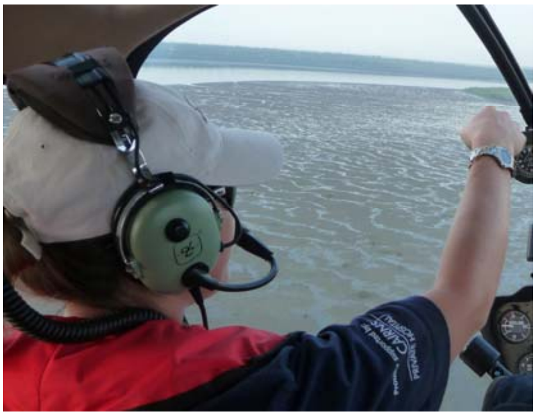
Port of Weipa Long Term Seagrass Monitoring
2000 - 2008



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EXECUTIVE SUMMARY

This report details results of the September 2008 seagrass monitoring survey in the Port of Weipa and evaluates changes in inter-annual seagrass meadow dynamics since monitoring began in 2000. The monitoring program was commissioned by the Ports Corporation of Queensland Limited (PCQ) as a joint project with the Department of Primary Industries and Fisheries (DPI&F) to ensure port activities have a minimal impact on the marine environment with special emphasis on sensitive fisheries habitat, particularly seagrass meadows.

Results of the 2008 monitoring indicate that seagrass habitat in the Port of Weipa was in a moderate condition. There have been substantial declines in density for a number of meadows compared with the previous 8 years of monitoring. These declines were particularly large for intertidal *Enhalus acoroides* meadows within the port. The largest of these meadows on the intertidal bank opposite Lorim Point has been declining since 2000 with biomass reaching a record low in 2008. The observed changes in biomass appeared to be partly a response to regional and local climate conditions, however other drivers including anthropogenic factors cannot be discounted. DPI&F are concerned that some meadows are at such density levels that they are particularly vulnerable to additional stresses and will require closer monitoring in the future. Meadows dominated by *Halodule uninervis* (narrow) had some density declines, however these were generally within the ranges of previous years. Despite the density declines the area of seagrass meadows within the port limits in 2008 was similar to previous surveys.

Since the baseline survey in 2000, DPI&F has been establishing the natural patterns of distribution and abundance of seagrass in Weipa. Through our state wide seagrass monitoring network we are able to put these changes into a regional perspective and better separate local versus regional drivers of seagrass change. While changes to seagrasses in Weipa were generally consistent with trends in other areas of the state, the large and consistent declines in *Enhalus acoroides* meadows warrant closer examination. DPI&F and PCQ are discussing measures to enhance the monitoring program in the future for a better understanding of the declines in this species. The continued monitoring program will provide port and fisheries management with information on the status and trends of the marine environment within the Weipa region.

INTRODUCTION

Ports Corporation of Queensland Limited (PCQ) is the organisation responsible for managing and monitoring Weipa's port environment. PCQ has recognised that seagrasses are ecologically important and provide valuable habitat in the Weipa region. PCQ, in collaboration with the Department of Primary Industries & Fisheries (DPI&F), established a long term seagrass monitoring program for the Port in 2000 (Roelofs *et al*. 2001, 2003, 2005). Seagrass habitats are valuable fisheries resources that show measurable responses to changes in water quality making seagrass meadows ideal candidates for monitoring the long term health of marine environments. The goals of the program are to minimise impacts of port activities and development on these habitats and to assess the health of Weipa's port environment.

The first three years (2000 to 2002) of the seagrass monitoring program provided important baseline information on the distribution, abundance and seasonality of seagrasses within the greater port limits. Due to the large area of the port, the approach for long term monitoring was to focus monitoring effort on seagrass meadows located near port and shipping infrastructure and activities (the Intensive Monitoring Area or IMA; Map 1). In August / September each year all seagrass meadows within the IMA are mapped. A selection of "core monitoring meadows" representing the range of seagrass meadow communities in the region are assessed for biomass and species composition. At the time of the IMA survey, an aerial reconnaissance of seagrasses in the greater port limits is conducted with re-mapping of the entire port limits occurring every 3 years (i.e. 2002, 2005 & 2008).

This report presents the results of the long term seagrass monitoring survey conducted in September 2008. The objectives of the 2008 long term seagrass monitoring of the Port of Weipa were to:

1. Map the distribution and abundance of selected seagrass monitoring meadows;
2. Map the distribution and confirm species composition of seagrass meadows in the Intensive Monitoring Area (IMA) and in the greater port limits;
3. Assess changes in seagrass meadows and compare results with previous monitoring surveys;
4. Incorporate the results into the Geographic Information System (GIS) database for the Port of Weipa.

Results of the seagrass monitoring surveys are used by PCQ to assess the health of the port marine environment. Additionally results are used to help identify any possible detrimental effects of port operations and developments (e.g. dredging) on seagrasses and assist in formulating management measures for the port. The program also forms part of DPI&F's network of long term monitoring sites for important fish habitats.

METHODS

Seagrass surveys within the Port of Weipa were conducted between the 24th and 28th of September 2008. Five core seagrass meadows were selected from the baseline surveys (Roelofs *et al.* 2001) for long term annual monitoring since 2003. These meadows were representative of the range of seagrass meadows communities identified in the baseline survey, and were also located in areas likely to be vulnerable to impacts from port operations and developments.

Three levels of sampling were used in the September 2008 survey:

1. Assess seagrass distribution, species composition and abundance in the five core monitoring meadows (A2, A3, A5, A6, A7) (Map 1 & 2).

2. Map seagrass distribution and confirm species composition in other seagrass meadows within the IMA (Map 1).

3. Map seagrass distribution and confirm species composition in seagrass meadows within the greater Weipa port limits and compare to those previously mapped in the 2005 whole of port limit survey (Map 1).

A variety of sampling methods were used to survey the seagrass meadows within the Port of Weipa. A complete outline of these methods can be found in Roelofs *et al.* 2001. Briefly, seagrass habitat observations in the core monitoring meadows included species composition, above ground biomass, percent algal cover, sediment type, time and position (Global Positioning System (GPS)). Monitoring meadows were surveyed using a combination of helicopter aerial surveillance and boat-based camera surveys. Seagrass community type in non-monitoring meadows was determined by a visual estimate of species composition (from helicopter surveillance) as only the core monitoring meadows were assessed specifically for biomass and species composition.

The results of the baseline surveys (Roelofs et al 2003) suggested that meadows where *Enhalus acoroides* was present but not dominant required a different approach to the analysis of biomass for meadows where *Enhalus acoroides* was dominant. The dry weight biomass for *Enhalus* is many orders of magnitude higher than other tropical seagrass species and dominates the average biomass of a meadow where it is present. Therefore, isolated *Enhalus* plants occurring within the *Halodule*/*Halophila* dominated meadows (A3, A5) were excluded from all biomass and species analyses in order to track the dynamics of these morphologically distinct species within the IMA.

Geographic Information System

Spatial data from the September 2008 survey were entered into the PCQ / DPI&F Weipa Geographic Information System (GIS). Three GIS layers were created:

- **Site information** – site data containing above ground biomass (for each species), sediment type, time, Global Positioning System (GPS) fixes (±10m) and sampling technique.

- **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 the Queensland region (Table 1).
- **Seagrass landscape category** – area data showing the seagrass landscape category (Figure 1) determined for each meadow

Figure 1. Landscape categories used to describe seagrass cover within individual meadows.

Isolated seagrass patches
The majority of area within the meadows consisted of unvegetated sediment interspersed with isolated patches of seagrass

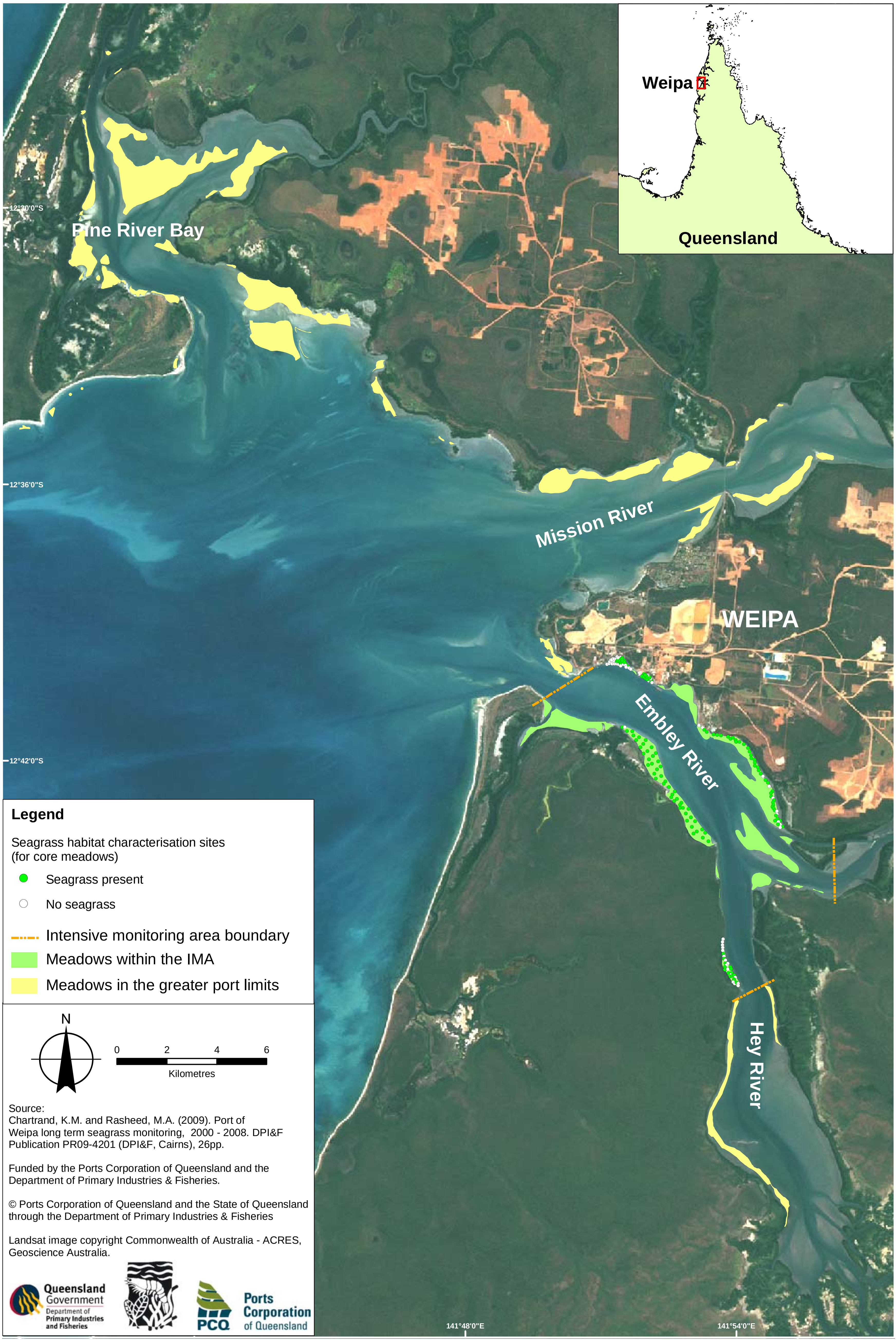
Aggregated seagrass patches
Meadows are comprised of numerous seagrass patches but still feature substantial gaps of unvegetated sediment within the meadow boundaries

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

Table 1 Nomenclature for community types in the Port of Weipa, September 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

Map 1. Location of 2008 seagrass monitoring meadows in the Port of Weipa



RESULTS

Seagrass species, distribution and abundance

Four seagrass species (from 2 families) were identified in the September 2008 monitoring survey (for a complete list of the 6 species present in the Weipa area see Roelofs *et al.* 2001):

Family **Cymodoceaceae** Taylor

Halodule uninervis (narrow leaf morphology) (Forsk.) Aschers

Family **Hydrocharitaceae** Jussieu

*Enhalus acoroides (*L.*f.*) Royle
Halophila ovalis (Br.) D.J. Hook.
Thalassia hemprichii (Ehrenb.) Aschers. in Petermann

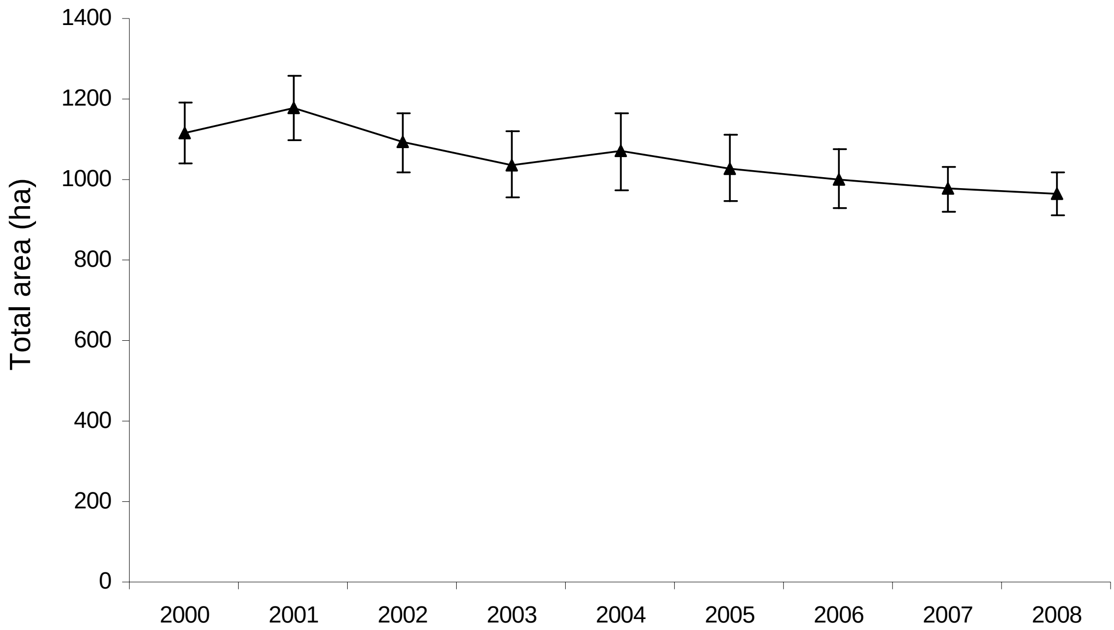
Figure 2. Species of seagrass found in the Port of Weipa in 2008

	***Enhalus acoroides*** • Very distinctive seagrass • Very long, ribbon-like leaves (30-150cm long, 1.25 - 1.75cm wide) • Thick leaves with many parallel veins • Very thick rhizome (at least 1cm) with black, fibrous bristles
	***Halodule uninervis*** • Narrow leaf blades 0.25-5mm wide • Trident leaf tip ending in three points • 1 central longitudinal vein which does not usually split into two at the tip • Usually pale ivory rhizome, with clean black leaf scars along the stem • Dugong preferred food
	***Halophila ovalis*** • Small oval shaped leaves (0.5 - 2cm long) • 8 or more cross-veins on leaf • No hairs on leaf surface • Dugong preferred food
	***Thalassia hemprichii*** • Long, ribbon-like leaves 10-40cm long • 10-17 longitudinal leaf veins • Short black bars of tannin cells on leaf blade • Leaf sheaths 3-7cm long • Thick rhizome (up to 5mm) with conspicuous scars between shoots

Intensive Monitoring Area

A total of 965 ± 52 ha of seagrass habitat, comprising twenty seagrass meadows, was mapped within the Intensive Monitoring Area (IMA) in September 2008 (Map 2). This is the lowest recorded seagrass area since surveys began in September 2000 (Figure 3, Maps 2 & 3). Communities dominated by *Enhalus acoroides* were the most common, with thirteen of the twenty monitoring meadows dominated by this species (Map 2). Large *Enhalus acoroides* meadows dominated the intertidal banks and shallow subtidal areas of the Embley River (Map 2). Lower biomass *Halodule uninervis* also occurred in meadows in the Hey River (A3) and the southern section of the Embley River (A4 and A5). Meadow area ranged from 0.07ha to 245 ha with the smallest meadow an isolated patch of *Enhalus acoroides* along the western bank of the Hey River and the largest located along the western bank of the Embley River (meadow A2; Map 2). The condition known as burning – the browning and subsequent death of seagrass blades – was prevalent throughout the study area as has been observed during surveys since 2002.

Figure 3. Total area of seagrass within the Weipa Intensive Monitoring Area from 2000 to 2008 (error bars = "R" reliability estimate)



Core Monitoring Meadows

Meadow biomass and species composition

A total of 201 seagrass habitat characterisation sites were surveyed within the core monitoring meadows, 71% of which (143 sites) had seagrass present (Map 1, Map 2). All core monitoring meadows in the Weipa IMA declined in biomass during the 2008 monitoring survey (Map 2; Figure 4). Mean above ground biomass for the five monitoring meadows (A2, A3, A5, A6 & A7) ranged from 0.24 ± 0.13g DW m^{-2} for the A3 meadow in the Hey River to 5.85 ± 1.28 g DW m^{-2} for the A7 meadow at Evan's Landing (Table 2; Figure 4).

The most notable change in biomass has been in the large intertidal *Enhalus* dominated meadow (A2) in the Embley River opposite the port facility. This meadow has become increasingly patchy in recent years with bare spaces between *Enhalus* plants becoming greater, especially on the fringes of the meadows. High seagrass biomass hotspots found in the north and south of the meadow have substantially decreased since 2001 (Map 4; Figure 4; see Appendix). Mean above ground biomass for A2 in 2008 was 4.66 ± 0.63 g DW m^{-2} down from a peak of 33.63 ± 5.82 g DW m^{-2} in 2000 (Table 2; Figure 4). Burning of *Enhalus* blades was observed frequently in the meadow (>25% of sites).

Biomass of subtidal *Enhalus* dominated core meadows (A6 & A7) has also had significant declines over the course of the monitoring program (Map 2; see Appendix). The Lorim Point Wharf *Enhalus* meadow (A6) first showed a drop in biomass in 2004. This meadow appeared to be recovering over the following 3 years yet biomass was lower again during the 2008 survey. The *Enhalus* meadow adjacent to Evan's Landing (A7) showed similar signs of recovery in the past with only a slight decrease in biomass in 2008 (Figure 4).

Biomass in the *Halodule* dominated A3 and A5 meadows has had high inter-annual variability over the course of the monitoring program with significant declines and increases over multiple years (Figure 4; Table 2; see Appendix). These changes are considered within the normal scope for this meadow type with a characteristically dynamic dominant species, *Halodule uninervis*.

Overall, seagrass species composition within all monitoring meadows has remained fairly constant since 2000 (Figure 4). However, there was a notable shift in species composition in the A3 meadow in 2007 and 2008. An increase in frequency of occurrence of *Enhalus acoroides* (present at >25% of survey sites) warranted a shift in meadow type (Map 3) despite the focus on *Halodule uninervis* (narrow) in A3 (Figure 4; see Methods for details). Meadow A2 also had a small shift in seagrass composition with *Thalassia hemprichii* comprising a larger proportion of meadow seagrass than previously recorded. This shift is likely due not only to an increase in *Thalassia* but also to the decline in *Enhalus acoroides* (see above; Figure 4).

Meadow area

Total meadow area for all core monitoring meadows was 358 ± 23 ha in September 2008 (Table 3; Map 3), a slight decline from earlier dry season surveys. Meadow area ranged from 7 ha to 244 ha with the smallest meadow located at Lorim Point (meadow A6) and the largest located along the western bank of the Embley River (meadow A2) (Table 3; Map 2). The only meadow to show a significant shift in meadow area was A7 located at Evan's Landing. Meadow area dropped from 15 ± 2 ha in 2007 to 9 ± 2 ha in 2008 as the western portion of the meadow receded (Figure 4, Map 3).

The majority of monitoring meadows were located on intertidal substrate dominated by mud, with a smaller component of sand and shell.

Map 2. Meadow type and cover for seagrass meadows within the Intensive Monitoring Area 2008

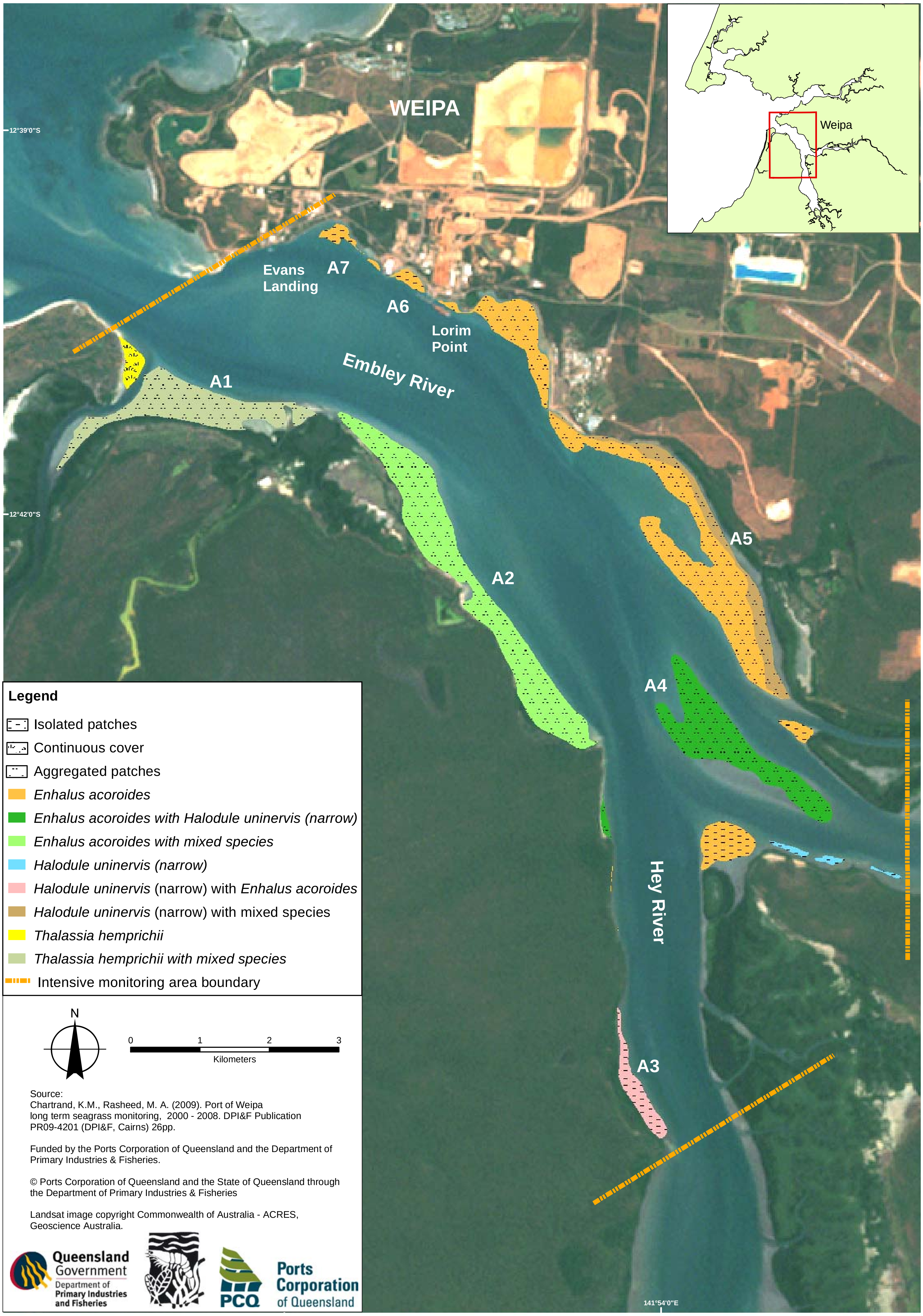


Figure 4. Changes in biomass, area and species composition for the core monitoring meadows in Weipa from 2000 to 2008 (biomass error bars = SE; area error bars = "R" reliability estimate).

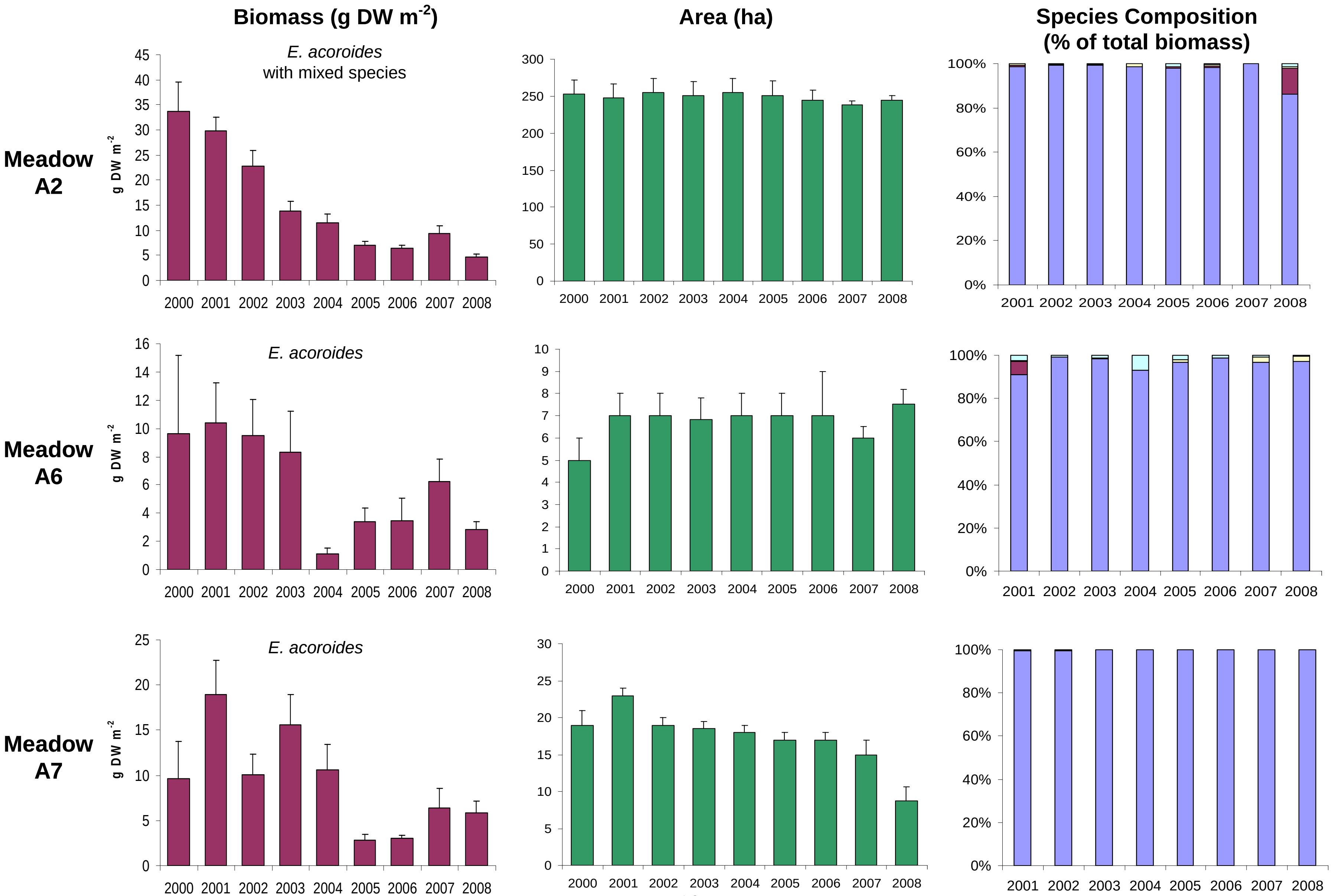
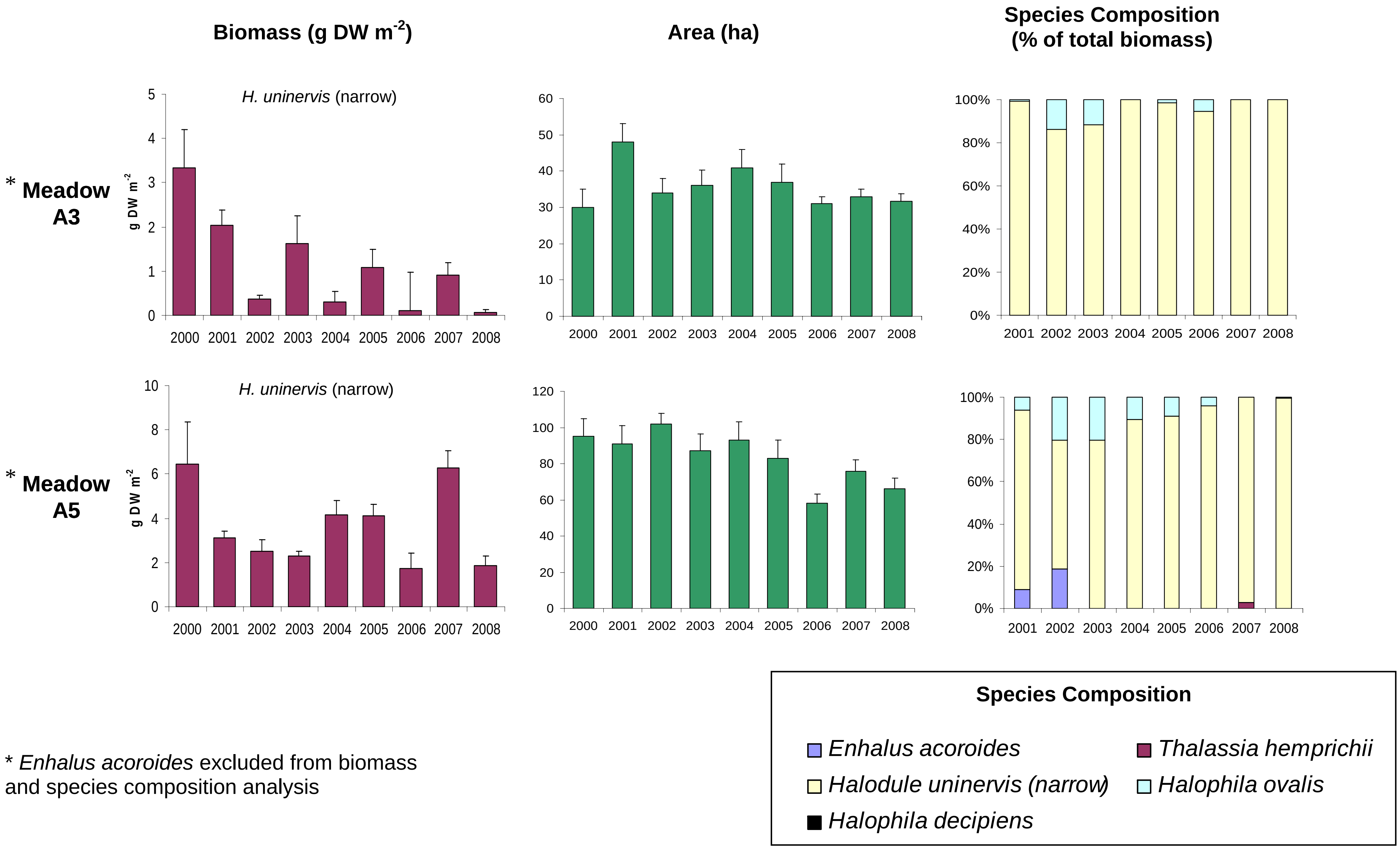
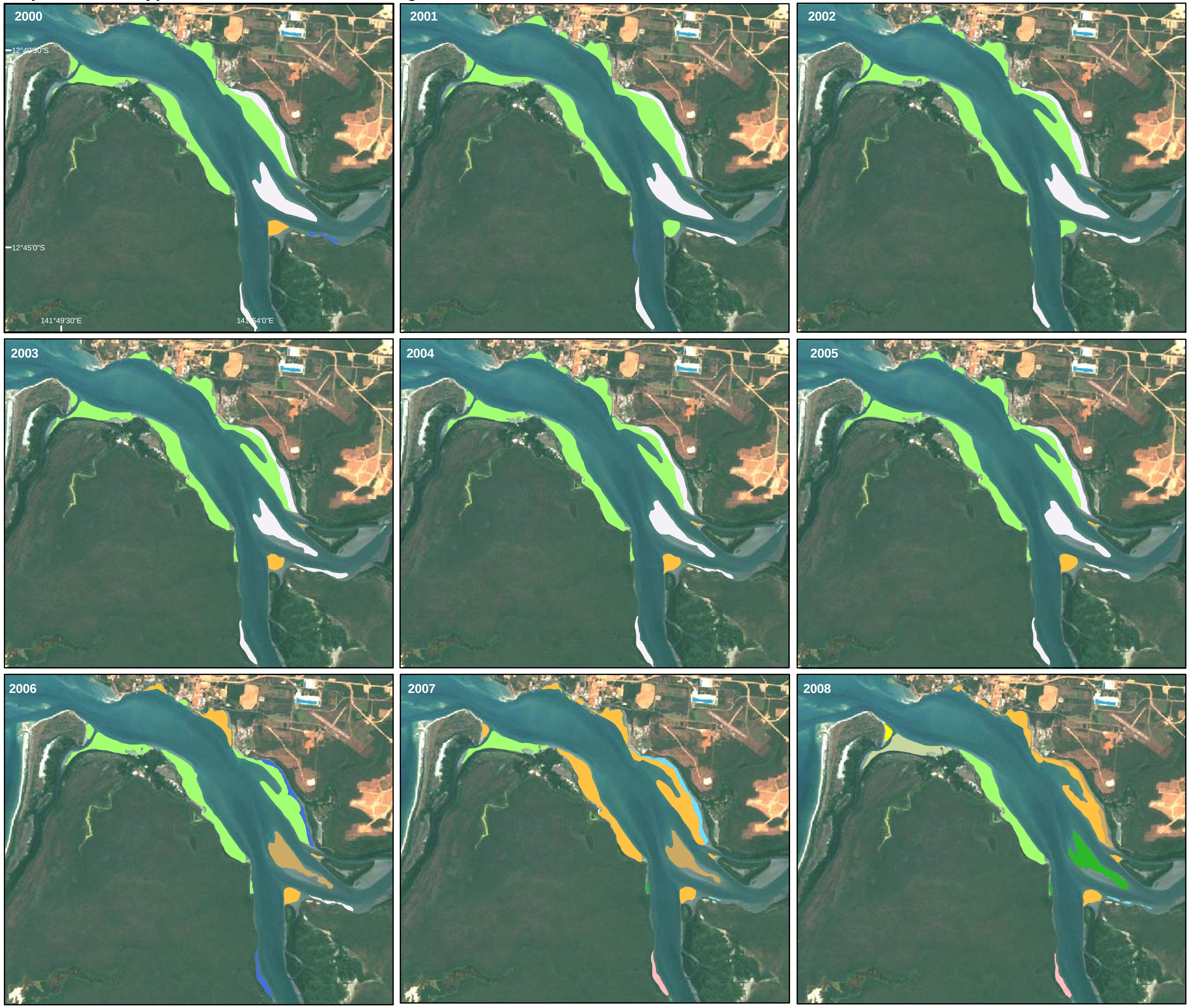


Figure 4. (cont)



* *Enhalus acoroides* excluded from biomass and species composition analysis

Map 3. Meadow type and distribution for the seagrass meadows within the IMA 2000 to 2008.



Legend

- *Enhalus acoroides*
- *Enhalus acoroides* with *Halodule uninervis* (narrow)
- *Enhalus acoroides* with mixed species
- *Halodule uninervis* (narrow)
- *Halodule uninervis* (narrow) with mixed species
- *Halodule uninervis* (narrow) with *Halophila ovalis*
- *Halodule uninervis* (narrow) / *Halophila ovalis* with mixed species
- *Halophila ovalis* with mixed species
- *Thalassia hemprichii* with mixed species
- *Halodule uninervis* (narrow) with Enhalus acoroides

Source:
Chartrand, K.M. & Rasheed, M. A. (2009). Port of Weipa long term seagrass monitoring, 2000 - 2008. DPI&F Publication PR0-4201 (DPI&F, Cairns) 26pp

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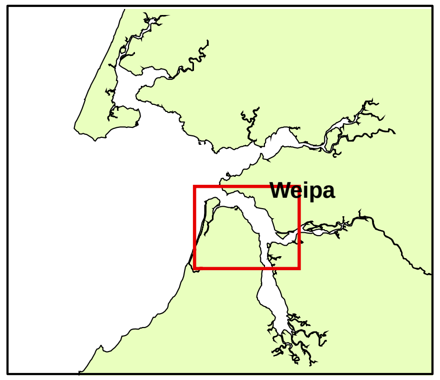


Map 4. Density of seagrass biomass in the A2 meadow from 2000 to 2008

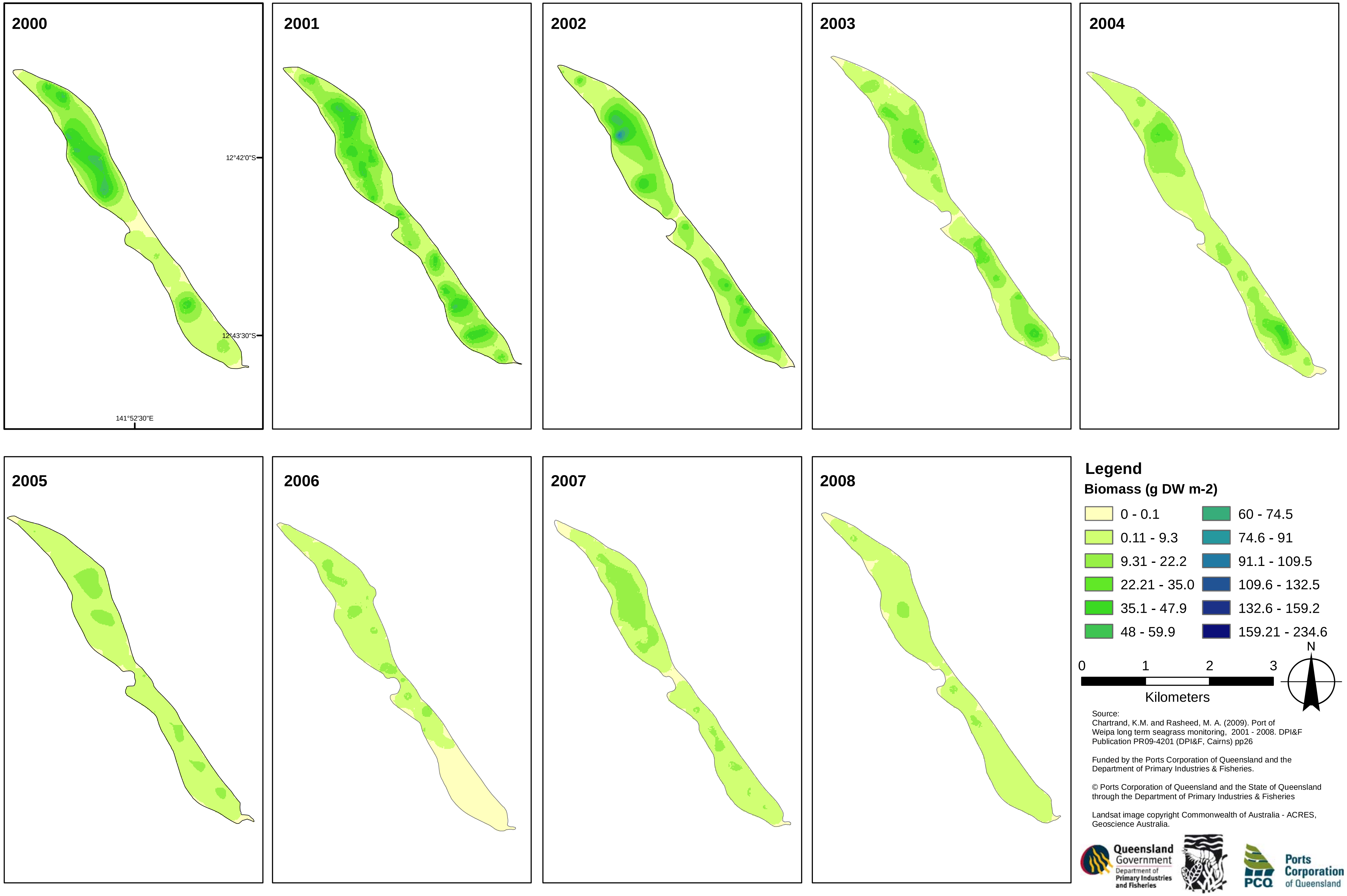


Table 2. Mean above-ground seagrass biomass and number of biomass sampling sites for each core monitoring meadow within the Port of Weipa. 2000 – 2008

Monitoring Meadow	Mean Biomass ± SE (g DW m^{-2}) (no. of sites)								
	September 2000	September 2001	September 2002	September 2003	August 2004	August 2005	August 2006	September 2007	September 2008
A2 Intertidal *Enhalus* dominated	33.63 ± 5.82 (17)	29.73 ± 2.88 (51)	22.84 ± 2.99 (50)	13.91 ± 1.96 (54)	11.47 ± 1.77 (51)	7.04 ± 0.72 (51)	6.43 ± 1.03 (55)	4.36 ± 1.06 (46)	4.66 ± 0.63 (48)
A3 Intertidal *Enhalus* dominated	3.34 ± 0.87 (11)	2.04 ± 0.33 (26)	0.37 ± 0.07 (30)	1.63 ± 0.61 (26)	0.31 ± 0.23 (26)	1.08 ± 0.41 (25)	0.11 ± 0.05 (31)	0.35 ± 0.19 (31)	0.24 ± 0.13 (29)
A5 Intertidal *Halodule* dominated	6.45 ± 1.90 (9)	3.11 ± 0.31 (51)	2.49 ± 0.52 (51)	2.29 ± 0.23 (50)	4.18 ± 0.61 (50)	4.11 ± 0.54 (50)	1.75 ± 0.38 (56)	3.62 ± 0.57 (54)	1.94 ± 0.45 (48)
A6 Intertidal *Enhalus* dominated	9.63 ± 5.52 (9)	10.4 ± 2.79 (26)	9.5 ± 2.54 (25)	8.31 ± 2.91 (24)	1.14 ± 0.40 (26)	3.37 ± 1.00 (26)	3.45 ± 1.1 (26)	2.52 ± 0.91 (31)	2.83 ± 0.55 (25)
A7 Shallow subtidal *Enhalus* dominated	9.63 ± 4.12 (14)	18.89 ± 3.88 (30)	10.03 ± 2.34 (33)	15.57 ± 3.39 (31)	10.56 ± 2.82 (30)	2.84 ± 0.58 (30)	3.06 ± 0.76 (33)	6.41 ± 2.12 (34)	5.85 ± 1.28 (21)

Table 3. Total meadow area for each core monitoring meadow within the Port of Weipa. 2000 – 2008

Monitoring Meadow	Total meadow area ± R (ha)								
	September 2000	September 2001	September 2002	September 2003	August 2004	August 2005	August 2006	September 2007	September 2008
A2 Intertidal *Enhalus* dominated	253 ± 19	248 ± 19	255 ± 19	250 ± 20	255 ± 19	251 ± 20	245 ± 13	238 ± 6	244 ± 6
A3 Intertidal *Enhalus* dominated	30 ± 5	48 ± 5	34 ± 4	36 ± 4	41 ± 5	37 ± 5	31 ± 2	33 ± 2	32 ± 2
A5 Intertidal *Halodule* dominated	95 ± 10	91 ± 10	102 ± 6	87 ± 9	93 ± 10	86 ± 10	58 ± 5	76 ± 6	66 ± 6
A6 Intertidal *Enhalus* dominated	5 ± 1	7 ± 1	7 ± 1	7 ± 1	7 ± 1	7 ± 1	7 ± 2	6 ± 0.5	7 ± 0.7
A7 Shallow subtidal *Enhalus* dominated	19 ± 2	23 ± 1	19 ± 1	19 ± 1	18 ± 1	17 ± 1	17 ± 1	15 ± 2	9 ± 2
Total	**402 ± 37**	**417 ± 36**	**417 ± 31**	**399 ± 35**	**414 ± 36**	**398 ± 37**	**358 ± 23**	**368 ± 17**	**358 ± 23**

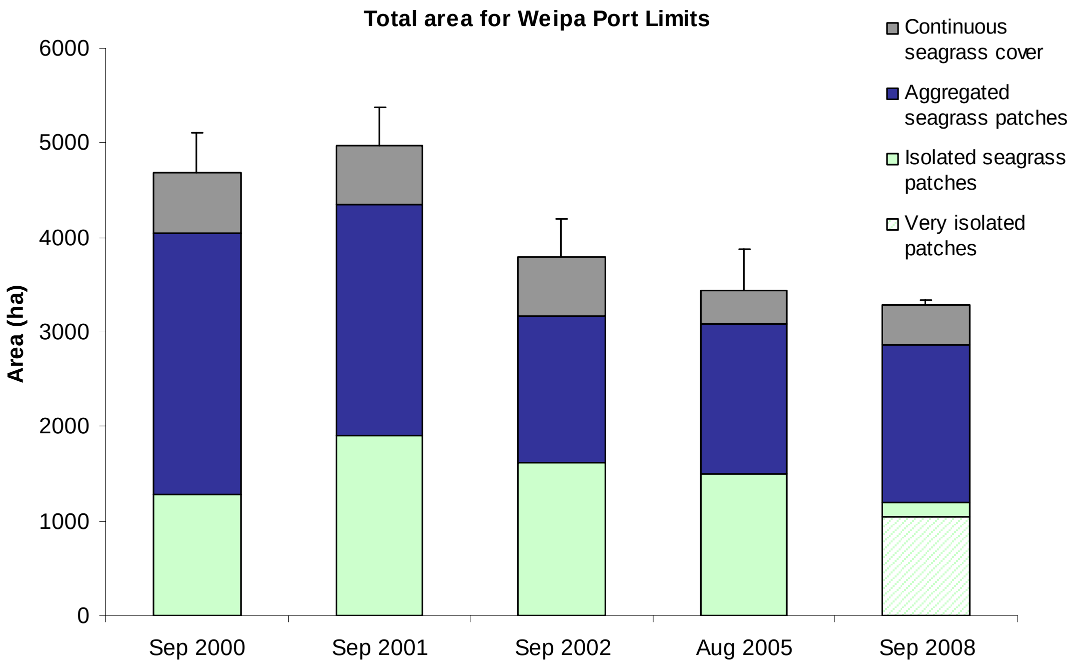
Seagrass outside of the IMA

In 2008, seagrass distribution and community type within the entire port limits was mapped to enable a comparison with previous whole of port mapping conducted from 2000 – 2002 and 2005 (Figure 5-7).

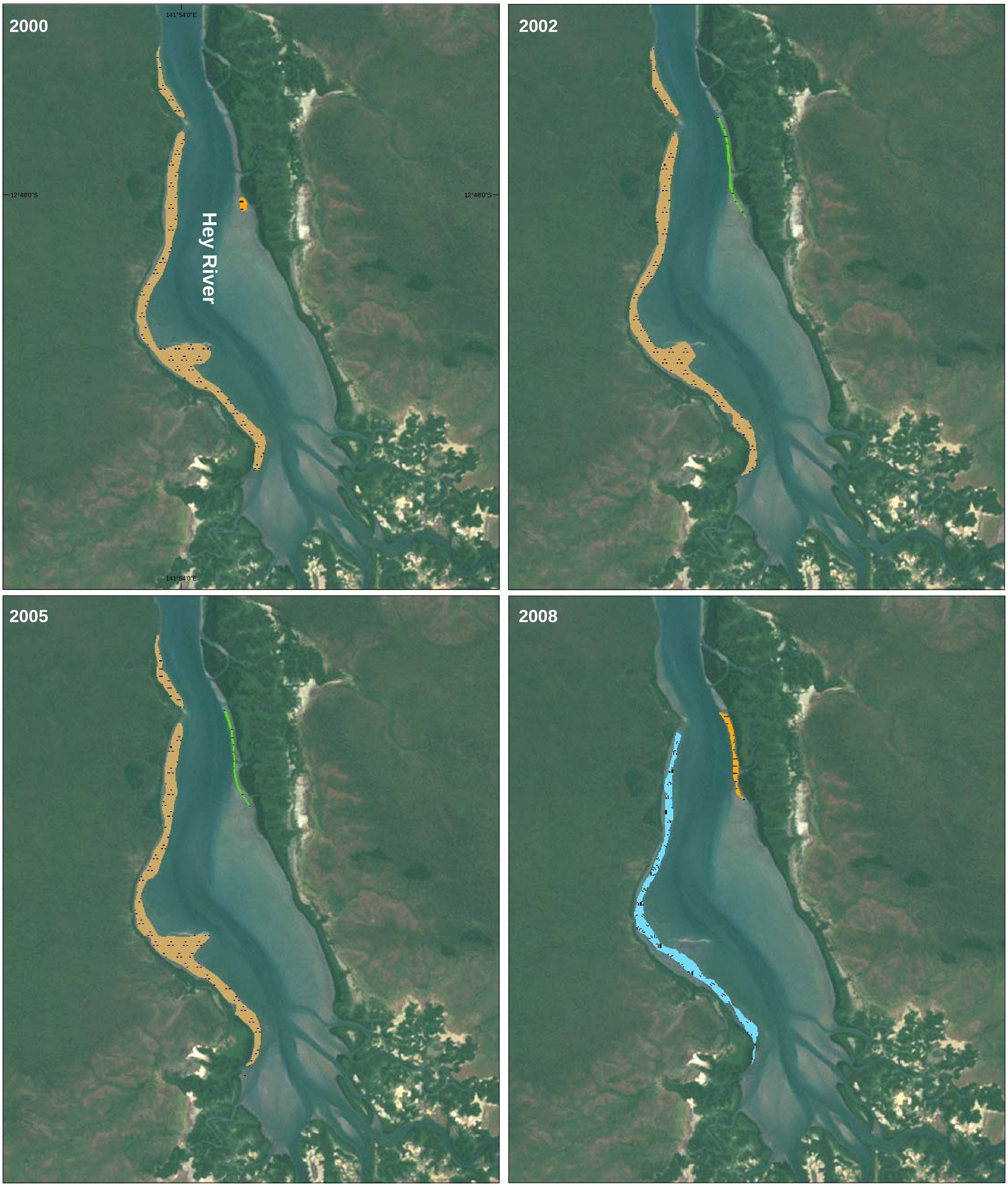
Total seagrass meadow area and landscape cover had remained at similar levels to the 2005 survey (Figure 5), however significantly lower than the 2001 and 2002 baselines. The most significant change within the greater port limits was a loss of diversity in the majority of meadows. Meadows in the Hey River, Mission River and Pine River Bay lost species from 2005, shifting from mixed-species to mono-specific seagrass beds in 2008 (Maps 5-7). This loss occurred in both *Enhalus acoroides* and *Halophila ovalis* dominated meadows.

In Pine River Bay, the *Halodule uninervis* (narrow) meadows originally mapped in 2000 along the western banks appeared well established in 2008 and covered an area similar to that of the first baseline survey (Map 7). The absence of *Syringodium isoetifolium* in 2008 surveys of Pine River Bay was likely to be linked to a poor tidal window during 2008 monitoring in this area of the bay. *Syringodium isoetifolium,* while only a very minor component of species type in the Weipa region, had been found previously in all Pine River Bay surveys but in deeper sections that were not able to be assessed in detail in the 2008 survey (Roelofs et al. 2006).

Figure 5. Total area of seagrass within the Weipa port limits and the percent of landscape cover from 2000-2002, 2005, and 2008



Map 5. Community type for seagrass meadows in the Hey River from 2000 to 2008.



Legend

- *Enhalus acoroides*
- *Halodule uninervis (narrow)*
- *Enhalus acoroides* with mixed species
- *Halodule uninervis* (narrow form) with mixed species
- Aggregated patches
- Continuous cover
- Isolated patches

N

0 1 2 3 4
Kilometers

Source:
Chartrand, K.M. and Rasheed, M. A. (2009). Port of Weipa long term seagrass monitoring, 2000 - 2008. DPI&F Publication PR09-4201 (DPI&F, Cairns) pp26.

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Map. 6 Seagrass meadows in Mission River - 2000, 2002, 2005 & 2008

Legend

Meadow Type

- *Enhalus acoroides*
- *Enhalus acoroides* with mixed species
- *Halodule uninervis* (narrow form)
- Aggregated seagrass patches
- Continuous seagrass cover
- Isolated seagrass patches
- *Halodule uninervis* (narrow form) with mixed species
- *Halophila decipiens*
- *Halophila ovalis* with mixed species
- *Thalassia hemprichii* with mixed species
- Poor visibility - not surveyed

N

0 2 4 6

Kilometers

Source:
Chartrand, K.M. & Rasheed, M. A. (2009). Port of Weipa long term seagrass monitoring, 2000-2008. DPI&F Publication PR09-4201 (DPI&F, Cairns) 26pp

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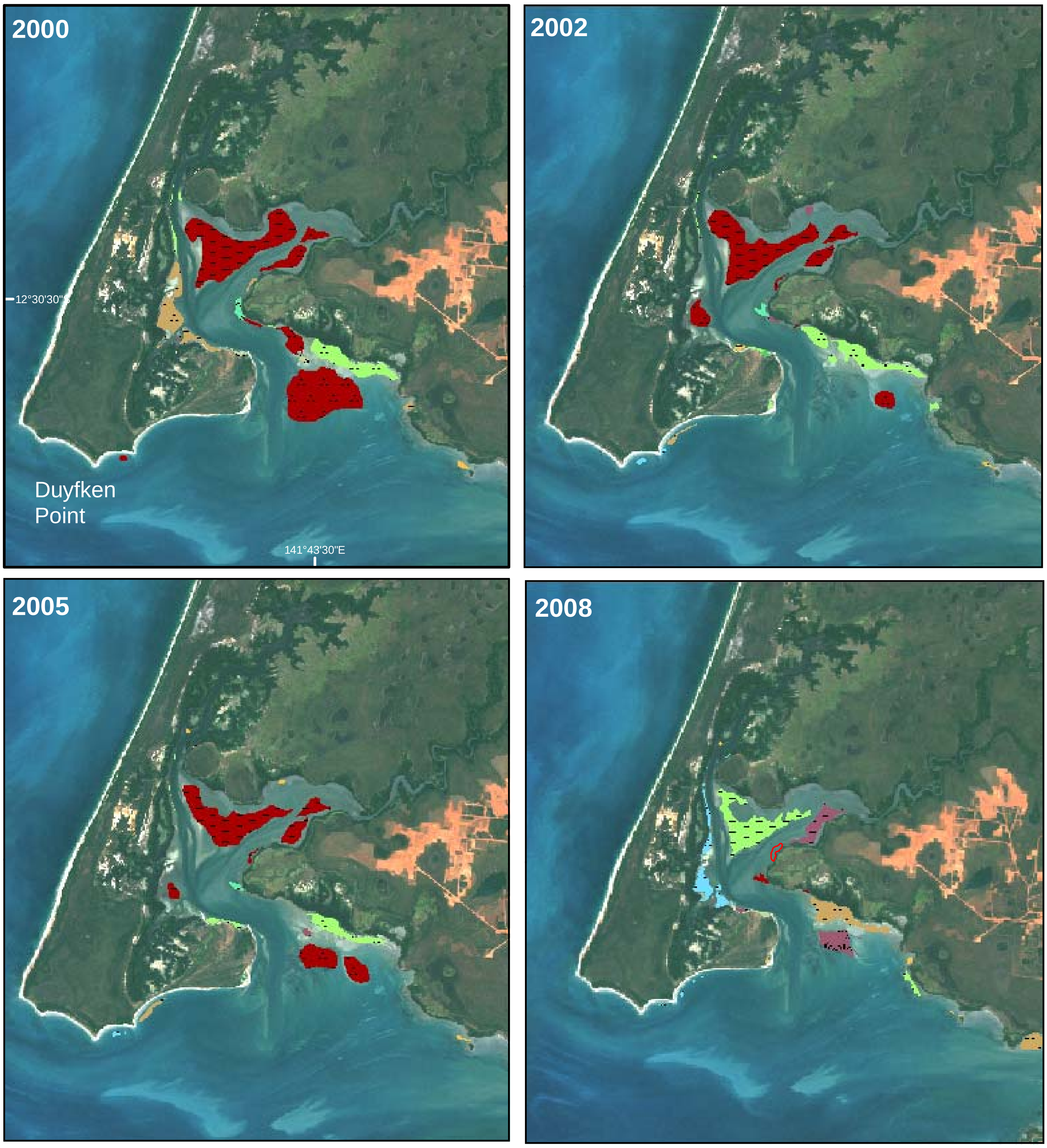
Map 7. Seagrass meadows in Pine River Bay from 2000 to 2008.



Legend

Community Type

- *Enhalus acoroides*
- *Enhalus acoroides* with mixed species
- *Halodule uninervis* (narrow form)
- *Halodule uninervis* (narrow form) with mixed species
- *Halodule uninervis* (wide form)
- *Halophila ovalis*
- *Halophila ovalis* with mixed species
- *Syringodium isoetifolium* with mixed species
- Poor visibility - not surveyed

- Aggregated patches
- Continuous cover
- Isolated patches

N

0 3 6 9

Kilometres

Queensland Government Department of Primary Industries and Fisheries

Ports Corporation of Queensland PCQ

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Funded by the Ports Corporation of Queensland and the Department of Primary Industries & Fisheries.

Weipa Climate Data

Total annual rainfall in Weipa was above average in 2008 (since 1973; Figure 6). In the previous seven years Weipa has had below average rainfall, with the exception of 2004. Solar irradiance has varied over the last decade with peak levels in 2003 and 2004 (Figure 7). Solar irradiance during 2008 was up from 2007 and similar to higher levels mid-decade. Seasonally, highest solar radiation is typically from September to November, coinciding with annual seagrass surveys. Maximum average monthly air temperature has trended upwards from 2000 to present, with a mean increase of approximately 1ºC (Figure 8). These climate trends indicated drought-like conditions have occurred for the Weipa area from 2002 to 2007 with a return to “normal” conditions in 2008. For the Weipa region lying in the tropics, drought-like conditions would likely result in reduced freshwater river flows and lower levels of nutrient re-suspension and subsequent nutrient availability. The drought conditions may also result in fewer flood related high turbidity events, which may increase light penetration to subtidal areas in the rivers and bay during the ‘wet’ season compared with non-drought years.

Tidal exposure of intertidal seagrass banks in the Weipa region is typically high during the dry season with peak exposure from June to August (Figure 9). Naturally higher tide cycles during 2000, 2001 and 2008 has resulted in fewer daytime hours seagrass banks were exposed (Figure 10). A decline in exposure results in less desiccation and extreme temperature conditions at the seagrass blade surface. High temperature and desiccation can both lead to the condition known as burning.

Figure 6. Total annual rainfall recorded at Weipa airport from 1973 to 2008 (Bureau of Meteorology, 2008)

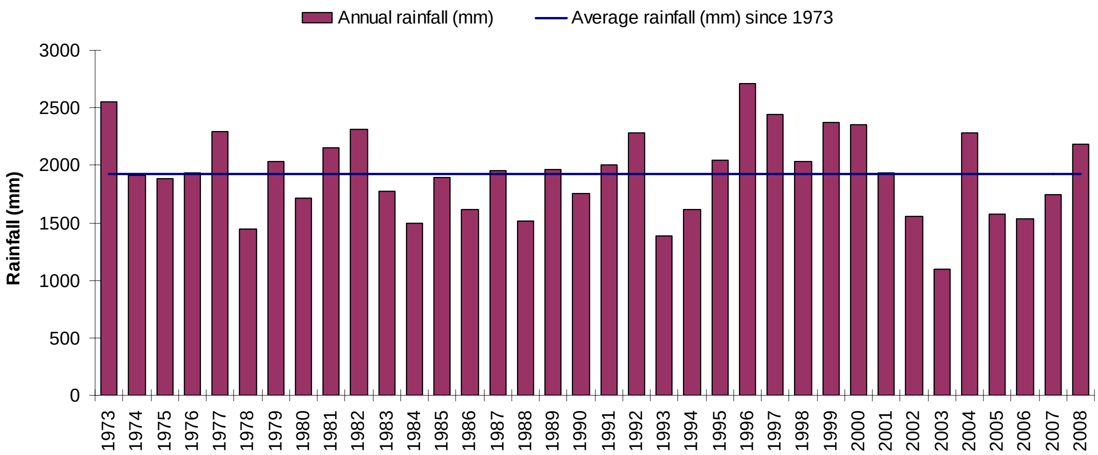


Figure 7. Mean monthly solar radiation recorded at Weipa airport from 2000 to 2008 (Bureau of Meteorology, 2008)

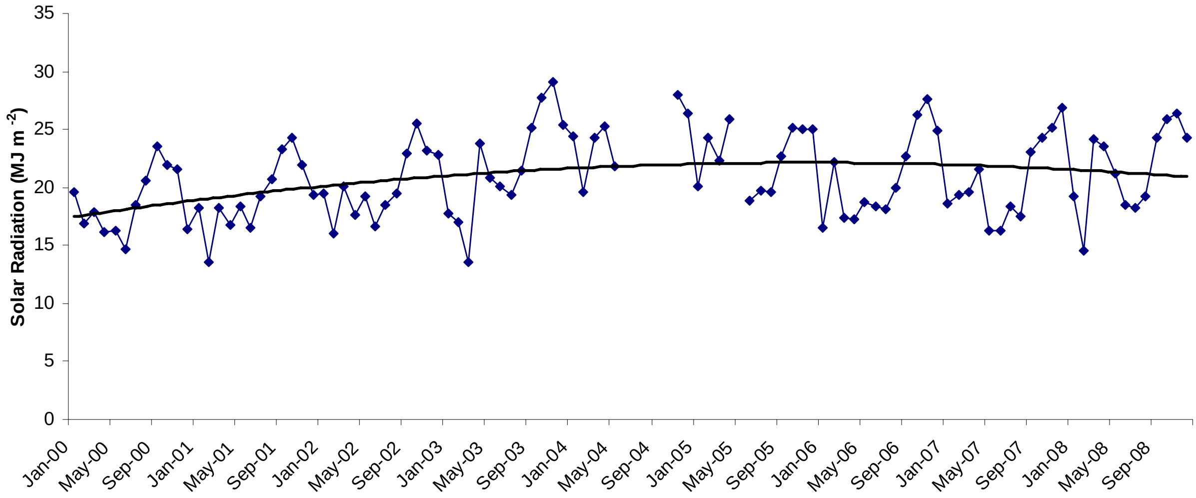


Figure 8. Average monthly maximum mean temperature recorded at Weipa airport from December 1999 to 2008 (Bureau of Meteorology, 2008)

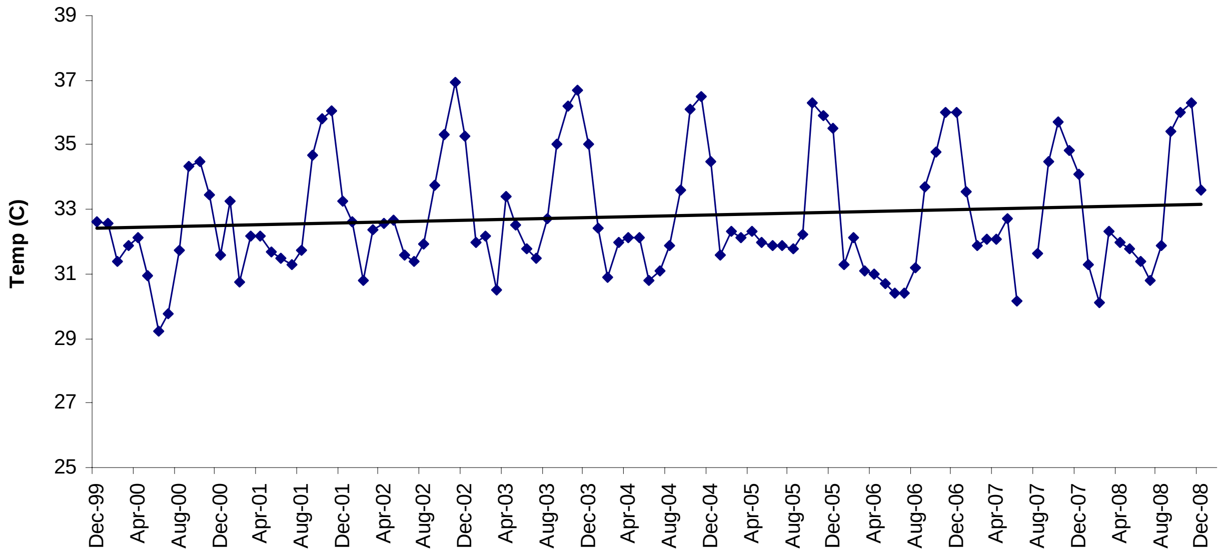


Figure 9. Total monthly hours intertidal seagrass meadows were exposed in the Weipa region, 2008 (adapted from Environmental Protection Agency 2008)

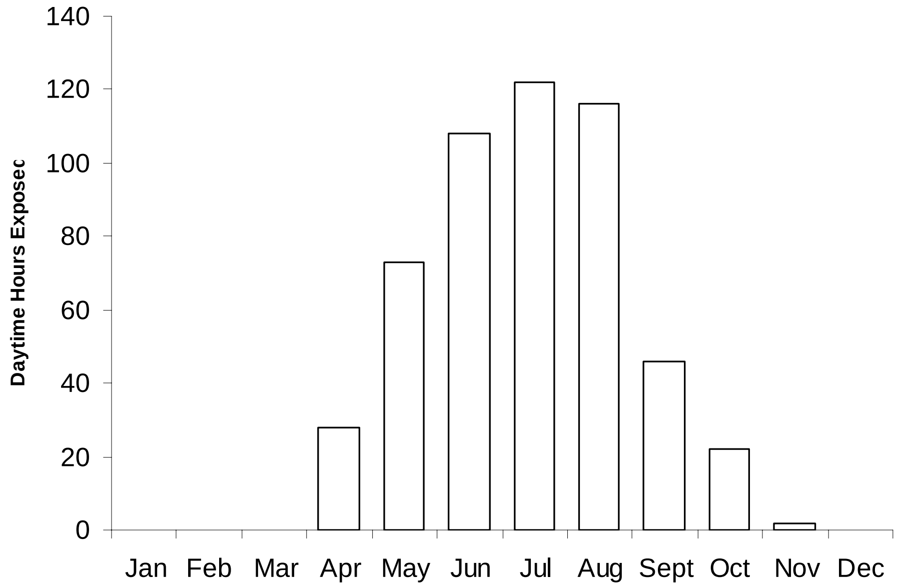
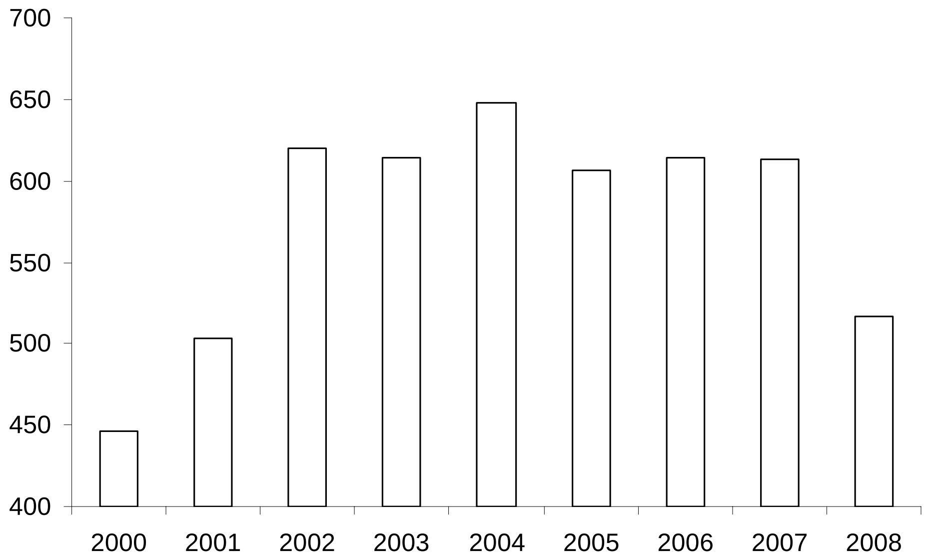


Figure 10. Total number of daylight hours intertidal seagrass banks were exposed, 2000 – 2008 (adapted from Environmental Protection Agency 2008)



Sampling Intensity

Prior to monitoring surveys being conducted in 2003, statistical power analysis was conducted to determine a statistically suitable sample size for each core monitoring meadow. Due to the large inter-annual variation observed throughout the meadows between 2000-2008 these power analyses were revisited in order to make future monitoring programs more statistically effective (Table 4). Using data collected in 2008, and analysed relative to mean values for 2007, the Minimal Detectable Difference (MDD) was calculated for each meadow. A low MDD value represents greater resolution of detectable change in biomass within a meadow. Calculation of MDD follows the methods of Bros and Cowell (1987), and Burdick and Kendrick (2001), and was based on change being detected with 90% power (i.e. Type I error or 10%) and with 90% probability of detecting a true difference (i.e. Type II error of 10%).

Results found that of the 5 meadows that were sufficient in size to be analysed, 2 (A2 & A5) were close to the detection goal of 30% change in biomass with current sampling intensity (Appendix, Table 4). Meadow A6 is currently able to detect a 42% change in biomass. The high intra meadow variability of A3 and A7 represents a minimal detection of 70% and 97% change respectively. In order to increase the power of the monitoring program in future surveys the number of biomass sampling sites will be changed in future surveys to enable a 30% change to be detected where practical and a maximum number of sites logistically feasible in remaining meadows (Table 7).

Table 4. Minimal detectable difference (MDD) (%) of the biomass of seagrass meadows in the Port of Weipa, and the number of samples necessary to detect 30% and 50% changes in biomass relative to previous data. " -- " indicates unrealistic sample size required to detect a 30% MDD

Meadow Number	A2	A3	A5	A6	A7
Current %MDD	32%	70%	34%	42%	97%
Current sample numbers	48	25	48	25	21
Samples required to detect 30% MDD	50	--	65	45	--
Samples required to detect 50% MDD	21	70	25	19	85

DISCUSSION

The 2008 monitoring survey has seen a return of declining trends in seagrass within the Port of Weipa. In 2007, meadows within the IMA appeared to stabilise with signs of recovery, yet in 2008 biomass levels were the lowest recorded since monitoring began. The declines over recent years have been linked to regional and local climate conditions. Low rainfall and a reduction in associated runoff, high air temperatures and greater exposure to more intense solar irradiation (i.e. drought-like conditions) were all likely to have contributed to the low densities recorded from 2002 - 2006 (Taylor *et al* .2007) and seen in other locations within the region (Unsworth et al. 2008). However in 2008 tidal exposure had reduced and rainfall was above-average compared with the previous year. Under these conditions it could have been expected that the recovery noted in 2007 would continue (Rasheed *et al.* 2008). However, high solar irradiance and temperature may have exacerbated the declines in already low biomass meadows in the IMA and surrounding region.

In the previous four years there has been evidence of widespread “browning” or “burning” of intertidal seagrasses most likely as a response to exposure and thermal stress associated with climate conditions. This was particularly true for meadows dominated by *Enhalus acoroides.* In 2008 observations in the field indicated that burning was still widespread while *Enhalus* meadows had become patchier compared with the opposite trends recorded the previous year (Rasheed *et al.* 2008).

Enhalus meadows are likely to be vulnerable to further impacts, above all for the largest *Enhalus* meadow A2 (opposite Lorim Point) which has had a steep decline in biomass across the entire meadow since baseline surveys in 2000. Seagrass cover and density in this meadow had improved in 2007 but its resilience to additional impacts remains low. Extra care should continue to be taken when conducting activities in the region that could further stress the meadow. *Enhalus* meadows in other areas of the state such as in the Torres Strait have also shown declines in recent years (Unsworth *et al.*2008) but not to the same extent as Weipa. These large and sustained declines in intertidal *Enhalus* warrant a closer examination of the influence of anthropogenic and climate factors and the growth habits of the species . DPI&F in partnership with PCQ are currently investigating ways to enhance our understanding of *Enhalus acoroides* dynamics in this meadow and throughout the IMA.

The decline in species diversity in a number of meadows in the greater port limits of Weipa during the 2008 survey may further indicate unfavourable conditions for seagrass in the region. The absence was most often in the meadow’s non-dominant species which was present during past monitoring surveys. Species absence ranged from the smaller *Halophila* and *Halodule* to the larger *Enhalus*. In mixed seagrass meadows subject to disturbance by climatic conditions, storms or human impacts, *Halophila* and *Halodule* often recede and later recolonise quicker than larger long-lived biomass species such as *Enhalus* (Birch and Birch 1984). The ability of these smaller “pioneering” species to form large seed bank reserves likely is a key factor in such meadow dynamics (Birch and Birch 1984; Preen *et al*. 1995). Conversely, the loss of slow growing *Enhalus* from *Halophila* dominated meadows in the Pine River Bay area will likely take longer to re-establish. Observations of growth patterns indicate the majority of *Enhalus* has expanded from clonal or asexual growth in the region (pers. observ.). However, other studies of *Enhalus* dynamics have found that seedling recruitment played a substantial role in the recolonisation process of a mixed species seagrass meadow (Olesen *et al.* 2004). A better grasp of the sexual reproductive effort by this species in the Weipa region may enhance our understanding of what recovery is likely for *Enhalus*.

Intertidal meadows of *Halodule uninervis* in Pine River Bay had recovered to near-baseline levels following their complete loss in 2002. First indications of this recovery were during the 2006 annual monitoring survey (Taylor et al. 2007). Existing low biomass meadows had increased in area and density, and seagrass had recolonised bare sediments to form new meadows. It is likely that this was driven by a combination of biological and environmental factors. Past surveys had indicated that there was a lack of seeds stored in the sediments in the Pine River Bay meadows from which recovery could be initiated (Roelofs *et al*. 2004). Once recruitment has occurred, however these species have the ability to rapidly spread through asexual reproduction (sending out rhizome runners), thus explaining its relatively rapid expansion from 2006 to present (Rasheed 2004).

Overall, meadow area and density appears to be stable in the greater Weipa port limits. In both the Mission River and Pine River Bay, meadows expanded in some areas while retracting in others. These changes may be due to a number of environmental shifts including the natural migration of sand/mudbanks, changes in turbidity and fluctuations in water quality parameters whereby areas are created for seagrass expansion while previously favourable habitat is lost.

Overall, results of the 2008 monitoring indicate that the seagrass habitat of the Port of Weipa was in a moderate condition.

- Changes in seagrass were somewhat consistent with changes to local and regional climate
- The seagrass meadow of highest concern is meadow A2 on the western bank of the Embley River. Further studies of the dominant meadow species, *Enhalus acoroides,* would be valuable.
- Declines in meadow diversity in the greater port limits should be carefully watched during future seagrass monitoring surveys

Many meadows are likely to continue to have a low resilience to further natural or human impacts and need to be carefully monitored in upcoming surveys. Furthermore, strategies to enhance seagrass monitoring would be useful in order to clarify current seagrass declines with options currently being considered by DPI&F and PCQ.

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APPENDIX

ANOVA Results – Kruskal-Wallis One Way Analysis of Variance on Ranks; Mean biomass for the five monitoring meadows from 2001-2008 (2000 not analysed due to small sample size). Years that share the same letter are not significantly different (P<0.05). ** indicates significant differences found among years for the meadow.

Meadow A2**		
Year	Mean Biomass	
2001	29.73	a
2002	22.84	ac
2003	13.91	bc
2004	11.47	bc
2005	7.04	b
2006	6.43	b
2007	9.40	bc
2008	4.66	b

Meadow A3**		
Year	Mean Biomass	
2001	2.04	a
2002	0.37	b
2003	1.63	a
2004	0.31	b
2005	1.08	b
2006	0.11	b
2007	0.92	b
2008	0.24	b

Meadow A5**		
Year	Mean Biomass	
2001	3.11	ac
2002	2.49	bc
2003	2.29	ac
2004	4.18	ac
2005	4.11	ac
2006	1.75	b
2007	6.27	ac
2008	1.94	b

Meadow A6	
Year	Mean Biomass
2001	10.40
2002	9.49
2003	8.31
2004	1.14
2005	3.37
2006	3.44
2007	6.22
2008	2.83

Meadow A7	
Year	Mean Biomass
2001	18.89
2002	10.03
2003	15.57
2004	10.56
2005	2.84
2006	3.06
2007	6.41
2008	5.85