Department of Employment, Economic Development and Innovation

Port of Weipa Long Term Seagrass Monitoring

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Port of Weipa Long Term Seagrass Monitoring September 2009

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On 26 March 2009, the Department of Primary Industries and Fisheries was amalgamated with other government departments to form the Department of Employment, Economic Development and Innovation.

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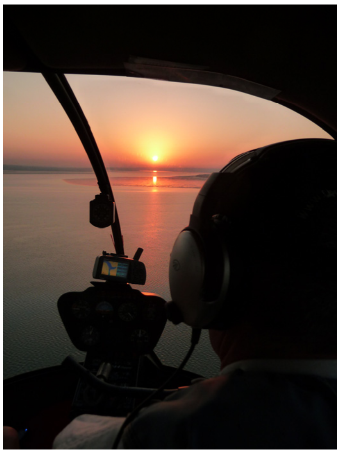
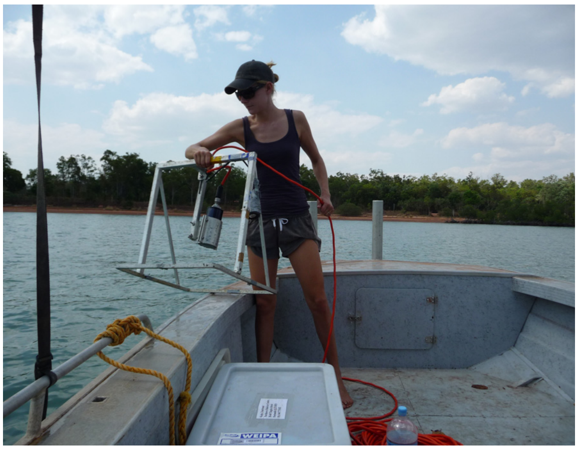
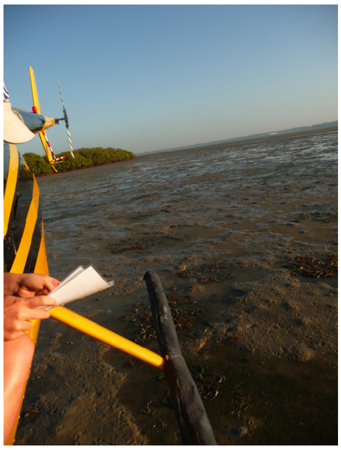




EXECUTIVE SUMMARY

This report details results of the September 2009 seagrass monitoring survey in the Port of Weipa and discusses changes in inter-annual seagrass meadow dynamics since monitoring began in 2000. Results of the program are used to ensure port and other human activities are having a minimal impact on the marine environment by using seagrasses as a key indicator of marine environmental health. The program is also used to assess the status of these important fisheries habitats and forms part of a network of seagrass assessment established throughout Queensland.

Results of the 2009 monitoring found seagrasses in the Port of Weipa to be in a reasonable but vulnerable condition. Seagrass changes observed were likely to be associated with natural shifts in tidal exposure combined with changing light and temperature associated with local climate. These conditions have led to several meadows showing a long term declining trend. This trend has been of particular concern for *Enhalus acoroides* meadows, especially the large intertidal meadow opposite Lorim Point, where biomass reached a record low in 2008. The declines have likely left some meadows in a highly vulnerable state with a low resilience to further natural or anthropogenic impacts.

In response to the declines North Queensland Bulk Ports (NQBP) and Fisheries Queensland conducted an additional survey of the intertidal *Enhalus acoroides* meadow in April 2009 to assess if the meadow was in a healthier state at times outside of the regular annual September survey. The April 2009 assessment showed an increase in seagrass from the previous September but biomass still remained significantly lower than for other assessments that have occurred in April (2000-2002). By the following September (2009), the meadow had once again declined to a similar low level recorded the previous year.

Not all meadow types in the Port declined with some intertidal *Halodule* meadows significantly increasing in biomass from 2008 and 2009 and despite the changes observed in seagrass density, the distribution and area for most meadows remained similar to previous years.

Seagrasses appear to have been resilient to the impacts associated with regular port maintenance dredging during the life of the current monitoring program. However, Fisheries Queensland remain concerned that the continued low density of some of the meadows in Weipa leaves them particularly vulnerable to additional stresses including those associated with dredging. Further enhancements to the established seagrass program including an examination of light and temperature conditions at vulnerable seagrass meadows would significantly enhance the ability of the program to pinpoint the causes of seagrass declines. An additional seasonal survey of the *Enhalus* meadow opposite Lorim Point in April 2010 may also be warranted. These measures would provide added assurance of the seagrass meadow's tolerance and capacity to withstand additional stresses. Fisheries Queensland and NQBP will be working on incorporating some of these measures into the long term monitoring program.

INTRODUCTION

North Queensland Bulk Ports Corporation (NQBP) is the organisation responsible for managing and monitoring Weipa's port environment. NQBP has recognised that seagrasses form a key ecological habitat in the Weipa region and 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 the 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. Within the IMA five "core monitoring meadows" that represent the range of seagrass meadow communities in the region are assessed for biomass and species composition. At the time of the annual monitoring 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 2009 and an interim reconnaissance survey in April 2009. The objectives of the 2009 long term seagrass monitoring of the Port of Weipa were to:

1. Map the distribution and abundance of the "core monitoring meadows";
2. Map the distribution and confirm species composition of seagrass meadows in the Intensive Monitoring Area (IMA);
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 NQBP to assess and demonstrate the marine environmental health of the port and to satisfy environmental monitoring requirements as part of the port's long term dredge management plan and by agencies to assess the status and condition of seagrass resources in the region. The program also forms part of Fisheries Queensland's' network of long term monitoring sites for important fish habitats.

METHODS

Seagrass surveys within the Port of Weipa were conducted between the 14th and 16th of September 2009. Five core seagrass meadows were selected from the baseline surveys (Roelofs *et al.* 2001) for long term annual monitoring and have been surveyed since 2003. These meadows were representative of the range of seagrass meadow communities identified in the baseline survey, and were also located in areas likely to be vulnerable to impacts from port operations and developments. In April 2009 an additional assessment of the large intertidal *Enhalus* monitoring meadow (A2) opposite Lorim Point was also conducted to check for any seasonal recovery.

Two levels of sampling were used in the September 2009 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).

Seagrass meadows were surveyed using a combination of helicopter aerial surveillance and boat-based camera surveys. At each survey site within the "core monitoring meadows', seagrass meadow characteristics, including seagrass species composition, above-ground biomass, percent algal cover, depth below mean sea level (MSL; for subtidal meadows), sediment type, time and position fixes (GPS; ±5m) were recorded. A complete outline of these methods can be found in Roelofs *et al.* 2001.

Seagrass community type in non-monitoring meadows within the IMA 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.

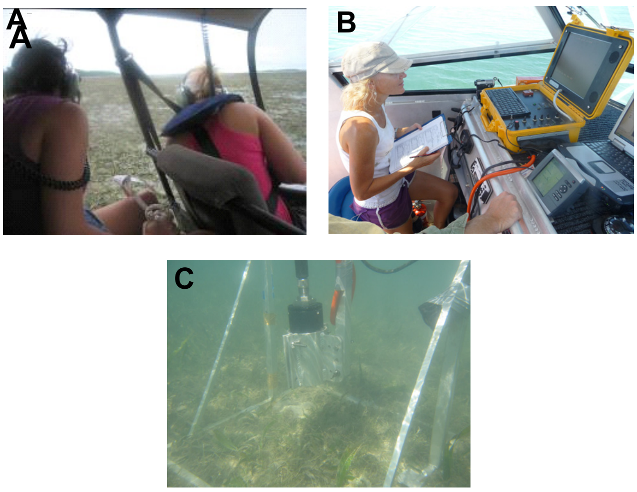


Plate 1. Seagrass methodology utilising (A) helicopter aerial surveillance and (B & C) boat based CCTV surveillance

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 compared 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 2009 survey were entered into the Port of Weipa Geographic Information System (GIS). Three seagrass GIS layers were created in ArcGIS®:

• **Site information** - site 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).

Table 1. Nomenclature for community types in the Port of Weipa 2009

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

• **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.

<u>*Isolated seagrass patches*</u>
The majority of area within the meadows consisted of unvegetated sediment interspersed with isolated patches of seagrass

<u>*Aggregated seagrass patches*</u>
Meadows are comprised of numerous seagrass patches but still feature substantial gaps of unvegetated sediment within the meadow boundaries

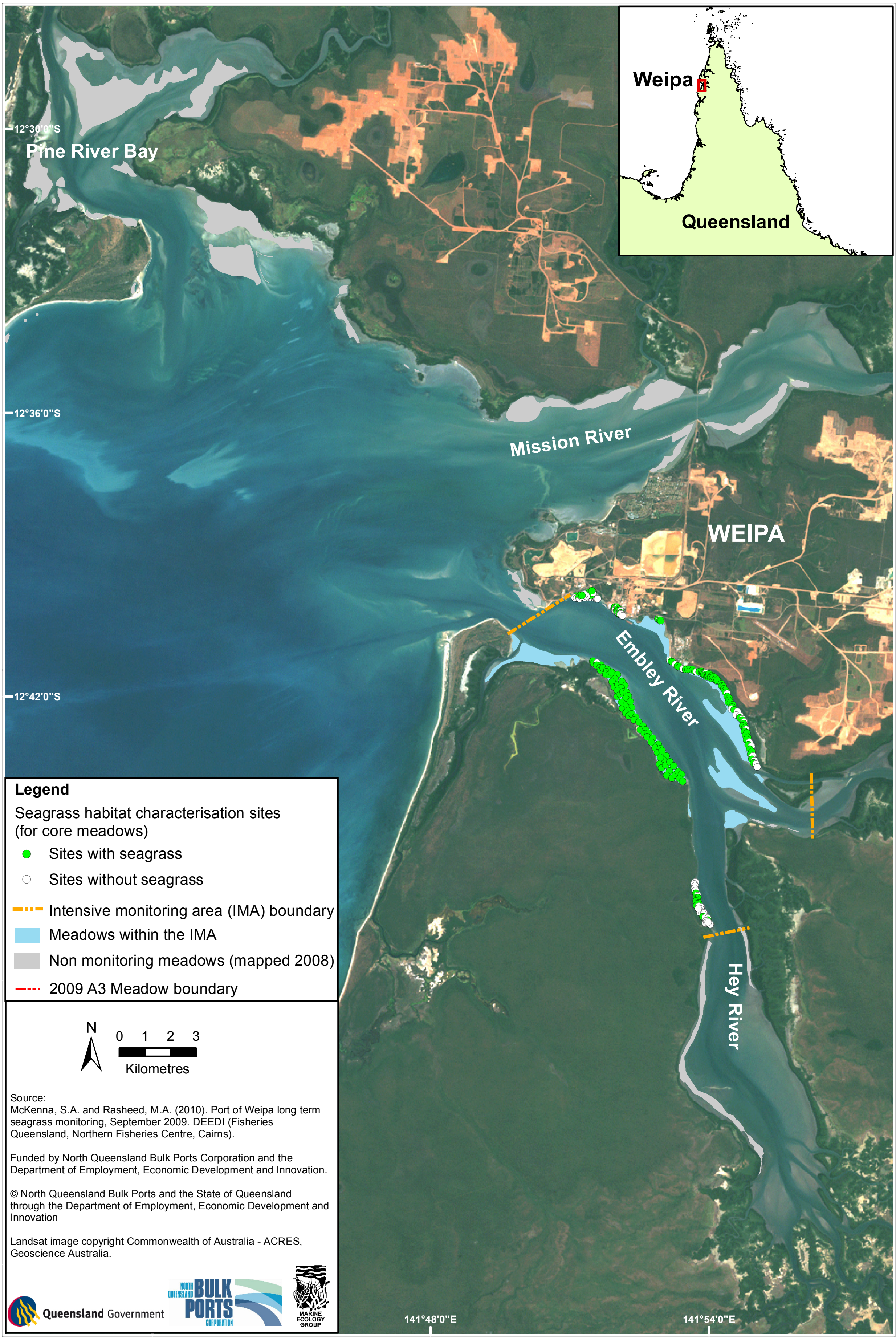
<u>*Continuous seagrass cover*</u>
The majority of area within the meadows comprised of continuous seagrass cover interspersed with a few gaps of unvegetated sediment.

Each seagrass meadow was assigned a mapping precision estimate (±m) based on the mapping methodology used for that meadow (Table 2). Mapping precision estimates ranged from 5m for isolated intertidal seagrass meadows to 20m for larger patchy intertidal/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. The reliability estimate for subtidal habitat is based on the distance between sites with and without the community-of-interest (i.e. seagrass) when determining the habitat boundary. Additional sources of mapping error associated with digitising aerial photographs into basemaps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 2. Mapping precision and methodology for seagrass meadows in the Port of Weipa 2009

Mapping precision	Mapping methodology
5m	Meadow boundaries mapped in detail by GPS from helicopter; Intertidal meadows completely exposed or visible at low tide; Relatively high density of mapping and survey sites; Recent aerial photography aided in mapping.
20m	Meadow boundaries determined from a combination of helicopter and camera/grab surveys; Inshore boundaries mapped from helicopter; Offshore boundaries interpreted from survey sites and aerial photography; Relatively high density of mapping and survey sites.

Map 1. Location of 2009 seagrass monitoring sites and seagrass meadows in the Port of Weipa



RESULTS

Seagrass species, distribution and abundance

Four seagrass species (from 2 families) were identified in the September 2009 monitoring survey (for a complete list of the 6 species present in the greater 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

	***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

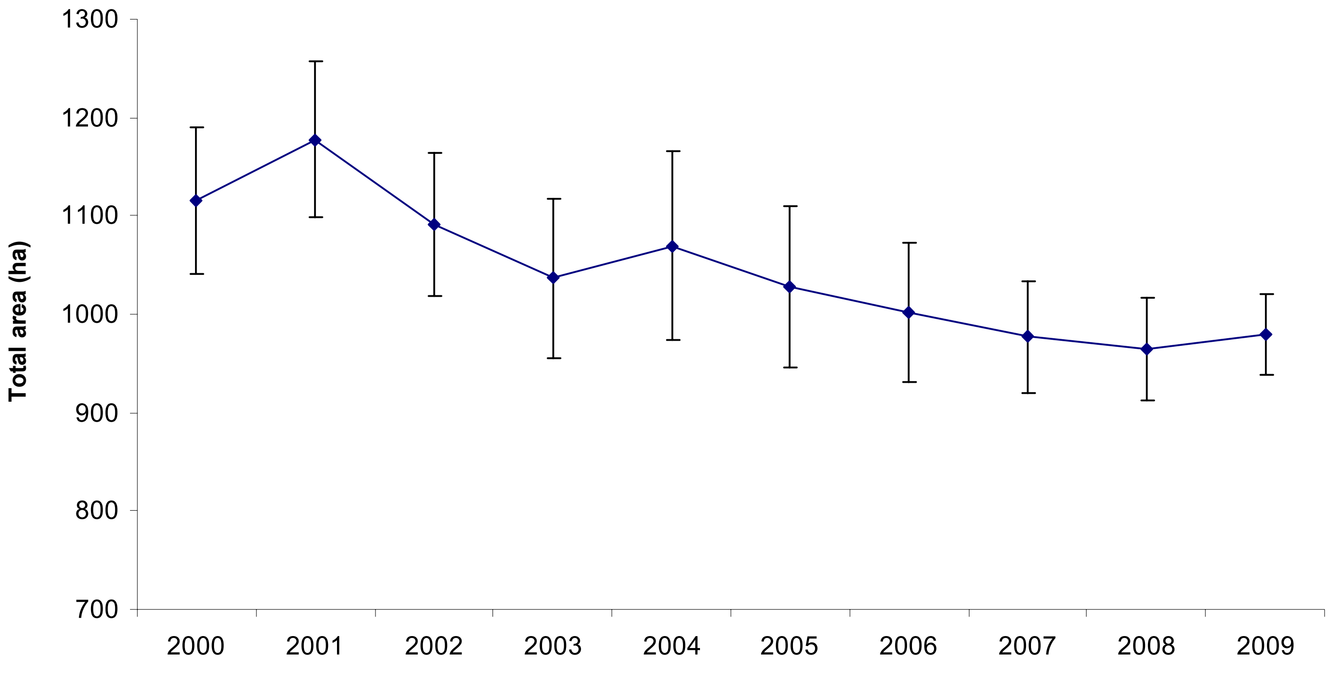
A total of 980 ± 42 ha of seagrass habitat, comprising thirteen seagrass meadows, was mapped within the Intensive Monitoring Area (IMA) in September 2009 (Map 2). This was similar to the last 3 years of monitoring where area of seagrasses within the IMA has been reduced compared with historical levels (Figure 3, Maps 2 & 3). Meadow area ranged from 0.4 ha to 251.3 ha with the smallest meadows located along the western bank of the Hey River and the largest located along the western bank of the Embley River (meadow A2; Map 2).

Communities dominated by *Enhalus acoroides* were the most common, with nine of the thirteen 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).

Some small *Halodule* meadows in the southern section of the Embley River that were present in 2008 had disappeared in 2009 as well as small *Enhalus* meadows on the western bank of the Hey River (Map 3).

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. This is an indication of a high level of exposure related stress to intertidal seagrasses. Dugong feeding trails were also evident throughout the A5 *Halodule* meadow (south of Napranum).

Figure 3. Total area of seagrass within the Weipa Intensive Monitoring Area from 2000 to 2009 (error bars = "R" reliability estimate)



Core Monitoring Meadows

A total of 197 seagrass habitat characterisation sites were surveyed within the core monitoring meadows, 84% of which (167 sites) had seagrass present (Map 1). In 2009 seagrass biomass within the core monitoring meadows (A2, A3, A5, A6 & A7) remained below historical peak densities (2000 to present). Mean above ground biomass for the five monitoring meadows ranged from 0.0012 ± 0 g DW m^{-2} for the A3 meadow in the Hey River to 6.39 ± 0.77 g DW m^{-2} for the A2 *Enhalus* meadow (Table 3; Figure 4). This variability was dependent on the mix of species present. Total meadow area for all core monitoring meadows was 345 ± 19 ha in September 2009, which is the lowest recorded value since monitoring began in 2000 (Table 4). The majority of this loss in area was due to the decline in the *Halodule* monitoring meadow in the Hey River (A3) (Table 4; Figure 4).

The most notable change in biomass over the last ten years of monitoring has been in the large intertidal *Enhalus* dominated meadow (A2) 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 and towards the southern end of the meadow. High seagrass biomass hotspots found in the north and south of the meadow have substantially decreased since 2001 (Map 4). In response to these declines NQBP commissioned an additional survey of this meadow in April 2009 to assess if the meadow was in a healthier state outside of the regular annual September monitoring. It was thought that in recent years the period leading up to August September was particularly stressful for seagrass due to higher temperatures, solar irradiance, and longer periods of daytime tidal exposure. Results of the April 2009 survey showed that seagrass biomass had increased from September 2008 (from 4.7 ± 0.6 to 10.8 ±1.2 g DW m^{-2}). However seagrass biomass for the meadow once again declined in September 2009 (6.39 ± 0.77 g DW m^{-2}) (Table 1, 2)(April & September 2009) and remained at historically low levels (Table 5).

Meadow A2 has also had a small shift in seagrass composition over the last two years with *Thalassia hemprichii* comprising a larger proportion of meadow seagrass than previously recorded (Figure 4). Burning of *Enhalus* blades was observed frequently in the meadow in September (50% of sites). Despite the changes to biomass and species composition area of the meadow has remained largely unchanged during the monitoring program.

Biomass of the remaining two *Enhalus* dominated core meadows (A6 & A7) has also had considerable declines over the course of the monitoring program (Map 2; see appendix). In 2004 the biomass of the Lorim Point Wharf *Enhalus* meadow (A6) reached the lowest levels recorded in the monitoring program. By 2007 this meadow showed signs of recovery increasing in biomass however, biomass declined again in 2008 and 2009. The *Enhalus* meadow adjacent to Evan's Landing (A7) showed similar signs of recovery in 2007 with only a slight decrease in biomass in 2008 & 2009 remaining relatively stable over the last three years (Figure 4). Both meadows showed signs of a slight increase in area in 2009 compared to 2008 but remain within the range of previously recorded area values.

Biomass and area 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 in biomass over multiple years (Table 3; Figure 4; see Appendix). These changes are considered within the normal scope for this meadow type with a characteristically dynamic dominant species, *Halodule uninervis*. In 2009, the *Halodule uninervis* component of the A3 meadow had reduced to a single isolated patch of seagrass towards the southern end of the meadow. This meadow has become increasingly patchy and dominated by patches of *Enhalus acoroides* (present in 33% of the survey sites). *Enhalus acoroides* is excluded from all biomass, area and species analyses in the A3 & A5 meadows in order to track the dynamics of the *Halodule* component of the meadow. The reduction of *Halodule uninervis* in the A3 meadow accounted for the considerable decline in area (0.4ha) of this meadow (Table 4). The boundary of the entire meadow including *Enhalus acoroides* however was 30 ± 2 ha. The A3 meadow has undergone a species shift from being dominated by *Halodule* from 2000-2006, then in 2007 & 2008 it became dominated by *Thalassia* and is now dominated by *Enhalus.*

In contrast to the A3 meadow, the other larger *Halodule* meadow (A5) underwent a significant increase in biomass compared to previous years, recording one of its highest biomass values in the program and also increased in area from 2008 (Table 4; Figure 4 see Appendix). Meadow A5 has also had a small shift in seagrass composition in 2009 with *Thalassia hemprichii* comprising a larger proportion of seagrass than previously recorded (Figure 4).

Table 3. Mean above-ground seagrass biomass and number of biomass sampling sites for each core monitoring meadow within the Port of Weipa. 2000 – 2009

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**	**September 2009**
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)	9.40 ± 1.55 (46)	4.66 ± 0.63 (48)	6.39 ± 0.77 (70)
A3 Intertidal *Halodule* 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)	0.92 ± 0.27 (31)	0.24 ± 0.13 (29)	0.0012 ± 0 (31)
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)	6.27 ± 0.80 (54)	1.94 ± 0.45 (48)	5.09 ± 0.61 (76)
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)	6.22 ± 0.1.62 (31)	2.83 ± 0.55 (25)	1.47 ± 0.47 (29)
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)	5.75 ± 1.32 (21)

Table 4. Total meadow area for each core monitoring meadow within the Port of Weipa. 2000 – 2009

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**	**September 2009**
A2 Intertidal *Enhalus* dominated	253 ± 19	248 ± 19	255 ± 19	250 ± 20	255 ± 19	251 ± 20	245 ± 13	238 ± 6	244 ± 6	251 ± 7
A3 Intertidal *Halodule* dominated	30 ± 5	48 ± 5	34 ± 4	36 ± 4	41 ± 5	37 ± 5	31 ± 2	33 ± 2	32 ± 2	0.4 ± 0.1
A5 Intertidal *Halodule* dominated	95 ± 10	91 ± 10	102 ± 6	87 ± 9	93 ± 10	86 ± 10	58 ± 5	76 ± 6	66 ± 6	73 ± 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	8 ± 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	13 ± 5
Total	**402 ± 37**	**417 ± 36**	**417 ± 31**	**399 ± 35**	**414 ± 36**	**398 ± 37**	**358 ± 23**	**368 ± 17**	**358 ± 23**	**345 ± 19**

Table 5. Mean above-ground seagrass biomass and number of biomass sampling sites for the A2 meadow within the Port of Weipa April and September 2000 – 2002 & 2009

Monitoring Meadow	Mean biomass ± SE (g DW m^{-2}) (No. of sites)							
	April 2000	**September 2000**	**April 2001**	**September 2001**	**April 2002**	**September 2002**	**April 2009**	**September 2009**
A2	71.15 ± 10.39 (29)	33.63 ± 5.82 (17)	45.39 ± 4.77 (49)	29.73 ± 2.88 (51)	34.61 ± 3.99 (52)	22.84 ± 2.99 (50)	10.8 ± 1.2 (62)	6.39 ± 0.77 (70)

Map 2. Meadow type and cover for seagrass meadows within the Intensive Monitoring Area 2009

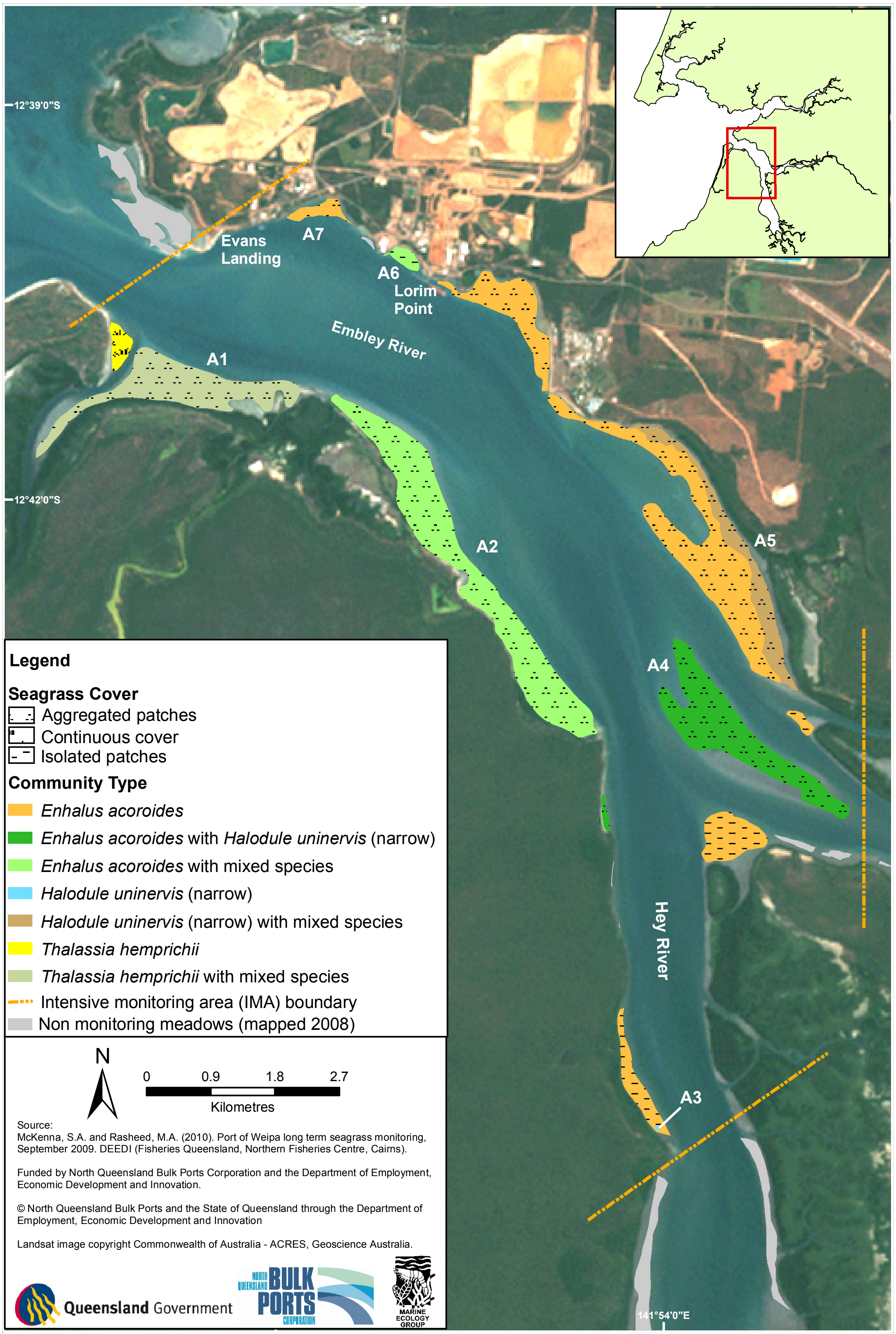
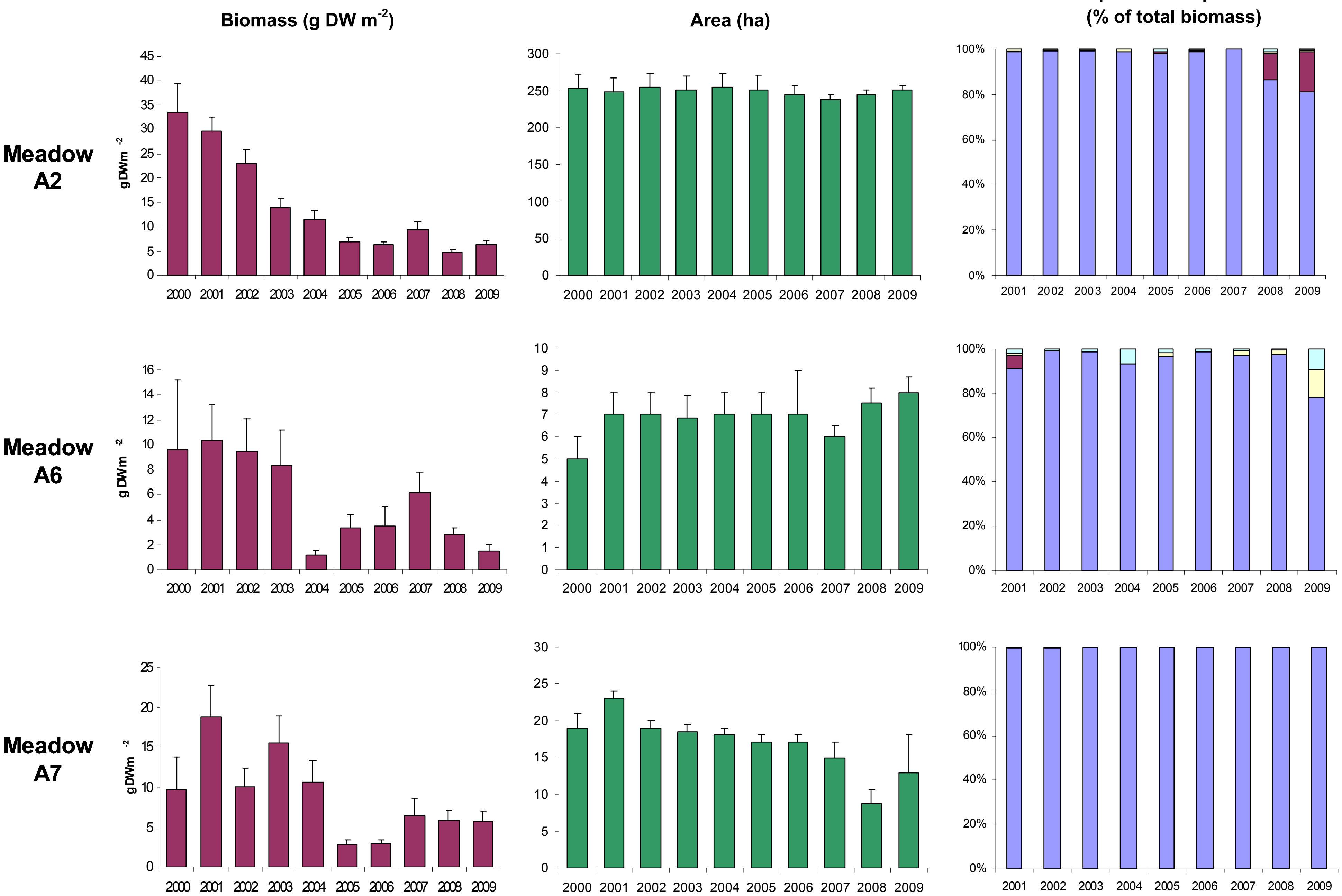
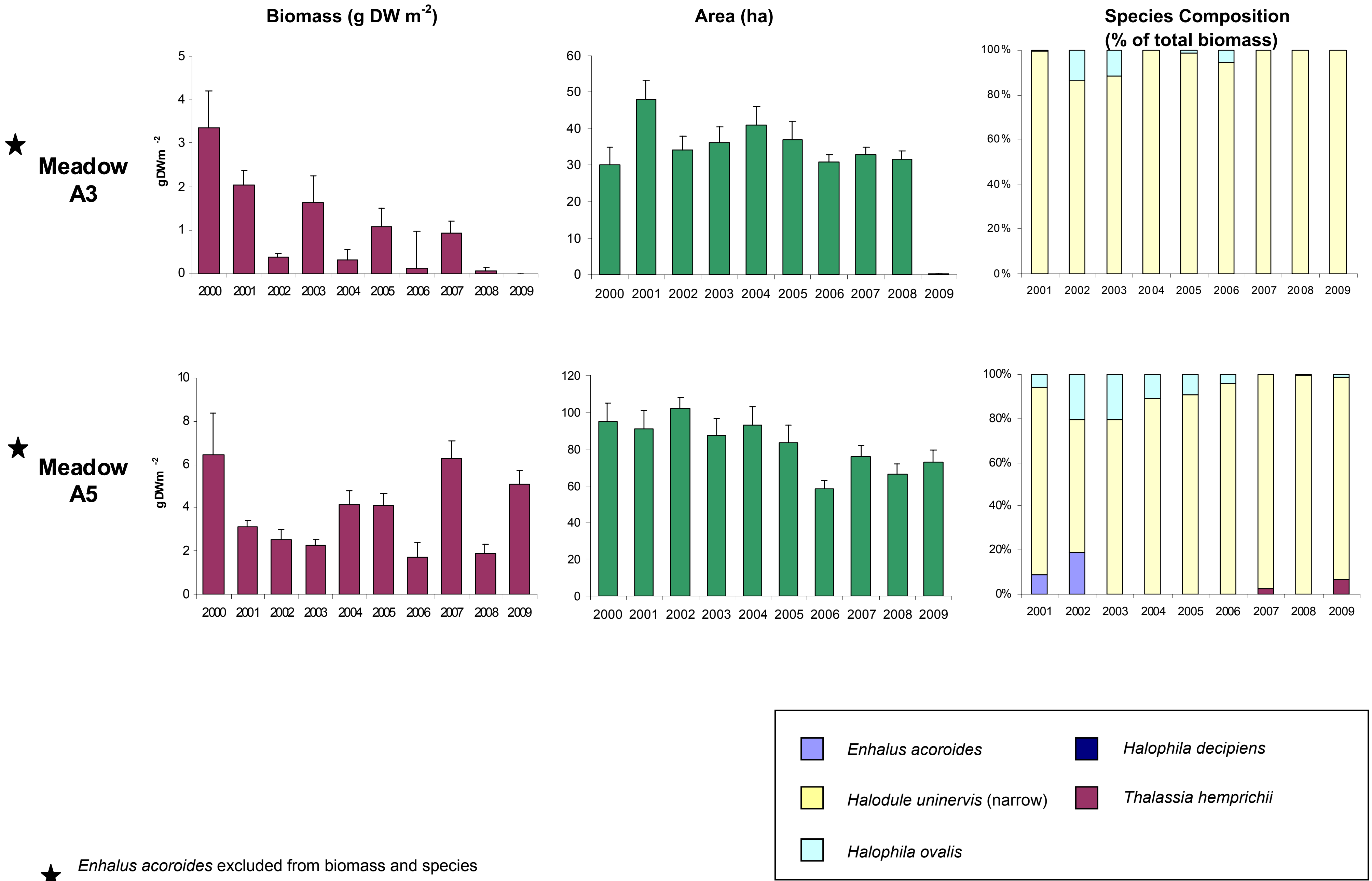


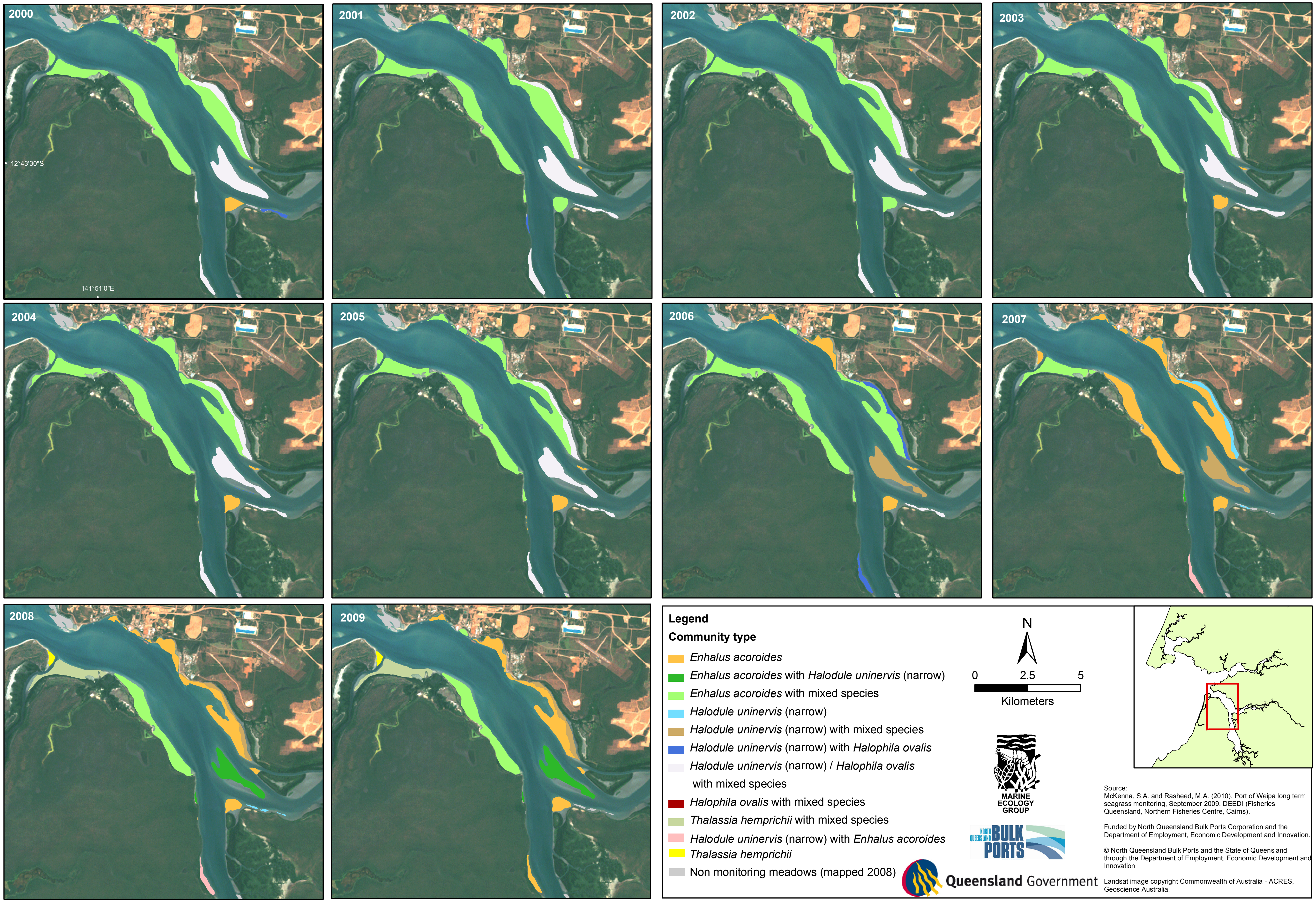
Figure 4. Changes in biomass area and species composition for the core monitoring meadows in Weipa from 2009 to 2009 (biomass error bars = SE; area error bars = “R” reliability estimate).



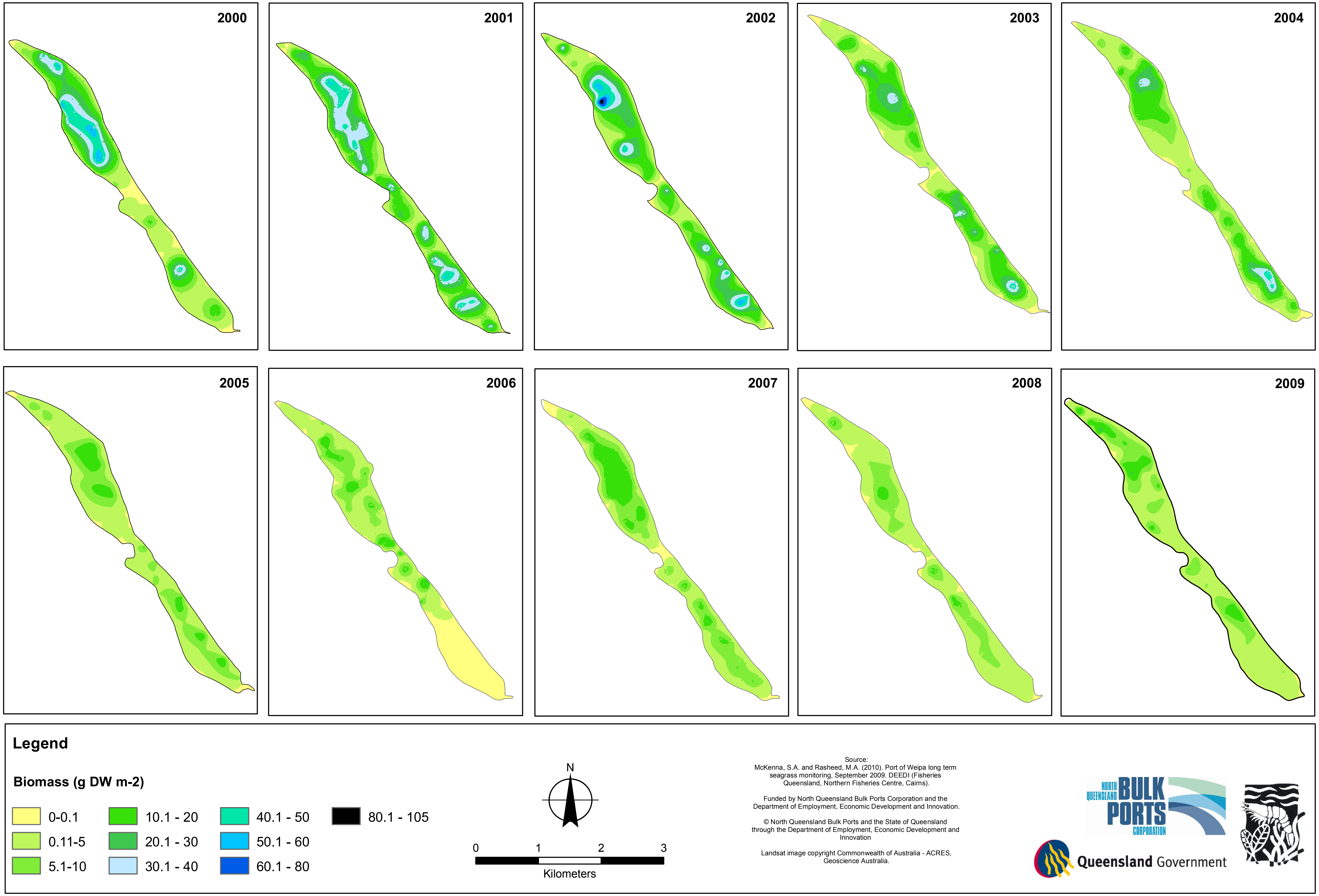


★ *Enhalus acoroides* excluded from biomass and species composition analysis

Map 3. Meadow type and distribution for the seagrass meadows within the IMA 2000 to 2009.



Map 4. Density of seagrass biomass in the A2 meadow from 2000 to 2009



Weipa Climate and Seagrass Change

Total annual rainfall in Weipa was below average in 2009 while the previous year saw above average rainfall (since 1973; Figure 5). Solar irradiance has varied over the last decade with peak levels in 2003 and 2004 (Figure 6). Seasonally, highest solar radiation is typically from September to November, coinciding with annual seagrass surveys. Solar irradiance during 2009 was slightly up from the previous four years at survey time. In August 2009; the month prior to the survey, solar radiation was the highest recorded value for this time of year in the last decade.

Maximum average monthly air temperature has trended upwards from 2000 to present (Figure 7). These climate trends indicated drought-like conditions have prevailed for the Weipa area from 2002 to present although there was above average rainfall in 2008. Maximum average monthly air temperature at survey time (September) in 2008 & 2009 has been the highest values recorded in the last decade. For the Weipa region lying in the tropics, drought-like conditions would likely result in reduced freshwater river flows and potentially lower levels of nutrient re-suspension and and availability to the coastal marine system. 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 8). Naturally higher tide cycles during 2000, 2001, 2008 & 2009 has resulted in fewer daytime hours seagrass banks were exposed (Figure 9). A decline in exposure is likely to result in less desiccation and extreme temperature conditions at the seagrass blade surface. High temperature and desiccation can both lead to burning of seagrass.

An analysis of the relationship between hours of daytime tidal exposure and seagrass biomass for the A2 *Enhalus* meadow shows a significant negative correlation for the hours of tidal exposure in the month leading up to the annual monitoring surveys (Appendix).

Figure 5. Total annual rainfall recorded at Weipa airport from 1973 to 2009 (Bureau of Meteorology, 2009)

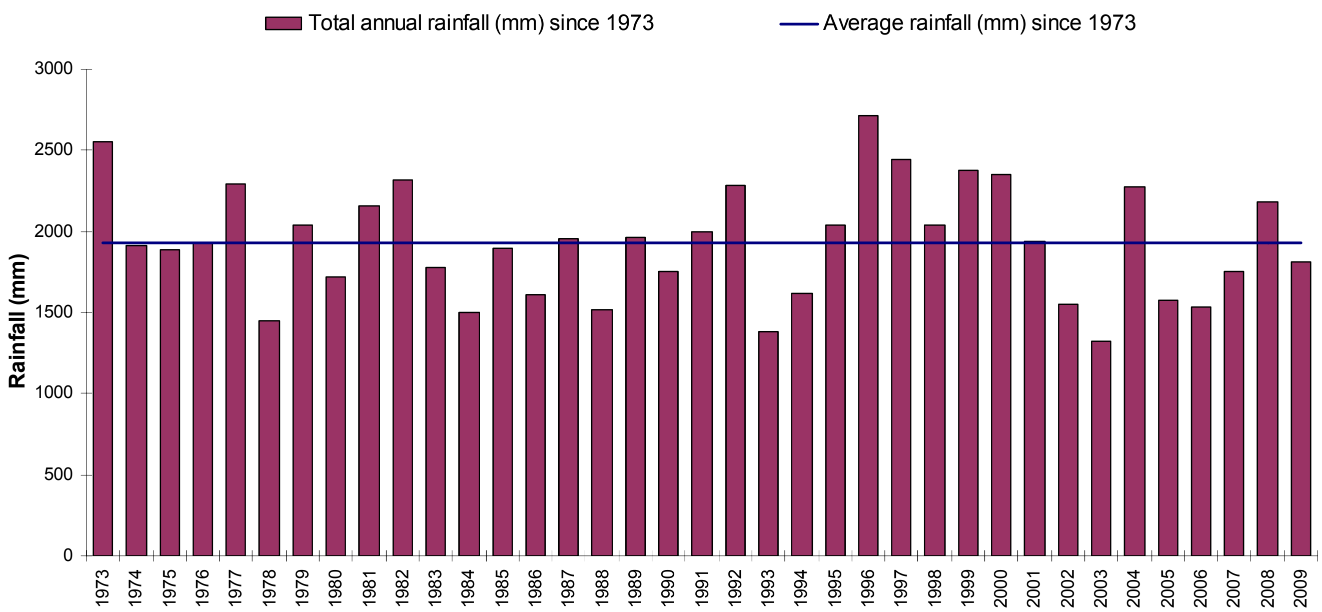


Figure 6. Mean monthly solar radiation recorded at Weipa airport from 2000 to 2009 (Bureau of Meteorology, 2009)

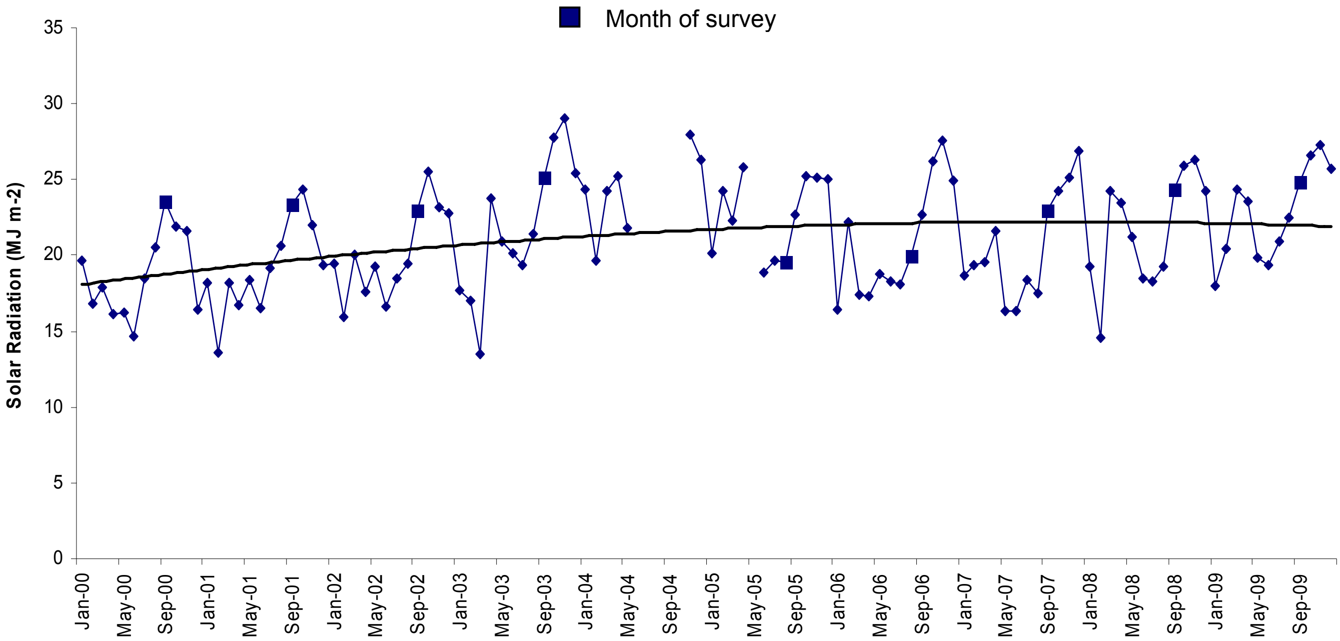


Figure 7. Average monthly maximum mean temperature recorded at Weipa airport from 2000 to 2009 (Bureau of Meteorology, 2009)

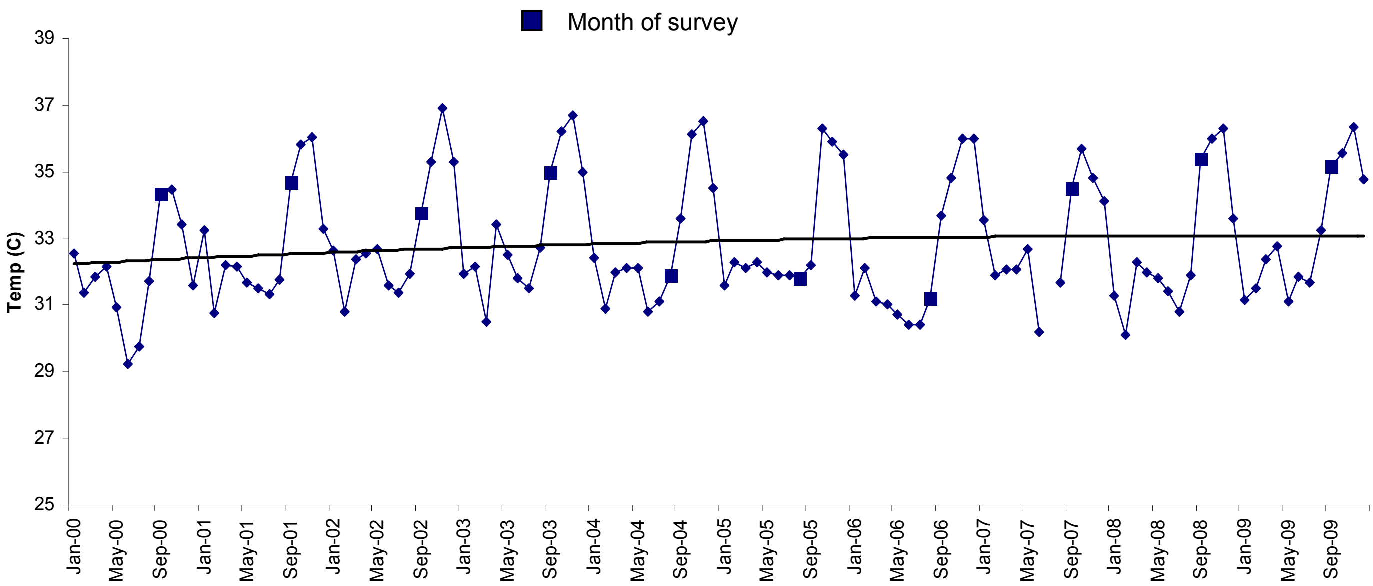


Figure 8. Total monthly hours intertidal seagrass meadows were exposed (<1m) in the Weipa region, 2009 (Maritime Safety Queensland, 2009)

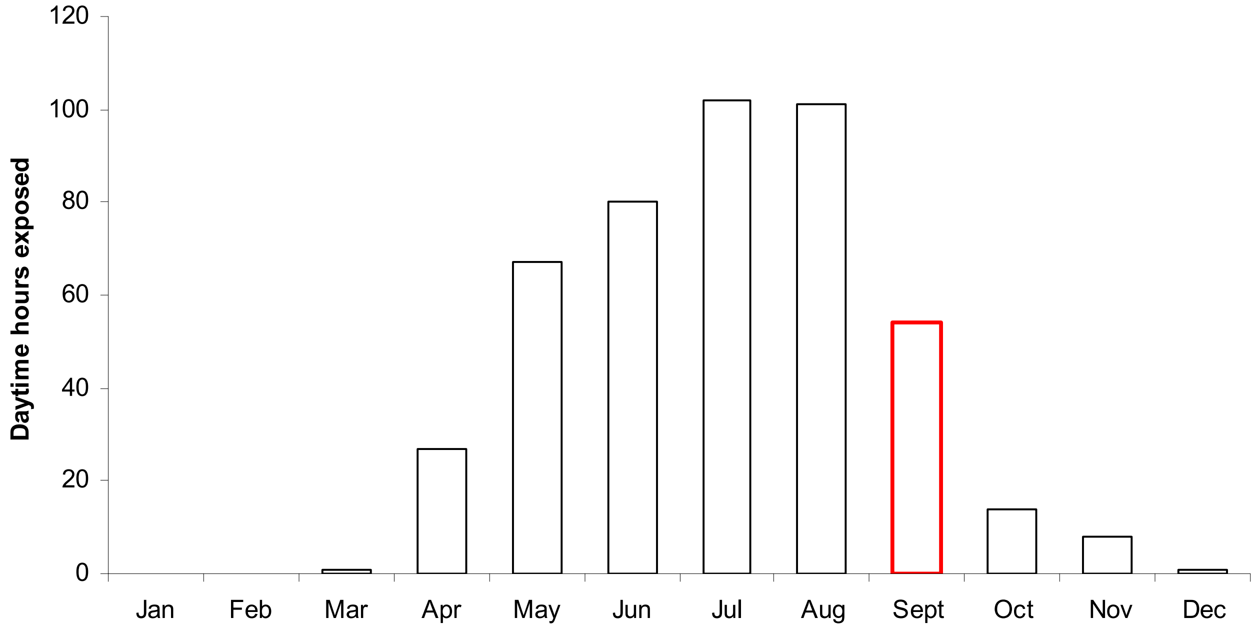
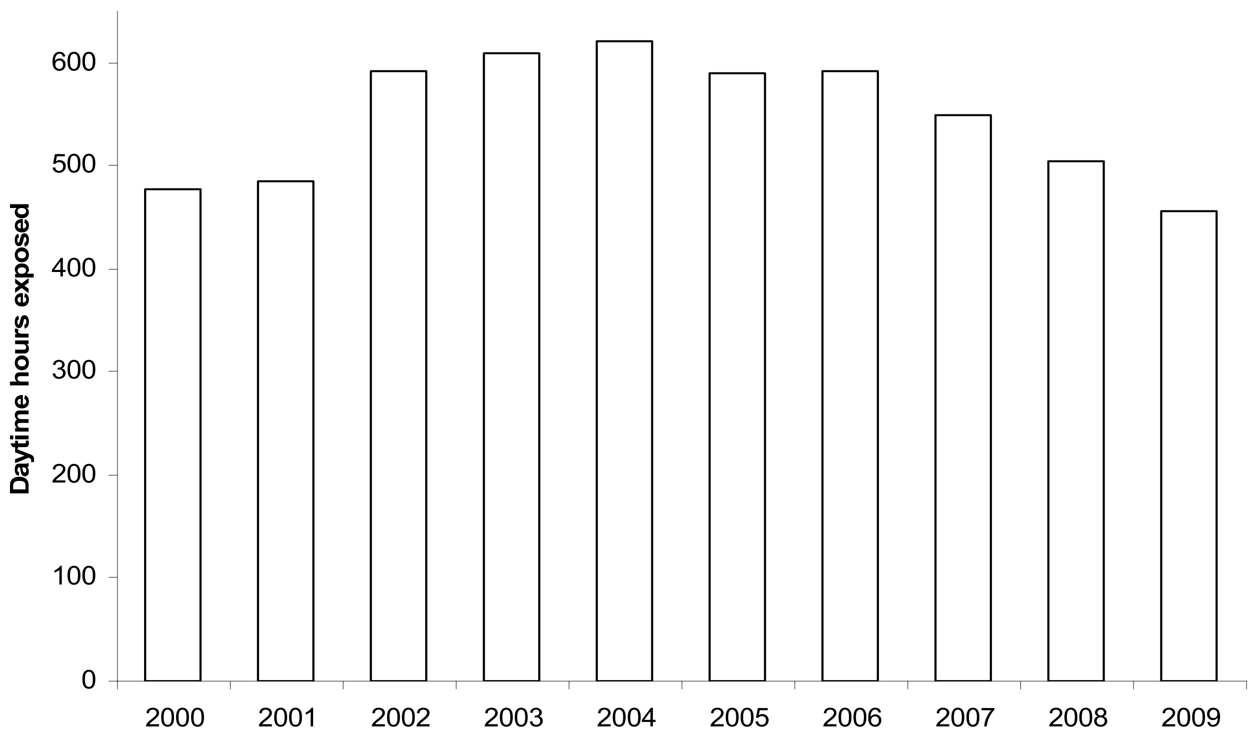


Figure 9. Total number of daylight hours intertidal seagrass banks were exposed (<1m) in the Weipa region 2000-2009 (Maritime Safety Queensland, 2009)



DISCUSSION

Results of the 2009 monitoring found seagrasses in the Port of Weipa to be in a reasonable but vulnerable condition. Seagrass changes observed were likely to be associated with natural shifts in tidal exposure combined with changing light and temperature associated with local climate. These conditions have led to several meadows showing a long term declining trend. This trend has been of particular concern for *Enhalus acoroides* meadows, especially the large intertidal meadow opposite Lorim Point, where biomass reached a record low in 2008. The declines have likely left some meadows in a highly vulnerable state with a low reliance to further natural or anthropogenic impacts.

In 2009 seagrass densities for most of the core monitoring meadows remained below historical peaks adding to the declining trends that have been observed in Weipa over recent years. These declines in above-ground biomass over the last 10 years have coincided with relatively small variations in meadow area. In 2007, meadow density showed signs of recovery, but by 2008 most meadows had declined again in biomass. In 2009 seagrass biomass was similar to that of 2008 indicating that conditions may have stabilised but there was little evidence of recovery in above-ground biomass for most of the core monitoring meadows.

The most likely drivers of seagrass change in Weipa are related to regional and local climate conditions rather than anthropogenic or port related factors. Low rainfall and a reduction in associated runoff, high air temperatures and greater exposure to more intense solar irradiation were all likely to have contributed to the low densities recorded in the past and may have contributed to a loss of natural resilience in these meadows (Taylor *et al*. 2007; Rasheed *et al*. 2010). However in 2008 & 2009 tidal exposure had reduced and rainfall was above average (in 2008) compared with previous years, which may have offered some respite to the meadows. Under these conditions it could have been expected that the recovery noted in 2007 would continue in following years (Rasheed *et al.* 2008). However high solar irradiance and temperatures in 2008 & 2009 combined with the already reduced resilience of these meadows may have hampered any recovery.

Field observations have indicated an increased occurrence of desiccated and burnt *Enhalus* leaves in intertidal meadows, most likely as a response to exposure and thermal stress associated with exposure to air at low tide. In addition these meadows have become sparser and patchier. Analysis of annual fluctuations in daytime tidal exposure and the relationship with changes to seagrass biomass in Weipa reveal significant negative correlations. Declines in seagrass biomass in the A2 meadow are significantly correlated with increases in the amount of daytime tidal exposure in the month prior to seagrass sampling (Appendix; Rasheed *et al*, In Review). A number of studies have found similar relationships, where tidal exposure coupled with high daytime temperature can result in seagrass declines. These conditions lead to high levels of photosynthetic active radiation and ultra violet radiation as well as desiccation and temperature stress leading to physiological stress to the leaf structure and photosystems (Erftemeijer and Herman, 1994; Stapel, 1997; Bjork *et al*, 1999; Seddon *et al*., 2000; Kahn and Durako, 2009). These conditions can lead to declines in seagrass density and area and probably explain much of the changes observed for intertidal seagrass meadows in Weipa.

Not all intertidal meadows have suffered the same declines as the *Enhalus* meadows. The large *Halodule* meadow south of Napranum increased in biomass in 2009. The differing responses may partly be due to the very different morphologies of the two species. The physical structure of *Enhalus* (thick waxy strap-like leaf blades) causes a portion of the leaf blade at the base to remain “proud” above the substrate rather than lying flat on the surface, exposing itself to extremes of both temperature and desiccation related stress. In contrast intertidal meadows made up of small species such as *Halodule uninervis* which have flexible petioles and lay flat on the moist sediment surface when exposed are more protected from these extremes (Tanaka and Nakaoka, 2007; Kahn and Durako 2009). It is also possible that *Halodule* meadows have been impacted by exposure related stress in the past but have been quicker to recover than *Enhalus* meadows.

Halodule uninervis has the ability to form large seed bank reserves and has the potential to colonise and spread quickly, increasing their capacity for recovery (Birch and Birch 1984; Preen et al 1995) compared to the bigger slower growing *Enhalus* species.

In contrast to the *Halodule* meadow south of Napranum the small very low density *Halodule meadows* in the southern section of the Embley River and the Hey River suffered substantial declines in area in 2009. These meadows have been highly patchy and variable throughout the monitoring program with no clear pattern to their changes. The make up of these meadows with only small isolated plants of low density seagrass makes them highly susceptible to impacts with a reduced resilience and capacity to recover. Their substantial reduction in area in 2009 is a further indication of conditions being difficult for seagrasses in recent times.

While it appears that tidal exposure is a key variable driving seagrass changes it is likely that other factors such as changes to the light environment and temperature are also influencing seagrass changes. There are a range and combination of other natural factors that influence seagrass growth and anthropogenic factors such as dredging and vessel movements can not be completely ruled out as having an effect. It is likely that the changes observed in the monitoring program are a result of a cumulative impact of the range of factors that effect seagrasses.

The *Enhalus* meadows in Weipa are likely to be vulnerable to further impacts, particularly the largest *Enhalus* meadow A2 (opposite Lorim Point). This meadow is adjacent to dredged sections of the shipping channel and extra care should continue to be taken when conducting activities in the region that could further stress the meadow. Further enhancements to the established seagrass program including an examination of light and temperature conditions at vulnerable seagrass meadows would significantly enhance the ability of the program to pinpoint the causes of seagrass declines. An additional seasonal survey of the *Enhalus* meadow opposite Lorim Point in April 2010 may also be warranted. These measures would provide added assurance of the seagrass meadow tolerance and capacity to withstand additional stresses such as those associated with port activity. Fisheries Queensland and NQBP will be working on incorporating some of these measures into the long term monitoring program.

In summary results of the 2009 monitoring indicate that;

- Seagrass habitat in the Port of Weipa was in a reasonable but vulnerable condition
- The *Enhalus* meadow on the western bank of the Embley River remains a concern to Fisheries Queensland and may be vulnerable to further impacts.
- Multi-year tidal patterns may explain a significant component of the long term decline in biomass for intertidal meadows however it is not the only factor that could be contributing to changes in seagrass.
- Additional seagrass monitoring and dredge management measures may be warranted to ensure protection of vulnerable seagrasses.

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APPENDIX

ANOVA Results – One Way Analysis of Variance on Ranks; Mean biomass for the five monitoring meadows from 2001-2009 (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. ★★ Indicates Kruskal-Wallis One Way ANOVA used.

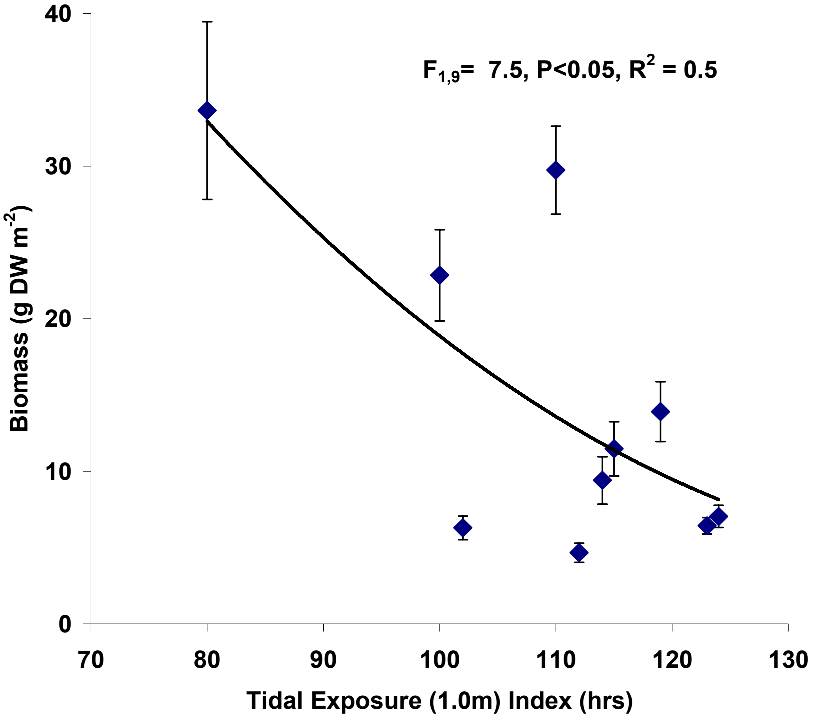
Meadow A2★	
Year	**Mean Biomass**
2001	29.73 a
2002	22.84 b
2003	13.91 c
2004	11.47 cd
2005	7.04 cde
2006	6.43 e
2007	9.4 cd
2008	4.66 e
2009	6.39 de

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
2009	n/a

Meadow A5★	
Year	**Mean Biomass**
2001	3.11 bc
2002	2.49 cd
2003	2.29 bc
2004	4.18 bc
2005	4.11 ab
2006	1.75 d
2007	6.27 a
2008	1.94 d
2009	5.09 bc

Meadow A6★	
Year	**Mean Biomass**
2001	10.40 a
2002	9.49 a
2003	8.31 a
2004	1.14 d
2005	3.37 cd
2006	3.44 bc
2007	6.22 a
2008	2.83 ab
2009	1.47 bc

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
2009	5.75



Relationship between hours of daylight exposure of the A2 Enhalus Meadow one month prior to sampling and above ground biomass