Long term seagrass monitoring in the Port of Thursday Island, March 2008

Richard Unsworth
Skye McKenna
Michael Rasheed

Department of Primary Industries and Fisheries
Marine Ecology Group
Northern Fisheries Centre

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Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A.

Marine Ecology Group
Northern Fisheries Centre

Department of Primary Industries & Fisheries
PO Box 5396 Cairns Qld 4870

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EXECUTIVE SUMMARY

Seagrass habitats are valuable fisheries resources that show measurable responses to changes in water quality. These attributes make seagrass meadows ideal candidates for monitoring the long term health of marine environments. A network of long term seagrass monitoring sites has been established at various port locations throughout Queensland to assist port managers in the planning and development of port operations to achieve minimal impacts on the marine environment and fish habitats. The programs are also used as an indicator of the overall marine environmental health of ports and are an example of international best practise in the management of port environments. This report details the latest findings from the Port of Thursday Island long term seagrass monitoring program from the most recent survey conducted in March 2008.

A baseline survey of seagrass habitat at the Port of Thursday Island in March 2002 identified some of the best examples of intertidal and subtidal seagrass habitat that have been found in Queensland. Nine seagrass meadows were selected for long term monitoring from the original baseline survey. The monitoring meadows were representative of the range of seagrass communities identified and encompassed those meadows located in areas likely to be vulnerable to impacts from port operations and developments. This current survey is the third of planned biennial long-term seagrass monitoring, with previous surveys conducted in March 2004 and 2006. The monitoring program assesses seagrass above ground biomass, individual meadow area and species composition (community types) and compares changes with previous surveys.

The results of the March 2008 monitoring survey found that seagrasses in the Port of Thursday Island were generally in good condition. Seagrass meadow area was similar to that detected during previous monitoring while coastal meadows dominated by *Halodule* and *Halophila* were at similar densities to previous surveys. However, meadows dominated by the large growing species *Enhalus acoroides* appear to have been under greater stress in recent years resulting in a decline in density. These declines in *Enhalus* meadows are thought to be in response to a combination of natural climate and exposure related drivers but their continuing decline may be cause for concern in the future. As monitoring is only conducted every two years, the exact cause of these declines is difficult to interpret. However these changes were consistent with changes that had occurred for the same species in other nearby monitoring locations and were unlikely to be due to human or port activities.

INTRODUCTION

Seagrass habitats are important fisheries resources providing habitat for juvenile commercial and recreational species as well as food for endangered and threatened species such as dugong and turtle. Seagrasses also show measurable responses to changes in water quality and anthropogenic disturbance making them ideal candidates for monitoring coastal environments (Orth et al. 2006), particularly for monitoring the "health" of port environments. Some of the best examples of seagrass meadows in Queensland occur in the sheltered waters associated with commercial ports and harbours (Lee-Long et al. 1996).

Marked seasonal and inter-annual changes have been found in seagrass meadows of other tropical Queensland ports such as Weipa (Rasheed *et al.,* 2008a), Karumba (Rasheed *et al.,* 2008b), Mourilyan (McKenna *et al.*, 2008) and Cairns (McKenzie, 1994; Rasheed *et al*., 2007b). Results from these long term monitoring programs and other Queensland port locations have provided valuable information on the relationships between climatic shifts, anthropogenic disturbance and seagrass abundance. They have also indicated that healthy and productive seagrass habitats can co-exist with appropriately managed port facilities. Long term seagrass monitoring programs have enabled port managers to make informed decisions regarding planning and development of port infrastructure that will have minimal impact on the marine environment. These interactive programs between environmental scientists and port managers are examples of international best practice in the environmental management of ports.

Due to the high reliance on fishing in the Thursday Island area, habitats that support commercial and traditional fisheries such as seagrasses are of critical importance to the region. Seagrass meadows occur in proximity to port facilities at the Port of Thursday Island. A fine-scale baseline survey of seagrass habitat conducted at the port in March 2002 identified seagrass as the dominant benthic habitat with over 1500 ha of seagrass habitat mapped in the survey area (Rasheed *et al*., 2003). This has important implications for future port and coastal developments that may impact upon these extensive meadows.

Ports Corporation of Queensland Limited (PCQ) is the authority responsible for management of the Port of Thursday Island and they have recognised the importance of maintaining the health of seagrasses located within the port environment. Based on results of the 2002 baseline survey, the Queensland Department of Primary Industries and Fisheries (QDPI&F) in conjunction with PCQ implemented a biennial long term seagrass monitoring program to ensure that the ongoing health of the port's marine environment could be maintained.

This was the third annual survey since the 2002 baseline survey and was a joint project between PCQ and QDPI&F. The objectives of the survey were to:

1. Monitor the seagrass species composition, area and abundance of the nine seagrass meadows identified for monitoring within the port limits; and,

2. Assess changes in these seagrass meadows that have occurred since the baseline survey; and,

3. Incorporate the results into the PCQ/QDPI&F Geographic Information System (GIS) developed for the Port of Thursday Island.

PCQ will use the results of seagrass monitoring to assist in long term management of the port to minimise potential impacts on seagrass. The information may also act as a reference tool for other organisations involved in management of community use of the inshore area.

METHODOLOGY

Seagrass surveys of the Port of Thursday were conducted on the 16th and 17th of March 2008. Nine seagrass meadows were selected from the baseline survey (Rasheed *et al.* 2003) for long term monitoring. These meadows were representative of the range of seagrass meadows and communities identified in the baseline survey, and were also located in areas likely to be vulnerable to impacts from port operations and developments.

Seagrass habitat observations 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 surveillance (Plate 1). A detailed description of the methods used to characterise the monitoring meadows is provided in Rasheed *et al*. (2003).

Plate 1. Seagrass monitoring methodology utilising (a) helicopter aerial surveillance and (b) boat based remote camera surveillance, Thursday Island, March 2008

Seagrass above ground biomass was determined using a modified "visual estimates of biomass" technique described by Mellors (1991). This technique involves 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 habitat for which the above ground biomass has previously been measured. Three separate biomass ranges were used: low-biomass; high-biomass; and an *Enhalus* range. 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 metre (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 was 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 determine above ground biomass estimates.

Habitat Mapping and Geographic Information System

Spatial data from the field surveys were incorporated into the PCQ/DPI&F Thursday Island Geographic Information System (GIS). Three GIS layers were created:

- **Site information** - site data containing above ground biomass (for each species), sediment type, time, GPS fixes (±1.5m) 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). 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 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

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 2 Density categories and mean above ground biomass ranges for each species used in determining seagrass community density

Density	Mean above ground biomass (g DW m^{-2})					
	H. uninervis **(narrow)**	***H. ovalis***	***H. uninervis*** **(wide)** ***C. serrulata*** ***S. isoetifolium***	***H. spinulosa***	***Z. capricorni***	***E. acoroides*** ***T. ciliatum***
Light	< 1	< 1	< 5	< 15	< 20	< 40
Moderate	1 - 4	1 - 5	5 - 25	15 - 35	20 - 60	40 - 100
Dense	> 4	> 5	> 25	> 35	> 60	> 100

Each meadow was assigned a mapping precision estimate (in metres) based on mapping methodology utilised for that meadow (Table 3). Mapping precision ranged from ±5m to ±10m for the monitoring 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 and rectifying aerial photographs onto base maps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 3. Mapping precision and methodology for seagrass meadows

Mapping precision	Mapping methodology
±5m	All meadow boundaries mapped in detail by GPS using a combination of the helicopter, divers and/or walking; Intertidal meadows completely exposed or visible at low tide; Relatively high density of mapping and survey sites; Recent aerial photography aided in mapping.
±10m	Inshore meadow boundary mapped in detail by GPS using a combination of the helicopter and/or walking; Offshore meadow boundary mapped by GPS using a combination of the helicopter and divers; Relatively high density of mapping and survey sites; Recent aerial photography aided in mapping.

RESULTS

Seagrass species, distribution and abundance for monitoring meadows in 2008

Eight seagrass species (from three families) were identified in the nine seagrass monitoring meadows (Plate 2). For a complete list of species found within the port limits see Rasheed *et al*. (2003).

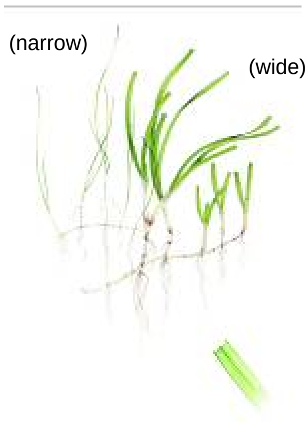
Family CYMODOCEACEAE Taylor:

Cymodocea rotundata Ehrenb. et Hempr. ex Aschers
Cymodocea serrulata (R.Br.) Aschers and Magnus
Halodule uninervis (wide and narrow leaf morphology) (Forsk.) Aschers. in Boissier
Thalassodendron ciliatum (Forsk.) den Hartog
Syringodium isoetifolium (Aschers.) Dandy

Cymodocea serrulata

Cymodocea rotundata

Thalassodendron ciliatum



Halodule uninervis

Syringodium isoetifolium

Family HYDROCHARITACEAE Jussieu:

Enhalus acoroides (L.F.) Royle
Halophila ovalis (R. Br.) Hook. F.
Thalassia hemprichii (Ehrenb.) Aschers. in Petermann

Enhalus acoroides

Thalassia hemprichii

Halophila ovalis

A total of 134 ± 8 ha of seagrass habitat was mapped in the nine seagrass monitoring meadows at the Port of Thursday Island in March 2008 (Table 5; Map 1). Meadow area ranged from 0.8 ha to 84 ha, with the smallest meadow located between the Engineers and Main Wharves on Thursday Island (meadow 3) and the largest located on Madge Reef (meadow 26) (Table 6; Maps 2 & 4). A total of 199 monitoring sites (excluding meadow boundary mapping sites) were surveyed, 85% of which (172 sites) had seagrass present. Of these monitoring sites 171 were surveyed from helicopter and the remaining 28 were surveyed using a boat.

The nine monitoring meadows that were surveyed included eight different community types (Maps 2, 3 & 4; Table 5). *Enhalus acoroides* dominated communities were the most common, followed by those dominated by *Halodule uninervis* (thin). The *H. uninervis* dominated meadows were all located high up on the intertidal banks on the southern and northern foreshores of Thursday Island. *E. acoroides* meadows were found in the lower intertidal region around Engineers Wharf (meadows 4 and 6), and on Madge Reefs.

A total of eight different seagrass species were recorded in the monitoring meadows (Table 5). Although individual meadows were dominated by either *E. acoroides* or *H. uninervis*, the species composition of each meadow mostly consisted of between two to six species.

Four seagrass meadows were comprised of aggregated patches, these were all dominated by *H. uninervis*. The five *E. acoroides* meadows were however all found to be continuous (Map 2; Table 5). The majority of monitoring meadows were located on intertidal substrates dominated by either mud or sand, with a smaller component of either mud/sand and/or shell. A number of meadows also contained areas that were dominated by reef structure.

Mean above ground biomass for the monitoring meadows in March 2008 ranged from 4.2 ± 0.4 g DW m^{-2} for the *H. uninervis* (thin) dominated meadow on the southern foreshore (meadow 1), to 26.3 ± 3.8 g DW m^{-2} for the *E. acoroides* dominated meadow near Engineers Wharf (meadow 6) (Table 6; Figure 1).

Table 5. Community type, seagrass cover and species present in the nine Thursday Island monitoring meadows, March 2008.

Monitoring Meadow	Community Type	Cover	Species Present
1	Moderate *H. uninervis* (thin) with *H. ovalis*	Aggregated patches	*H. uninervis (thin), H. ovalis, T. hemprichii*
2	Light *E. acoroides*	Continuous	*E. acoroides, T. hemprichii, H. uninervis (wide), S. isoetifolium, C. serrulata, C. rotundata*
3	Moderate *H. uninervis* (thin)/*E. acoroides*	Aggregated patches	*H. uninervis (thin), E. acoroides, H. ovalis, H. uninervis (wide), T. hemprichii*
4	Light *E. acoroides*	Continuous	*E. acoroides, C. serrulata, T. hemprichii, H. uninervis (wide)*
5	Moderate *H. uninervis* (thin) with mixed species	Aggregated patches	*H. uninervis (thin), H. ovalis, T. hemprichii, H. uninervis (wide), E. acoroides, S. isoetifolium*
6	Light *E. acoroides*/mixed species	Continuous	*E. acoroides, T. hemprichii, H. uninervis (wide), C. rotundata, C. serrulata, T. ciliatum*
8	Moderate *H. uninervis* (thin) with *H. ovalis*	Aggregated patches	*H. uninervis (thin), H. ovalis, E. acoroides, C. rotundata, C. serrulata*
26	Light *E. acoroides* with mixed species	Aggregated patches	*E. acoroides, C. rotundata, H. uninervis (thin), T. hemprichii, C. serrulata, H. ovalis, H. uninervis (wide)*
27	Light *E. acoroides*	Aggregated patches	*E. acoroides, T. ciliatum, T. hemprichii, H. uninervis (wide), S. isoetifolium, C. rotundata*

Map 1. Port of Thursday Island seagrass monitoring meadows and survey sites, 2008

Background: Beach Protection Authority, 1:50,000, 19/6/92

Legend

- Sites without seagrass
- Sites with seagrass
- Port limit

Community Type

- Light Enhalus acoroides
- Light Enhalus acoroides with mixed species
- Light Enhalus acoroides/mixed species
- Moderate Halodule uninervis (thin) with Halophila ovalis
- Moderate Halodule uninervis (thin) with mixed species
- Moderate Halodule uninervis (thin)/Enhalus acoroides
- Non monitoring meadows

Source: Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2008). Long term seagrass monitoring in the Port of Thursday, March 2008. DPI&F Publication PR08-4083 (DPI&F, Northern Fisheries Centre, Cairns), 27 pp.

Funded by Ports Corporation Queensland and the Queensland Department of Primary Industries and Fisheries. Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns,2008.

Map 2. Port of Thursday Island southern foreshore seagrass monitoring meadows, 2008

Backgraound image: Beach Protection Authority 1:50000, 19/6/92

Legend

Port limit

Seagrass Cover

Aggregated patches

Continuous cover

Community Type

Light *Enhalus acoroides*

Light *Enhalus acoroides*/mixed species

Moderate *Halodule uninervis* (thin) with *Halophila ovalis*

Moderate *Halodule uninervis* (thin) with mixed species

Moderate *Halodule uninervis* (thin)/*Enhalus acoroides*

NB: This is not a complete seagrass distribution

Source: Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2008). Long term seagrass monitoring in the Port of Thursday, March 2008. DPI&F Publication PR08-4083 (DPI&F, Northern Fisheries Centre, Cairns), 27 pp.

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Map 3. Port of Thursday Island northern foreshore seagrass monitoring meadow, 2008

Legend

Port limit

Seagrass Cover

Aggregated patches

Community Type

Moderate *Haloudle uninervis* (thin) with *Halophila ovalis*

Backgraound image: Beach Protection Authority 1:50000, 19/6/92

NB: This is not a complete seagrass distribution

Source: Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2008). Long term seagrass monitoring in the Port of Thursday, March 2008. DPI&F Publication PR08-4083 (DPI&F, Northern Fisheries Centre, Cairns), 27 pp.

 Funded by Ports Corporation Queensland and the Queensland Department of Primary Industries and Fisheries. Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns,2008.

Map 4. Port of Thursday Island seagrass monitoring meadows at Madge Reef, 2008

Legend

Port limit

Seagrass Cover

Aggregated patches

Community Type

Light *Enhalus acoroides*

Light *Enhalus acoroides* with mixed species

Backgraound image: Beach Protection Authority 1:50000, 19/6/92
NB: This is not a complete seagrass distribution

Source: Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2008). Long term seagrass monitoring in the Port of Thursday, March 2008. DPI&F Publication PR08-4083 (DPI&F, Northern Fisheries Centre, Cairns), 27 pp.
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Comparison with previous monitoring surveys

In 2008, seagrass meadow areas were mostly within the ranges recorded since 2002. Seagrass biomass however showed evidence of a declining trend between the three monitoring surveys in several of the higher biomass meadows dominated by *Enhalus acoroides*. The lower biomass *Halodule uninervis* and *Halophila ovalis* dominated meadows had either increased in biomass, or remained within the range of previous meadow variability (Table 6; Figure 1).

Enhalus acoroides dominated meadows generally had a lower biomass in the most recent surveys (2006 and 2008) than in 2002 and 2004. This was especially true for the meadows located in the lower intertidal to subtidal region on the southern foreshore of Thursday Island (2, 4 & 6) that have had a declining trend in biomass from 2004 to 2008. The majority of these meadows (all except meadow 6) recorded their lowest biomass to date in 2008 (Table 6; Figure 1). Biomass for 2 of these meadows (2 & 4) was significantly lower in 2006 and 2008 than all previous surveys (Table 6; Appendix 1). The other *E. acoroides* meadows (26 and 27) located on Madge Reefs also had a substantial decline in biomass between 2006 and 2008 with meadow 26 having a significant decline of 47% (Table 6; Appendix 1). The area of all the *Enhalus* meadows remained within the reliability range of previous years monitoring with some slight increases in area in meadows 2 and 6 (Table 6; Figure 1).

The intertidal, lower biomass *Halodule* and *Halophila* dominated meadows in 2008 remained within the range of previous biomass assessments, with only small increases or decreases occurring. These showed no overall pattern. Significant differences in biomass between years were found in meadows 1, 5 & 8, but these differences were not in one direction, and instead indicated high inter-annual variability. The *Halodule* and *Halophila* dominated meadow 3 (to the east of Engineers Wharf) had greatly increased in biomass from all previous assessments, but these increases were not statistically significant.

The area of 3 of the 4 inter-tidal *Halodule* and *Halophila* dominated meadows (1, 3 and 5) was at its highest level for the program in 2008. These increases were all outside the limits of reliability, indicating a real increase (Table 6; Figure 1). The other intertidal meadow, number 8, had decreased since 2006 but remained within previous levels of variability.

The species composition of the monitoring meadows remained relatively consistent between surveys (Figure 1). All meadows were dominated by the same species in the four sampling years, however some variation to the composition of the minor species did occur. The changes to the minor species composition were usually related to a small increase or decrease of one or two species. Of particular note is the reduction of *E. acoroides* in meadow 4 (Figure 1). This loss of *Enhalus acoroides* and a species shift to smaller species dominating this meadow may have contributed to the significant decline in biomass. Another note worthy point was the return of *Syringodium isoetifolium* and the loss of *Zostera capricorni* in the 2008 survey (Table 3). *S. isoetifolium* was absent in the 2006 survey but had previously been identified as a minor component in 2002 & 2004. While *Z. capricorni* was present in the 2004 & 2006 surveys at Meadow 26 although it was rare and formed a very small component.

Table 6. Number of survey sites, area and mean above ground biomass for Thursday Island monitoring meadows, March 2002, 2004, 2006 and 2008; 2005 for Meadow 26 and 27 only.

Meadow Number	Number of survey sites					Area (ha) (Reliability)				Mean biomass ± SE (g DW m^{-2}) (±% change)				
	2002	2004	2005	2006	2008	2002	2004	2006	2008	2002	2004	2005	2006	2008
1	10	28	-	23	22	2.3 (1.5-3.1)	2.5 (1.6-3.4)	2.2 (1.4-3.0)	3.8 (3.0-4.6)	0.3 ± 0.1	3.7 ± 0.8 (n/a)**	-	4.3 ± 1.2 (+16%)	4.2 ± 0.4 (-3%)
2	12	14	-	20	19	7.7 (5.4-10.0)	7.8 (6.2-9.4)	7.8 (6.2-9.4)	8.6 (7-10.2)	43.3 ± 6.3	75.4 ± 6.9 (+74%)	-	38.2 ± 3.7 (-49%)	23.4 ± 1.9 (-39%)
3	3	7	-	8	9	0.1 (0.05-0.15)	0.2 (0.1-0.3)	0.3 (0.1-0.5)	0.8 (0.6-1.0)	0.8 ± 0.1	2.5 ± 1.2 (n/a)**	-	1.0 ± 0.1 (-60%)	5.6 ± 2.0 (+460%)
4	14	6	-	5	5	1.3 (0.7-1.9)	1 (0.5-1.5)	0.8 (0.3-1.3)	1.1 (0.6-1.6)	32.8 ± 8.5	56.2 ± 13.1 (+71%)	-	30.2 ± 5.7 (-46%)	17.3 ± 4.6 (-43%)
5	8	26	-	25	26	2.1 (1.3-2.9)	1.9 (1.1-2.7)	2 (1.1-2.9)	5.3 (4.3-6.3)	3.4 ± 1.3	7.9 ± 1.2 (n/a)**	-	5.7 ± 1.1 (-28%)	4.8 ± 0.7 (-16%)
6	15	18	-	22	24	13.2 (10.6-15.8)	12.4 (10.0-14.8)	12.7 (10.2-15.2)	16.2 (13.3-19.1)	55.7 ± 8.9	48.2 ± 8.5 (-13%)	-	25.6 ± 6.0 (-47%)	26.3 ± 3.8 (+3%)
8	5	31	-	3	34	12.3 (10.3-14.3)	10.4 (8.2-12.6)	12.2 (10.4-14.0)	8.9 (7-10.8)	0.4 ± 0.3	7.4 ± 1.3 (n/a)**	-	10.5 ± 1.6 (+42%)	4.6 ± 0.5 (-56%)
26	18	31	25	32	33	94.5 (93.0-96.0)	87.7 (84.2-91.2)	89 (85.9-92.1)	83.5 (80.9-86.1)	68.8 ± 9.8	48.8 ± 5.4 (-29%)	24.1 ± 3.0 (-51%)	41.9 ± 4.7 (+74%)	22.0 ± 2.0 (-47%)
27	1*	13	8	10	10	6.1 (5.4-6.8)	7 (6.1-7.9)	5.8 (5.1-6.5)	5.9 (5.2-6.6)	175.9 ± 0*	47.8 ± 10.6 (n/a)**	24.4± 5.7 (-23%)	32.4 ± 6.2 (+32%)	16.7 ± 3.5 (-48%)
Total	**86**	**174**	**33**	**176**	**182**	**139.6 (128.2-151.0)**	**130.9 (117.9-143.9)**	**132.8 (120.7-144.9)**	**134.1 (121.9-146.3)**					

*Based on one site not representative of entire community
**Too few sites surveyed in March 2002 to allow reasonable biomass comparison

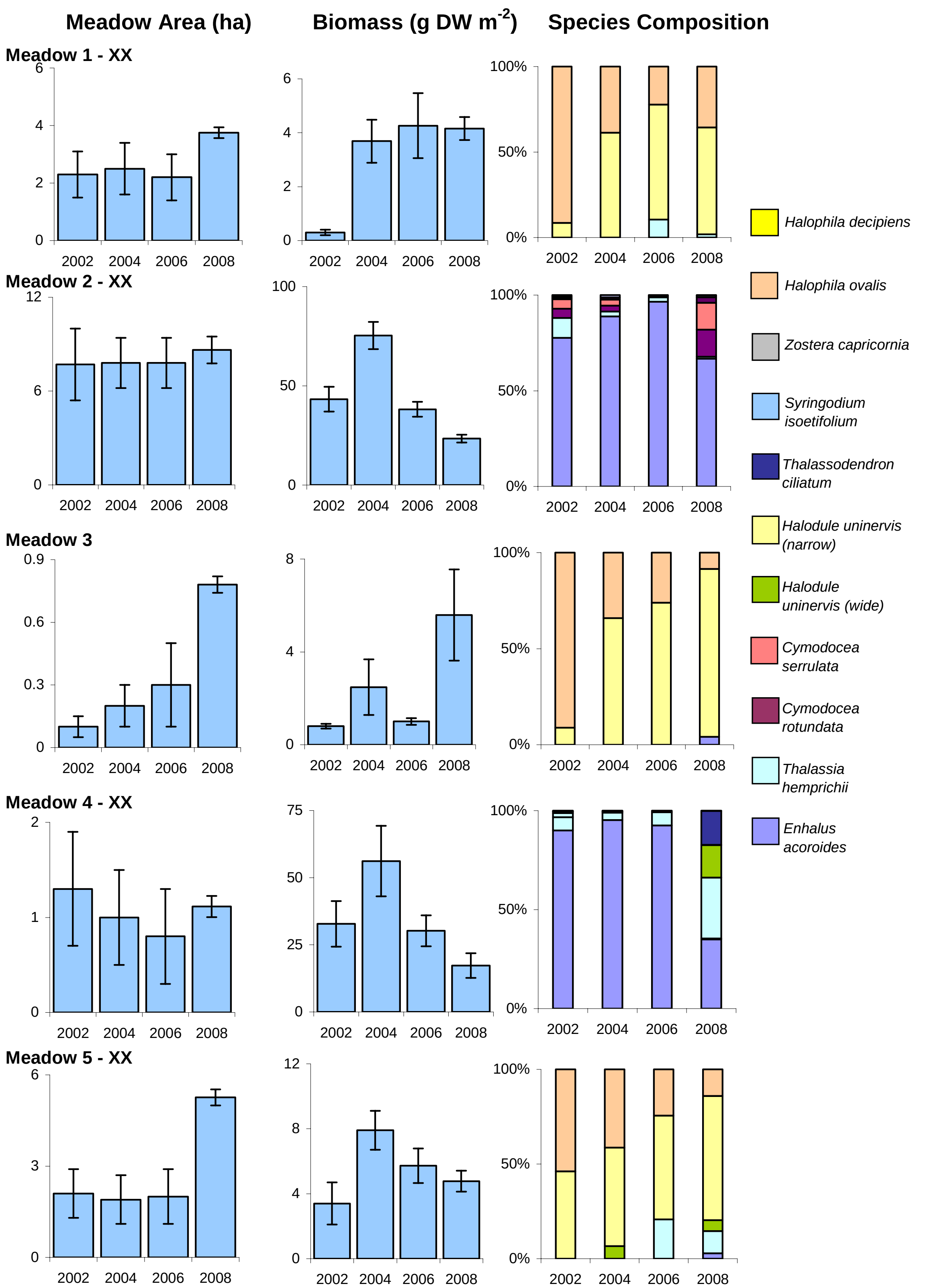


Figure 1 (a) Changes in biomass, area and species composition for monitoring meadows in 2002, 2004, 2006 and 2008 (Biomass error bars = SE; Area error bars = "R" reliability estimate).

XX Represents meadows displaying significant differences in above ground biomass between years (Appendix 1 – Pairwise results).N.B. 2002 data for Meadow 3 was excluded from statistical analysis. Data was based on three sites and not representative of entire community.

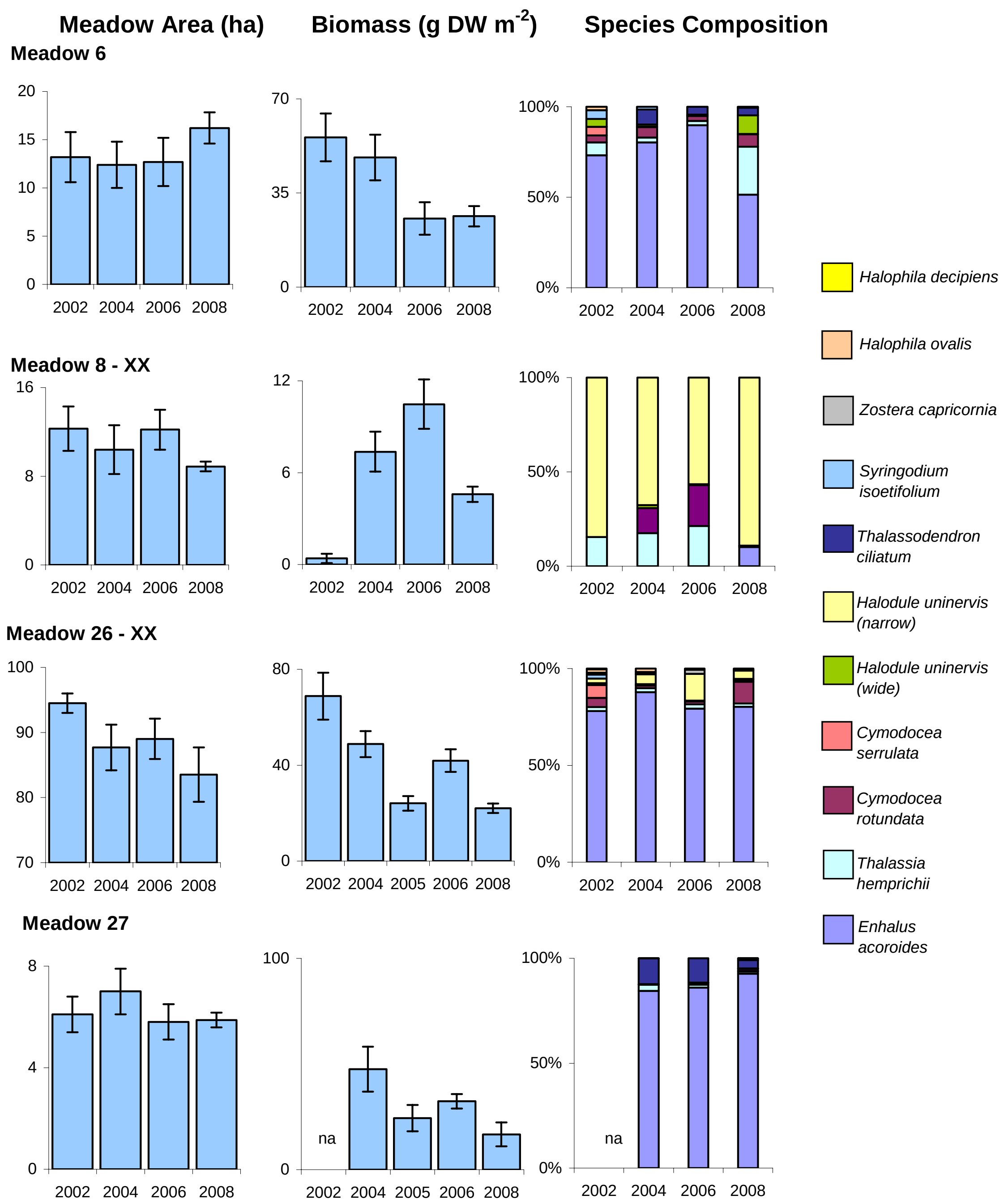


Figure 1 (b) Changes in biomass, area and species composition for monitoring Meadows 6, 8, 26 and 27 in 2002, 2004, 2006, and 2008 (Biomass error bars = SE; Area error bars = "R" reliability estimate).

XX Meadows significantly different in above ground biomass between years (Appendix 1).

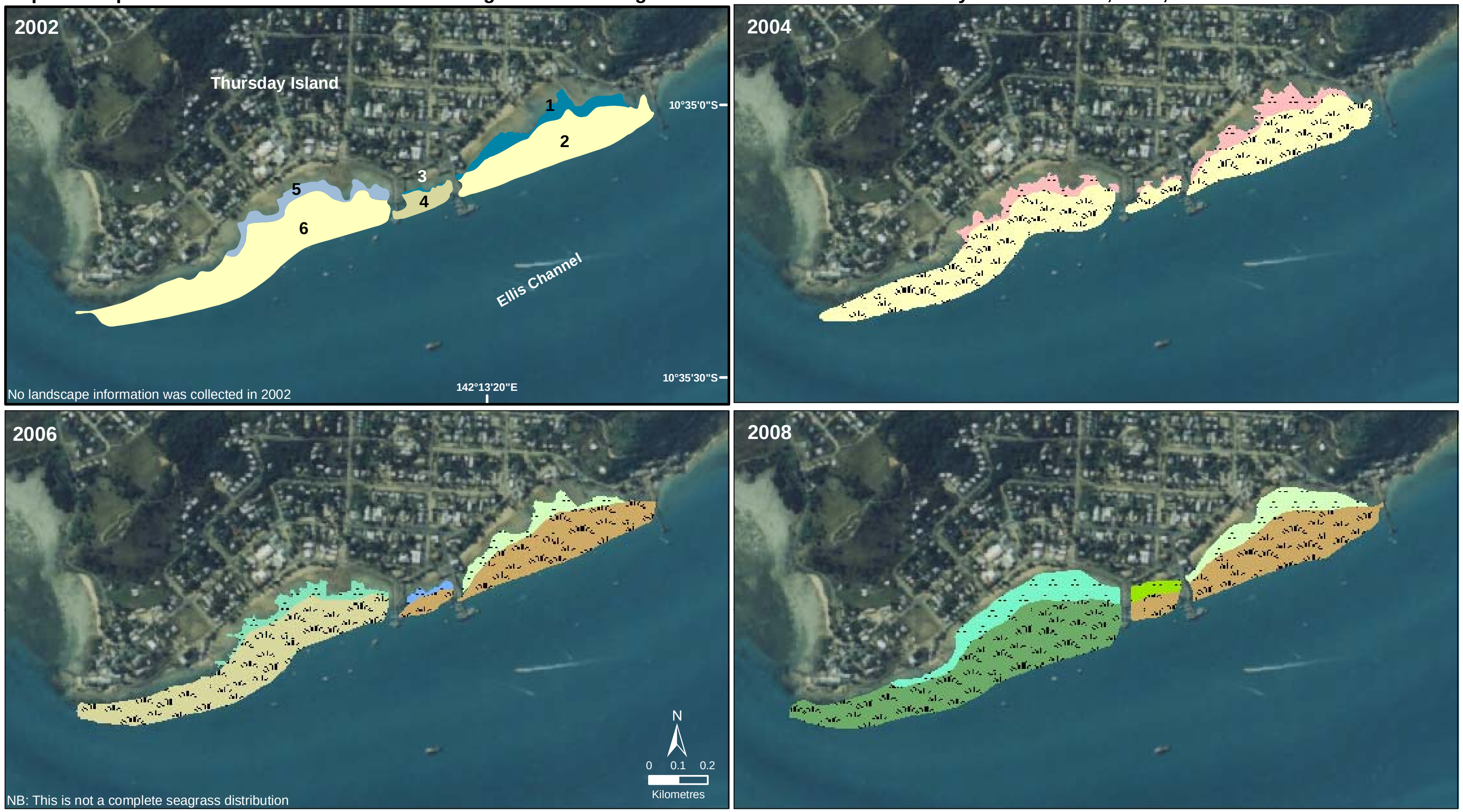
Sampling Intensity

Prior to baseline surveys being conducted in 2002, statistical power analysis was conducted to determine a statistically suitable sample size for each meadow. Due to the large inter-annual variation observed throughout the meadows between 2002-2006 these power analyses were revisited in order to make future monitoring programs more statistically effective (Table 7). Using data collected in 2008, and analysed relative to mean values for 2006, the Minimal Detectable Difference (MDD) was calculated for each 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 (ie. 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 8 meadows that were sufficient in size to be analysed, 3 (Meadows 2, 8 and 26) could detect a 30% change in biomass with current sampling intensity. Four of the meadows could detect approximately a 50% change (Meadows 1, 4, 5 and 27), whilst the high intra meadow variability of meadow 6 resulting in the present number of samples being able to detect a minimum 87% change in biomass. 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 in most meadows (Table 7).

Table 7. Minimal detectable difference (MDD) (%) of the biomass of seagrass meadows in the Port of Thursday Island, and the number of samples necessary to detect 30% and 50% changes in biomass relative to previous data. Shaded cells indicate new proposed minimum samples to be collected

Meadow Number	M1	M2	M4	M5	M6	M8	M26	M27
Current %MDD	49%	33%	53%	53%	87%	23%	22%	55%
Current sample numbers	22	25	19	27	20	35	35	10
Samples required to detect 30% MDD	45	28	35	50	35	20	20	20
Samples required to detect 50% MDD	20	12	20	30	28	9	7	12

Map 5. Comparision of the southern foreshore seagrass montiroing meadows in the Port of Thursday Island in 2002, 2004, 2006 & 2008



Background image: Beach Protection Authority 1:50000, 19/6/92

Legend

Seagrass Cover

- Aggregated patches
- Continuous

Community type

- Light *H. uninervis* (thin) with *H. ovalis*
- Moderate *H. uninervis* (thin)/*H. ovalis*
- Moderate *H. uninervis* (thin) with *H. ovalis*
- Moderate *H. uninervis* (thin) with *H. ovalis / T. hemprichii*
- Moderate *H. uninervis* (thin) with mixed species
- Moderate *H. uninervis* (thin)/*E. acoroides*
- Light *E. acoroides*
- Light *E. acoroides* with mixed species
- Light *E. acoroides*/mixed species
- Moderate *E. acoroides* with mixed species
- Light *H. ovalis* with *H. uninervis* (thin)
- Moderate *H. ovalis* with *H. uninervis* (thin)

Source: Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2008). Long term seagrass monitoring in the Port of Thursday, March 2008. DPI&F Publication PR08-4083 (DPI&F, Northern Fisheries Centre, Cairns), 27 pp.

 Funded by Ports Corporation Queensland and the Queensland Department of Primary Industries and Fisheries. Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns,2008.

Map 6. Comparison of the northern foreshore seagrass monitoring meadow in Port of Thursday Island in 2002, 2004, 2006 & 2008

Legend

Seagrass Cover

Aggregated patches

Community type

Light H.uninervis with

Moderate *H. uninervis* (thin) with *H. ovalis*

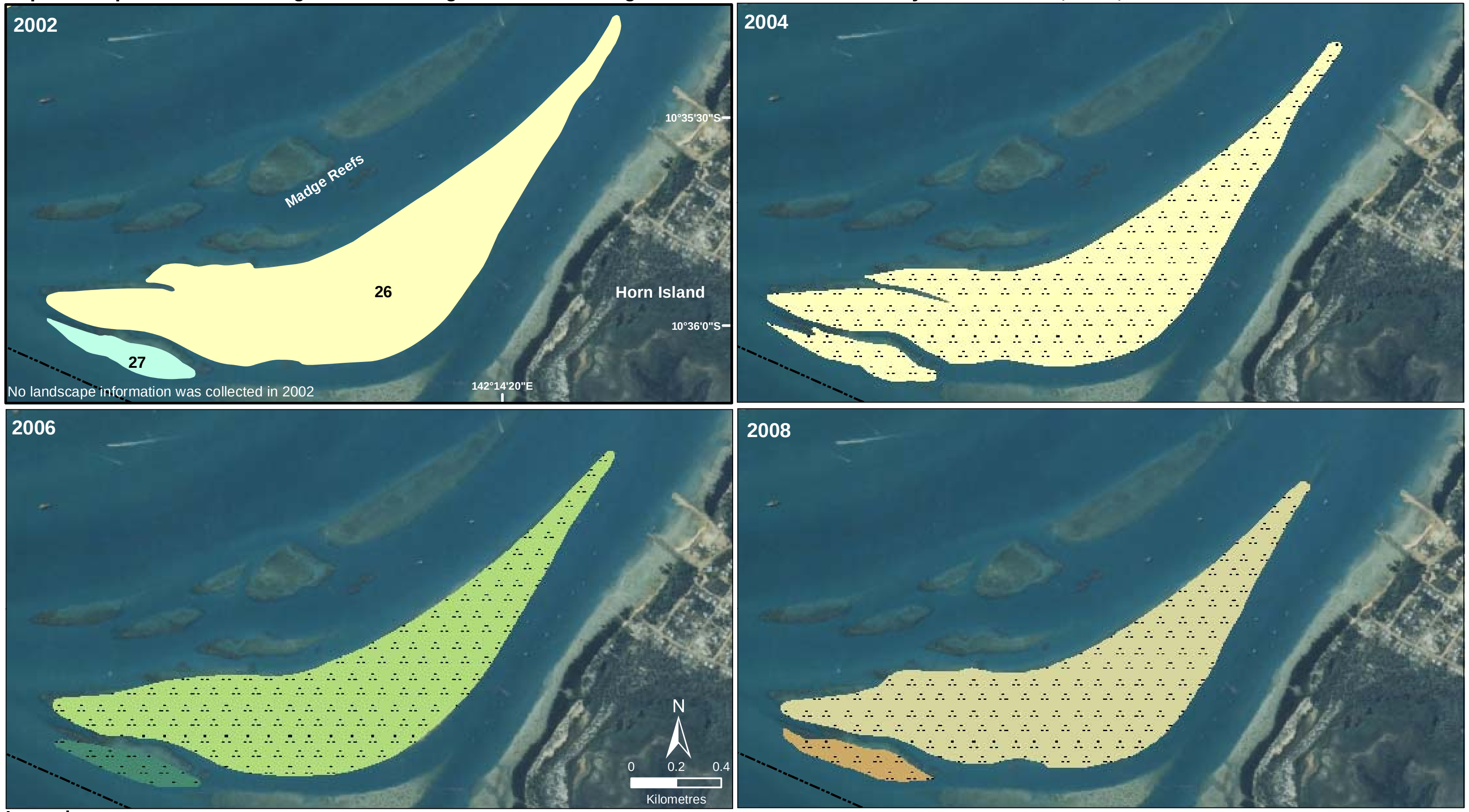
Dense *H. uninervis* (thin) with mixed species

Background image: Beach Protection Authority 1:50000, 19/6/92
NB: This is not a complete seagrass distribution

Source: Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2008). Long term seagrass monitoring in the Port of Thursday, March 2008. DPI&F Publication PR08-4083 (DPI&F, Northern Fisheries Centre, Cairns), 27 pp.

 Funded by Ports Corporation Queensland and the Queensland Department of Primary Industries and Fisheries. Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns,2008.

Map 7. Comparision of the seagrass monitoring meadows at Madge Reef in the Port of Thursday Island in 2002, 2004, 2006 & 2008



Legend

Background image: Beach Protection Authority 1:50000, 19/6/92

Port limit

Seagrass Cover

Aggregated patches

Community type

Light *E. acoroides*

Light *E. acoroides* with mixed species

Moderate *E. acoroides* with mixed species

Dense *T. cilliatum* with *E. acoroides*

Light *E. acoroides* with *T. cilliatum* / mixed species

Light *E. acoroides* with *H. uninervis* (thin) / mixed species

Source: Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2008). Long term seagrass monitoring in the Port of Thursday, March 2008. DPI&F Publication PR08-4083 (DPI&F, Northern Fisheries Centre, Cairns), 27 pp.

DISCUSSION

The results of the 2008 monitoring survey found that seagrasses in the Port of Thursday Island were in generally good condition. Seagrass meadow area was similar to previous monitoring and coastal meadows dominated by *Halodule* and *Halophila* were at similar densities to previous surveys. However, meadows dominated by the large growing species *Enhalus acoroides* appear to have been under greater stress in recent years resulting in them declining in density. These declines in *Enhalus* meadows are thought to be in response to a combination of natural climate and exposure related drivers but their continuing decline may be cause for concern in the future.

Some recovery of *Enhalus* meadow biomass was recorded in 2006 following interim assessments in 2005 (Taylor *et al.,* 2006). However, in 2008 these meadows once gain declined in biomass. Previously it was suspected that climate was the most likely cause of this reduction (Taylor *et al*., 2006). However, the available data on air temperature and rainfall suggests that these two factors alone would not account for the observed declines as they have remained similar for the last few years (Figure 2). Seagrasses in the Port of Thursday Island are influenced by a complex interaction of a number of different climatic factors including rainfall, wind, solar irradiance, temperature and daytime tidal exposure, which are known to affect seagrass growth, recruitment and mortality (e.g. Rasheed *et al*. 2006a; 2006b; 2006c). It is likely that a combination of these factors has led to the observed declines. For example less cloud cover and higher solar irradiation during the hottest time of the year combined with increased daytime tidal exposure could result in declines of *Enhalus.* These conditions have lead to desiccation and thermal stress of intertidal *Enhalus acoroides* meadows in other Queensland locations such as nearby in Weipa (Roelofs et al. 2006) and elsewhere in the tropics (Erftemeijer & Herman 1994).

While the exact causes of the declines in *Enhalus* are not clear, it is unlikely that the port or other anthropogenic (human) factors are responsible. While the meadows that were most affected occurred on the southern side of Thursday Island in the area where boating traffic and coastal development is most concentrated, there is little evidence suggesting that nutrient or effluent discharges have changed, or that boating disturbance or port activity has increased during this time. Also these changes are consistent with changes to other nearby *Enhalus* meadows. For example, recent monitoring in Weipa has found that *Enhalus* meadows also declined between 2007 and 2008 (in preparation). However, if declines continue it may be prudent to investigate the influence of anthropogenic and climate factors further.

The intertidal *Halodule uninervis* dominated monitoring meadows did not decline in area or biomass in the same manner as *Enhalus* meadows. *Halodule uninervis* (thin) is commonly referred to as a colonising species (Neinhuis *et al*. 1989), and is therefore capable of recovering from impacts much more rapidly through asexual rhizome extension than the bigger slower growing *Enhalus* (Nienhuis *et al*., 1989; Terrados *et al*., 1998). If climatic events are interacting to cause the reduction of the biomass of *Enhalus* meadows at the Port of Thursday Island, it is possible that the similar impacts are resulting in some loss of *Halodule* but recovery is quick and impacts are short-lived.

Enhalus acoroides and *Halodule uninervis* (thin) are also morphologically quite different species, with the smaller, less rigid *Halodule uninervis* (thin) capable of lying flat on the moist sediment surface when exposed at low tide and may therefore be less prone to desiccation and “burning off” than the rigid *Enhalus acoroides* a condition suspected of leading to large biomass declines for *Enhalus* in other locations (see Roelofs *et al.* 2006).

The recording of *Syringodium isoetifolium* in 2008 following its absence in 2006 was likely to be linked to changes in sampling methods that occurred in 2006. *Syringodium isoetifolium,* while only a very minor component of meadows, had been found previously in several intertidal to subtidal meadows (Thomas & Rasheed, 2004). This seagrass species has been documented in a number of studies as being an outer intertidal and/or subtidal species (Gallegos & Kenworthy 1996; Jupp *et al*. 1996). Data from 2002 and 2004 showed that the majority of sites in which *Syringodium isoetifolium* was found were located along the outer intertidal edge of meadows. Due to safety concerns during the 2006 surveys diving sampling was unable to be conducted in this area and consequently there were fewer sites where *Syringodium* had been most commonly found. In 2008, this area was re-sampled and *Syringodium* was again detected.

On the intertidal Madge Reef however, *Syringodium isoetifolium* had been found in sites scattered throughout the meadow and despite sampling at these locations in 2006 *Syringodium isoetifolium* was still absent. This scattered distribution throughout the Madge reef meadow (26) returned in the 2008 surveys. It is possible that *Syringodium isoetifolium* was affected by exposure and high light levels in 2005 and 2006. Research has found that *S. isoetifolium* is highly light sensitive (Gallegos & Kenworthy 1996), particularly when located in the intertidal zone. Unlike the other meadows where *Syringodium* was previously found, all of the Madge Reef meadow was located in the exposed upper intertidal zone and thus *Syringodium* may have been more vulnerable to the influences of high light although this was not measured as part of our monitoring surveys.

In summary, the 2002 baseline survey provided a good foundation from which the biennial monitoring surveys could be based. This third biennial survey has established a clearer picture of the natural inter-annual variations and the relationship between seagrass change and climate. However correctly interpreting the causes of seagrass change is difficult when surveys are undertaken biennially. An annual seagrass program similar to other port locations would provide a greater understanding of seagrass health and dynamics. The existing biennial program suggests seagrasses and the marine environment in the port appear to be relatively healthy. The range of natural seagrass changes measured to date will enable any future changes to be placed in a clearer perspective.

(A)

(B)

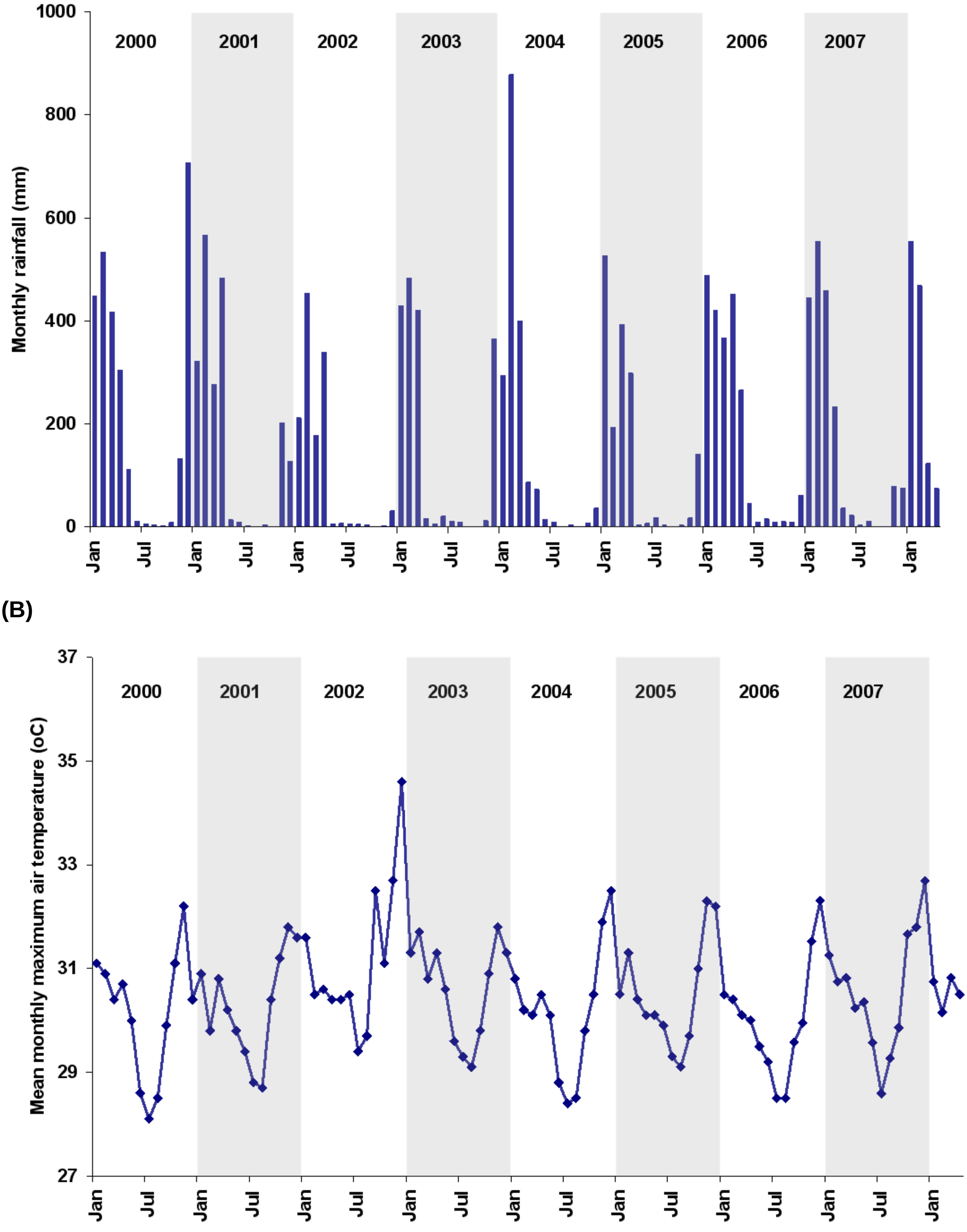


Figure 2. (A) Mean monthly rainfall and (B) Mean monthly maximum air temperature for Horn Island (January 2000 to September 2006).

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APPENDIX 1 – Biomass Analysis

Results of one-way ANOVA for mean above ground biomass versus year for the six seagrass monitoring meadows displaying significant differences between years at the Port of Thursday Island (March 2002, 2004, 2006 and 2008; 2005 Meadow 26 & 27 only) (H^o = no difference in meadow biomass between years). **Indicates log transformed data.

Meadow 1**	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	2.365	0.788	6.26	<0.001
Within Years	80	10.083	0.126		
Total	83	12.448			
Meadow 2**	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	4.305	1.435	6.83	<0.0001
Within Years	67	14.077	0.21		
Total	70	18.382			
Meadow 3	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	39.36	13.12	2.87	>0.05
Within Years	22	100.53	4.57		
Total	25	139.89			
Meadow 4	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	11157	3719	8.03	<0.0001
Within Years	40	18534	463		
Total	43	29691			
Meadow 5**	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	1.11	0.37	3.19	<0.05
Within Years	83	9.617	0.116		
Total	86	10.727			
Meadow 6**	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	1.794	0.598	2.34	>0.05
Within Years	70	17.916	0.256		
Total	73	19.71			
Meadow 8**	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	2.175	0.725	3.93	<0.01
Within Years	97	17.901	0.185		
Total	100	20.076			
Meadow 26**	**DF**	**SS**	**MS**	**F**	**P**
Between Years	4	3.709	0.927	7.02	<0.0001
Within Years	132	17.438	0.132		
Total	136	21.147			
Meadow 27**	**DF**	**SS**	**MS**	**F**	**P**
Between Years	4	1.345	0.336	0.97	>0.05
Within Years	37	12.781	0.345		
Total	41	14.126			

Results of Tukeys pair-wise comparisons of mean above ground biomass for the six seagrass monitoring meadows displaying significant differences between years. Means that share the same individual letters for each meadow are not significantly different (P < 0.05).

Meadow 1*	
Year	**Mean Biomass**
2002	0.30a
2004	0.80b
2006	4.26b
2008	4.15b

Meadow 2	
Year	**Mean Biomass**
2002	43.30ab
2004	75.38a
2006	38.16ab
2008	23.40b

Meadow 4	
Year	**Mean Biomass**
2002	32.80a
2004	56.20b
2006	28.92ab
2008	17.30a

Meadow 5	
Year	**Mean Biomass**
2002	3.40a
2004	1.20b
2006	5.73ab
2008	4.77ab

Meadow 8	
Year	**Mean Biomass**
2002	0.40a
2004	7.40b
2006	10.48b
2008	4.59a

Meadow 26	
Year	**Mean Biomass**
2002	68.8a
2004	48.8a
2005	24.10b
2006	41.89a
2008	22.01b

APPENDIX 2 - Rainfall Data

Total monthly precipitation for Horn Island from 2000 to 2008 (Australian Bureau of Meteorology, 2008).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2000	447.8	533.8	417.4	303.8	110.6	10.6	5.6	4.6	2.2	8.2	132.0	707.2	**2683.8**
2001	322.4	565.8	276.2	482.8	13.8	9.2	2.6	0.8	4.0	0.4	201.8	127.0	**2006.8**
2002	211.4	454.0	178.0	339.0	5.6	6.4	6.2	4.8	3.8	1.0	2.6	31.4	**1244.2**
2003	429.8	483.8	421.2	16.4	6.2	20.4	11.0	9.4	0.8	1.0	11.8	365.4	**1777.2**
2004	293.8	878.6	399.2	86.6	72.6	14.2	9.6	0	3.4	0	7.2	36.6	**1801.8**
2005	526.4	193.6	393	298.6	4.2	6.4	17.2	3.8	0.2	3.8	16.8	141.6	**1605.6**
2006	488.4	420.2	366.8	451.8	265.4	45	9	15.6	9.6	10	8.6	61.6	**2152**
2007	445	554.2	459.4	233.4	36	22.2	3.2	11.4	0.4	0.8	79	74.8	**1919.8**
2008	553.8	468.8	122.8	74.4	14.2	4							
n	9	9	9	9	9	9	8	8	8	8	8	8	**8**
Mean	388.6	504.3	350.3	282.7	68.3	16	8.7	5.6	2.4	2.4	62	234.9	**1853.2**
Lowest	211.4	193.6	178	16.4	4.2	6.4	2.6	0	0.2	0	2.6	31.4	**1244.2**
Highest	526.4	878.6	421.2	482.8	265.4	45	17.2	15.6	4	8.2	201.8	707.2	**2683.8**