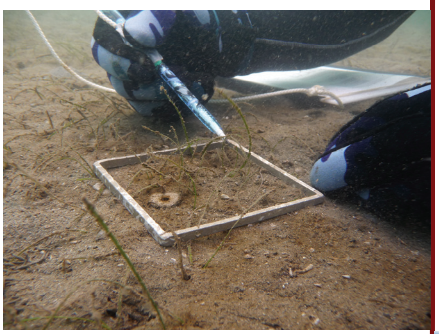
Port of Abbot Point Seagrass Baseline Surveys

Wet & Dry Season 2008



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EXECUTIVE SUMMARY

The Port of Abbot Point, approximately 25km north of Bowen, forms part of the State Government's infrastructure development plan for the Northern Economic Triangle. To complement a planned industrial precinct at Abbot Point, the Ports Corporation of Queensland Limited (PCQ) is investigating options to expand the current port and develop a Multi Cargo Facility (MCF). As part of the planning for this project, PCQ has commissioned the Marine Ecology Group at the Department of Primary Industries and Fisheries (DPI&F) to conduct seagrass baseline assessments and monitoring programs. The seagrass studies will assist in planning for the development so as to minimize impacts on seagrass habitats and to develop appropriate management and mitigation measures.

This report describes the baseline seagrass assessments undertaken during 2008. Results detail the seasonal abundance, species composition, and distribution of seagrass communities surrounding Abbot Point including those potentially affected by proposed port developments. It also provides the foundation to establish long-term monitoring and to asses future seagrass changes.

Seagrass coverage was extensive with meadows comprising 42% of the survey area covering the inshore region from Branch Creek to Bowen. Seagrass meadows occurred from the shoreline to a distance of approximately 10km offshore. The survey area contained a variety of species and meadow types ranging from low biomass coastal *Halodule uninervis* meadows, to higher biomass deep water *Halophila spinulosa* meadows.

The meadows identified within the Abbot Point port limits were likely to play a number of important ecological roles, including supporting endangered and threatened species such as dugong and turtles, providing nursery grounds for commercial fisheries species as well as providing a substantial component of the primary productivity for the regions marine ecosystem.

Results of the seagrass baselines have already been used to assist with planning and design of port developments in a manner likely to minimise or reduce potential impacts. However the location of seagrass meadows throughout the port means they are likely to face some level of direct and indirect impact from port development. The second phase of the seagrass study is currently under way and aims to better quantify what these impacts are likely to be and includes quarterly monitoring of selected seagrass meadows to:

- Assess natural seasonal and interannual variability in seagrass density and abundance;
- Determine the value of seagrass meadows in terms of primary and fisheries productivity;
- Determine capacity for, and rate of, recovery from disturbance

Preliminary results of these ongoing studies are also presented in this report.

INTRODUCTION

Background

The Port of Abbot Point is located 25 km north of Bowen in north Queensland (Map 1). At present the major activity within the port is the export of coal, with 12.5 million tonnes of coal exported in 2007/08 (PCQ 2008). Existing port infrastructure includes a trestle, jetty and offshore wharf at Abbot Point (managed by Ports Corporation of Queensland Limited (PCQ)), and mooring facilities in the nearby Bowen Wharves (managed by Queensland Transport).

The Queensland Government is investigating the development of a new industrial precinct in the Abbot Point / Bowen area as part of its "Northern Economic Triangle" State Development Area program. Part of the requirement for the industrial precinct is the expansion of the Port of Abbot Point into a multi-purpose port facility to support the north's heavy industry sectors which include an alumina refinery, aluminium smelter, iron and steel making, nickel refinery, shale oil exports, liquefied natural gas exports, coke, chlor-alkali plant and power station.

The construction period for the Multi-Cargo Facility is expected to span a 3-4 year period beginning in 2010/11 and is expected to cost around $1.0 billion (PCQ, 2008). Conceptual development options for a suitable wharf/berthing facility have been developed by PCQ and their consultants Connell Hatch (Map 1). This development will require a major capital dredging campaign and reclamation to establish a protected harbour for the expanded facilities.

PCQ, the port authority responsible for the Port of Abbot Point, is committed to the environmentally responsible management and maintenance of its' ports. They have previously recognised that seagrasses make up an ecologically important and environmentally sensitive habitat in the Port of Abbot Point (see Rasheed *et al*. 2005). Previously mapped seagrass meadows are likely to play a significant role in fisheries productivity and the overall ecological productivity of the region. Any future port activities and infrastructure developments such as the Multi-Cargo Facility could therefore potentially impact these seagrass communities through direct removal (dredging), burial (reclamation) and indirectly through turbid plumes created during dredging operations.

PCQ aims to minimise marine impacts associated with future port activities and infrastructure developments by conducting further detailed studies of core seagrass habitat and its' resources. The following study provides key information to the State and Commonwealth agencies that will aid selecting the most sound port development option. The present study will also act as a foundation for the development of suitable guidelines and environmental trigger levels to protect seagrasses, should the development proceed. The Marine Ecology Group (MEG) through the Department of Primary Industries and Fisheries (DPI&F) was commissioned to undertake these baseline surveys and experiments, and design a monitoring program to satisfy the aforementioned goals. The following information arises from experiments still in progress that aim to determine the resilience and capacity for recovery of seagrasses at Abbot Point.

Port of Abbot Point Seagrasses

The importance of seagrass as a structural component of coastal ecosystems is well recognised. On a global scale, seagrass/algal beds have been rated the third most valuable ecosystem (on a per hectare basis) for their efficiency in nutrient trapping and cycling, preceded only by estuaries and swamps/flood plains (Constanza *et al*. 1997). Seagrasses in Queensland provide many additional ecosystem services acting as an important food resource for dugong and sea turtles, assisting with sediment and bank stabilisation, and acting as the key primary producer underpinning much of the coastal marine food-web.

Seagrass was first mapped within the Abbot Point port limits during broad-scale surveys of the east coast of Queensland conducted by DPI&F in 1987 (Coles *et al*. 1992). In 2005 PCQ commissioned DPI&F to conduct a more detailed study of the seagrass, algae and benthic macro invertebrate communities in the vicinity of the existing port facilities (Map 2) (Rasheed *et al*. 2005). The 2005 survey concluded that seagrass meadows were the dominant benthic habitat with no significant areas of habitat forming benthic macro-invertebrates and a very low coverage of algae in the region. The area of seagrass mapped at Abbot Point in 2005 occurred in the footprint and proximate area of potential development options within the port.

The large areas of seagrass mapped (8779.5 ha) in 2005 were considered likely to play a role in fisheries productivity, and contribute significantly to the overall ecological productivity of the area. Many of the seagrass meadows were found to be of a type preferred as food for dugong and turtle. These were thought to provide an important food source for dugong moving along the coast between the nearby Dugong Protection Areas (DPA's) to the north and south of the port (Coles *et al.* 2002). Studies of Abbot Bay have also recorded fish, prawn and crab species in seagrass beds (Coles *et al*. 1992; Rasheed *et al*. 2005). This is consistent with the role of other seagrass beds in Queensland of similar community type that have commonly been found to provide food and nursery grounds for juvenile fish and prawns (Coles *et al*. 1992; Watson *et al*. 1993).

Five species of marine turtles have been observed nesting, or foraging in seagrass beds within the Port limits at Abbot Point (Bell, 2003; Agnew *et al.* 2004). Bell (2003) conducted a baseline turtle foraging and nesting study in 2003, which identified the port area as a nesting habitat for Flatback (*Natator depressus*) and Green (*Chelonia mydas*) turtles, as well as being a foraging habitat for adult Green and Loggerhead (*Caretta caretta*) turtles. Bell (2003) also found that the port area supported a notable number of foraging juvenile and sub-adult turtles. Furthermore, the presence of the endangered Hawksbill (*Eretmochelys impricata*) turtle has been noted in the port limits of Abbot Point (Agnew *et al*. 2004).

Study Site

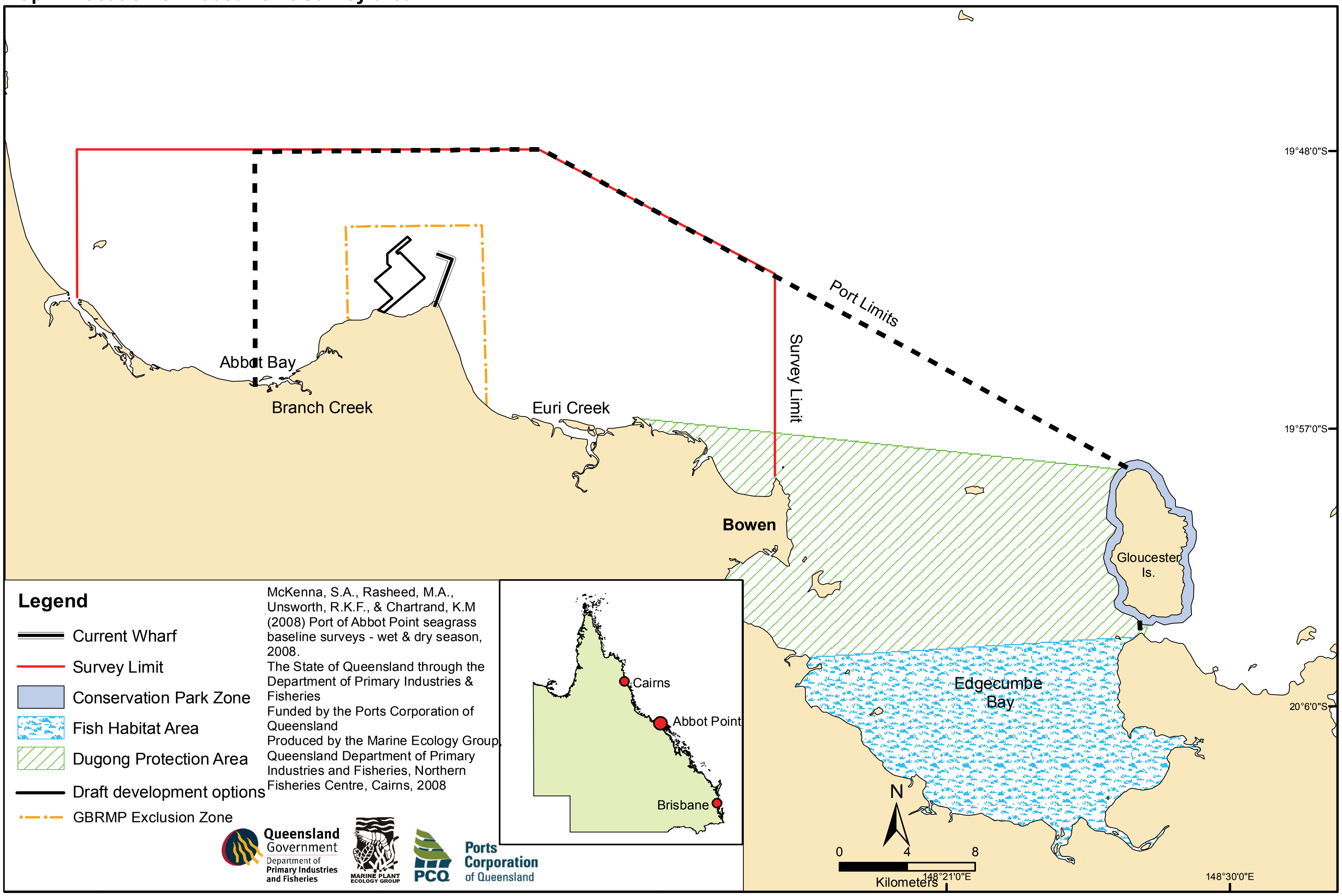
The port of Abbot Point is located on the eastern coast of north Queensland, 25 kms north of Bowen (Map 1). The port limits extend from Abbot Bay (to the west) to Gloucester Head (to the southeast). The port area is wholly enclosed by the Great Barrier Reef World Heritage Area (GBRWHA). In addition, two 'Dugong Protection Areas' have been established, one being outside the Port limits in Upstart Bay to the northwest of Abbot Point and the other inside the Port limits encompassing most of Edgecumbe Bay. A declared Fish Habitat Area (FHA) also lies within the port limits (Map 1).

Abbot Point is located in the dry tropics with dry winters and wet humid summers. The wet season is commonly from December to March with an average annual rainfall of 817mm

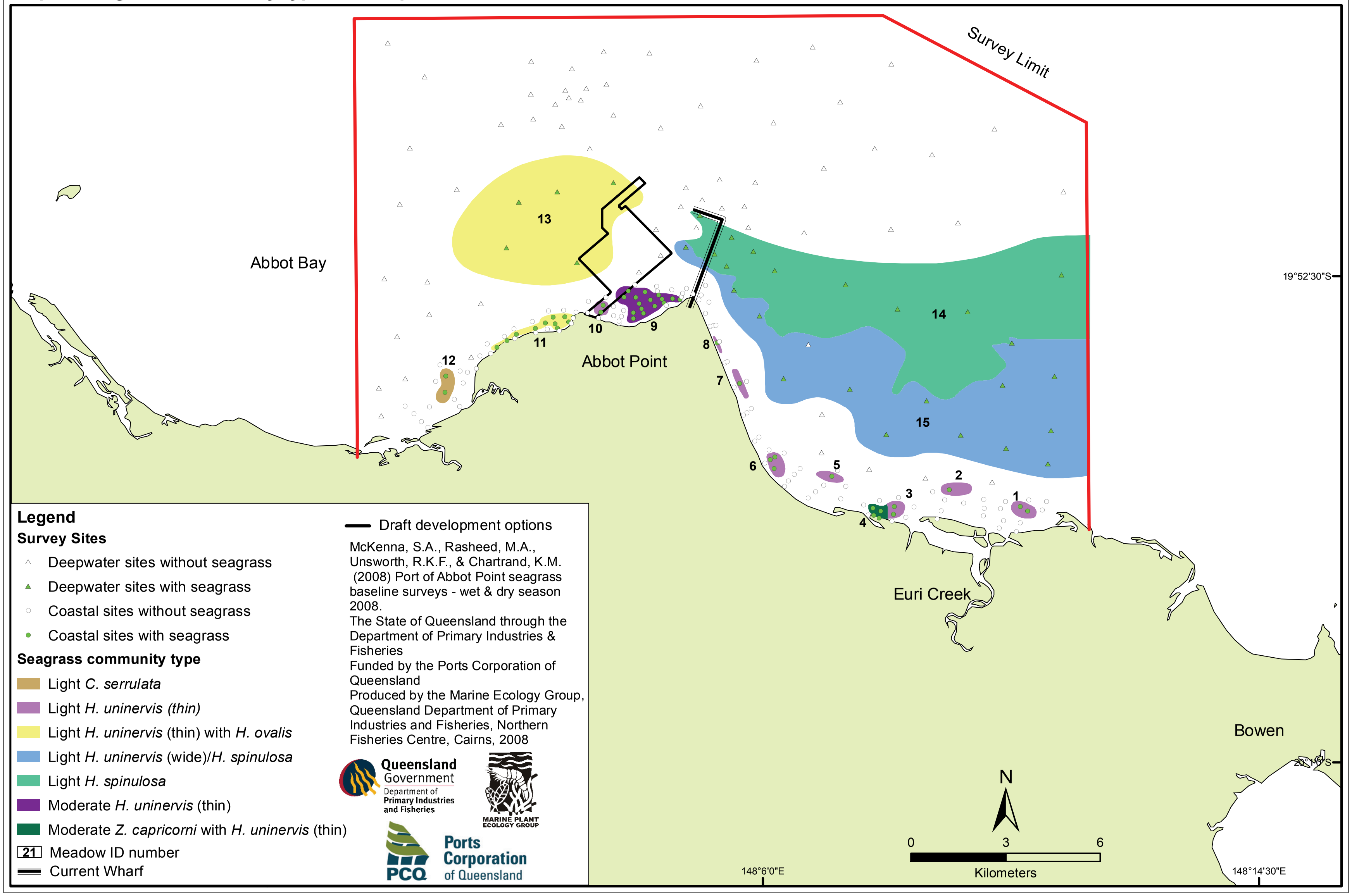
(February being the wettest month at 228.4mm; (Bureau of Meteorology (BOM), 2008)). Mean daily temperatures range from a minimum in July of 13.5°C to a maximum of 31.5°C in January (BOM, 2008).

The subtidal and intertidal area within the port limits has been described as typical of those found in other regions of north Queensland (PCQ 2005; Rasheed *et al*. 2005). The area is dominated by open silty/sandy substrate with seagrass communities being the dominant benthic habitat feature with no significant areas of habitat forming benthic macro-invertebrates or reef/coral areas, and only a very low percent cover of algae. Eight species of seagrass have previously been identified within the port limits (Coles *et al*. 1992, Rasheed *et al*. 2005). The seagrass meadows (see Rasheed *et al*. 2005; Coles *et al*. 1992) are patchy, highly variable in density, and consist principally of *Halophila spinulosa* in offshore meadows, while coastal meadows have been dominated by *Halodule uninervis*. Seagrass abundance and distribution in North Queensland has been shown to vary seasonally, typically with a spring/summer maxima and a winter minima (McKenzie 1994; Rasheed *et al*. 2001, Rasheed *et al*. 2008) as it relates to differences in wet and dry season conditions.

Map 1. Location of Abbot Point Survey area



Map 2. Seagrass community types in the port of Abbot Point March 2005



METHODS

Sampling Approach

The sampling approach for the baseline seagrass surveys was based on the need to provide PCQ with a better understanding of seagrasses within the port of Abbot Point to assist selecting a suitable development option with minimal marine impact. The studies will also be used as a basis for the development of suitable guidelines and environmental thresholds to protect seagrasses based on measurements of their resilience and capacity for recovery.

There are two major components to the project;

1. A baseline mapping and assessment project;

2. (**a**) Quarterly long-term monitoring of a subset of key seagrass meadows representative of the range of seagrass species and habitat types (intertidal and subtidal) present in the Port of Abbot Point;
(**b**) Manipulative experiments to determine resilience, productivity and recovery of the various seagrass species found in the area.

This draft report contains maps and information pertaining to the results of the baseline surveys conducted in the wet season (February/March) and dry season (August/September) 2008 (part 1) and preliminary results of experimental investigations and quarterly monitoring (part 2) (Table 1).

The **objectives** of the baseline studies reported here were to;

- Establish seasonal baseline information on the seagrass communities in close proximity to proposed port development options.

- Identify suitable seagrass areas for longer-term monitoring

1. Baseline Mapping and Assessment

Two major baseline surveys were conducted in 2008 covering the entire area likely to be affected by the proposed port expansion. The surveys were conducted in the wet season (February/March) and dry season (August/September) in order to capture seagrasses at their likely seasonal extremes of distribution and abundance (Table 1). There were 2 separate components of the baseline survey: (**i**) an offshore video survey conducted from a large research vessel, the *Gwendoline May*; and (**ii**) a coastal diver/camera survey conducted from a smaller vessel. The two methods combined encompass all habitat that could potentially be affected by all port development, including areas indirectly affected from dredge plumes.

2. Long term monitoring and Manipulative Experiments

(a) Monitoring of key seagrass meadows

From the results of the first baseline survey a subset of representative meadows suitable for longer term monitoring were selected. These meadows have been assessed quarterly since their establishment in March 2008 and will continue under the planned contract between PCQ and DPI&F through February to 2009. Quarterly assessments will be used to better establish seasonal variation in the Abbot Point seagrass meadows. This information on the natural variability of seagrass meadows close to the port will be essential in interpreting potential impacts of capital dredging and port expansions. Should the port development program proceed, the subset of monitoring meadows would provide sites to establish a 'Before/After/Control/Impact' (BACI) type design (Underwood 1991) to detect potential impacts of the development on seagrass meadows.

(b) Seagrass Resilience, Productivity & Capacity for Recovery

Key aspects of seagrass recovery, productivity, resilience and fisheries values will be examined at representative seagrass meadow types in Abbot Point. The study will provide information on how meadows will likely to respond to capital works-related disturbance by quantifying aspects of their ecological and fisheries values. There are four major components of the investigation:

1. Capacity for recovery
2. Productivity
3. Fisheries value
4. Resilience to reduced light

Investigations into the first 3 components began in March 2008 while component 4 is proposed to begin in the next financial year should the Abbot Point port development project proceed.

Table 1. Time line of sampling events

Task	Feb/Mar 2008	May 2008	July 2008	Aug/Sept 2008	November 2008	February 2009
Baseline surveys of entire area of interest	✓			✓		
Monitoring subset of meadows			✓	✓	✓	TBC
Recovery experiments	Establish sites	✓	✓	✓	✓	TBC
Productivity experiments		✓	✓	✓	✓	TBC
Seed bank and flowering sampling			✓	✓	✓	TBC
Fisheries sampling (beam trawling)			✓	✓	✓	TBC
Resilience to shading	Identified suitable meadows					

TBC = To be conducted

Sampling Design

The project has two major components; a coastal intertidal to shallow subtidal survey, and an offshore (deepwater) seagrass and algae survey. Due to the large area that was surveyed a stratified sampling approach was taken. Sampling was more intense within areas around the port expansion options and areas previously identified as containing seagrass (Rasheed *et al*. 2005).

Baseline Mapping and Quarterly monitoring Assessment

(i) Offshore survey

Offshore sites were surveyed using a CCTV camera system, with real-time monitor; this was towed from a research vessel. At each sampling site the camera system was towed for 100 metres at drift speed (approximately one knot). Footage was observed on a TV monitor and recorded. The camera was mounted on a sled that incorporates a sled net 600mm width and 250mm deep with a net of 10mm-mesh aperture (Plate 1). Surface benthos was captured in the net (semi-quantitative bottom sample) and used to confirm seagrass, algal and benthic macro-invertebrate habitat characteristics and species observed on the monitor. A Van Veen grab was used to confirm sediment type. This method has been used extensively by the MEG for deepwater benthic surveys in the Ports of Abbot Point, Hay Point Mackay and Gladstone (see Rasheed *et al*. 2001; 2003; 2004; 2005; 2007) as well as throughout the Great Barrier Reef Lagoon and other locations off the Queensland coast (Coles *et al*. 1996; 2000; 2002). The technique ensured a large area of seafloor was integrated at each site so that patchily distributed seagrass and benthic life that typifies deepwater habitats in the region can be detected.

Data recorded at each site included:

1. **Seagrass species composition** – Seagrass identifications in the field and from video according to Kuo and McComb (1989). Species composition measured from the sled net sample and from the video screen when species are distinct.

2. **Seagrass biomass** – Estimates of seagrass biomass from video images using a calibrated visual estimates technique adapted from Mellors (1991). This involves making random video grabs from the digital videotape with the constraint that visibility is acceptable for the selection. A visual estimate of above ground biomass is made by an observer viewing the screen. All observers were calibrated to a standard set of video images that have been harvested and measured.

3. **Algae** – Presence/absence, algae type and percent cover (identified according to Cribb 1996). Percent cover was estimated from the video grab. Algae collected in the sled net and grab will provide a taxa list.

    - ***Erect Macrophytes*** - macro algae with an erect growth form and high level of cellular differentiation e.g. *Sargassum, Caulerpa* and *Galaxaura* species

    - ***Erect Calcareous*** - algae with erect growth form and high level of cellular differentiation containing calcified segments e.g. *Halimeda* species

- ***Filamentous*** - thin thread like algae with little cellular differentiation.

- ***Encrusting*** - algae growing in sheet like form attached to substrate or benthos e.g. coralline algae.

- ***Turf Mat*** - algae that forms a dense mat or turf on the substrate.

4. **Sediment type** – A one-litre Van Veen grab was used to obtain a sediment sample at each site. Grain size categories were then identified visually as; shell grit, rock, gravel shell grit, rock, gravel (>2000µm), coarse sand (>500µm), sand (>250µm), fine sand (>63µm) and mud (<63µm).

5. **Site location** – by GPS including weather conditions at the time of sampling

Plate 1. Offshore video sampling sled and sorting benthic samples from the sled net

(ii) Coastal survey

Methodology and sample design for the coastal survey sites were similar to that developed by the MEG for seagrass/marine habitat surveys and monitoring programs previously used at Abbot Point (Rasheed *et al*. 2005) and established in other north Queensland locations, such as in Cairns, Mourilyan Harbour, Upstart Bay, Mackay, Weipa, Karumba and Thursday Island (See Rasheed *et al*. 2001; 2002; 2003). Sampling was of a sufficient intensity that a monitoring program was able to be developed from the results of the first (wet season) baseline survey.

Two methods were used to assess benthos at each sampling site; sites were assessed by free-divers (Plate 2); and where diver safety was an issue, sites were assessed by observers using the real-time underwater video camera. This camera was mounted to a 0.25m^2 quadrat that provided live images which were viewed and ranked from a colour 22cm CRT monitor aboard the research vessel. A Van Veen sediment grab was also used at each camera site to determine sediment type and to confirm species viewed on the video screen.

Sampling sites were located along transects that ran perpendicular to the shoreline, extending approximately 1km offshore. Additional random sites were sampled between transects to check for habitat continuity. Sampling intensity of sites was approximately 50-100m intervals along each transect or where major changes in bottom topography occurred. Transects continued to at least the seaward edge of any seagrass meadows encountered. At each survey site, seagrass habitat characteristics, including seagrass species composition, above-ground biomass, percent algal cover and sediment type were determined from three random placements of a 0.25m^2 quadrat within a radius of 10m (Plate 2). The percent cover of other major benthos, time, depth below mean sea level (MSL) and position (GPS) was also recorded at each site.

Seagrass biomass (above-ground biomass) at each site was determined using a modified “visual estimates of biomass” technique described by Mellors (1991). This technique involved an observer ranking seagrass biomass in the field in three random placements of a 0.25m^2 quadrat at each site. Ranks were made in reference to a series of quadrat photographs of similar seagrass habitats for which the above-ground biomass has previously been measured. The relative proportion of the above-ground biomass (percentage) of each seagrass species within each survey quadrat was also recorded. Field biomass ranks were then converted into above-ground biomass estimates in grams dry weight per square meter (g DW m^{-2}). At the completion of sampling each observer ranked a series of calibration quadrats that represented the range of seagrass biomass in the survey. After ranking, seagrass in these quadrats were harvested and the actual biomass determined in the laboratory. A separate regression of ranks and biomass from these calibration quadrats was generated for each observer and applied to the field survey data to standardise the above-ground biomass estimates.

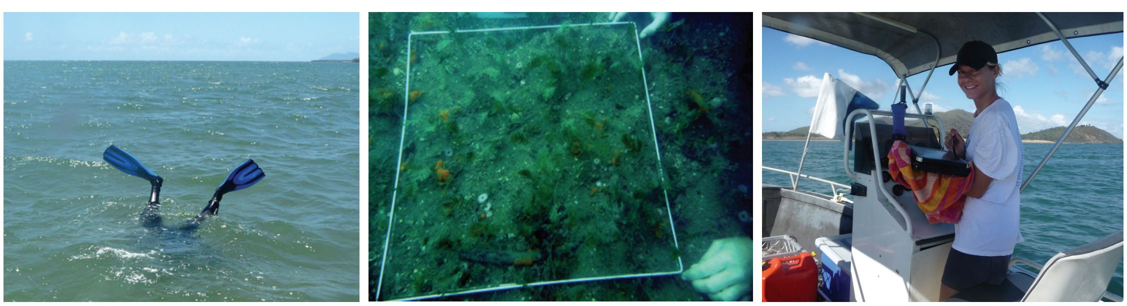


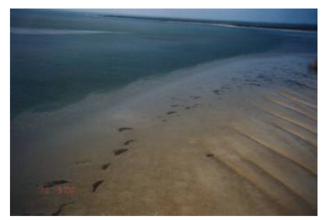
Plate 2. Sampling sites recorded by GPS were assessed by free divers to measure seagrass biomass and species composition to characterise the coastal habitat

Habitat Mapping and Geographic Information System

All survey data was entered into a Geographic Information System (GIS) for presentation of seagrass species distribution and abundance. Satellite imagery of the Bowen/Abbot Point area with information recorded during the helicopter surveys were combined to assist with mapping seagrass meadows. Three seagrass GIS layers were created in ArcMap:

- **Habitat characterisation sites** – point data containing above-ground biomass (for each species), dbMSL, sediment type, time, latitude and longitude from GPS fixes, sampling method and any comments.
- **Seagrass meadow biomass and community types** – area data for seagrass meadows with summary information on meadow characteristics. Seagrass community types were determined according to species composition from nomenclature developed for seagrass meadows of Queensland (Table 1). Abundance categories (light, moderate, dense) were assigned to community types according to above-ground biomass of the dominant species (Table 2).
- **Seagrass landscape category** – area data showing the seagrass landscape category determined for each meadow :

Isolated seagrass patches
The majority of area within the meadows consisted of un-vegetated sediment interspersed with isolated patches of seagrass



Aggregated seagrass patches
Meadows are comprised of numerous seagrass patches but still feature substantial gaps of un-vegetated sediment within the meadow boundaries

Continuous seagrass cover
The majority of area within the meadows comprised of continuous seagrass cover interspersed with a few gaps of un-vegetated sediment.

Table 2. Nomenclature for community types in the Port of Abbot Point 2008

Community type	Species composition
Species A	Species A is 90-100% of composition
Species A with Species B	Species A is 60-90% of composition
Species A with Species B/Species C	Species A is 50% of composition
Species A/Species B	Species A is 40-60% of composition

Table 3. Density categories and mean above-ground biomass ranges for each species used in determining seagrass community density in the Port of Abbot Point 2008

Density	Mean above ground biomass (g DW m^{-2})				
	H. uninervis (narrow)	*H. ovalis* *H. decipiens*	*H. uninervis* (wide) *C. serrulata/rotundata*	*H. spinulosa*	*Z. capricorni*
Light	< 1	< 1	< 5	< 15	< 20
Moderate	1 - 4	1 - 5	5 - 25	15 - 35	20 - 60
Dense	> 4	> 5	> 25	> 35	> 60

Each seagrass meadow was assigned a mapping precision estimate (±m) based on the mapping methodology utilised for that meadow (Table 4). Mapping precision estimates ranged from 10m for isolated intertidal seagrass meadows to 500m for larger subtidal meadows. The mapping precision estimate was used to calculate a range of meadow area for each meadow and was expressed as a meadow reliability estimate (R) in hectares. Additional sources of mapping error associated with digitising aerial photographs onto basemaps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 4. Mapping precision and methodology for seagrass meadows in the Port Abbot Point 2008

Mapping precision	Mapping methodology
10-20m	Subtidal meadow boundaries determined from diver surveys only; All meadows subtidal; Relatively high density of survey sites; Recent aerial photography aided in mapping
50m	Subtidal meadow boundaries determined from diver surveys only; All meadows subtidal; Moderate density of survey sites; Recent aerial photography aided in mapping
100-500m	Larger subtidal meadows with boundaries determined from camera/grab surveys only; All meadows subtidal; Relatively low density of survey sites;

Manipulative Experiments

Seagrass Resilience, Productivity & Capacity for Recovery

Three seagrass meadows representative of the range of community types found within the port of Abbot Point were selected for detailed experimentation (Map 3). These experimental sites were established to determine key characteristics of seagrass meadow resilience for the various seagrass meadow types likely to be affected by the proposed developments, including capacity for recovery, productivity, fisheries values and resilience to reduced light.

Experimental studies began in March 2008 (Table 1). At this time clearance/recovery experiments commenced at two sites, while the third experimental site was established in May 2008. Productivity measures were first conducted during May and continued in July, September and November 2008 along with fisheries sampling (ie. beam trawling) (Table 1). All experimental studies are ongoing and require further monitoring in February 2009 and analysis. The final planned experimental survey will incorporate a complete 12 month dataset.

1. Capacity for recovery

The rate of seagrass recovery, the role of sexual and asexual reproduction, and the species involved in re-colonisation following loss/removal, was investigated at three sub-tidal meadows within the Port limits (Map 3). These investigations followed the methodology developed by Rasheed (1999; 2004) for investigating seagrass recovery after loss/removal. Each of the three experimental sites was subject to a randomised block design of 12 (0.25 m^{-2}) treatment plots of seagrass. The blocks were located randomly within the meadows, excluding meadow edges and other areas unlikely to remain free from additional non-experimental disturbance for the duration of the study. The 12 plots were subject to 3 replicates of 4 different treatments and were randomly located within the block design (Table 5).

At each site, 6 of the 0.25 m^{-2} plots of seagrass had seagrass material including roots and rhizomes removed. To determine how recolonisation is influenced by asexual reproduction (seagrass runners), half (3) of the cleared plots in each block had an aluminium border sunk 250mm into the sediment. The border isolates treatments from asexual colonisation by stopping rhizome extension from seagrass surrounding the plots. To investigate how recolonisation is influenced by the availability of sexual propagules (seeds), recovery of seagrass will be compared among plots that have all material removed but the seed bank left intact. Recolonisation of all the cleared plots are compared to control plots in each block that are left undisturbed. Seagrass recovery and re-growth from each individual 0.25 m^{-2} plot was measured using leaf shoot density and visual estimates of above ground biomass (Rasheed 1999; 2004). These are two non-destructive methods of measuring regrowth. The number of flowering and fruiting bodies of each seagrass species present in the plots was also counted by observers.

Measurements of the seed bank and the occurrence of flowers and fruits were also recorded in the sampling trips for the meadows (Table 1). The density of seeds in the meadows (seeds m^{-2}) is determined from the average number of seeds per cylindrical core (15cm diameter x 25cm depth) which are taken randomly in the target meadows (n = 12) (Plate 3). The number of shoots, flowering shoots seedlings, and attached fruits of each species were also recorded for seagrass from each core. Sediment cores were sieved through a stack of test sieves (4mm, 2mm and 1mm) to separate out seagrass seeds and fruits from the sediment.

Plate 3. Diver taking seed bank cores at experimental sites

Table 5. Description of treatments for recolonisation experiments.

Treatment	Cleared	Not Cleared	Bordered	Not Bordered	Replicates
C1		✓	✓		3
C2		✓		✓	3
E1	✓		✓		3
E2	✓			✓	3

2. Productivity

The primary productivity of the selected seagrass meadows (including meadows in the footprint of proposed reclamation) was measured using techniques recently applied by the MEG to determine productivity of seagrass meadows in the Torres Strait (see Rasheed *et al.* 2008a). This followed methods outlined in Short and Duarte (2001), and will be used to determine the above and below ground productivity of each seagrass species found within the meadows. Three methods were used according to the growth habits of the species found in the meadows:

1. ***Leaf marking*** - For leaf replacing seagrass species in the present study (*Halodule uninervis*), the leaf growth rate was determined using the *in situ* leaf marking method. A hole was punched through all the leaves of an individual shoot using a syringe (Plate 4). This was just below the top of the basal meristem (sheath) of each shoot. As a leaf grows the pinhole scar from needle punching moves upwards from the basal meristem. The new leaf growth was any growth that occurs between the hole in the sheath and the scar on the leaf. Plants were harvested 3 to 8 days after marking and brought back to the laboratory for separation into old and new growth (Plate 5). The dry weight biomass of each leaf section was then calculated by multiplying the measured surface area of each leaf section by the weight per unit area.
2. ***Rhizome tagging*** – Rhizome tagging was used to determine the leaf growth rate for non-leaf replacing species such as *Halophila ovalis* and *Halophila spinulosa* and the below ground production of all species. Rhizomes were tagged at the basal meristem with a coloured wire loop (Plate 7). Subsequent growth of the tagged seagrass produced a new shoot and roots that trap the wire loop in the newly formed node. Tagged seagrasses were harvested 3 to 8 days after tagging and biomass of new leaf material measured in the laboratory.
3. ***Leaf clipping*** - For the di-meristematic non-leaf replacing species, *Halophila spinulosa*, a leaf clipping method was used in addition to rhizome tagging (Plate 6). This species has a meristem at the tip of the leaf cluster where new leaves are produced on existing shoots as well as the new leaf shoots produced at the basal meristem on the rhizome. The youngest leaf on the tip of individual shoots was clipped in the field at a “radical” angle that can be recognised when the plants are harvested 3-8 days after clipping. New growth added was determined by removing drying and weighing any leaves that were produced above the “clipped” leaf on the shoot.

Information collected on individual species productivity will be used to calculate productivity of the target meadows using biomass and shoot density values collected as part of the baseline and monitoring assessments.

Plate 4. Diver punching holes to mark "new" versus "old" growth

Plate 5. "New" and "old" biomass samples ready to be measured and dried

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Plate 6. Diver clipping *H. spinulosa* leaf clusters

Plate 7. Diver tagging rhizomes at the basal meristem

3. Fisheries value

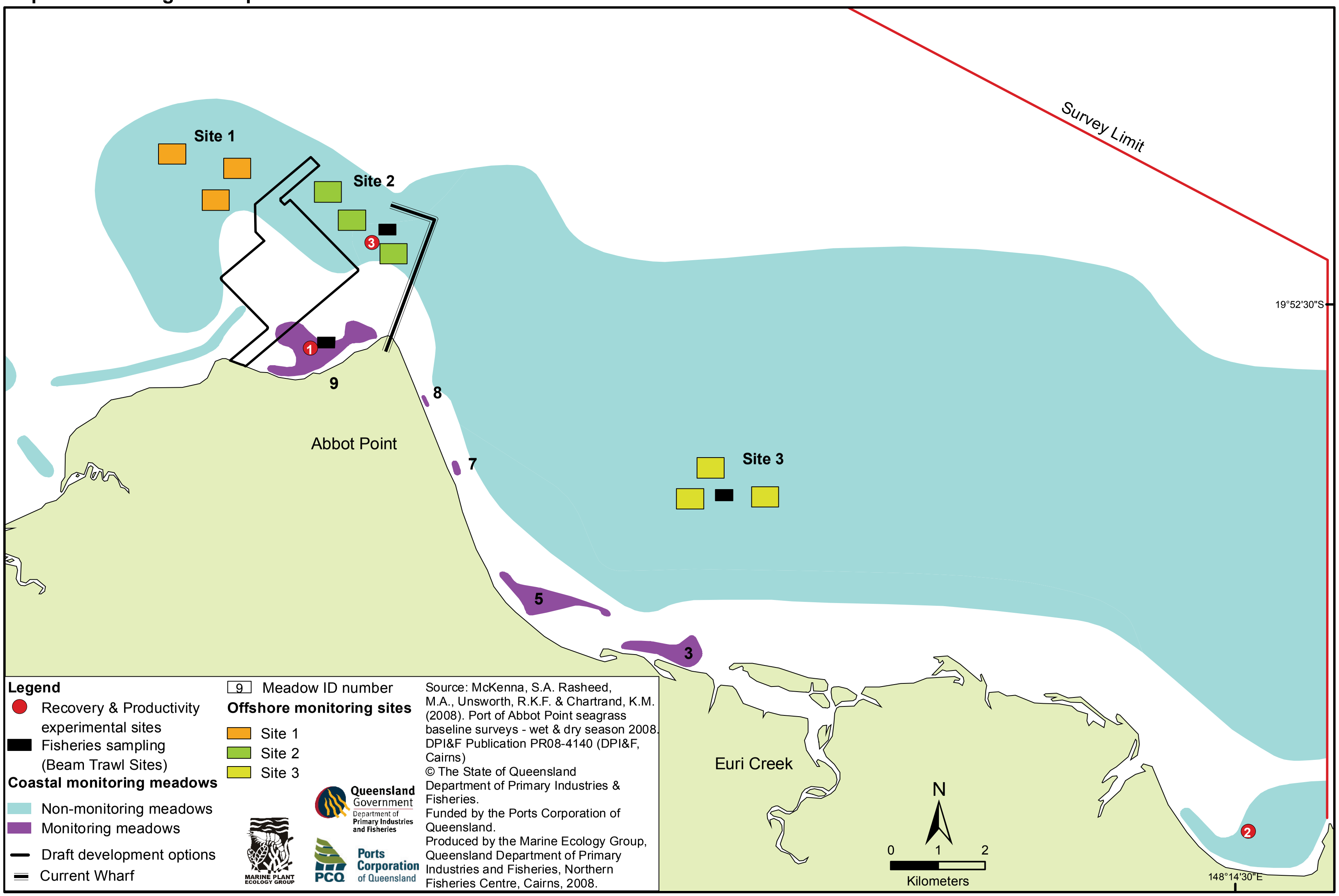
Three sites (one inshore and two offshore) were identified to conduct beam trawling to examine the fisheries nursery value of the seagrass meadows and their utilisation by invertebrate and fish communities (Map 3). Sampling at these sites has been conducted in July, September and November 2008 (Table 1). Sampling has been conducted at 3 monthly intervals to pick up any seasonal recruitment of invertebrates and fish.

Sampling has been conducted at the time of high water at night with a beam trawl (1.5m wide, 0.5m high with a 2.0mm mesh) (Plate 8) towed along a 100m transect (a total of 150m^2 sampled). Three replicate trawls have been conducted at each of the beam trawl sites as previous studies in North Queensland have shown that this is sufficient to adequately sample the representative fauna (Chartrand *et al*. 2008; Coles *et al*. 1993).

Plate 8. Beam trawling was conducted at night to assess prawn stocks and other commercially valuable stocks around the Port of Abbott Point

The Penaeid taxonomic work associated to this study is currently incomplete, therefore results will be included in the full report during 2009. All penaeidae (prawns) will be identified to species according to Dall (1957) and Grey *et al*. (1983) and carapace length measured. All fish will be identified as far as possible and standard length (tip of snout to last vertebra) measured. Numbers of Brachyura (crabs), squid, sepiolids (cuttlefish) and miscellaneous crustaceans (shrimps, isopods, amphipods and stomatopods) will be recorded for each trawl. Biomass (grams dry weight) of fish, penaeids (all species pooled), crustaceans and miscellaneous from each trawl will also be determined by drying (60°C, 48 hours) and weighing samples.

Map 3. Monitoring and Experimental sites in the Port of Abbot Point 2008



RESULTS – BASELINE SURVEYS

Seagrass species, distribution and abundance

Extensive coverage of seagrass was found in shallow coastal and deepwater areas in both the wet and dry season baseline surveys (Maps 4 & 5). Seagrass occurred in a strip of small meadows adjacent to the coast, and in four large offshore meadows. Seven seagrass species (from 3 families) were identified in the survey area with *Halophila spinulosa* dominating the deeper sub-tidal areas and *Halodule uninervis* (wide & thin varieties) dominating the inshore areas (Table 6). Seagrass was present throughout the potential port facility expansion region.

A total of 427 and 492 habitat characterisation sites were surveyed in the 2008 wet season and dry season baseline surveys respectively (Maps 4 & 5). The majority of the meadows found in both surveys were of low density, with the only moderate/dense seagrass meadows occurring adjacent to the coast east of the Abbot Point Jetty. These higher density meadows were not located within the footprint of the proposed port development. Seagrass was found to a maximum depth of 19.4m below MSL in the wet season and 18.3m below MSL in the dry.

The broad distribution and location of seagrass meadows was similar between the two seasonal surveys. However there were some changes to biomass and species composition and the disappearance and creation of several smaller meadows between surveys. Several new meadows formed in the dry season, whilst some small meadows identified in the wet season were absent, and several isolated meadows had increased in area. (Maps 4 & 5; Table 7).

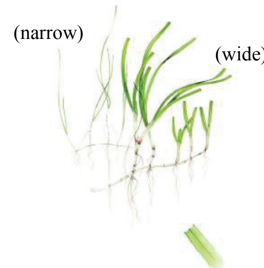
A total of 20,803 ± 6,595 ha (42% of the survey limits) of seagrass habitat was mapped in the wet season, and 17,527 ± 6,478 ha (35% of the survey limits) in the dry season (Table 7). The area of seagrass habitat mapped encompassed a total of 23 meadows in each survey (Maps 4 & 5; Table 7) with a total of 14 meadow types categorised according to the nomenclature and density tables described above; Tables 2 & 3).

Meadow biomass was generally higher in the dry season than in the wet for the majority of meadows (9 out of 13 directly comparable meadows; Table 7, Figure 2). Mean above-ground biomass in the wet season survey ranged from 0.01 ± 0 g DW m^{-2} in the light *Halophila ovalis* (ID 19) and *Halophila spinulosa* (ID 12) coastal meadows to 4.06 ± 0.96 g DW m^{-2} in the offshore meadow (ID 14) dominated by *Halophila spinulosa* (Table 7). In the dry season, biomass ranged from 0.02 ± 0 g DW m^{-2} in the coastal light *Halodule uninervis* meadow (ID 27), to 8.91 ± 4.17 g DW m^{-2} in the moderately dense coastal *Zostera capricorni* meadow (ID 3).

For all coastal meadows combined (all sites pooled from Branch Creek – Bowen), the mean meadow biomass significantly increased from wet season (1.36 ± 0.03g DW m^{-1}) to dry season (2.76 ± 0.74g DW m^{-1}) baseline surveys (Figure 1). The total meadow area of all coastal meadows combined marginally decreased in the dry season from 1,482 ± 436ha to 1,016 ± 635 ha.

For all deep-water meadows combined (ID 13, 14, 15 & 22), the mean meadow biomass and total meadow area decreased in the dry season, however, these were not significant differences (Figure 1).

Table 6. Seagrass species found within the survey area during the wet and dry season baseline surveys 2008.

Family	Species			
CYMODOCEACEAE Taylor	*Cymodocea serrulata* (R.Br.) Aschers and Magnus		*Halodule uninervis* (wide and narrow leaf morphology) (Forsk.) Aschers. in Boissier	
	Cymodocea rotundata			
ZOSTERACEAE Drummortier	*Zostera capricorni* Aschers.			
HYDROCHARITACEAE Jussieu	*Halophila decipiens* Ostenfield		*Halophila ovalis* (R. Br.) Hook. F.	
	Halophila spinulosa (R. Br.) Aschers. in Neumayer			

Branch Creek to Abbot Point Coastal Seagrasses

Coastal seagrass from the western boundary of the survey limits to Abbot Point were variable in distribution and biomass between seasons yet similar in species composition (Maps 4 & 5). These coastal meadows were generally dominated by *Halodule uninervis* with *Halophila ovalis, Halophila spinulosa* and *Halophila decipiens* also present in the area.

Several new meadows were present in the dry season whilst some small meadows identified in the wet season were absent (ID 16 & 18). Additionally, several isolated meadows had increased in area; particularly the *Halophila ovalis* dominated meadows (ID 19 & 21). The area of meadow 20 also increased, while the areas of meadows 9 & 12 substantially decreased in the dry season compared to the wet season (Map 4 & 5).

Mean above-ground biomass only decreased in meadow 9, located beneath and adjacent to the proposed coal terminal facility (Table 7; Figure 2; see Appendix 1). Meadow 20, dominated by *Halodule uninervis* (wide), had a significant increase in biomass between the two baseline surveys, increasing from 0.05 ± 0.01 g DW m^{-1} to 0.94 ± 0.36 g DW m^{-1} in the dry season. Species composition within this meadow remained the same between the baseline surveys. Species composition remained the same for all other meadows in this area with the only noticeable change being that of the presence of *Halophila decipiens* in meadow 21 in the dry season but not in the wet season survey.

Abbot Point to Bowen Coastal Seagrasses

The inshore region from Abbot Point to Bowen was dominated primarily by *Halodule uninervis* meadows in both baseline surveys with one *Zostera capricorni* meadow (3) located west of Euri Creek (Map 4 & 5). This region encompassed the only meadows that had dense and moderate covers of seagrass (ID's 3, 5, 7 & 8) within the survey limit. The distribution of seagrasses in this region was broadly similar between the two baseline surveys; however there were some small shifts in density, species composition and biomass in some meadows.

Four low density meadows were only present in the dry season survey with two adjacent to the coast (a *Halodule uninervis* (ID 27) and a *Zostera capricorni* meadow (ID 26)) and two offshore meadows dominated by *Halophila decipiens* (ID 24 & 25).

Two coastal meadows (ID 7 & 8) increased in area from wet to dry season surveys, whilst two meadows noticeably decreased in area (ID 5 & 23) (Table 7; Figure 2). The area of the only *Halodule uninervis/Zostera capricorni* meadow present remained stable with a shift in dominance from *Halodule uninervis* (wide) in March to *Zostera capricorni* in August.

Above-ground biomass in the coastal meadows east of Abbot Point tended to be higher than all other areas within the survey limit in both baseline surveys. Meadow 3 recorded the highest biomass values with 3.71 ± 1.72 g DW m^{-2} and 8.91 ± 4.17 g DW m^{-2} for wet and dry respectively (Table 7). This was the only meadow with a substantial coverage of the large growing species *Zostera capricorni*. Biomass increased from March to August surveys for all coastal meadows except meadow 23, which significantly decreased from 3.56 ± 0.36 g DW m^{-2} to 2.86 ± 1.79 g DW m^{-2} (see Appendix 1). The only significant increase in above-ground biomass was in meadow 5.

Abbot Point Deepwater Seagrasses

Significant areas of low biomass deep-water seagrass was found within the survey limits in both baseline surveys (Maps 4 & 5). Deep-water meadows covered a total of 19,320 ± 6,160ha (93% of the total area of seagrass) in the wet season and 15,510 ± 5,843ha (89% of the total area of seagrass) in the dry season (Table 7). The distribution and species composition of the four deep-water meadows was broadly similar between the two baseline surveys.

Four different community types were observed in deepwater meadows (Maps 4 & 5). Two meadows were dominated by *Halophila spinulosa* (ID 14 & 22) while *Halodule uninervis* and *Halophila ovalis* were the dominant species in meadows 13 & 15.

The largest deepwater meadow (ID 14), dominated by *Halophila spinulosa*, reduced in size from the wet to dry season (Map 4 & 5). The western boundary shifted to encompass an area previously occupied by a *Halodule uninervis/Halophila ovalis* meadow (ID 13). During the dry season, meadow 13 had reduced to a single isolated patch of *Halophila ovalis*. The area and distribution of meadows 22 and 15 were similar between the two surveys.

In addition to area, the above-ground biomass of meadow 14 also significantly increased from 4.06 ± 0.96 g DW m^{-2} in the wet season to 5.23 ± 0.96 g DW m^{-2} in the dry season. Species composition for the meadow remained similar with a total of five species found in this meadow (see Appendix 1).

Due to low visibility, video biomass ranks were not recorded for meadows 21 and 15 in the wet season survey.

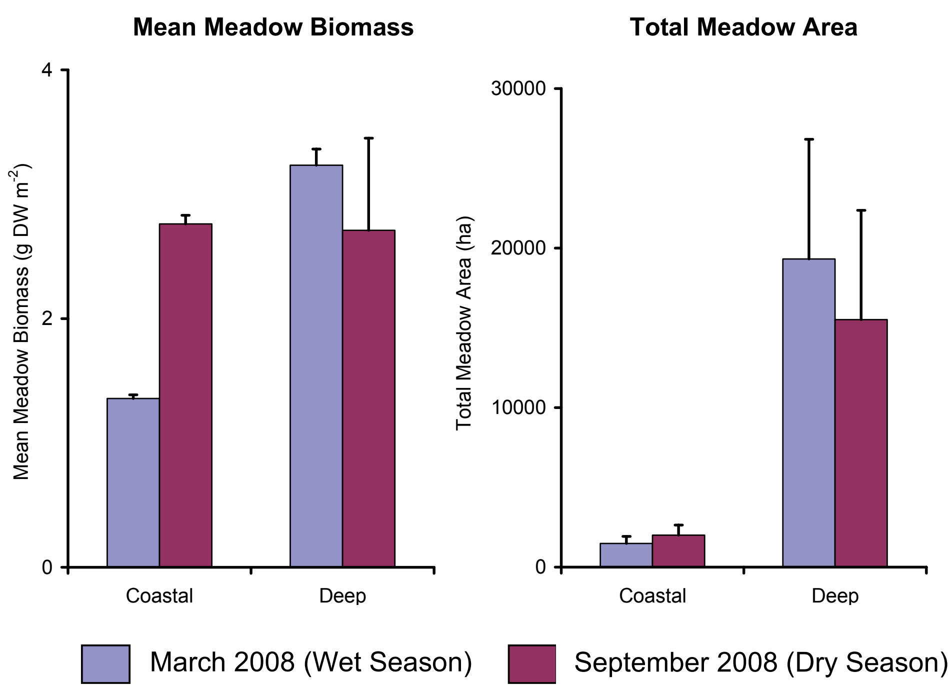
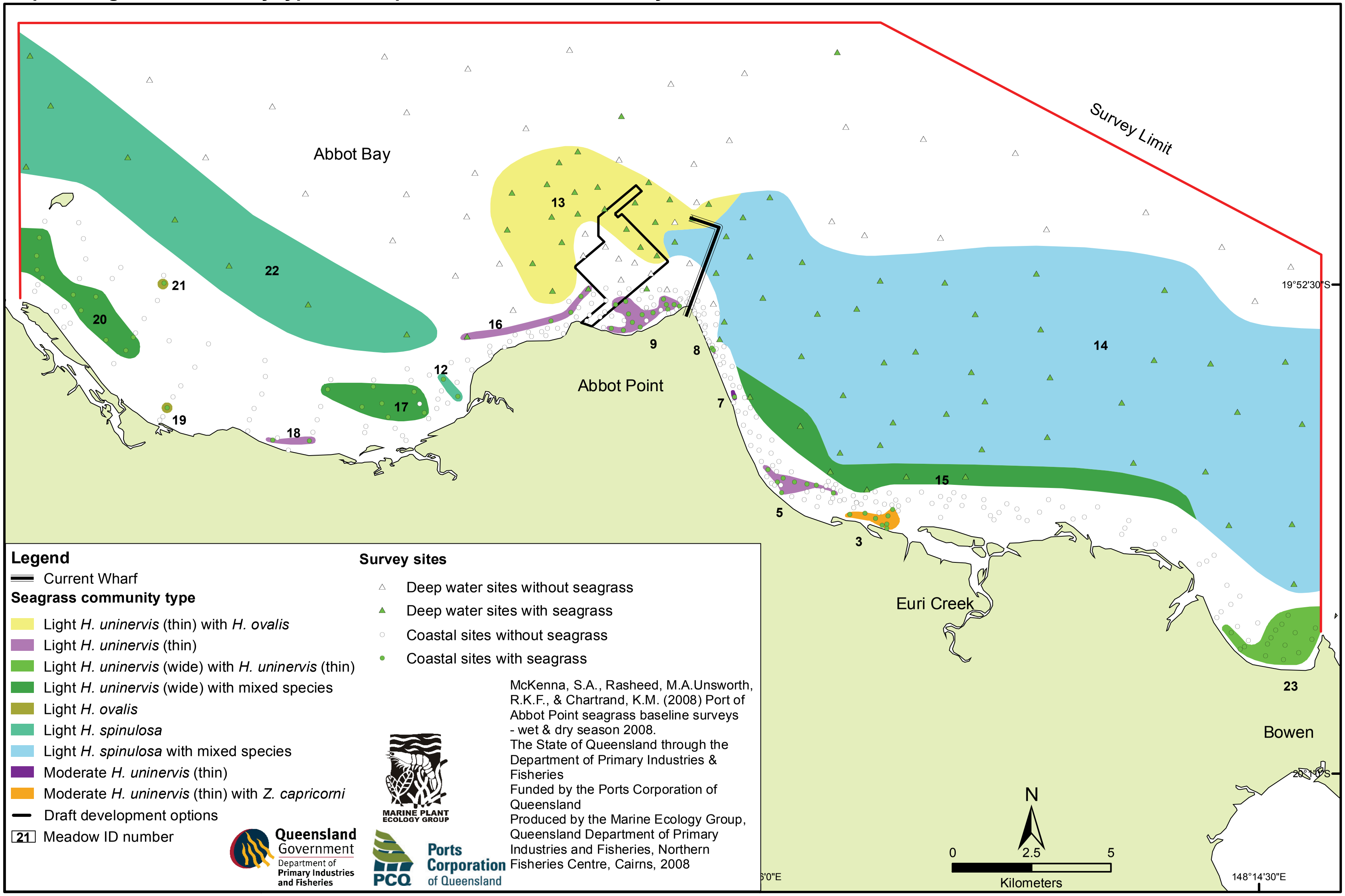


Figure 1. Mean meadow biomass (g DW m^{-2}) and area (ha) for all coastal and deep-water sites pooled.

Map 4. Seagrass community types in the port of Abbot Point February & March 2008



Map 5. Seagrass community types in the Port of Abbot Point August & September 2008

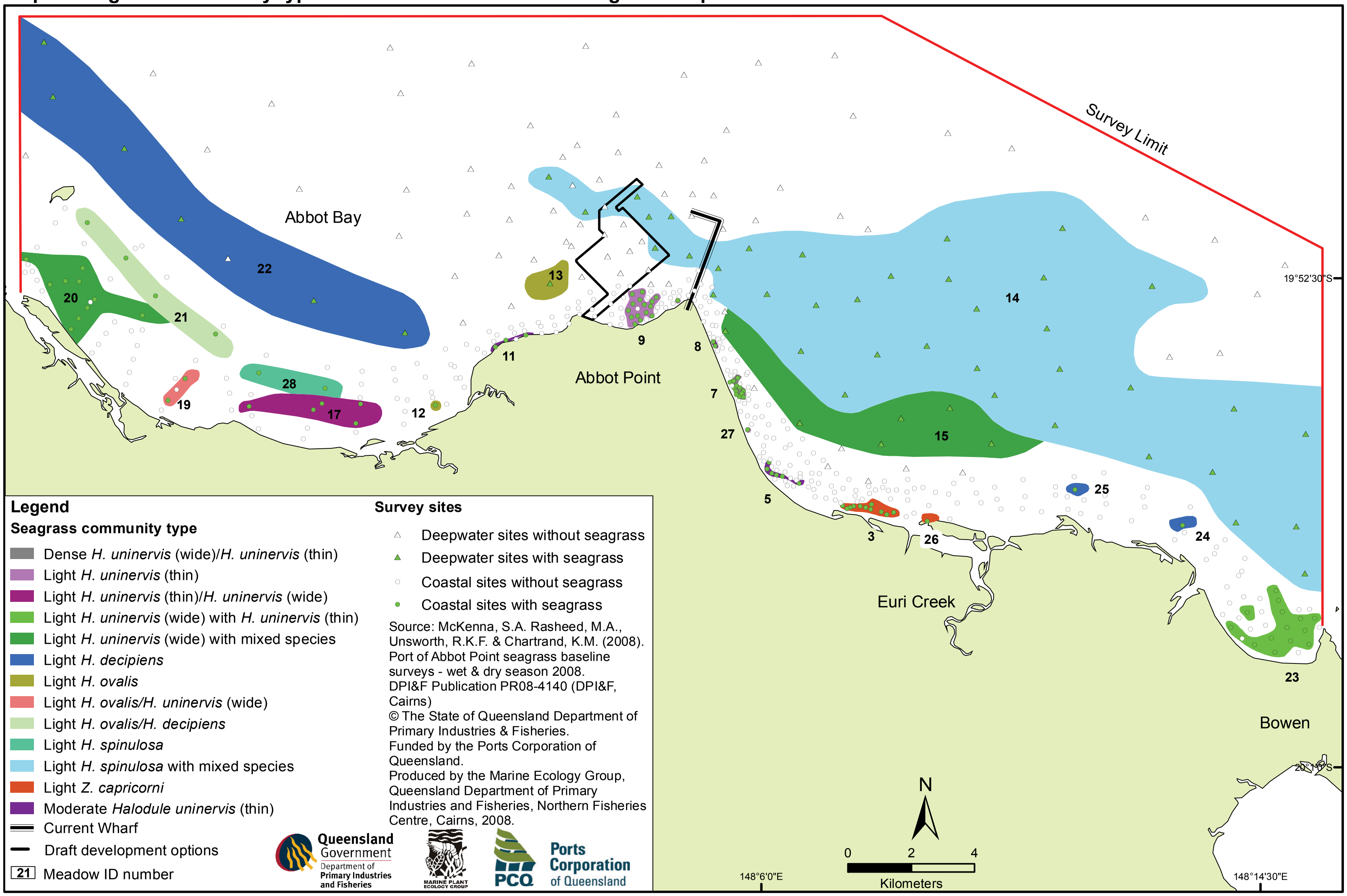


Table 7. Location of meadows relative to the proposed port development, mean above-ground biomass and total meadow area of seagrass within the Port of Abbot Point during the wet and dry seasons of 2008. (np – not present)

			Mean biomass ± SE (g DW m^{-2})		**Total meadow area ± R (ha)**	
Meadow ID	**Meadow Location**	**Dominating seagrass species**	**Wet Season**	**Dry Season**	**Wet Season**	**Dry Season**
3	Coastal East	*H.uninervis & Z. capricorni*	3.71 ± 1.72	8.91 ± 4.17	55 ± 8	57 ± 8
5	Coastal East	*H. uninervis* (thin)	0.05 ± 0.02	1.54 ± 0.57	68 ± 28	20 ± 17
7	Coastal East	*H. uninervis* (wide) and (thin)	2.84 ± 0.00	6.70 ± 2.21	4 ± 1	21 ± 2
8	Coastal East	*H. uninervis* (thin)	0.52 ± 0.52	1.65 ± 0.33	2 ± 1	4 ± 1
9	Coastal East	*H. uninervis* (thin)	0.86 ± 0.47	0.40 ± 0.15	121 ± 71	84 ± 10
11	Coastal West	*H. uninervis* (thin)	np	2.25 ± 1.05	np	10 ± 6
12	Coastal West	*H. ovalis & H.spinulosa*	0.01 ± 0	0.19 ± 0.0	29 ± 5	9 ± 6
13	Deep Adjacent	*H. uninervis* & *H. ovalis*	0.19 ± 0.14	0.19 ± 0.0	1823 ± 1219	117 ± 288
14	Deep East	*H. spinulosa*	4.06 ± 0.96	5.23 ± 1.37	12729 ± 2801	10950 ± 3516
15	Deep East	*H. uninervis* (wide)	na	0.61 ± 0.33	1050 ± 320	1354 ± 240
16	Coastal Adjacent	*H. uninervis* (thin)	0.13 ± 0.13	np	95 ± 18	np
17	Coastal West	*H. uninervis* (thin) and (wide)	0.42 ± 0.15	0.90 ± 0.63	292 ± 78	294 ± 96
18	Coastal West	*H. uninervis* (thin)	0.53 ± 0.26	np	29 ± 7	np
19	Coastal West	*H. ovalis* and *H. uninervis* (wide)	0.01 ±	0.15 ± 0.08	9 ± 2	56 ± 18
20	Coastal West	*H. uninervis* (wide)	0.05 ± 0.01	0.94 ± 0.36	446 ± 124	491 ± 126
21	Coastal West	*H. ovalis* and *H. decipiens*	na	0.12 ± 0.04	9 ± 2	437 ± 141
22	Deep West	*H.* spinulosa & *H. decipiens*	0.72 ± 0.35	0.10 ± 0.04	3718 ± 1820	3089 ± 1799
23	Coastal East	*H. uninervis* (thin) (wide)	3.46 ± 0.36	2.86 ± 1.79	324 ± 90	275 ± 119
24	Coastal East	*H. decipiens*	np	0.32 ± 0.0	np	30 ± 4
25	Coastal East	*H. decipiens*	np	0.13 ± 0.0	np	22 ± 4
26	Coastal East	*Z. capricorni*	np	0.30 ± 0.0	np	14 ± 3
27	Coastal East	*H. uninervis* (thin)	np	0.02 ± 0.0	np	2 ± 1
28	Coastal West	*H. spinulosa*	np	0.37 ± 0.0	np	191 ± 73

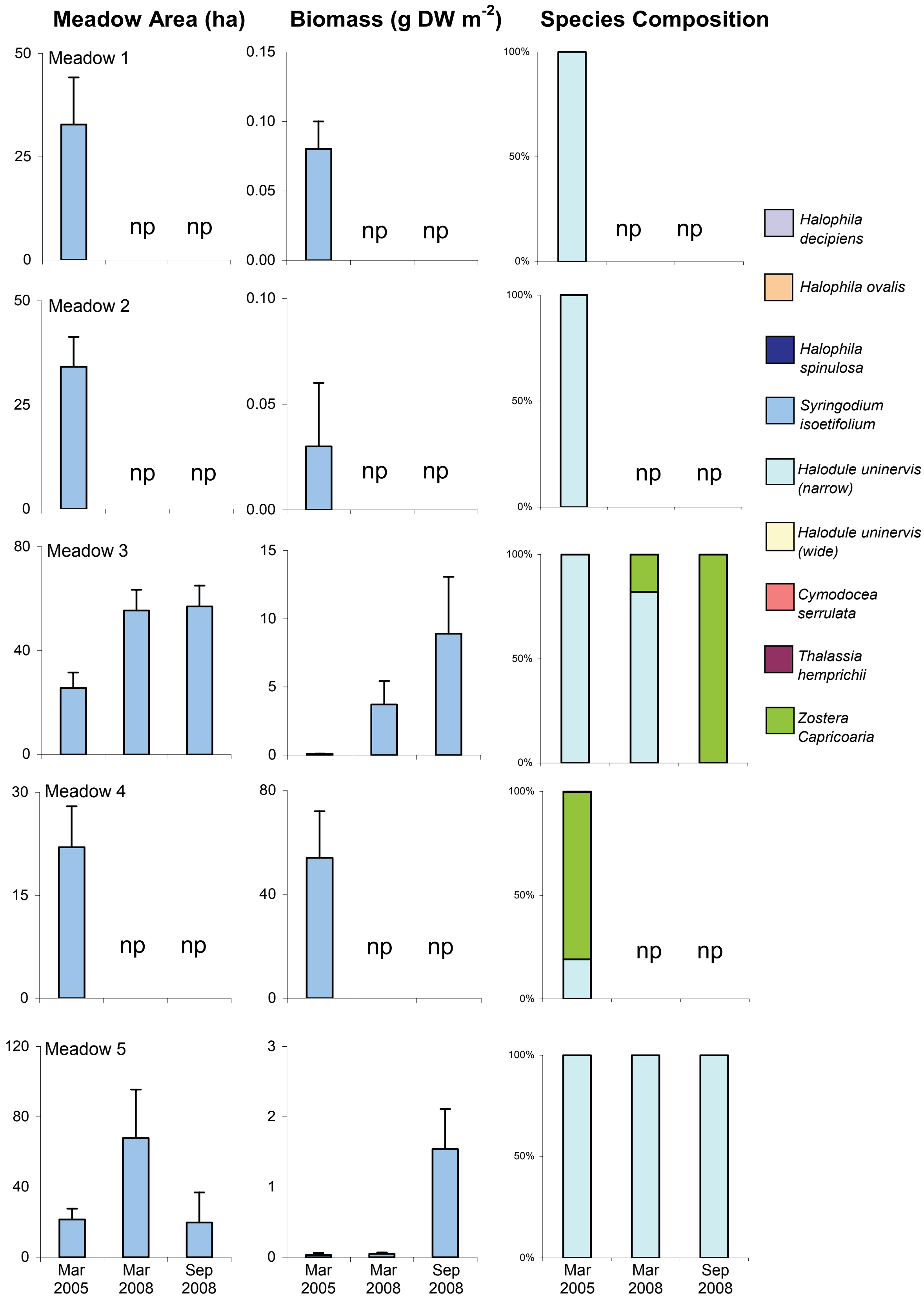
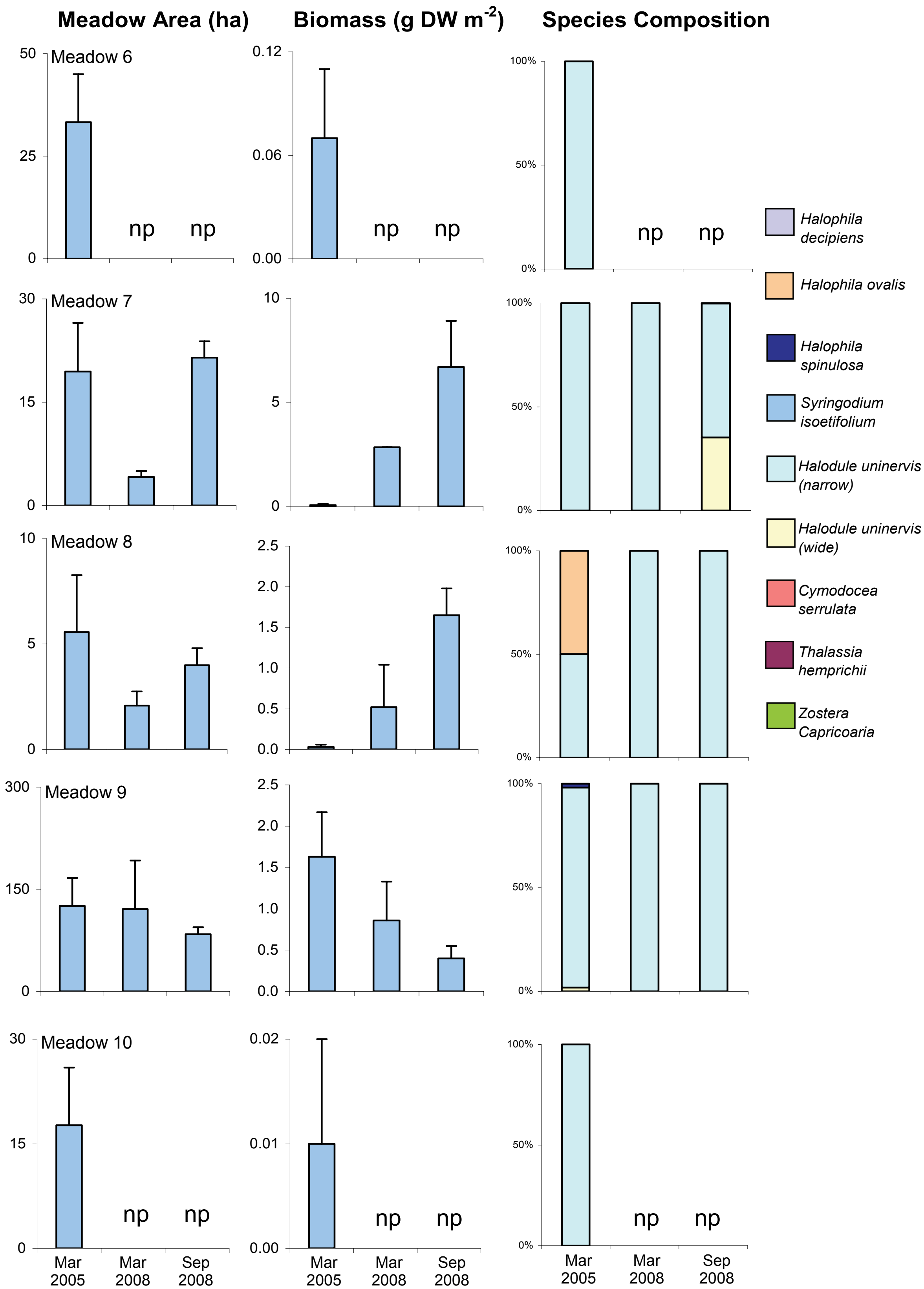


Figure 2. Changes in meadow area, biomass and species composition for seagrass meadows in the Port of Abbot Point between March 2005, March 2008 & September 2008 (np – not present, nr – not recorded).



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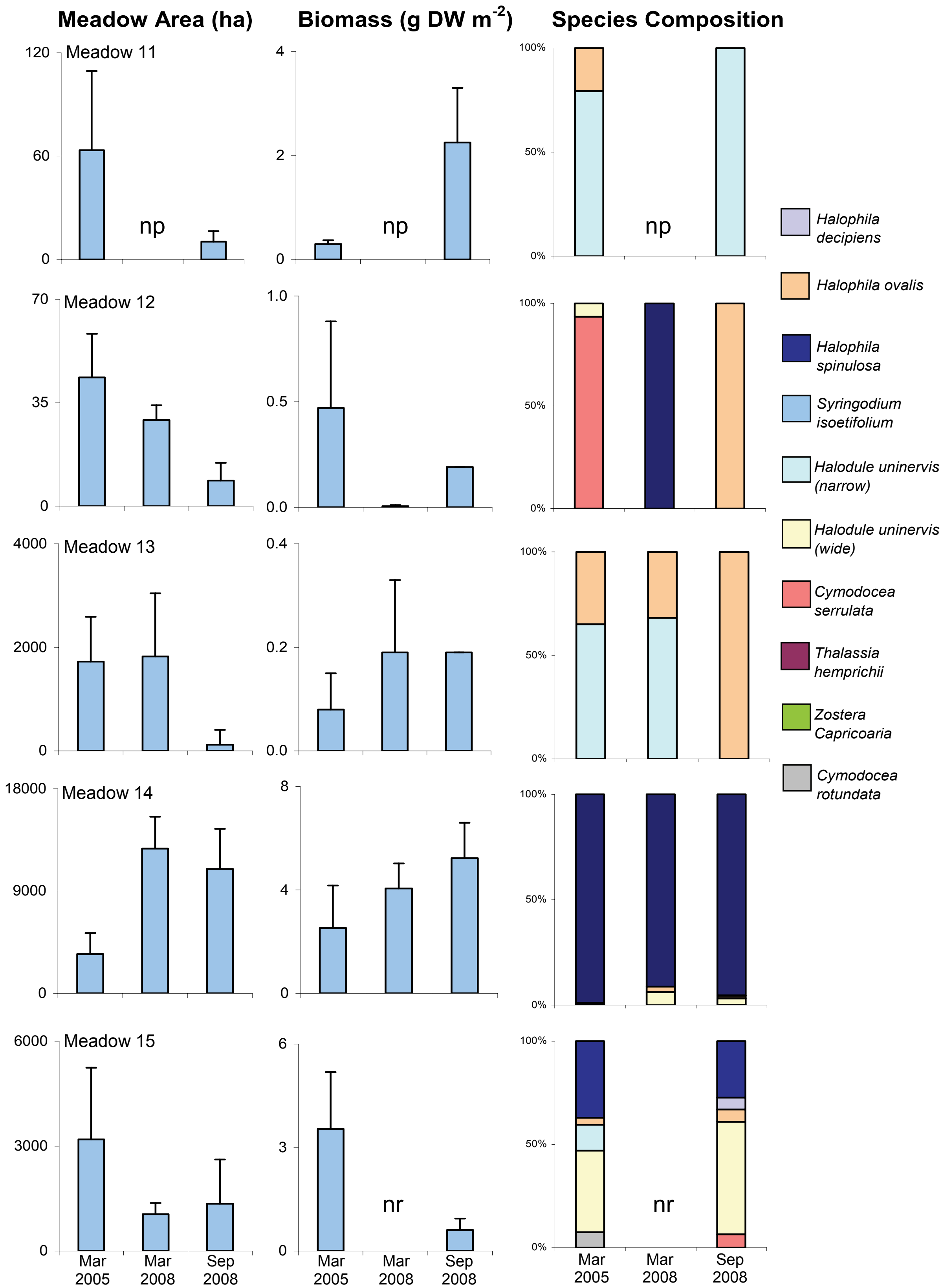

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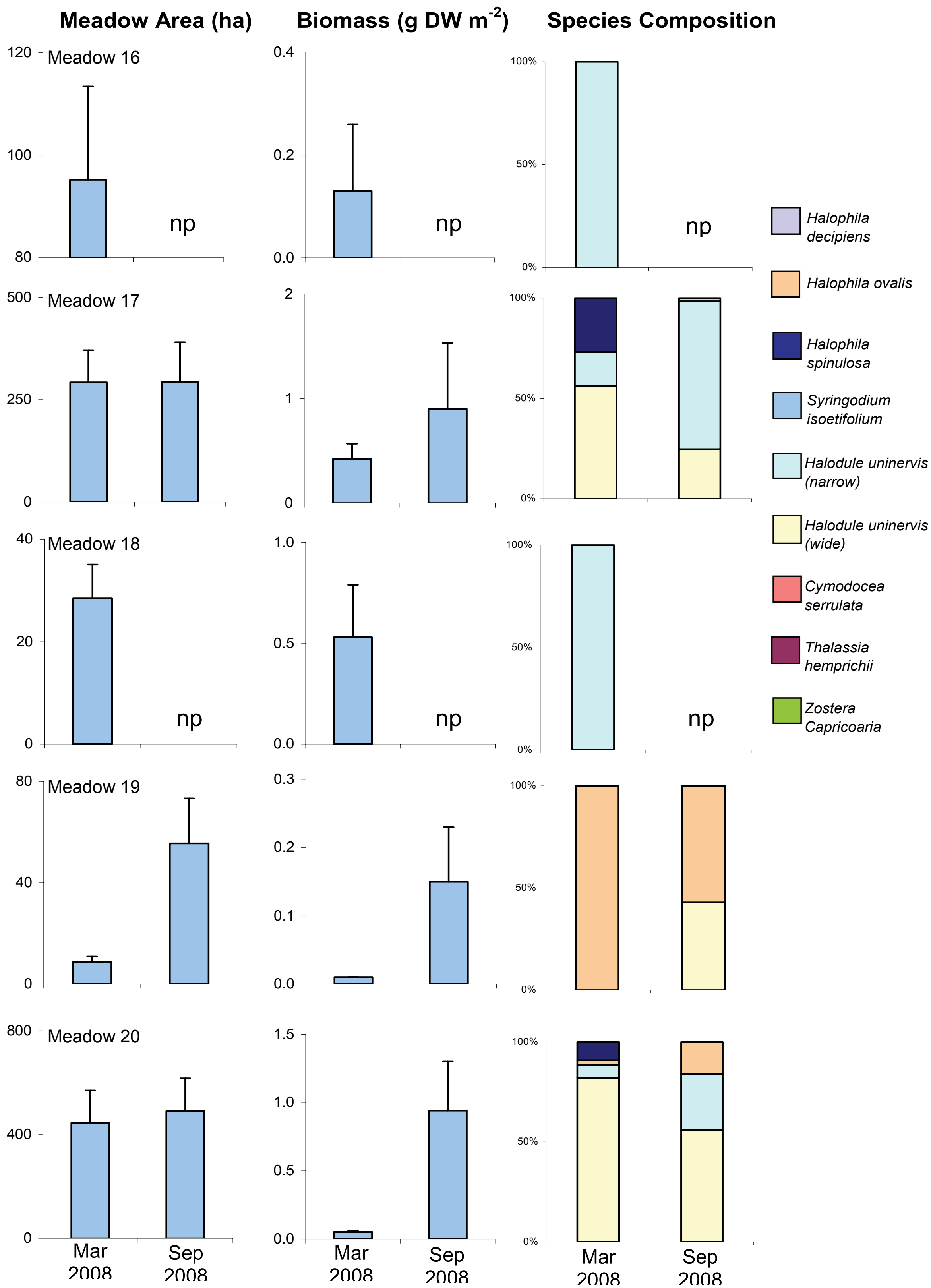


Figure 2. Changes in meadow area, biomass and species composition for seagrass meadows in the Port of Abbot Point between March 2008 & September 2008 (np – not present, nr – not recorded).

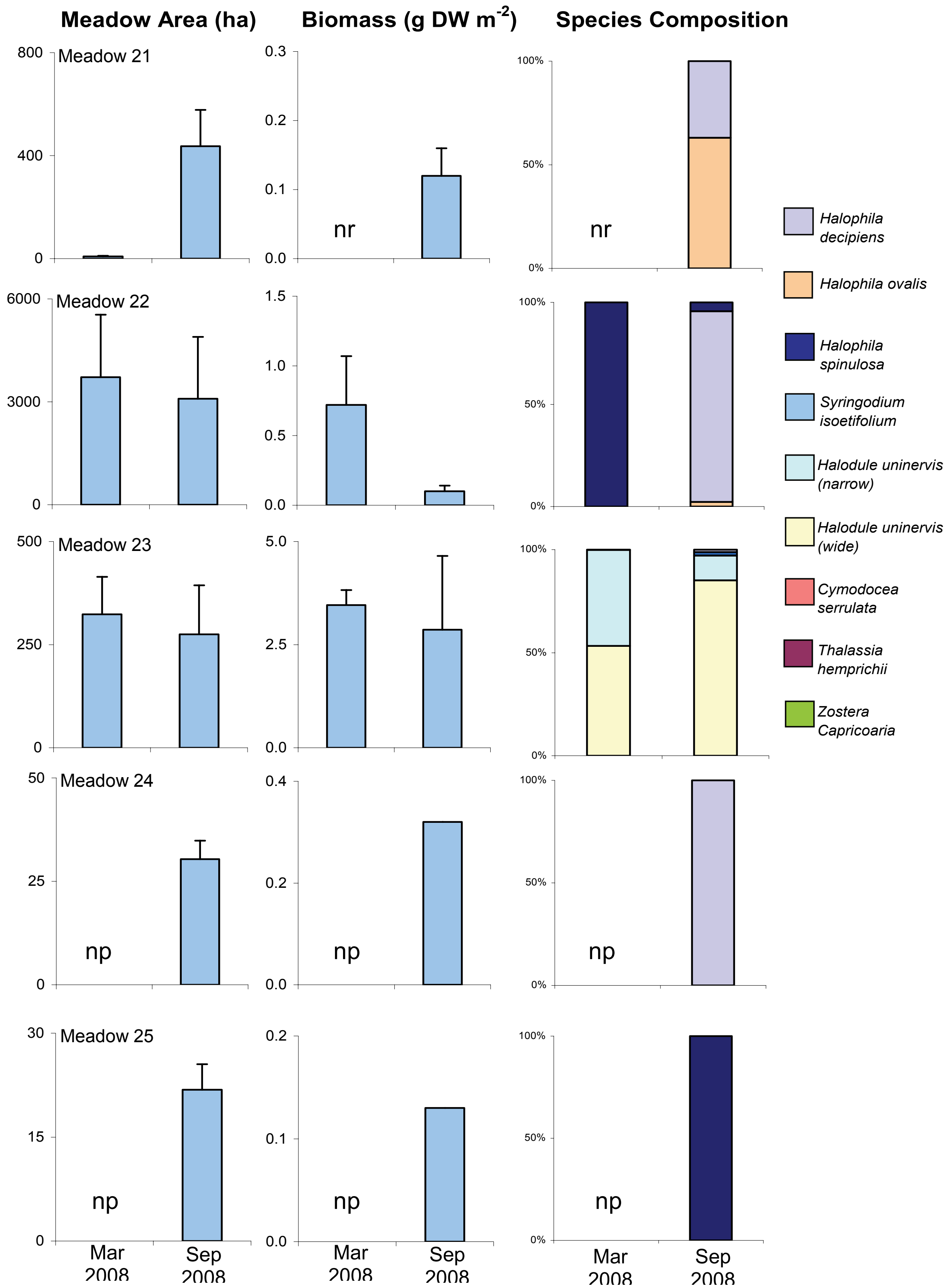


Figure 2. Changes in meadow area, biomass and species composition for seagrass meadows in the Port of Abbot Point between March 2008 & September 2008 (np – not present, nr – not recorded).

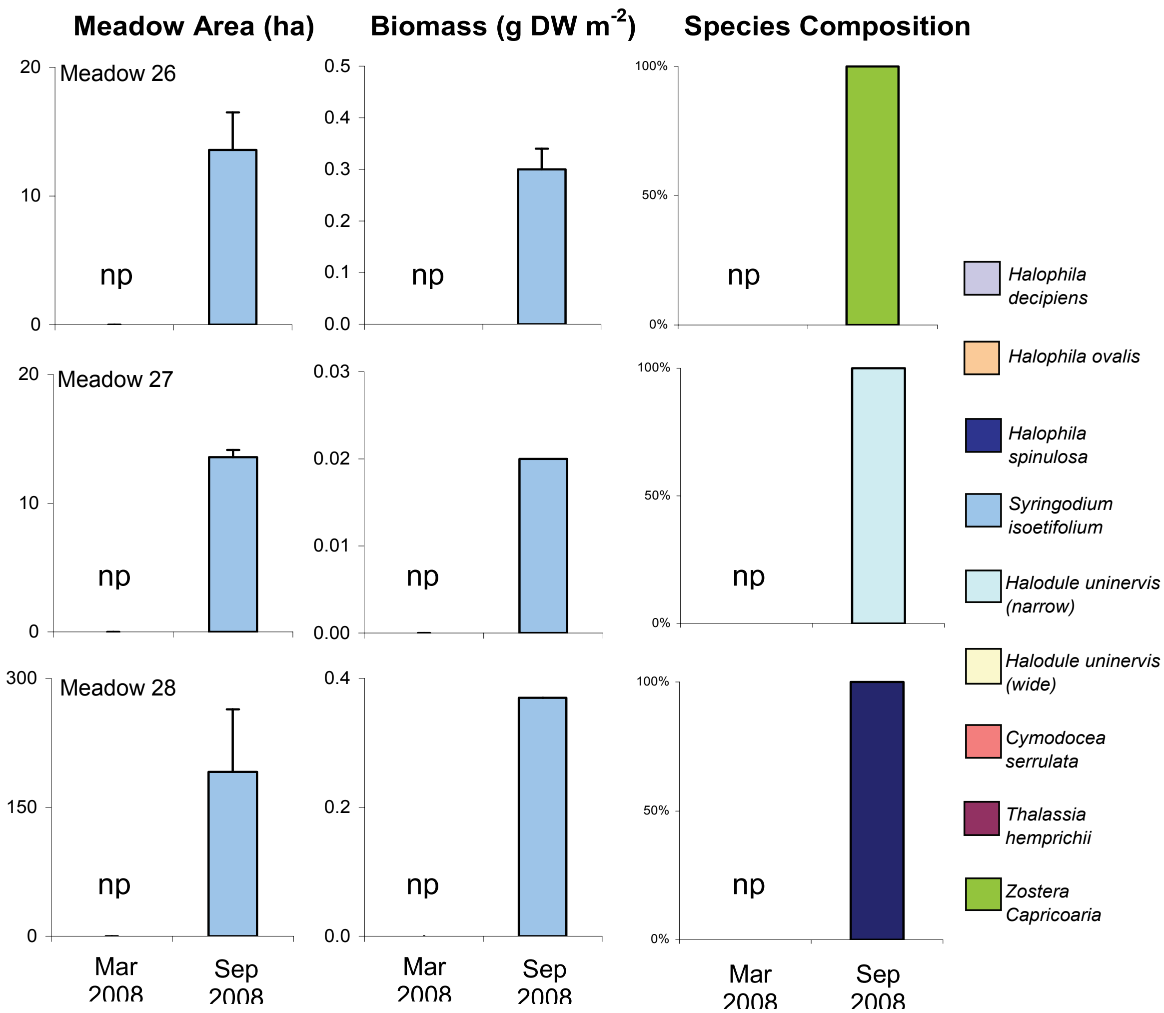


Figure 2. Changes in meadow area, biomass and species composition for seagrass meadows in the Port of Abbot Point between March 2008 & September 2008 (np – not present, nr – not recorded).

Comparison with Historical Seagrass Data

There have been two previous surveys of the coastal seagrass (1987 & 2005) and one previous survey that included the deep-water seagrass within the Abbot Point port limits (2005). The 1987 survey was conducted as part of a broad-scale mapping project by DPI&F (Coles *et al*. 1992) and as such was not sampled at the same intensity as the present baseline surveys or with the same technique.

The 2005 (Rasheed *et al.* 2005) Abbot Point survey was done at the same scale and intensity as the present baseline surveys although it covered a smaller section of the port limits. The March 2005 survey used the same techniques, and allows a direct comparison with seagrass found within the same survey area in March 2008 (Map 6). Comparisons were feasible for at least 11 meadows (ID 3,5,7-9,12-15) within the 2005 survey limits between the 2005 and 2008 baseline surveys (Table 8; Map 2 & 6).

Overall, location, distribution and species composition of coastal and deep-water seagrass meadows (where comparable) were similar between 1987, 2005 and 2008 (Table 8; Map 6). *Halodule uninervis* dominated coastal meadows and the *Zostera capricorni* found west of Euri Creek was present in all three surveys. *Halophila spinulosa* dominated deep-water areas in both 2005 and 2008 (area not surveyed in 1987). With all sites occurring in the area common to both surveys pooled, coastal and deep-water meadow area was larger in 2008 compared to 2005 (Table 8; Figure 3).

There were no significant differences in above-ground biomass between any corresponding coastal meadows from the March 2005 and March 2008 baseline surveys, or for all coastal meadows combined between years (Figure 3). The above-ground biomass for analogous deep-water meadows were similar between March 2005 and March 2008. Similarly, for all deep-water meadows combined there was no significant difference in above-ground biomass between the years.

Table 8. Location of meadows relative to the proposed port development, mean above-ground biomass and total meadow area of seagrass within the Port of Abbot Point during the Wet seasons of March 2005 & March 2008. (na – biomass data not available)

			Mean biomass ± SE (g DW m^{-2})		Total meadow area ± R (ha)	
Meadow ID	**Meadow Location**	**Dominating seagrass species**	**March 2005**	**March 2008**	**March 2005**	**March 2008**
3	Coastal East	*H.uninervis* & *Z. capricorni*	0.09 ± 0.03	3.71 ± 1.72	26 ± 6	55 ± 8
5	Coastal East	*H. uninervis* (thin)	0.03 ± 0.03	0.05 ± 0.02	22 ± 6	68 ± 28
7	Coastal East	*H. uninervis* (wide & thin)	0.06 ± 0.06	2.84 ± 0.00	19 ± 7	4 ± 1
8	Coastal East	*H. uninervis* (thin)	0.03 ± 0.03	0.52 ± 0.5	6 ± 3	2 ± 1
9	Coastal East	*H. uninervis* (thin)	1.63 ± 0.54	0.86 ± 0.47	126 ± 41	121 ± 71
12	Coastal West	*H. ovalis* & *H.spinulosa*	0.47 ± 0.41	0.01 ± 0	44 ± 15	29 ± 5
13	Deep Adjacent	*H. uninervis* & *H. ovalis*	0.08 ± 0.07	0.19 ± 0.14	1721 ± 867	1823 ± 1219
14	Deep East	*H. spinulosa*	2.53 ± 1.64	4.06 ± 0.96	3464 ± 1900	12729 ± 2801
15	Deep East	*H. uninervis* (wide)	3.54 ± 1.65	na	3190 ± 2055	1050 ± 320

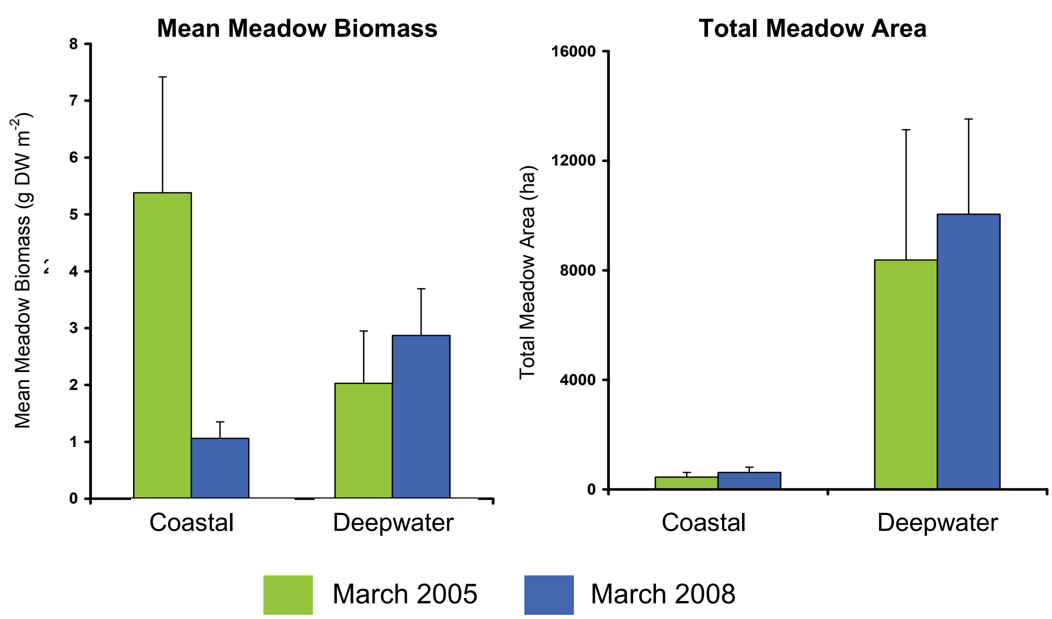
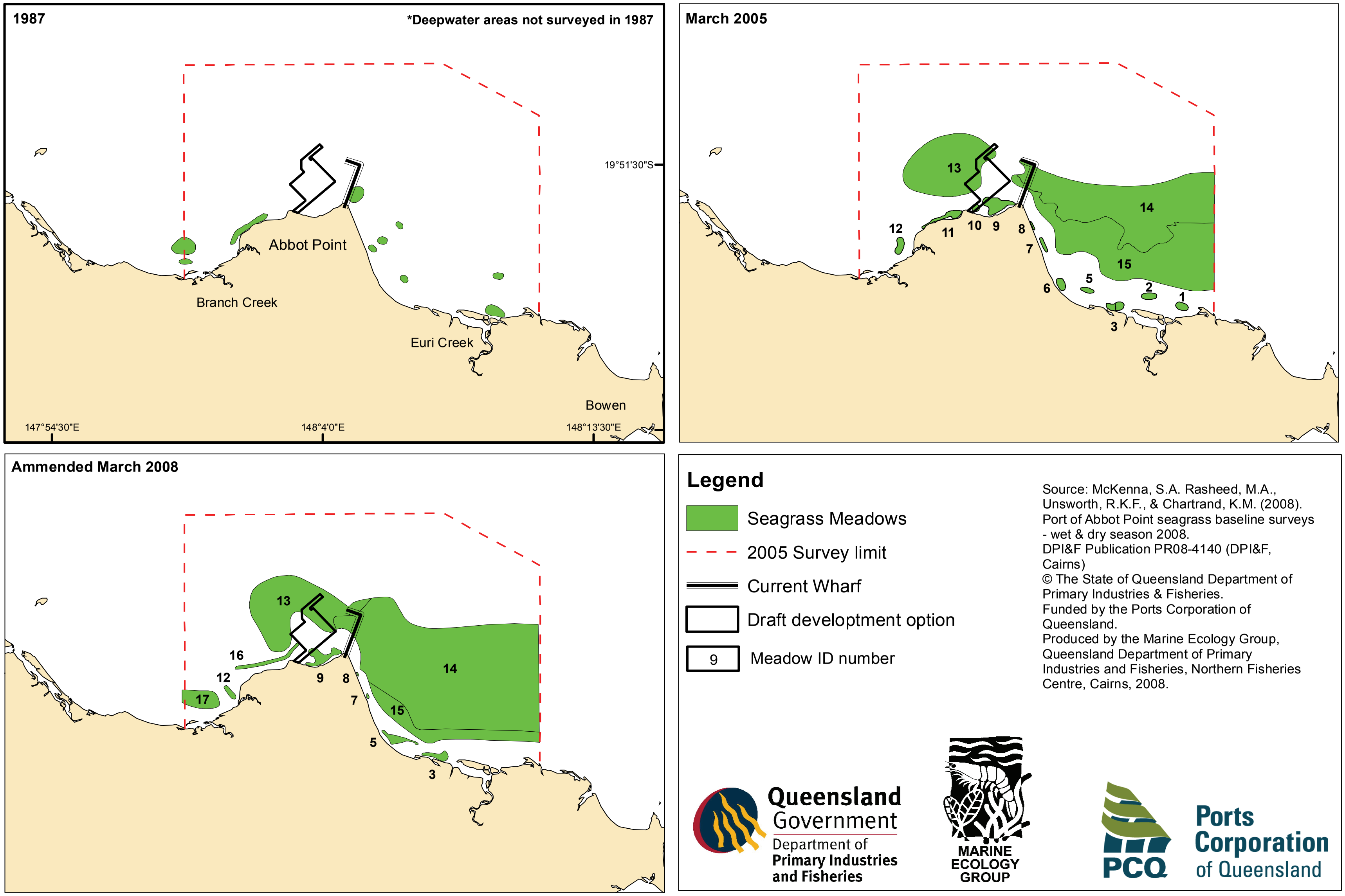


Figure 3. Mean meadow biomass (g DW m^{-2}) and area (ha) for all coastal and deep-water sites pooled in the Wet season 2005 & 2008.

Map 6. Comparison of seagrass meadows in the Port of Abbot Point - 1987, March 2005 and March 2008 (comparison based on common area within 2005 survey limits)



PRELIMINARY RESULTS - QUARTERLY MONITORING & MANIPULATIVE EXPERIMENTS

Although it is not the obective of this report to present information in relation to Part 2 of the project, some preliminary results of the quarterly long-term monitoring and manipulative experiments are presented below.

(a) Quarterly Monitoring of Key Seagrass Meadows

From the wet season baseline survey five coastal and three offshore meadows were identified as suitable for a long-term seagrass monitoring program (Map 3). These areas were selected because they represented the full range of seagrass species and habitat types (intertidal and subtidal) present in the Port of Abbot Point. Monitoring surveys of the selected meadows were carried out in July, September and November 2008 (Table 1).

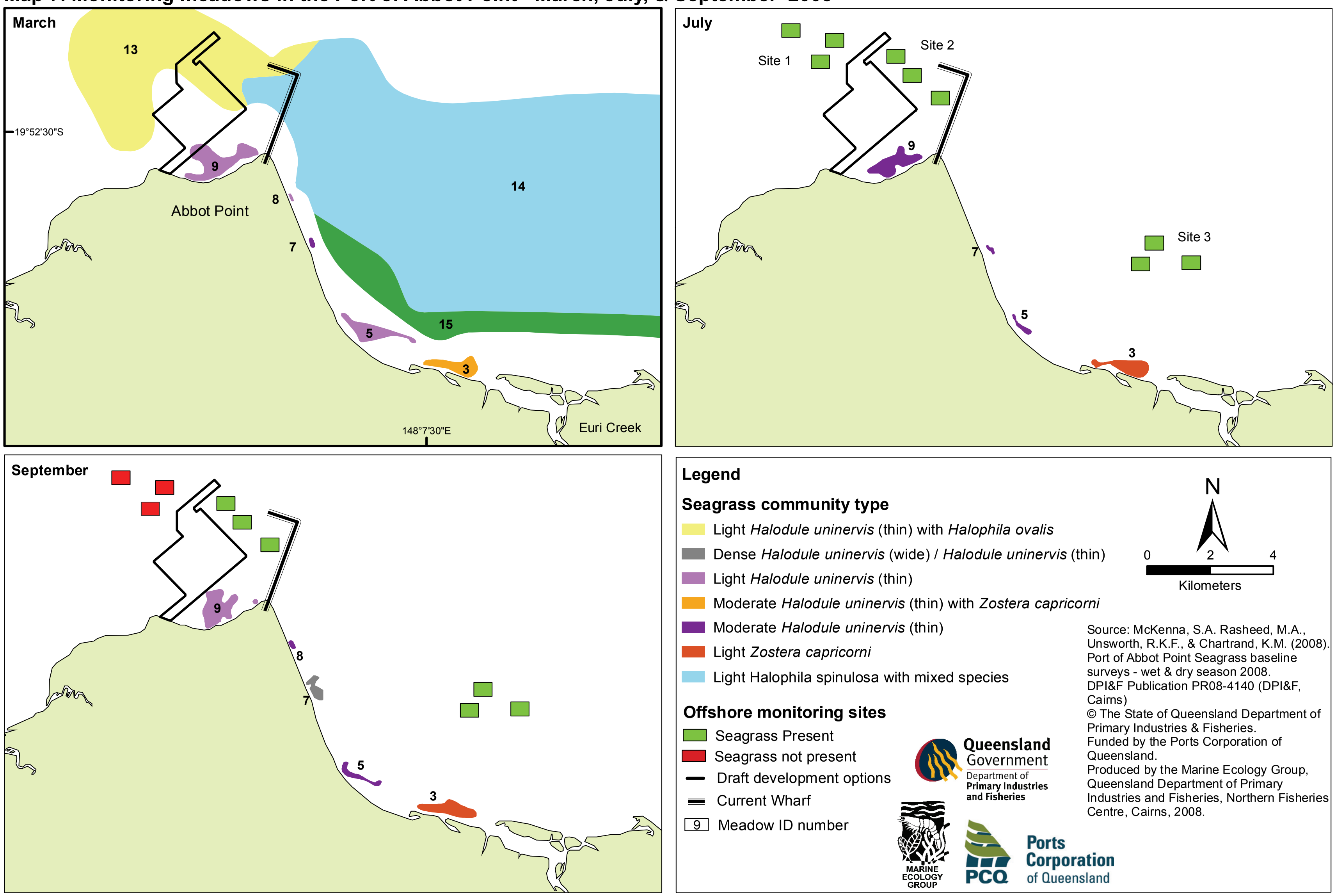
Preliminary results indicate that the distribution, density and species composition of seagrasses in the coastal monitoring meadows were similar between March (baseline), July and September surveys (Map 7). The dominant species for all meadows and surveys was *Halodule uninervis* while *Zostera capricorni* continued to dominate the meadow west of Euri Creek. Among the most notable changes included the loss of meadow 8 in the July survey and then returning in the September survey at a greater density than previously found in March (Table 9). Meadow 3 and 7 also increased in biomass from March to September.

Above-ground biomass data for the three deep-water monitoirng sites will be available in the first monitoring report, however seagrass presence or absence at these sites is available for the July and September surveys (Map 7). In July seagrass was present at all three off-shore monitoring sites while absent at the deepest monitoring site in September.

Table 9. Mean above-ground biomass and total meadow area within the Port of Abbot Point during the 2008 monitoring surveys.

. Meadow	Mean biomass ± SE g DW m^{-2}			Total meadow area ± R in ha		
	March	July	Sept	March	July	Sept
3	3.71 ± 1.72	4.55 ± 1.68	8.91 ± 4.17	55 ± 8	53 ± 8	57 ± 8
5	0.05 ± 0.02	1.57 ± 0.08	1.54 ± 0.57	68 ± 28	10 ± 2	20 ± 17
7	2.84 ± 0	3.72 ± 0.33	6.70 ± 2.21	4 ± 1	4 ± 1	21 ± 2
8	0.52 ± 0.5	Absent	1.65 ± 0.33	2 ± 1	Absent	4 ± 1
9	0.86 ± 0.47	1.10 ± 0.53	0.40 ± 0.15	121 ± 71	67 ± 9	84 ± 10

Map 7. Monitoring meadows in the Port of Abbot Point - March, July, & September 2008



(b) Capacity for Recovery, Productivity & Seagrass Resilience

From the March 2008 baseline survey three experimental sites examining the capacity for recovery and primary and fisheries productivity of seagrasses were established in meadows representing the major seagrass community types (Map 3). Preliminary observations are reported here with more detailed analysis and results to be presented after March 2009 when 12 months of data will be available.

1. Capacity for Recovery

Preliminary observations on the recovery of seagrass within experimentally manipulated plots have shown the beginnings of the recovery process. Some of the sites have been established for 9 months and results have shown that the total shoot density had recovered in some cleared plots to be similar to the undisturbed controls (Figure 4). However this only occurred for plots that did not have the isolation border installed and that were open to vegetative colonisation ("seagrass runners" / asexual reproduction) from the surrounding undisturbed meadow. Cleared plots that were isolated from the meadow and relied on seeds for recovery (sexual reproduction) took longer to start recolonising and shoot densities remained lower than the controls 9 months after disturbance (Figure 4). Species composition of the recovering community in these bordered treatments was different to control plots six months after clearing. At sites 1 & 2, cleared plots isolated from the surrounding meadow were dominated by *Halodule uninervis* prior to disturbance yet were colonised by *Halophila* species 6 months later.

A change in species composition within the control plots from *Halodule uninervis* and *Halophila ovalis* to *Halophila spinulosa* occurred from September to November (9 months after the establishment of experiments. Similar changes to species composition also occurred in the experimental plots (Figure 4). By November control plots were found to be devoid of all species except *Halophila spinulosa*. These changes may reflect natural seasonal differences in meadow composition or may possibly be a result of disturbances created by the experiment. The patterns of change and recovery will become more apparent as the experiment progresses. Results for all three meadows and an analysis of seed, flower and fruit production combined with biomass measurements will be reported on following a full 12 months of the program after March 2009.

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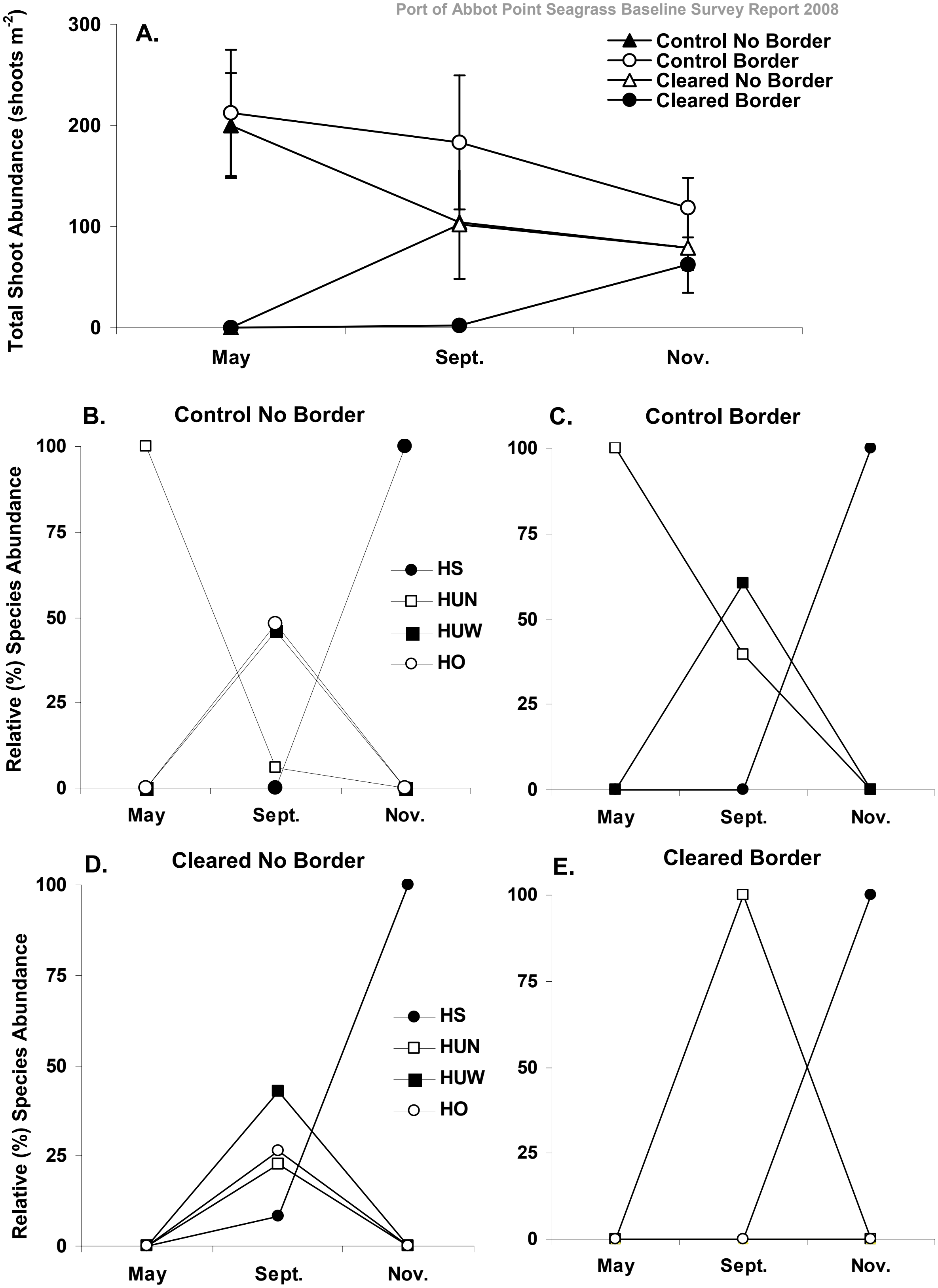

Figure 4. Change in seagrass shoot abundance at Site 2 within experimentally altered seagrass plots. Seagrass was cleared in May 2008. A) Total shoot abundance for all plots over time; Relative species abundance for assigned plots over time: B) control without a border, C) control with a border, D) cleared without a border, and E) cleared with a border. HS = *Halophila spinulosa*, HUN = *Halodule uninervis* (narrow), HUW = *Halodule uninervis* (wide), HO = *Halphila ovalis*

2. Productivity

In general, seagrass growth (g DW day^{-1}) at Abbot Point was similar to measurements found in recent studies of similar species in the Torres Strait (see Rasheed *et al*. 2008a), but was highly variable over time and between sites (Table 10).

The growth of *Halophila spinulosa* was measured by two methods due to its di-meristematic growth pattern, leaf clipping and rhizome tagging. The growth of its leaves was highest in November, and some small inter-site differences were present. The highest growth occurred at Site 3 during September and at Site 2 in the November survey. *Halophila spinulosa* leaf growth rate was generally lower at Abbot Point relative to levels recorded within the Torres Strait (Rasheed *et al*. 2008a). The rhizome extension of *Halophila spinulosa* was similar between months, sites and relative to the Torres Strait. However, growth at Site 2 during November was approximately double that of all other observations.

Similar to *Halophila spinulosa*, *Halophila ovalis* recorded higher growth rates in November relative to September, and growth was not different between sites.

Leaf marking data of *Halodule uninervis* is currently only available for September from Sites 1 and 2. Observations for Site 1 are similar to those recorded within the Torres Strait but measurements made at Site 2 were much lower (Table 10; Rasheed *et al*. 2008a).

3. Fisheries value

In order to examine the fisheries nursery value of the seagrass meadows and their utilisation by invertebrate and fish communities, three sites (one inshore and two offshore) were identified to conduct beam trawling (Map 3).

Beam trawling was conducted in July, September and November (Table 1); however, data analysis is still pending and will be reported in the 2009 monitoring report.

Table 10. Seagrass growth of three different species at three sites near to the Port of Abbot Point, measurement technique, and comparison to data collected from other locations (Rasheed *et al*. 2008a). All data is g DW day^{-1} presented as x10^3 for ease of interpretation.

		Abbot Point												Orman Reefs (Torres Strait) Rasheed *et al.* 2008a
		Site 1				Site 2				Site 3				
		Sept		Nov		Sept		Nov		Sept		Nov		
Species	**Marking technique**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**
Halophila ovalis	Rhizome tagging	-	-	13.1	± 2.3	4.1	± 3.1	12.7	± 0.5	-	-	-	-	5.0
Halophila spinulosa	Rhizome tagging	-	-	-	-	29.9	±12.9	74.0	± 8.0	36.7	± 9.2	31.9	± 7.4	30.6
Halophila spinulosa	Leaf clipping	-	-	-	-	3.0	± 0.4	9.0	± 1.2	4.8	± 0.5	6.3	± 0.5	11.4
Halodule uninervis	Rhizome tagging	-	-	-	-	-	-	24.3	± 4.3	-	-	-	-	na
Halodule uninervis	Leaf marking	4.8	± 1.7	-	-	1.5	± 1.6	-	-	-	-	-	-	4.1

DISCUSSION

This study provides a detailed seasonal baseline of the abundance, species composition, and distribution of seagrass meadows at and around Abbot Point. It builds on the results of an initial baseline conducted in March 2005, and provides the foundation to establish long term monitoring and an assessment of seagrass changes. Seagrass coverage was extensive with meadows comprising 42% of the survey area that reached from Branch Creek to Bowen. Seagrass meadows occurred from the shoreline to a distance of approximately 10km offshore. The survey area contained a range of species and meadow types ranging from low biomass coastal *Halodule uninervis* meadows, to higher biomass deep water *Halophila spinulosa* meadows. The meadows identified within the Abbot Point port limits were likely to play a number of important ecological roles, including supporting endangered and threatened species such as dugong and turtles, providing nursery grounds for commercial fisheries species as well as providing a substantial component of the primary productivity for the regions marine ecosystem.

Seagrass distribution and abundance

Seagrass meadows at Abbot Point contained 7 different species. These were all typical of coastal and deepwater seagrass meadows along the north Queensland coast (Coles *et al*. 1985, Coles *et al*. 2003). This diversity was high compared with surveys of similar port areas in the region such as Mackay (2 species; Rasheed *et al*. 2001) and Hay Point (2 species; Chartrand *et al*. 2008). However unlike these areas, Abbot Point contained shallow coastal meadows explaining some of this diversity (Rasheed *et al*. 2005).

The deepwater seagrass meadows also contained species more commonly found in shallow sub-tidal and intertidal areas such as *Halodule uninervis, Cymodocea rotundata*, and in 2005, *Syringodium isoetifolium*. The presence of these species in deeper areas of Abbot Point may be an indication of comparatively low turbidity in the area allowing greater seagrass depth penetration (Rasheed *et al*. 2005).

The majority of the area covered by the deepwater meadows was dominated by *Halophila spinulosa*. This species has been found to be highly shade adapted (Campbell *et al*. 2008), hence its ability to thrive in deeper water where low light conditions prevail. The large meadows either side of the current port facilities were both *Halophila spinulosa* dominated. Between them, these meadows covered approximately 14000 ha (or 70% of the total meadow area within the survey limits). Other smaller deepwater meadows were also found close to the Port and fringing the very large deepwater meadow to the east of the Port. These meadows were dominated by *Halodule uninervis* and *Halophila ovalis*.

While substantially smaller in area than the deepwater meadows, Abbot Point also contained several inshore coastal meadows in the shallow sub tidal region. These meadows were dominated by species commonly observed in shallow and inter-tidal waters, *Halodule uninervis* with *Halophila ovalis* and a small *Zostera capricorni* meadow west of Euri Creek (Rasheed *et al.* 2006;2008c). Other small *Halophila decipiens* meadows were also located along the coastline. The majority of these coastal meadows were low biomass compared with dense coastal meadows in north Queensland such as Townsville (Rasheed & Taylor 2008) and Cairns (Rasheed *et al.* 2008b).

The 20,800 ha of seagrass in proximity to Abbot Point represents a large ecological resource in the region. The nearest area of seagrass to the north occurs in Upstart Bay and is an order of magnitude smaller (2,987 ha) (Coles *et al.* 2002). The closest seagrass region of comparable size is in Cleveland Bay Townsville (14,300 ha; Rasheed & Taylor 2008).

Seagrass meadows in and around the Port of Abbot Point were generally of a low density in comparison to coastal areas elsewhere in Queensland (Rasheed *et al*. 2008b, Rasheed *et al*. 2008c, Rasheed & Taylor 2008, Rasheed *et al*. 2008d). However, the majority of Abbot Point seagrasses were located in deeper offshore waters where seagrass biomass is typically lower (Chartrand *et al.* 2008; Rasheed *et al.* 2001; 2004). Compared to similar deepwater areas such as Mackay and Hay Point, the Abbot Point seagrass meadows were more substantial with higher percent cover, species diversity and density (Chartrand *et al*. 2008). While denser compared to other deepwater seagrass areas, these spatially expansive meadows probably lack the productivity of shallow water high biomass seagrass meadows from locations such as Cairns, Townsville, Weipa and Gladstone. Shallow water depth allows for greater seagrass primary productivity due to lower light attenuation (Hemminga & Duarte 2000). Studies into productivity of seagrasses at Abbot Point are being conducted (preliminary results reported here) that will provide information on the relative productivity of the meadows identified in the baseline surveys.

Seasonality and Interannual change

Seagrass biomass was higher for the majority of meadows in the dry-season (September) survey than in the wet season (March). While there was a trend for higher biomass, the difference was not statistically significant for the majority of the meadows. The change was significant for the large deepwater meadow to the east of Abbot Point that comprises approximately 50% of the seagrass area and for some of the smaller coastal meadows. These changes are consistent with natural seasonal changes that have been recorded for other north Queensland coastal meadows. On the east coast of Queensland seagrasses tend to reach their peak density in late spring to early summer (McKenzie 1994; Rasheed 1999; 2004). Similarly, deepwater meadows in the region have been found to reach their peak distribution and abundance between July and November before declining during summer (Chartrand *et al.* 2008).

Seagrass meadows in proximity to the coast are influenced by local climatic conditions including turbid run-off related to elevated wet season rainfall. Climate has been found to highly influence seagrass density in several Queensland locations including Karumba (Rasheed & Unsworth 2008; Rasheed *et al*. 2003), Weipa (Rasheed *et al*. 2008d) and Thursday Island (Taylor *et al*. 2006) and large floods have had major detrimental impacts upon coastal seagrass (Preen *et al*. 1995, Campbell & McKenzie 2004).

Analysis of rainfall data for the nearby town of Bowen revealed that January and February periods between 2005 and 2007 have had highly elevated rainfall relative to their long-term average, whilst February 2008 had rainfall approximately 5 times the 20 year average (see Appendix 2). This high rainfall may have resulted in elevated surface run-off, increasing coastal turbidity, and increasing the light attenuation. This may have resulted in reducing seagrass photosynthesis, and hence growth (Ralph *et al*. 2007).

While there appears to be strong seasonal differences in seagrass density, the variation between years may not be as pronounced as in other nearby locations. There were no significant differences in seagrass meadow biomass or area between the March 2005 and March 2008 baseline surveys at Abbot Point indicating that these meadows may be relatively stable compared with nearby locations such as Hay Point (Chartrand *et al.* 2008). A more complete picture of natural seagrass seasonality and year to year variability will be developed as the ongoing studies of seagrass at Abbot Point continue. Part of these studies includes quarterly monitoring of seagrass abundance and area for several key monitoring meadows in the region.

Value of Abbot Point Seagrass Meadows

Seagrass meadows at Abbot Point represent an important regional resource as they cover such a large area, and contain species known to be important to the feeding of threatened and endangered species such as dugong and green turtle (Sheppard *et al*. 2007). Species such as *Halophila spinulosa* and *Halodule uninervis (narrow)* have been found to be an important food resource for dugong (Anderson 1994, Sheppard *et al*. 2007). Seagrass meadows mapped around Abbot Point may form an important corridor between dugong Protection Areas (DPA's) located to both the east and west of the port limits (Preen 2000).

Seagrasses throughout the Queensland region support high value Penaeid fisheries (Watson *et al*. 1993). It is likely that the seagrass meadows at Abbot Point will have a high fisheries value, although this may not be within the same magnitude as some of the more structurally complex productive seagrass of other areas within the region such as Townsville (Rasheed & Taylor 2008). Assessing the value of Abbot Point seagrasses as fisheries nursery areas is currently in progress, and will provide a stronger picture of the relative value of seagrasses in the area.

Although seagrasses are well known for their fisheries value, and their support of dugong and turtle populations, seagrass meadows also have an important role in providing primary production and other ecosystem services. Recent research has documented seagrasses in the Torres Strait to have a higher primary productivity than many terrestrial plant communities including tropical and temperate forests (Rasheed *et al*. 2008a). Although it is unlikely that seagrasses at Abbot are as productive as high light reef seagrasses such as those in the Torres Strait, they are still expected to contribute significant productivity to the local environment. Research utilising growth measures of seagrasses at Abbot Point is currently in progress, and the initial results have been tabulated in this report. These indicate high but variable productivity. Eventually these results will be used to calculate the primary productivity of the various seagrass meadows at Abbot Point and how this varies seasonally and between years.

Seagrass resilience and future Port Developments

The most recent draft plan for the development of the Multi Cargo Facility (MCF) at the Port of Abbot Point appears to result in a much reduced direct impact on seagrass meadows than earlier options for the facility (see maps throughout the report). The draft design has been developed using results of the seagrass baseline surveys in order to minimise any detrimental effects. However, the proposed MCF and other port developments are still likely to have both direct and indirect impacts on seagrass meadows. The proposed MCF dredging and reclamation will have direct impacts through loss of some sections of seagrass meadows and surrounding seagrasses are also likely to face higher levels of turbidity associated with the dredging project.

Increased sedimentation and turbidity from dredging commonly act as a significant mechanism for change in the biological composition and function of sensitive habitats such as seagrass meadows (Erftemeijer & Lewis 2006). Seagrass survival is also linked closely to light availability (Ralph *et al*. 2007). It is therefore expected that should these developments occur, some areas of seagrass will at the very least be placed under light stress. The impacts of these stresses and rate of seagrass recovery depend on a number of factors including: the magnitude of the disturbance; the species of seagrass affected; the physical and environmental conditions of the affected area and; the existence of seed banks that may aid recovery (Carruthers *et al*. 2002).

Persistent turbid plumes over a sustained period have been shown to be detrimental to deepwater seagrasses in north Queensland, but these areas began to recover within 12 months (Chartrand *et al.* 2008). *Halophila* species such as those abundant at Abbot Point display a typical colonising growth strategy with fast growth and high reproductive output (Birch & Birch 1984; Rasheed 2004) including the production of long lived seeds that remain viable in the sediment for several years (McMillan 1991). *Halophila* species can rapidly colonise areas that have been disturbed, yet due to their small size, they lack large stores of energy reserves and rapidly decline when conditions become unfavorable for seagrass growth (Birch & Birch 1984; Rasheed 2004). Larger growing species such as *Zostera capricorni* and *Cymodocea serrulata* have a greater capacity to endure unfavorable conditions and tend to be more stable in their distribution and abundance. However these species take substantially longer to recover should they be lost (Rasheed 2004).

As part of the Abbot Point seagrass studies, experiments have been established to assess the capacity for recovery of the various seagrass meadow types likely to be impacted by future developments. Early results from these studies have shown the re-colonisation of seagrasses into the plots where seagrass had been removed occurred slowly and went through a similar cycle of changes in species composition to the undisturbed plots. However where plots were isolated from surrounding undisturbed seagrass, recovery has been much slower and a full species assemblage or seagrass density had not been observed in the 9 months the study has been running. This indicates that should seagrass loss occur, it may take more than nine months to recover with recovery dependant on the scale of the disturbance.

The scale of disturbance resulting from dredging, if it occurs, would be larger than that conducted within the experimental plots. For re-colonisation of these areas to occur, sexual reproduction would probably be required through the presence of a suitable seed bank or a nearby source of seed production. Small scale disturbances of seagrasses in experimental plots have been observed to recover in a short space of time where recruitment can occur from adjacent healthy seagrass (1 year) (Rasheed 1999, Rasheed 2004). However for larger disturbances, recovery proceeds much more slowly. Large seagrass areas that have been lost to the impacts of sedimentation and turbidity plumes can take 3 years or longer to recover (Campbell & McKenzie 2004). The experiments at Abbot Point include plots that are bordered and isolated from the surrounding meadow and simulate conditions likely to occur for much larger disturbances. These experimental plots are isolated from asexual colonisation from the surrounding meadow and rely on recruitment of seeds or a seedbank to recover. Initial results of these studies are consistent with similar work conducted in tropical Queensland and the full picture of seagrass meadow capacity for recovery will become clearer as the study progresses.

Long-term Monitoring

This study has provided a detailed baseline of the seagrass communities surrounding Abbot Point including those potentially affected by proposed port developments. Results of these baselines have already been used to assist with planning and design of port developments in a manner likely to minimise or reduce potential impacts. The second phase of the seagrass study is under way and includes quarterly monitoring of selected seagrass meadows to:

- Assess natural seasonal and interannual variability in seagrass density and abundance;
- Determine the value of seagrass meadows in terms of primary and fisheries productivity;
- Determine capacity for, and rate of, recovery from disturbance

These studies will build a solid picture of natural seagrass change that can be used to place future changes associated with port development into perspective. The programs will also determine the relative values of the various seagrass communities to assist in management and planning decisions. The design of the program also forms the basis for assessment of potential impacts of the port development should it proceed using established methodology and protocols for other seagrass areas in Queensland. The initial results of these studies have been documented in this report with a more detailed assessment due after the first 12 months of monitoring.

The longer-term seagrass monitoring and assessment partnership developed by PCQ and DPI&F seagrass scientists represents a world leading approach to management and protection of seagrass habitats during a major coastal/port development. The program will ensure the best possible information on seagrass habitat condition and value is available to inform the decision making process and to develop appropriate mitigation strategies to minimise impact to these valuable marine ecosystems.

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APPENDIX 1

Results of significant one-way ANOVA and Kruskal-Wallis tests for mean above-ground biomass versus year for the Port of Abbot Point seagrass meadows in wet season and dry season baselines 2008. Only results of specific seasonal comparisons between March 2008 and September 2008 are shown, as all other results were non-significant (p>0.05).

March 2008 vs September 2008 Comparisons						
Meadow 5	**DF**	**SS**	**MS**	**F**		**P**
Between years	5	1	0.385	15.72		0.002
Within years	13	0.3185	0.0245			
Total	14	0.7035				
Meadow 14	**N**	**Median**	**Rank**	**Z**	**H**	**p**
Mar-08	28	2.8119	48.2	2.01	4.04	0.044
Sep-08	53	0.22	37.2	-2.01	4.07	0.044
Overall	81	41				
Meadow 20	**N**	**Median**	**Rank**	**Z**	**H**	**p**
Mar-08	10	0.01911	7.1	-2.75	7.54	0.006
Sep-08	11	0.20412	14.5	2.75	7.56	0.006
Overall	21	11				
Meadow 23*	**DF**	**SS**	**MS**	**F**		**P**
Between years	2	1	0.5486	6.41		0.017
Within years	28	2.3971	0.0856			
Total	29	2.9458				
All Coastal Meadows	**N**	**Median**	**Rank**	**Z**	**H**	**p**
Mar-08	78	0.145	75.5	-2.64	6.96	0.008
Sep-08	94	0.45	95.6	2.64	6.98	0.008
Overall	172	86.5				

*Data was log10+1 transformed

APPENDIX 2

Weather patterns during baseline monitoring

Figure (i) and (i) illustrate the within year variability of the temperature, rainfall and wind speed at Abbot Point throughout the baseline monitoring program of 2008. Rainfall and temperature are not considered to be high relative to previous average conditions, however, rainfall during February was found to be almost three times the 20 year average for that month (Figure (ii)). Anecdotal observations indicate that this resulted in the flow of some rivers in the area that have not flowed for the majority of the last decade. This was prior to monitoring work conducted at the end of February and the beginning of March 2008. Conditions leading up to the surveys in September were not thought to be indifferent to previous years.

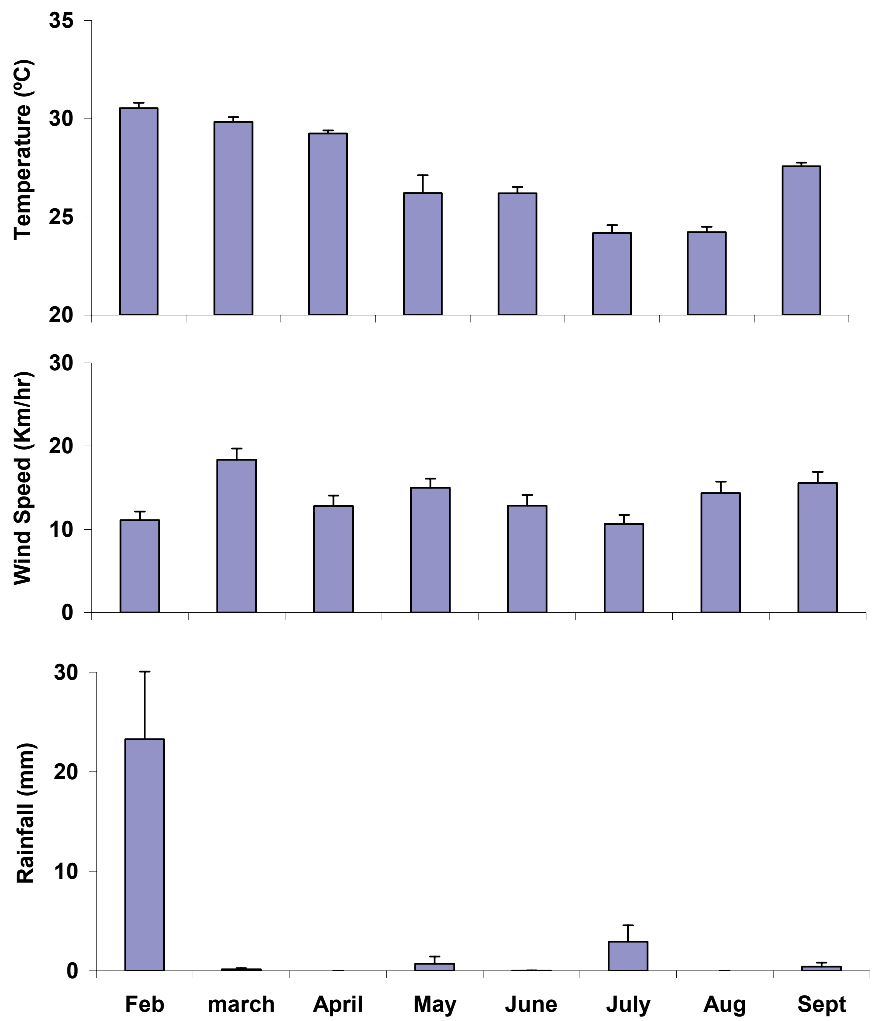

Figure (i) Mean maximum daily temperature, mean 3pm wind speed, and mean daily rainfall for February to September 2008 recorded in Bowen (Weather Station No. 033257, Source: http://www.bom.gov.au)

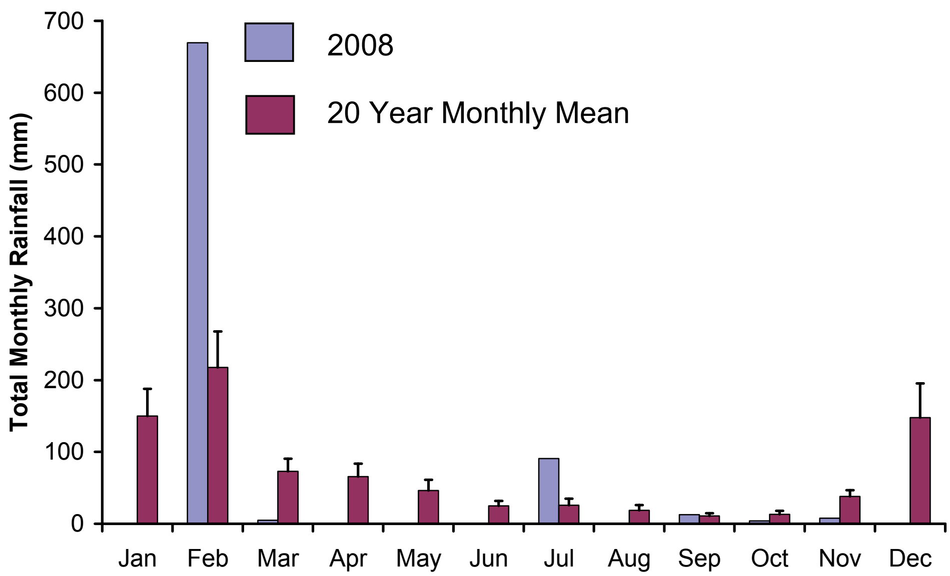

Figure (ii) Total monthly rainfall for each month of 2008 in comparison to the 20 year monthly mean recorded in Bowen (Weather Station No. 033257, Source: http://www.bom.gov.au).