2006. Profile B showed a similar reduction in the extent in *C. taxifolia* over time with only one site containing this alga in 2006, compared to four sites in 2003.

- *Caulerpa taxifolia* was recorded at Manly during November 2003 (Profile 'B'), but was not recorded at any other time at this location (profile data for November 2003 not shown).

- There was an increase to the extent of seagrasses at the Port of Brisbane (A) and Cleveland (A & B) with corresponding increases in the maximum growing depth of these seagrass beds between April 2005 and July 2006;

- Beds of *H. spinulosa* present at Cleveland (Profile 'A & B') in 2003 were replaced by sparse meadows of *H. ovalis* in April 2005. In July 2006 the distribution of *H. ovalis* had expanded, particularly in deeper waters;

- Large shifts in community structure of subtidal seagrass beds were recorded at all locations.. At the Port of Brisbane (Profile 'B') the *H. spinulosa* / *C. taxifolia* assemblage present in 2003 was replaced by another multi-species assemblage in April 2005, comprising *H. ovalis*, *H. spinulosa* and *Z. muelleri* and further recorded in 2006.

- Despite large spatial variations in the extent of deeper water seagrasses, there were no major shifts in the depth distribution of intertidal beds of *Z. muelleri* over time at all locations.

Table 3-1 Maximum recorded growing depths of seagrass species[5] during depth profiling at Port of Brisbane, Manly and Cleveland during the July 2006 survey.

Location	Profile	Seagrass Species	Max. Growing Depths
Cleveland	**A**	**Ho**	**-5.887**
		Zc	-1.296
	B	**Ho**	**-5.73**
		Zc	-0.57
		Ct	-2.46
		Hs	-3.16
Manly	**A**	**Hs**	**-2.645**
		Ho, Zc	-2.227
	B	**Zc**	**-2.083**
		Ho	-0.391
Port of Brisbane	**A**	**Ho**	**-3.818**
		Hs	-3.818
		Zc	-1.963
	B	**Ho**	**-2.569**
		Hs	-2.469
		Zc	-1.264

[5] *Ho = Halophila ovalis; Zc = Zostera capricorni; Ct = Caulerpa taxifolia; Hs = Halophila spinulosa*

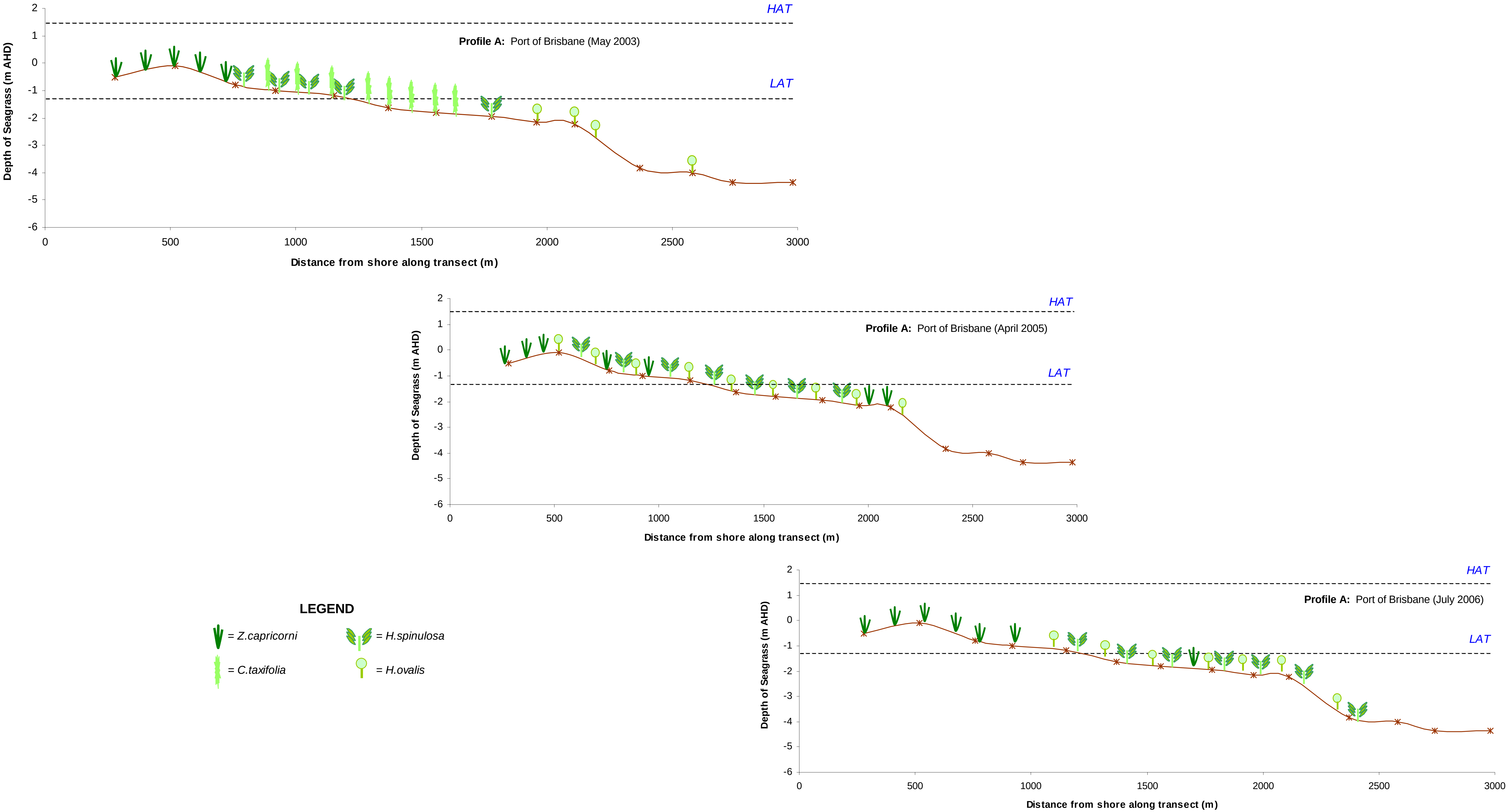


Figure 3-1 Seagrass Depth Profile 'A' – Port of Brisbane (April 2005 and May 2003)

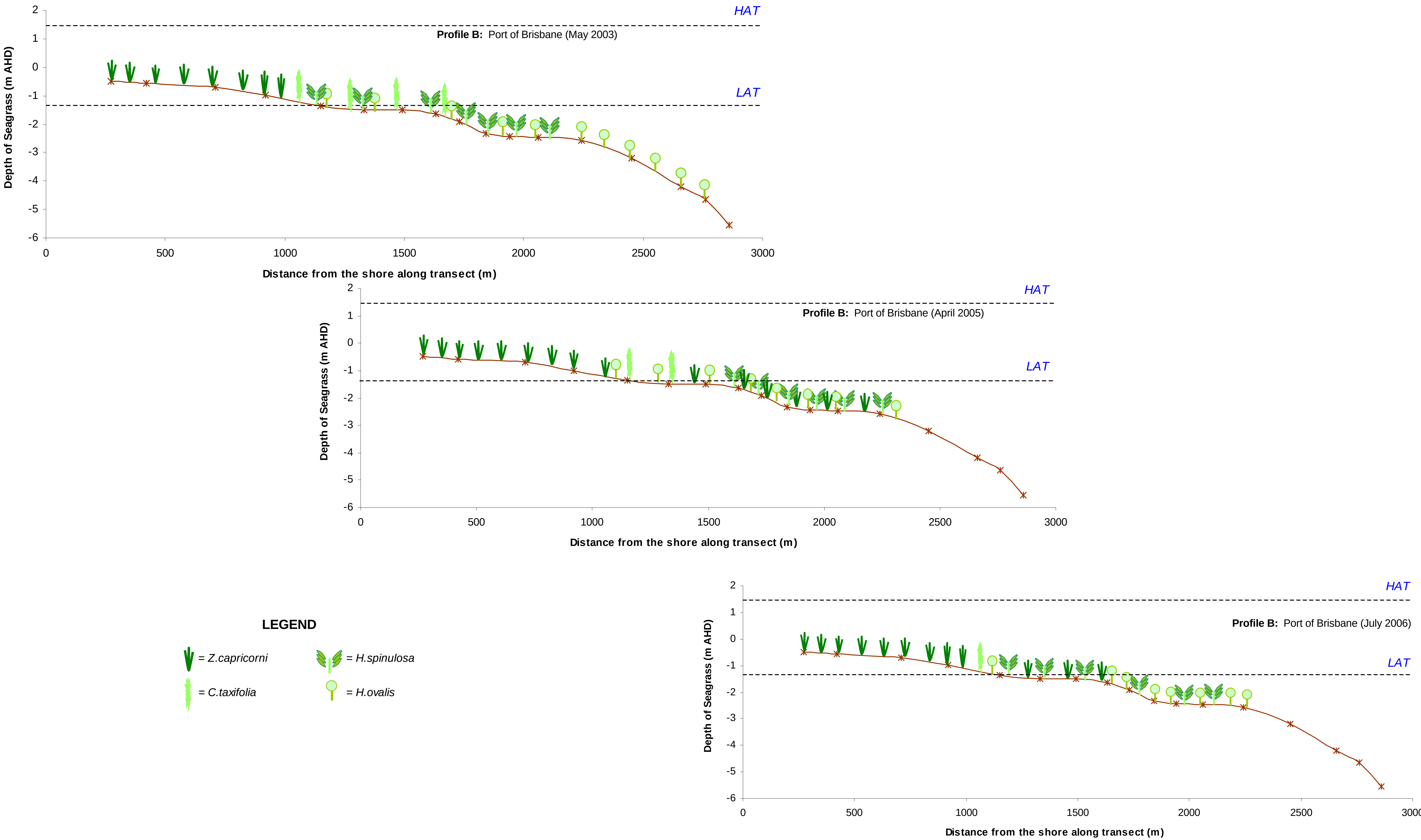


Figure 3-2 Seagrass Depth Profile 'B' – Port of Brisbane (April 2005 and May 2003)

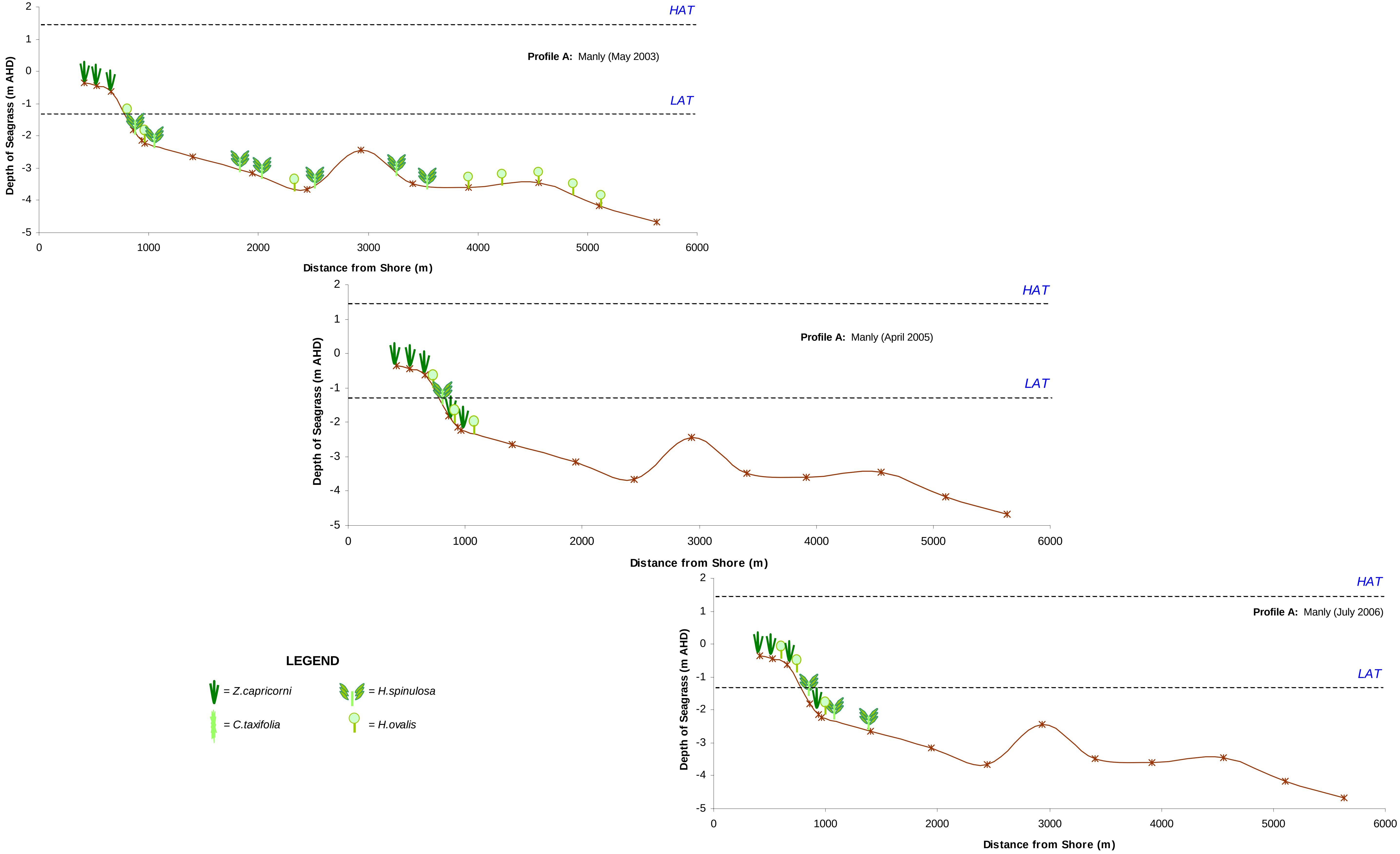
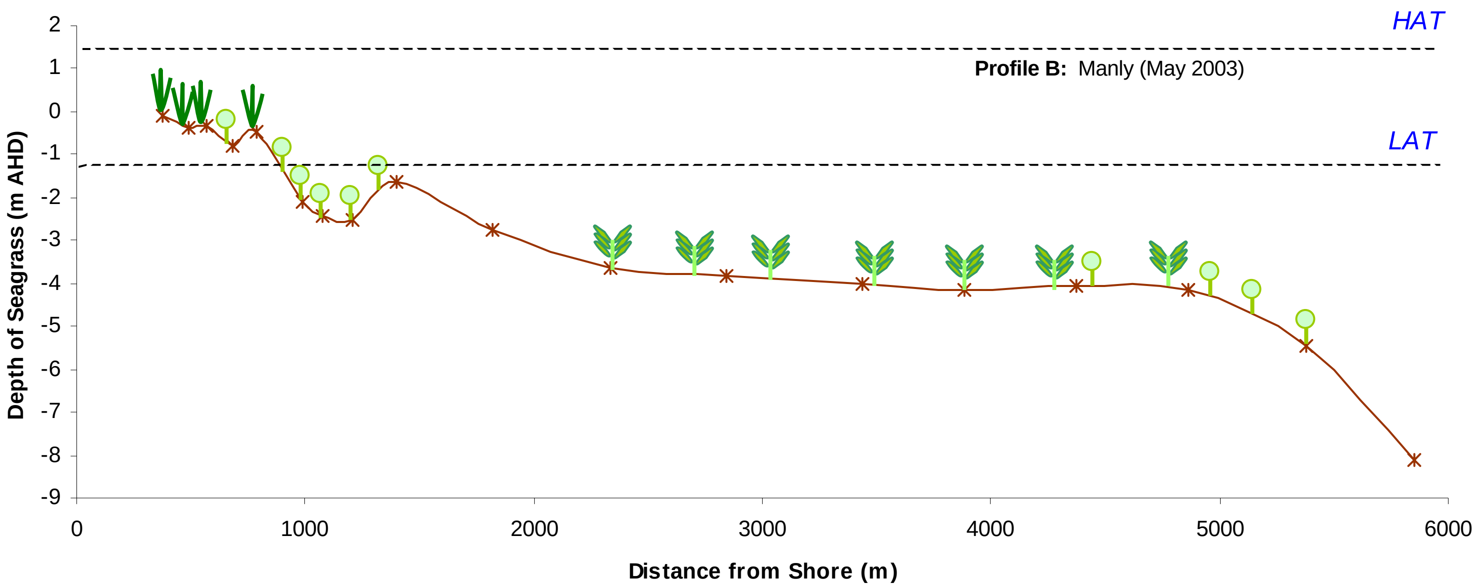
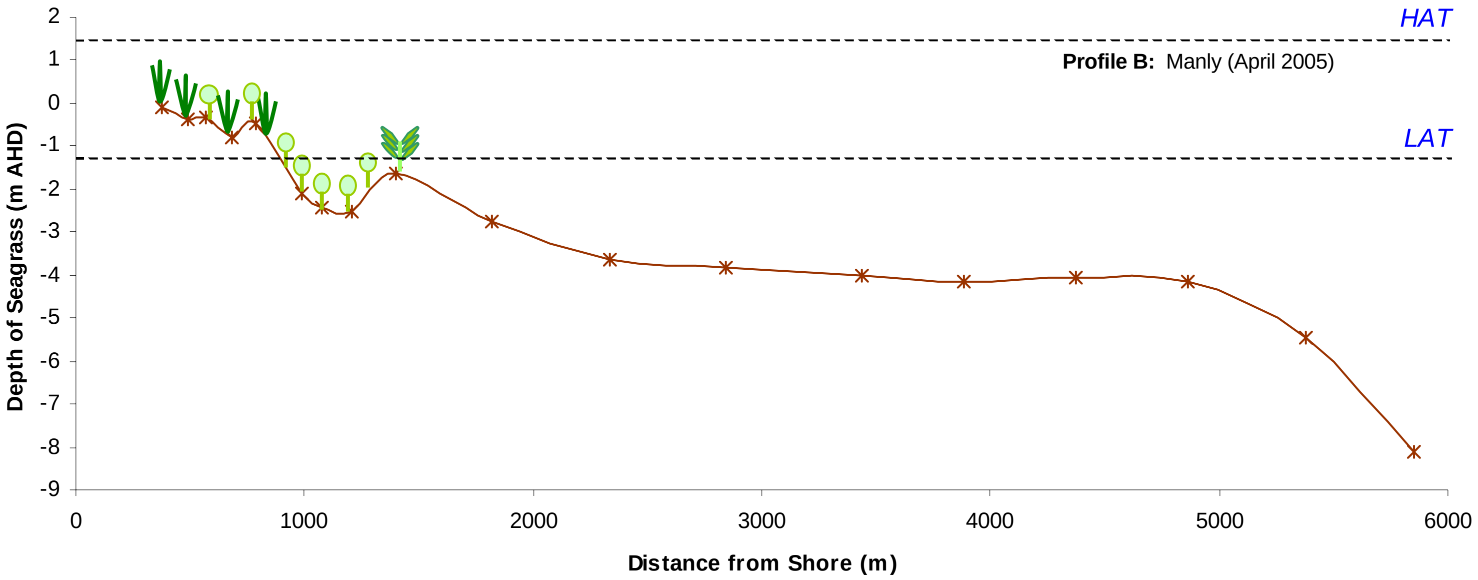
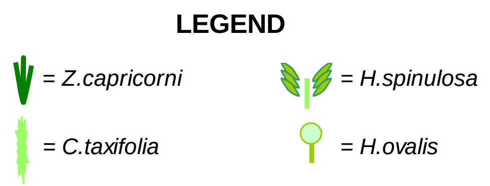


Figure 3-3 Seagrass Depth Profile 'A' – Manly (April 2005)







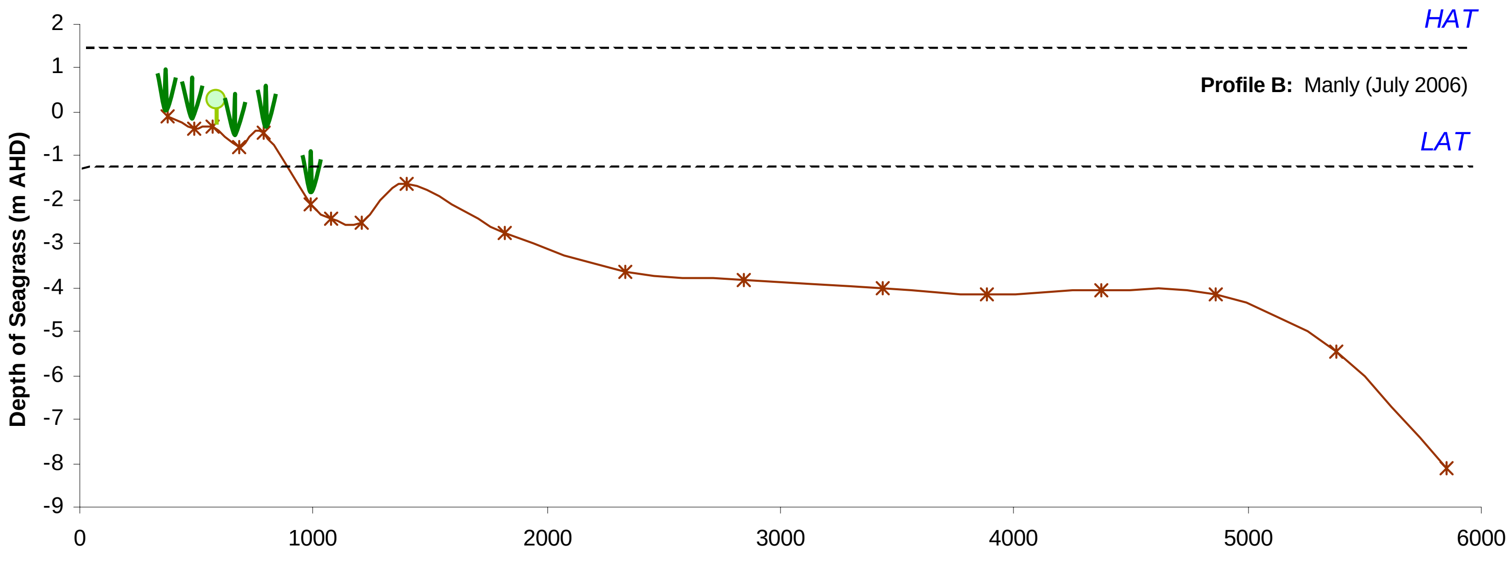


Figure 3-4 Seagrass Depth Profile 'B' – Manly (April 2005)

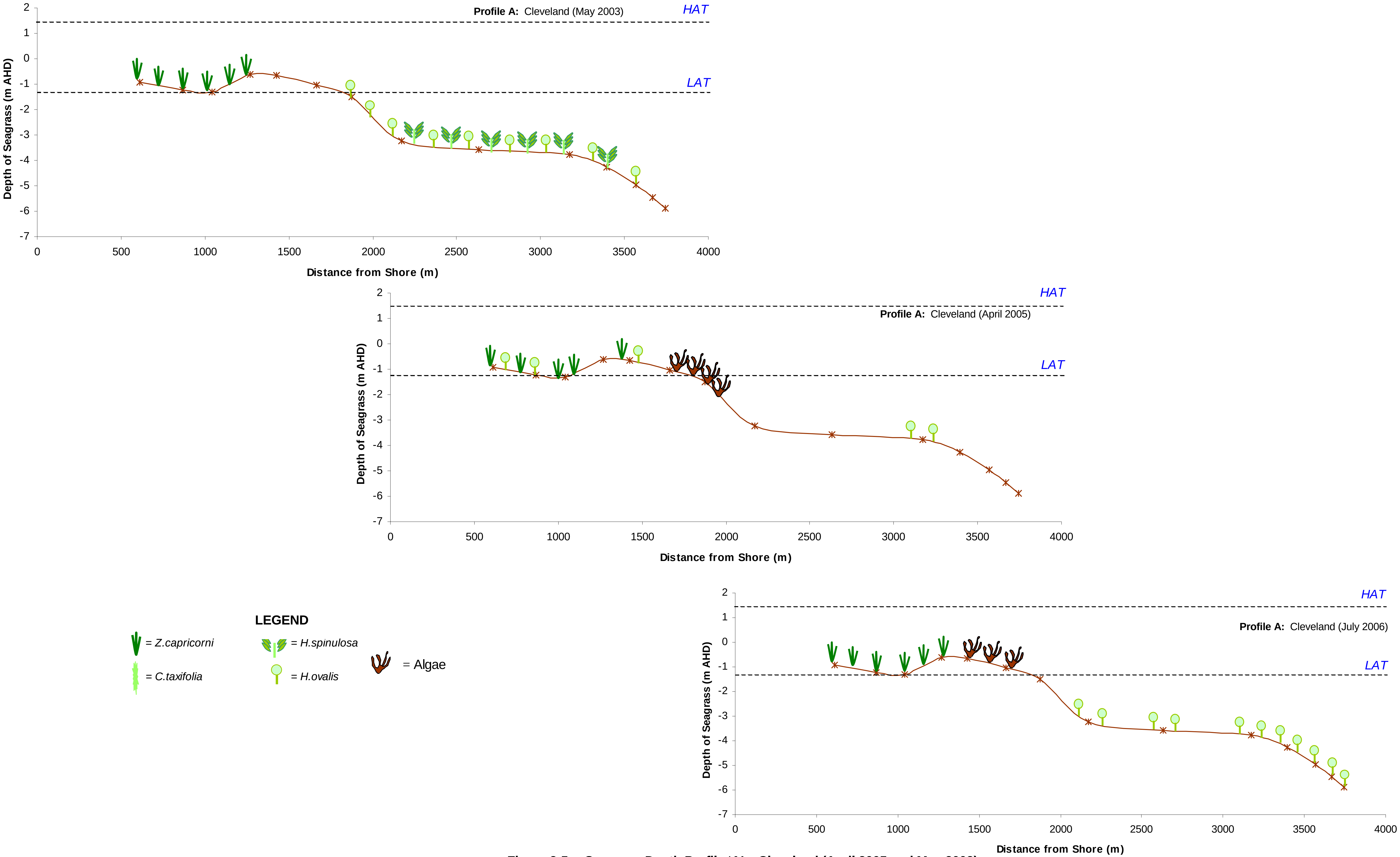


Figure 3-5 Seagrass Depth Profile 'A' – Cleveland (April 2005 and May 2003)

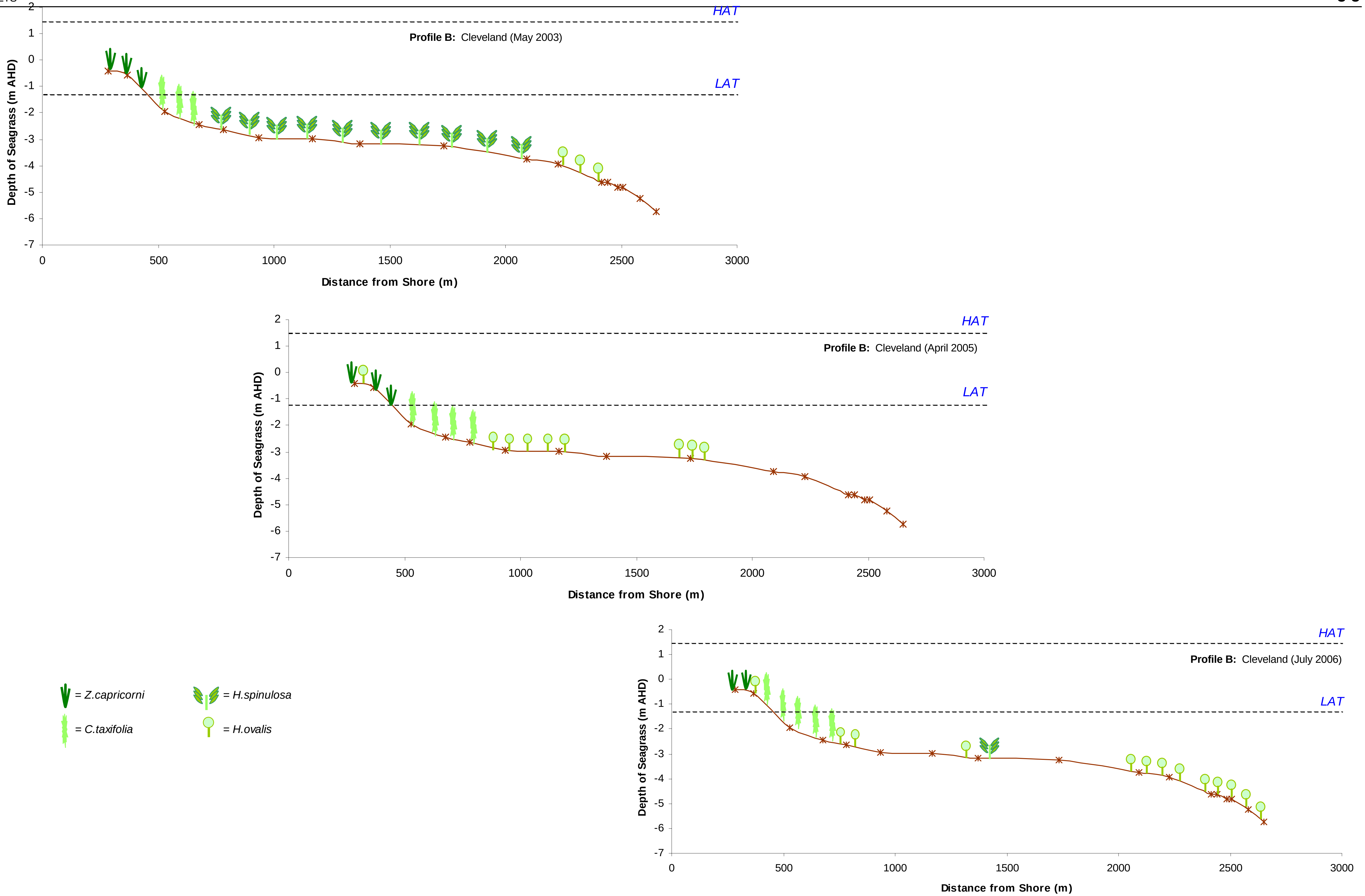


Figure 3-6 Seagrass Depth Profile 'B' – Cleveland (July 2006; April 2005; May 2003)

3.2 Monitoring the Edge of Bed

Water depths[6] of the seaward (deep) edge of seagrass beds at the Port of Brisbane, Manly and Cleveland between May 2003 and July 2006 are shown in Figures 3-7 to 3-9. These results[7] are displayed in maps (plan view) in Appendix B for the Port of Brisbane and Cleveland only. Seagrasses were not recorded at Manly edge of beds sites during this survey period.

Key findings of edge of bed monitoring for July 2006 and patterns over time are provided below:

- There was an increase to the extent of seagrass beds at three Port of Brisbane (A, D & E) and two Cleveland edge of bed monitoring sites between April 2005 and July 2006';
- The seaward expansion of seagrass at the Port of Brisbane and Cleveland was consistent with a 1-2 metre increase in the maximum growing depth of the edge of seagrass beds at these locations.
- Seagrass was absent from the Manly edge of bed monitoring sites in July 2006, and was last recorded at this location in November 2003. This is the fourth consecutive monitoring episode that seagrass was absent from the Manly monitoring location;
- The remainder of monitoring sites at the Port of Brisbane and Cleveland showed no change in maximum seagrass growing depths;
- Maximum growing depths were greatest at Cleveland (-6.62m, site 'A') followed by the Port of Brisbane (-5.20m, site 'D'),
- Overall, 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;
- The July 2006 survey recorded the greatest range of seagrass edge depth across sites among monitoring locations during a single sampling period; and
- Edge of bed monitoring location 'C' at the Port of Brisbane and 'D' at Cleveland has maintained a relatively constant depth over time. Site 'C' is located across a shallow sand spit subject to wave action, while Site 'D' traverses a boating channel;
- There was a notable reduction to the extent of seagrass beds at the Port of Brisbane and Cleveland between November 2004 and the April 2005 monitoring episodes.

[6] All water depths referred to in the text, are relative to Australian Height Datum.
[7] It should be noted that the edge of bed monitoring surveys provides only indicative information on the maximum depth of seagrass (at fine scales). For instance, there can be a pronounced change in depth over a short distance thereby limiting the precision of any estimate of maximum depth.

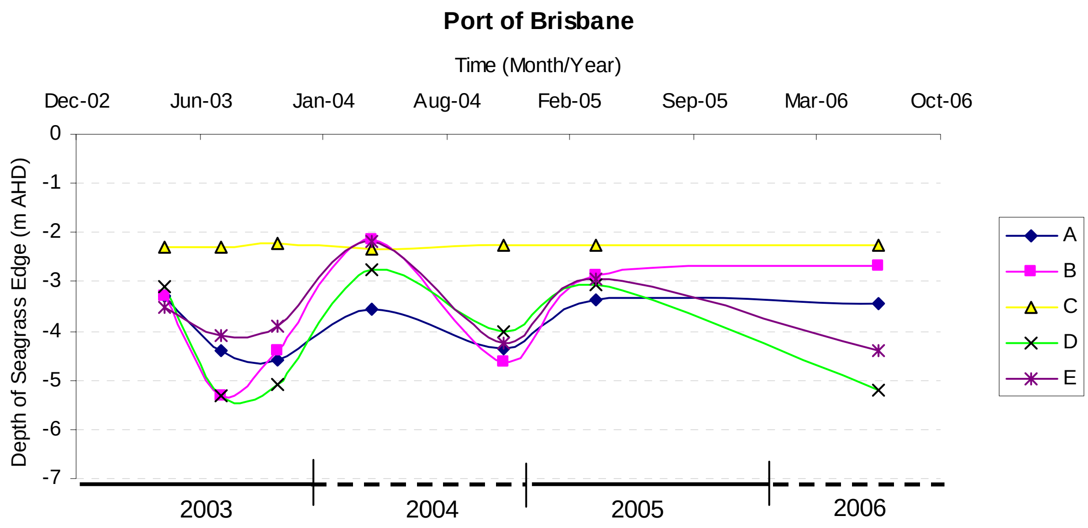


Figure 3-7 Depth of the seaward (deep) edge of the seagrass bed at the Port of Brisbane between May 2003 and July 2006 (depth in metres relative to AHD)

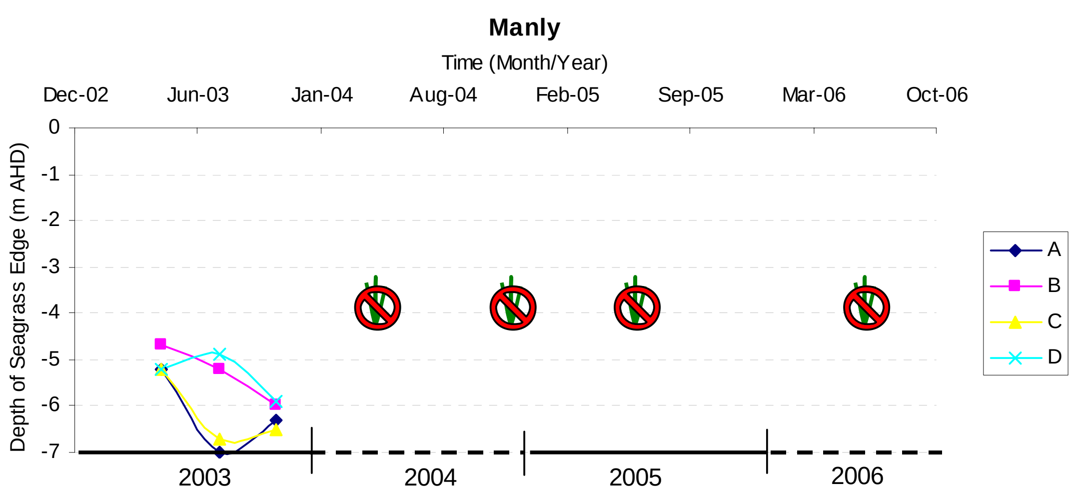


Figure 3-8 Depth of the seaward (deep) edge of the seagrass bed at Manly between May 2003 and July 2006 (depth in metres relative to AHD)

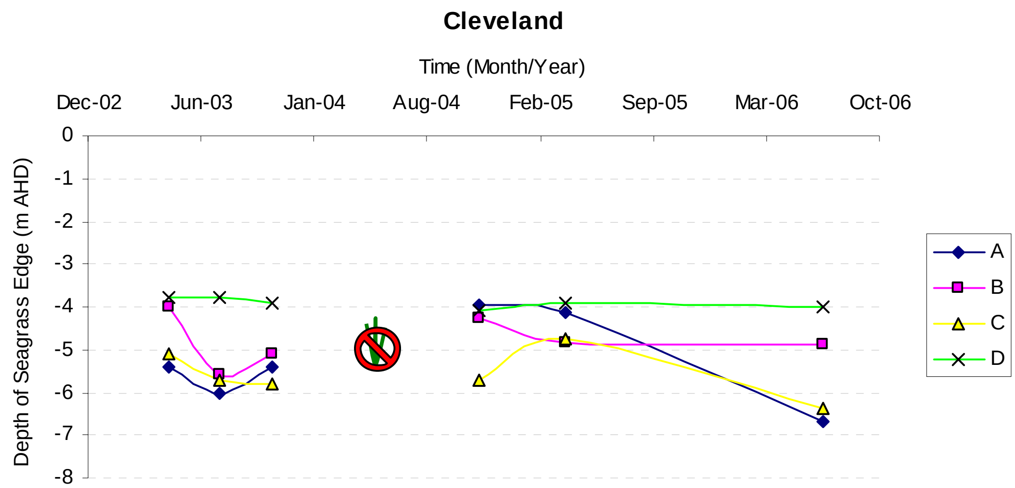


Figure 3-9 Depth of the seaward (deep) edge of the seagrass bed at Cleveland between May 2003 and July 2006 (depth in metres relative to AHD)

3.3 Seagrass Mapping at Fisherman Islands

Figure 3-10 shows the distribution and maximum growing depths of seagrasses at Fisherman Islands (adjacent to the Port of Brisbane) incorporating information collected in seagrass edge of bed, depth profile and mapping transects.

Key patterns in the seagrass mapping across the Fisherman Islands tidal flats are discussed below:

- Approximately 80 points were surveyed across the Fisherman Islands tidal flats, recording three seagrass species (*Z. muelleri, H. ovalis, H. spinulosa*) and one species of green alga of interest namely, *C. taxifolia*;

- *Halophila ovalis* and *H. spinulosa* formed the seaward edge of the Fisherman Islands seagrass bed;

- *Zostera muelleri* formed the landward edge of the seagrass bed adjacent to the Fisherman Islands mangrove fringe. This species comprised a mono-specific bed which was approximately 1.3 kilometres at its widest point. Seaward of this zone was a mixed species community, which showed no defined 'zones' or patterns in seagrass depth distribution;

- Maximum growing depths of seagrasses across intertidal and sub-tidal areas of Fisherman Islands were variable, ranging between -2.2 and -5.29 metres[8]. *Halophila ovalis* was the deepest recorded seagrass species at Fisherman Islands, growing at a maximum depth of -5.29m;

- The extent of seagrass in August 2003 was considerably larger than recorded in July 2006, which was attributable to the greater maximum growing depth of seagrass species *H. ovalis* (refer to Appendix C).

[8] All depths referred to in the text are relative to Australian Height Datum

Figure 3-10 Seagrass mapping exercise at Fisherman Islands, July 2006. Depths of the edge of bed shown on this figure are relative to Australian Height Datum (AHD)

4 DISCUSSION

The present monitoring program was designed to monitor any gross-scale changes to the seagrass distribution and extent of seagrasses adjacent to the FPE Seawall, comparing these to control locations in western Moreton Bay.

The specific objectives of this study (as per section 1.2) were to:

1. 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 Fisherman Islands and control areas remote from activities from the FPE;
2. Determine whether broad-scale spatial and/or temporal patterns in seagrass extent are consistent among Fisherman Islands and control areas remote from activities at the FPE;
3. On the basis of the above, identify possible broad-scale operational impacts of the FPE on the distribution and extent of seagrass beds at Fisherman Islands.

The following Sections (4.1 and 4.2) discuss these objectives in terms of the monitoring program results, while Section 4.3 draws conclusions as to potential versus actual impacts of the FPE Seawall development.

4.1 Spatial Patterns in the Distribution of Seagrasses

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: *Zostera muelleri*, *Halophila ovalis* and *Halophila 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. In Waterloo Bay (i.e. Manly and Port sites). *Halophila ovalis* was regularly recorded interspersed with *Z. muelleri* communities in the lower intertidal zone.

Since the outset of the monitoring program, *Halophila ovalis* has consistently formed the deepest edge of seagrass beds, growing in depths ranging between –7 and –0.5m metres. In July 2006, this species was recorded in depths ranging between –0.5 and -5.3m. 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 are very different at each monitoring location (Port, Manly, Cleveland). Seagrass assemblages adjacent to Fisherman Islands occur over broad intertidal and subtidal sand and mud banks, which have gradual bathymetric profiles and consistent gradients in sediment particle size with depth. The only exception to this is the large shallow sand spit that extends to the north-east of Fisherman Islands, and is largely exposed to wave action. This area has consistently contained very little seagrass. Overall, the primary driver of seagrass depth distribution is likely to be light availability at Fisherman Islands.

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 was that the depth distribution of seagrass species was inconsistent between sites, and often reflected changes in sediment quality and other factors (e.g. exposure to wave resuspension/ boat wash and channels) rather than being driven entirely by light availability.

Despite this, seagrass has consistently grown at greater depths at Cleveland and Manly (prior to its disappearance) than at Fisherman Islands. In July 2006, *Halophila ovalis* was recorded at a depth of -6.2m at Cleveland, while the maximum recorded depth of seagrasses at Fisherman Islands was -5.29m. This spatial variation in maximum growing depths may be due to the greater exposure of the Fisherman Islands seagrass area to higher levels of wave resuspension and associated higher levels of turbidity (see following section for more discussion on turbidity). Furthermore, Fisherman Islands is situated at the mouth of the Brisbane River, Moreton Bay's largest river catchment. This location would therefore experience consistently higher levels of turbidity through pulsed or periodic flows, which would bring suspended sediments, freshwater and nutrients to this location.

4.2 Long-term Variations in Seagrasses

4.2.1 Seagrass Community Structure

Seagrass assemblages at Fisherman Islands, Manly and Cleveland monitoring sites have shown enormous variation in community structure since monitoring commenced in May 2003. *Halophila ovalis* and *H. spinulosa* are responsible for the majority of this observed variation, particularly in shallow subtidal areas.

Seagrass depth profiling has demonstrated that sub-tidal seagrass beds at the Port of Brisbane, Cleveland and Manly are not stable entities, but form communities that can show considerable change in composition measured over short time-scales (i.e. months). 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. Similar changes in community structure were documented by Young and Kirkman (1975) in Moreton Bay. The authors recorded a small subtidal seagrass bed comprised of *H. spinulosa* interspersed with *H. ovalis* growing between a shallow intertidal bed of *Z. muelleri* and a deep channel. Within one year, the species composition of the seagrass bed had changed, with the area dominated by *H. ovalis*, and only a few shoots of *H. spinulosa* remained. Dieback of seagrass *H. spinulosa* and concurrent expansion of *H. ovalis* has been observed at several Port of Brisbane seagrass depth profile sites.

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 seagrass species *H. ovalis* and *H. spinulosa* but also in some instances with green alga *Caulerpa taxifolia*. While both *H. ovalis* and *H.*

spinulosa are typically grouped together as 'pioneer' species, and each are 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. seagrass bed dominated by *H. ovalis* shifting to a community dominated by *H. spinulosa*). It is suspected that these patterns could possibly 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 mobile marine megafauna (including dugong and turtle grazing) (e.g. Preen 1995). Sub-tidal seagrass beds at Fisherman Islands 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 (c.f. populations in eastern Moreton Bay, Lanyon and Morrice 1997). Dugongs can remove a large proportion (up to 95%) of above and below ground seagrass biomass (Preen 1995), leaving distinctive feeding trails. By comparison, green turtles feed on above ground seagrass biomass (i.e. shoots), but can still remove a significant proportion of this biomass during feeding. High growth rates of *H. ovalis* have been cited as being responsible for its persistence under grazing by dugongs.;
- 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).

There has been no broad scale variations to the depth range or composition of intertidal beds of seagrass in this study. Lee Long *et al* (1993) suggested that *Zostera 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). Despite its intertidal advantage, *Z. muelleri* also frequently inhabited subtidal areas at the Port of Brisbane, where it was interspersed sparsely amongst *H. ovalis* and *H. spinulosa*.

4.2.2 Seasonal Variation in Seagrass Extent

Comparison of the extent and depth of the edge of seagrass beds in July 2006 and April 2005 shows that there was an significant increase in the maximum growing depth (1-2m) of *Halophila ovalis* and a corresponding increase to overall seagrass extent (100-600m) at Fisherman Islands and Cleveland. Similar, but more pronounced spatial variations to the extent of deep water seagrass *H. ovalis* have been recorded in this monitoring study since commencement in May 2003. Overall, seagrass grows deepest and is greater in extent between the months of June and October, with a reduction in this growing depth and extent occurring between November and May. 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). Seasonal variations in the availability of light to seagrasses in western Moreton Bay are hypothesised to have resulted in the observed large variations in the extent of deeper water seagrasses, in particular *H. ovalis*, and associated variability in its maximum growing depths in western Moreton Bay.

The following sections describes the primary drivers of light availability of western Moreton Bay, and how they may relate to the observed seasonal fluctuations in seagrass extent.

4.2.2.1 Drivers of Light Availability for Seagrasses

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 orientation of the intertidal and sub-tidal seagrass beds at Fisherman Islands results in winds from the south-east to north-east 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 length for predominant wind directions indicates that winds 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. South-east to north-east 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 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 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).

4.2.2.2 Light Availability and Deep Water Seagrass Extent

Changes in *Halophila ovalis* has been responsible for the largest changes in seagrass extent over time. This study has recorded large retractions and expansions to the extent of this seagrass species at Fisherman Islands. However, these patterns have been broadly consistent at control locations at Manly (prior to April 2004) and Cleveland.

Seasonal light deprivation is likely to provide an explanation for the observed patterns in the depth distribution and extent of *H. ovalis*. Longstaff *et. al* (1999) investigated the effects of light deprivation on *H. ovalis* through a series of aquaria based experiments. The research indicated that plant sugar concentrations (a bi-product of photosynthesis) decreased rapidly for the first two days of light deprivation before stabilising, indicating an increase in plant respiration and decrease in plant growth. Seagrass biomass started to decrease after 3-6 days of light deprivation, and death occurred after only 30 days. This one month period of light deprivation is significantly less than recorded for other seagrass species (Longstaff *et al*. 1999).

In summary, Longstaff *et al* (1999) demonstrated that *H. ovalis* is tolerant of only short term (2-3 day) reductions in light availability, such as may be expected during sustained wind events and sediment resuspension in western Moreton Bay. However, extended periods of light deprivation (i.e. greater than 1 month) can reduce seagrass biomass sufficiently to cause seagrass death. This may explain the observed retractions of deeper water seagrass beds between November and May when water clarity can be poor.

When water clarity conditions improve in western Moreton Bay, typically during winter months, *H. ovalis* may recolonise these deeper subtidal areas. This process can occur relatively rapidly from the seabed seed bank, which is regenerated from seeds deposited into deeper areas following seeding of these flowering plants. Flowering and seeding can occur all year round in *H. ovalis*, although during late summer and spring flowering and seeding in this species appears to occur more dense than other times. The recolonisation of an area *H. ovalis* following complete removal by dugong herbivory was estimated to be quite rapid in a Thailand seagrass bed, occurring in less than 20 days (Nakaoka and Aioi 1999).

Between November 2003 and April 2004 there was a significant landward retraction to the extent of seagrass beds at Manly, which resulted in the loss of between two to four kilometres of seagrass (i.e. linear extent). 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. Seagrasses were not recorded in water depths greater than -2.65m at seagrass depth profile sites at Manly, nor were they observed at any edge of bed monitoring sites. Although partial recovery of rapid colonisers (i.e. *H. ovalis*) may have occurred between April 2005 and July 2006 at Manly (during which no survey have been conducted), there is no evidence of longer-term recovery of seagrass at this location at present. These patterns may suggest a localised long-term change to water quality conditions is being experienced at this location.

4.3 Impacts of FPE Seawall

The purpose of this annual seagrass monitoring study was to identify whether changes to the physical environment created by the FPE Seawall construction has resulted in broad scale changes to the extent and distribution of seagrasses at Fisherman Islands. The FPE Seawall structure has modified tidal current dynamics at a localised spatial scale at Fisherman Islands. Observations would suggest that seagrasses immediately to the south of FPE Seawall structure are now largely protected from wind generated waves and swell from the north-west and westerly directions, whereas previously these areas were more exposed.

The present study demonstrated that there have been no gross scale changes to the community structure of seagrass beds at Fisherman Islands since the FPE Seawall construction was completed in April 2005. Furthermore, seagrass species *Halophila ovalis* appeared to have recolonised deeper subtidal areas of seabed that were unvegetated in Apriil 2005, resulting in an expansion to the overall extent of seagrasses at Fisherman Islands since this time. It is also interesting to note that there was a reduction to the extent of potentially invasive green alga *Caulerpa taxifolia* since April 2005.

Overall, the Port of Brisbane seagrass monitoring study has recorded large range extensions of deepwater seagrasses (principally *Halophila ovalis*) through winter months, and similar range reduction with the on-set of summer winds and associated increases in ambient turbidity. However, 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.

5 SUMMARY

There has been a seaward expansion of seagrass at Fisherman Islands and Cleveland since April 2005. Interestingly, the Manly edge of bed monitoring location has displayed little evidence of longer-term recovery since its disappearance between the November 2003 and April 2004 monitoring episodes. It is possible that the loss of seagrass at Manly is a result of longer term changes to water quality (e.g. turbidity and/or nutrient loading). Overall, the present seagrass monitoring program has reported large retractions and expansions to seagrass beds adjacent to the FPE Seawall. However, 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 Department of Primary Industry and Fisheries (DPI&F), 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.

6 RECOMMENDATIONS

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 PBC 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 PBC to detect seasonal and inter-annual changes to the distribution and extent of seagrass beds, offering greater temporal resolution to the study.
- Manly edge of bed monitoring sites should be moved to a shallower location, given that no seagrass has been recorded at edge of bed transects at this location since November 2004.

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APPENDIX A: SEAGRASS DEPTH PROFILES AT MANLY AND CLEVELAND IN JULY 2006

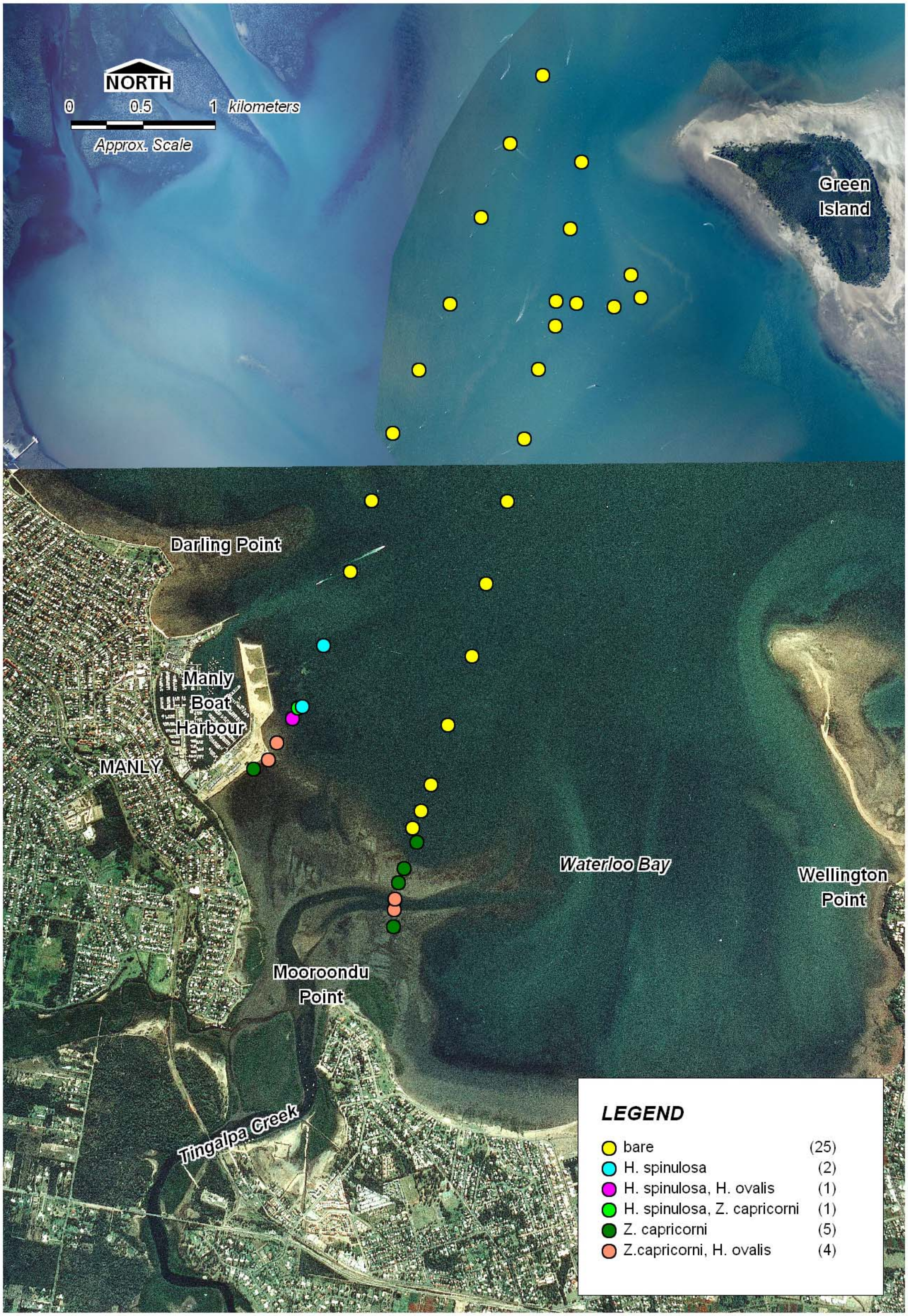

Figure A-1 Results of seagrass depth profiling at Manly (July 2006)

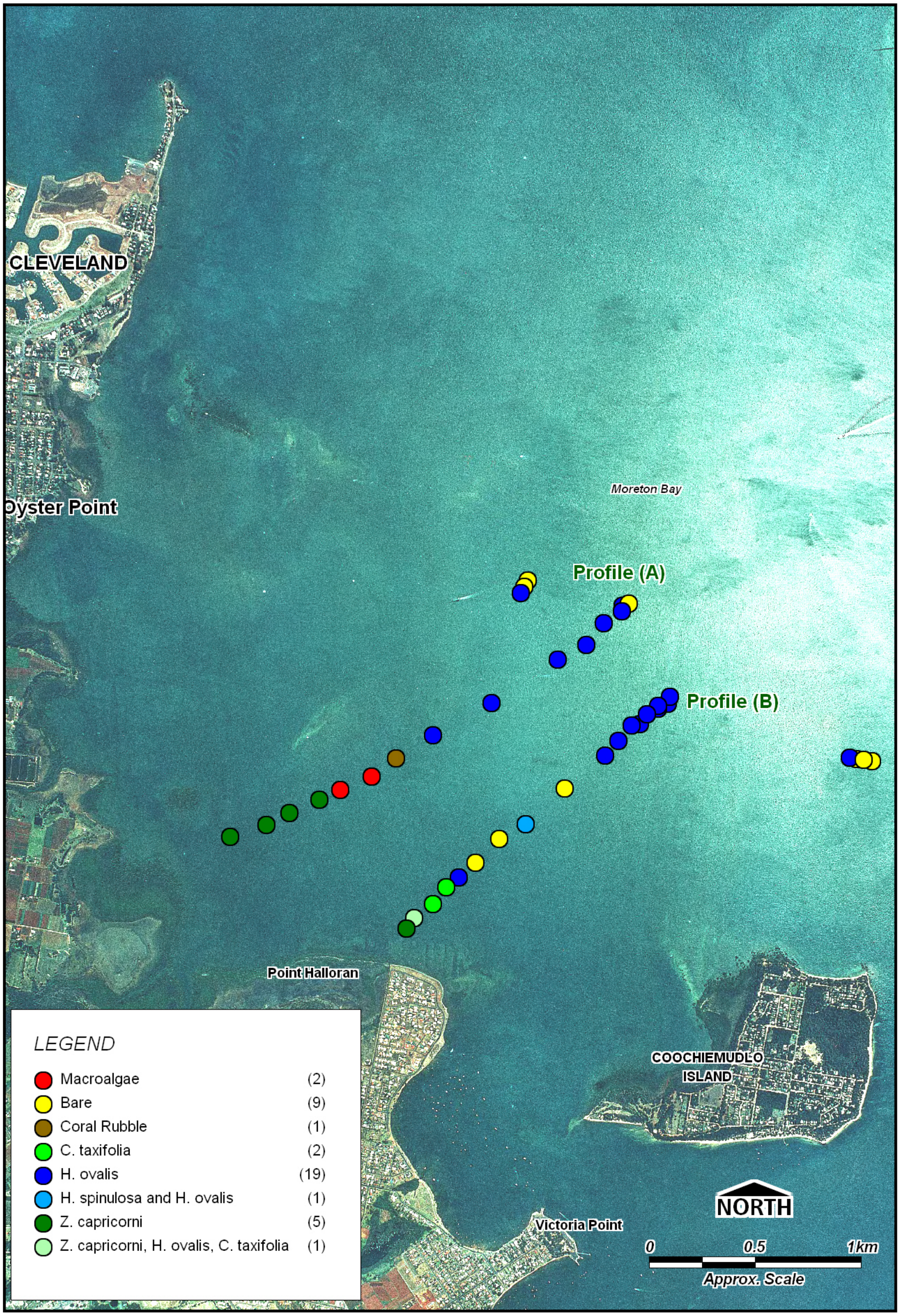

Figure A-2 Results of seagrass depth profiling at Cleveland (July 2006)

APPENDIX B: SEAGRASS EDGE OF BED MONITORING RESULTS FOR PORT OF BRISBANE AND CLEVELAND, JULY 2006

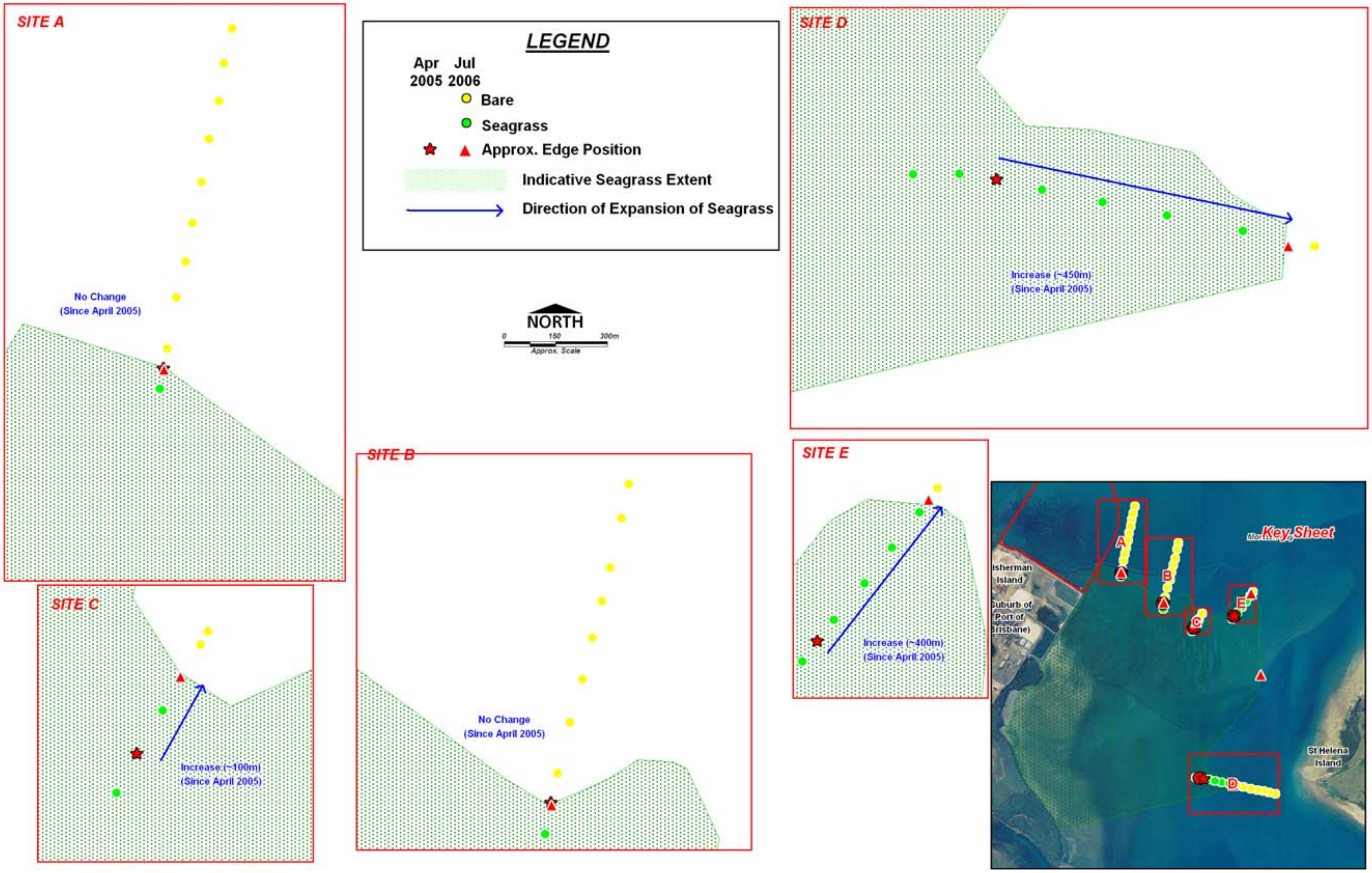

Figure B-3 Seagrass edge of bed monitoring results for the Port of Brisbane (July 2006).

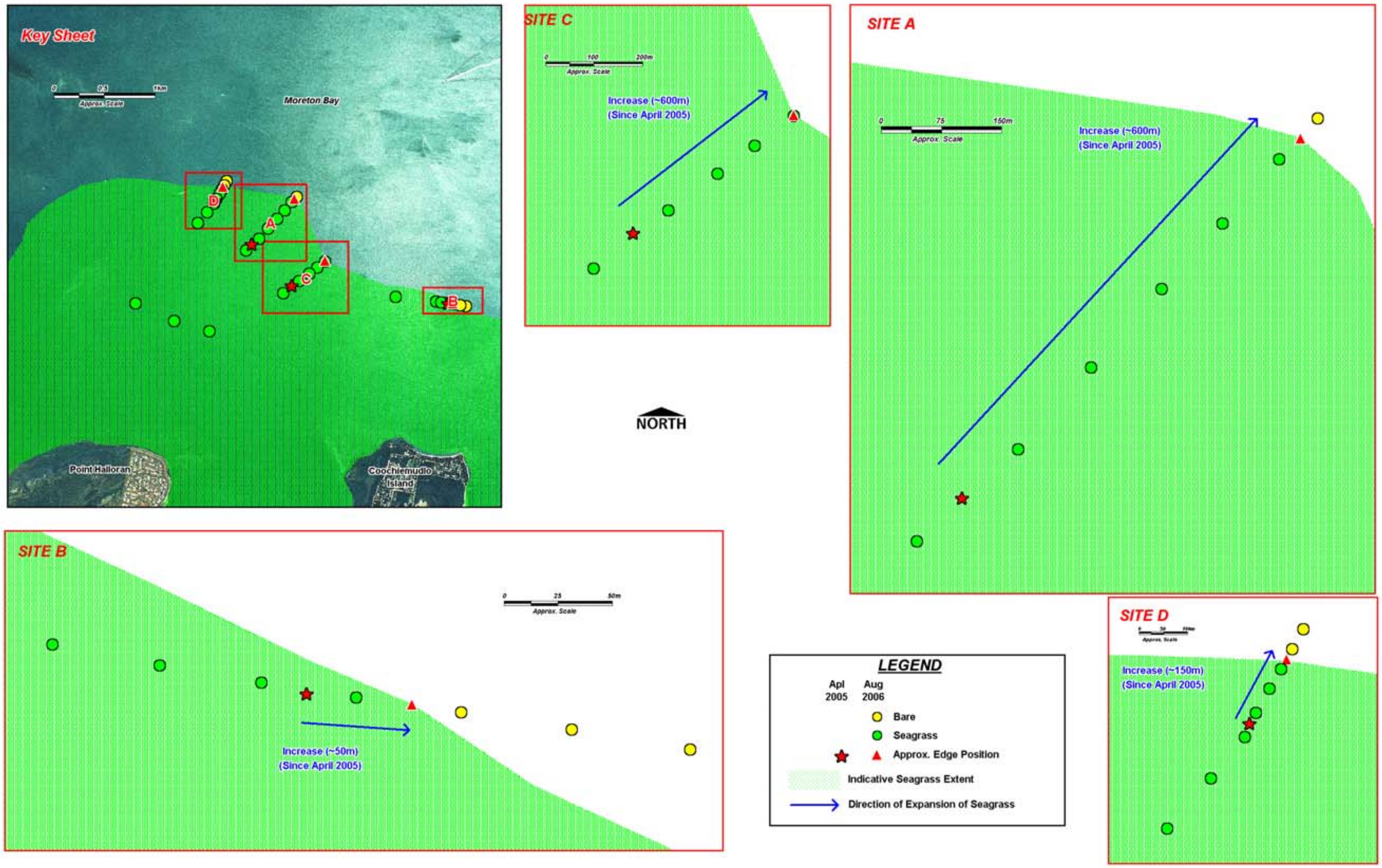

Figure B-4 Seagrass edge of bed monitoring results for Cleveland (July 2006).

APPENDIX C: DISTRIBUTION OF SEAGRASS AT FISHERMAN ISLANDS IN AUGUST 2003

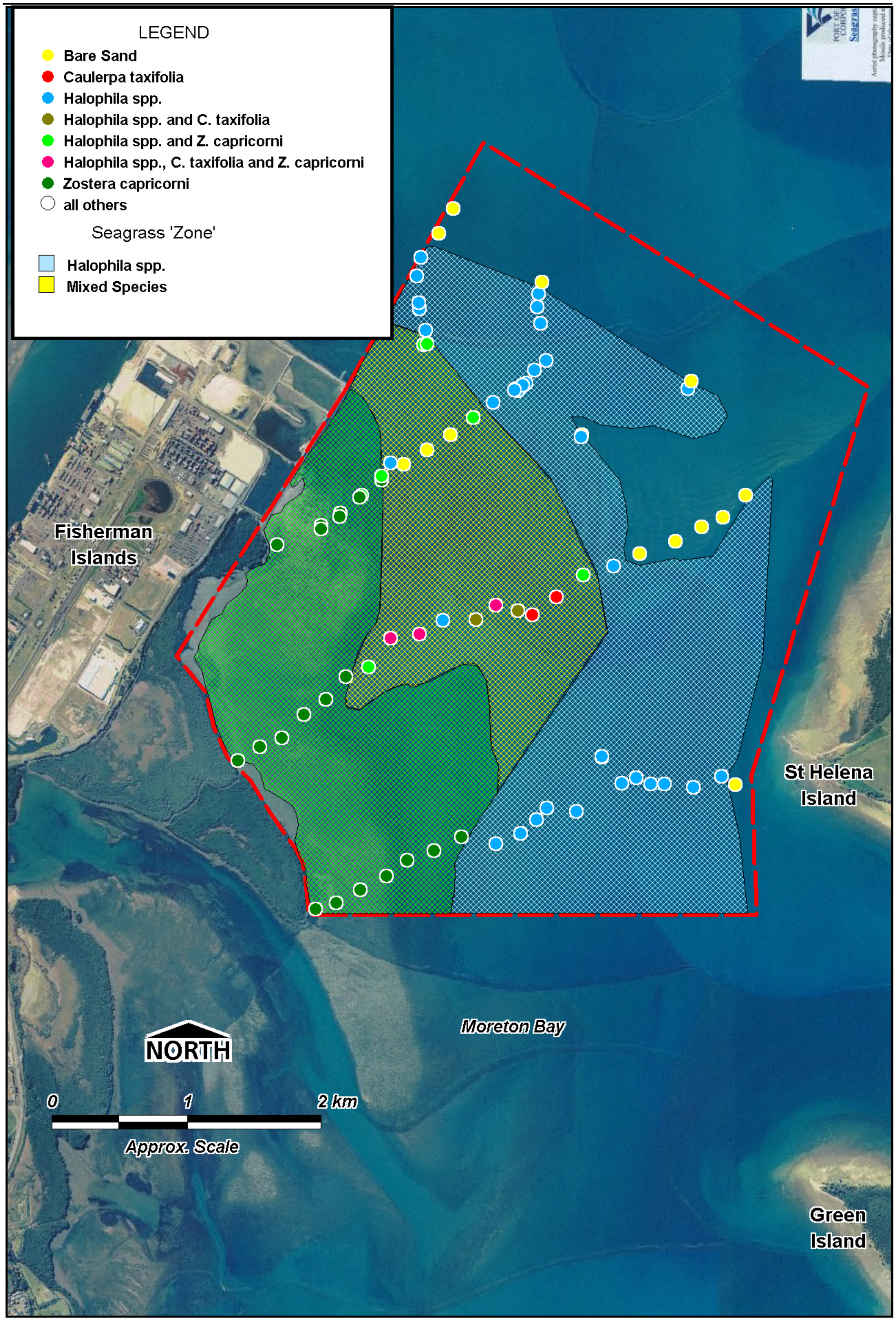

Figure C-5 Distribution of Seagrasses at Fisherman Islands, August 2003