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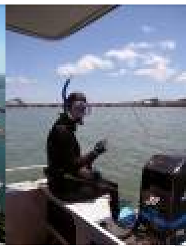
Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone - November 2006



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EXECUTIVE SUMMARY

This report details findings of the 2006 annual seagrass monitoring survey for Port Curtis and Rodds Bay. The program was developed from a baseline survey conducted in 2002 and from recommendations of the Port Curtis Integrated Monitoring Program (PCIMP) review.

Results of the 2006 monitoring indicate that both intertidal and subtidal seagrasses in Port Curtis and Rodds Bay were healthy. Subtidal meadows had recovered substantially from 2005 and many intertidal meadows had increased to record high densities. The changes observed in the monitoring program appear to be strongly linked to climate and tidal exposure rather than recent port or other anthropogenic activities.

In this survey the seagrass meadows near Wiggins Island and Fishermans Landing had increased substantially in density and area for the first time since 2004. Several of these meadows had been almost completely lost in 2005 but had returned to levels not seen since the baseline survey in 2002. The changes to seagrasses observed in the monitoring program appear to be largely linked to a combination of climate factors and tidal exposure and the natural resilience and capacity for recovery in individual seagrass meadows. Intertidal meadows appear to be particularly susceptible to drought like conditions of high solar irradiation and temperature leading to thermal stress and desiccation when meadows are exposed at low tide. Differences in the amount of daytime tidal exposure of meadows between years were likely to be driving some of the observed inter annual changes.

The survey was also the first in the regular monitoring program to be conducted after the oil spill in Port Curtis in January 2006. The survey supports the findings of the post spill seagrass assessment conducted in February 2006 that indicated that the oil spill has not had a significant effect on seagrasses in the region and that changes were related to natural seasonal variation.

The presence of dugong feeding trails in the majority of intertidal meadows indicates the region remains an important food resource for dugong. The highest density of dugong feeding trails was observed in the vicinity of Wiggins Island with trails recorded at 81% of sampling sites. Increases in density of the highly productive intertidal *Zostera capricorni* meadows in the port and Rodds Bay also had positive implications for local fisheries production as these meadows are especially valuable as nursery habitat for juvenile tiger prawns and other commercial and recreational fish species.

The 2006 annual survey indicated that seagrasses in Port Curtis were healthy, and changes to meadows were likely related to climatic and environmental factors, rather than port related activities. This was the third survey in the established annual monitoring program and while still in the early stages of establishing the ranges of natural change, the program has already identified the major climate related drivers of seagrass change. As the program matures, future monitoring will help to strengthen these links and identify other potential drivers of change for Port Curtis seagrasses. The development of these links is placing us in a stronger position to assess any anthropogenic (human induced) impacts to seagrass meadows that may arise in the future.

INTRODUCTION

Seagrass meadows in Queensland are known to provide valuable nursery habitats for juvenile commercial and recreational fisheries species, as well as important food resources for endangered and threatened species such as dugong and turtles. The value of seagrasses in the Port of Gladstone area (Port Curtis) to dugong has been recognised by the declaration of the Rodds Bay Dugong Protection Area (DPA). Seagrasses also show measurable responses to changes in water quality making them ideal candidates for monitoring the “health” of port environments. Results from long term monitoring programs throughout other Queensland port locations have provided valuable information on the relationships between climatic changes, 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 fisheries and the marine environment.

Central Queensland Ports Authority (CQPA) is committed to maintaining the health of the marine environment within the Gladstone port limits, and recognises that seagrass meadows comprise an important and sensitive component of the marine habitats within the port. As part of that commitment CQPA commissioned the DPI&F Marine Ecology Group (MEG) to conduct a baseline survey of seagrass resources within the port limits and nearby Rodds Bay in 2002 (Rasheed *et al.* 2003). The baseline survey identified large areas of seagrass within the port limits, with seagrass communities often occurring adjacent to port facilities and infrastructure. The baseline survey mapped 13,578 ha of seagrass habitat within Port Curtis and Rodds Bay finding that these habitats appeared to be healthy, however, detailed historical comparisons were not possible as the baseline survey was the first fine scale survey of the complete area.

Following the 2002 baseline survey, DPI&F in conjunction with CQPA developed a long-term seagrass monitoring strategy for the port. The proposed seagrass monitoring program was recommended to be implemented by the Port Curtis Integrated Monitoring Program (PCIMP) following a review of environmental monitoring for Port Curtis by Sinclair Knight Mertz (SKM 2004). An annual long term seagrass monitoring program was considered valuable given the proximity of meadows to port and industrial infrastructure and possible impacts associated with future port and coastal developments. Long term monitoring of seagrass meadows would also provide information required to aid in the planning of port development and maintenance programs with minimal effects on the marine environment, as well as provide a tool to assess the health of the Port Curtis marine environment. The ability of seagrasses to show measurable growth responses to changes in water quality, and their extensive distribution through the port made them an ideal candidate for monitoring marine environmental health in the Port.

From the results of the 2002 baseline survey and consultation with port users, thirteen seagrass meadows were selected to monitor. These monitoring meadows represented the range of seagrass communities within the port, and a good coverage of meadows that would most likely be impacted by port facilities and developments. Monitoring meadows included both intertidal and subtidal seagrasses as well as meadows preferred as food by dugong and those likely to support high fisheries productivity. Three meadows in Rodds Bay (outside of the port limits) were also selected to monitor to provide information on seagrasses unlikely to be impacted by port activity and to assist in separating out port related versus regional causes of seagrass change detected in the monitoring program.

This report details the results of the third of planned annual long term monitoring surveys, conducted in November 2006. The objectives of the survey were to:

1. Conduct annual long term seagrass monitoring within the Gladstone port limits (Port Curtis) and Rodds Bay area based on information collected in the 2002 baseline survey
2. Monitor distribution, abundance and species composition of selected seagrass meadows within the port limits and Rodds Bay
3. Analyse changes in seagrass meadows measured since the baseline and subsequent annual monitoring surveys
4. Discuss the implications of the survey results for port development and maintenance programs, endangered and threatened species, and fisheries
5. Place observed changes within a regional and state-wide context

METHODOLOGY

Seagrass surveys of the Gladstone port limits (Port Curtis) and Rodds Bay were conducted between the 4th and 10th of November 2006. The survey was conducted in November as seagrasses in the region were likely to be at their maximum density and distribution in late spring, and also to allow direct comparisons with previous surveys in the monitoring program which were all conducted in October/November. Thirteen meadows from the baseline survey (Rasheed *et al*. 2003) were selected for long term monitoring. These meadows were representative of the range of seagrass 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, depth below mean sea level (MSL) (for subtidal sites), sediment type, time and position (differential Global Positioning System (dGPS). Two sampling methods were used to survey the seagrass meadows; helicopter and divers. Methodology depended on the depth and size of area to be surveyed, as well as dive safety constraints. A detailed description of the methods used to characterise the monitoring meadows is provided in Rasheed *et al*. (2003).

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 had previously been measured. Two separate biomass ranges were used: low biomass; high biomass. 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 CQPA/DPI&F Geographic Information System (GIS) database. Three GIS layers were created:

Site information – site data containing above ground biomass (for each species), depth below mean sea level (MSL) (for subtidal sites), sediment type, time, differential Global Positioning System (dGPS) 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 in Port Curtis and Rodds Bay, November 2006

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 in Port Curtis and Rodds Bay, November 2006

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

Meadows were also assigned a mapping precision estimate (in metres) based on mapping methodology utilised for that meadow (Table 3). Mapping precision for coastal seagrass meadows ranged from ±5m to ±20m for the monitoring meadows (Table 3). 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 dGPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 3 Mapping precision and methodology for seagrass meadows in Port Curtis and Rodds Bay, November 2006

Mapping precision	Mapping methodology
≤5m	Meadow boundaries mapped in detail by dGPS 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
10m	Meadow boundaries determined from helicopter and diver surveys Inshore boundaries mapped from helicopter Offshore boundaries interpreted from survey sites and aerial photography Relatively high density of mapping and survey sites
20m	Meadow boundaries determined from helicopter and diver surveys Some boundaries mapped from helicopter Offshore boundaries interpreted from diver survey sites Lower density of survey sites for some sections of boundary

RESULTS

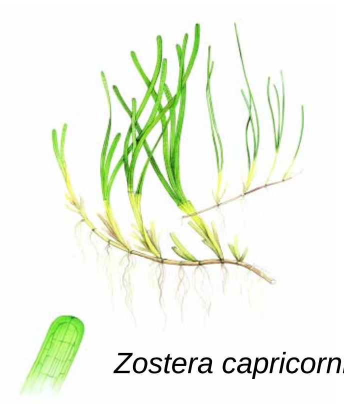
Seagrass species, distribution and abundance for monitoring meadows in 2006

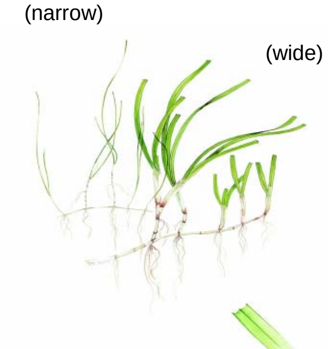
Five seagrass species (from three families) were identified in the thirteen seagrass monitoring meadows (Plate 1). For a complete list of species found within the port limits see Rasheed *et al.* (2003):

Family CYMODOCEACEAE Taylor:
Halodule uninervis (wide and narrow leaf morphology) (Forsk.) Aschers. in Boissier

Family HYDROCHARITACEAE Jussieu:
Halophila decipiens Ostenfeld
Halophila ovalis (R. Br.) Hook. F.
Halophila spinulosa (R. Br) Hook. F.

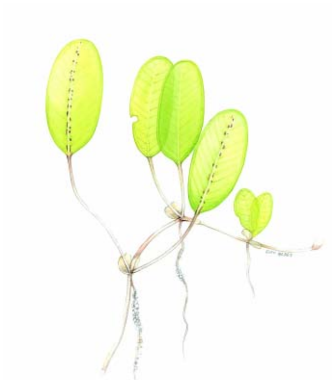
Family ZOSTERACEAE Drummortier:
Zostera capricorni Aschers.


Zostera capricorni



Halodule uninervis


Halophila spinulosa


Halophila ovalis


Halophila decipiens

A total of 2520 ± 100.8 ha of seagrass habitat was mapped in the thirteen seagrass monitoring meadows in November 2006 (Table 4). Meadow area ranged from 2.9 ha to 606.8 ha with the smallest meadow situated at Rodds Bay and largest meadow located at Pelican Banks (Table 5; Map 3). A total of 486 monitoring sites (excluding meadow boundary mapping sites) were surveyed, 74% (360 sites) of which had seagrass present (Map 1). Of these monitoring sites 394 intertidal sites were surveyed from helicopter and 92 subtidal sites were surveyed using boat based methods (diver).

The thirteen monitoring meadows that were surveyed included six different community types depending on species presence and dominance (Maps 2, 3 and 4; Table 4). Communities that were dominated by *Zostera capricorni* were the most common followed by communities dominated by *Halophila ovalis* and *Halophila decipiens*. In the north of the survey area, *Halophila ovalis* and *Zostera. capricorni* communities dominated the intertidal sand and mud banks between Mud Island and Fishermans Landing Wharves. Further south, *Zostera capricorni* communities occurred between South Trees Inlet and Barney Point.

Seagrass cover in the monitoring meadows was comprised of isolated patches in the intertidal north Fishermans Landing meadow (meadow 8) and the Wiggins Island east meadow (meadow 4), isolated patches for the partially subtidal meadow at Quion Island (meadow 48) and both the intertidal and subtidal meadows south of Fishermans Landing (meadows 6 & 7), and continuous cover for the remainder. The majority of the monitoring meadows were located on sediments dominated by mud often combined with a smaller component of sand and/or shell. The exceptions were Pelican Banks (meadow 43), Quoin Island (meadow 48) and South Trees (meadow 58) which occurred on sediments dominated by sand.

Mean above ground biomass for the monitoring meadows ranged from 0.44 ± 0.34 g DW m^{-2} in the light *Halophila ovalis / Zostera capricorni* meadow near South Trees Point (meadow 58) to 14.17 ± 1.07 g DW m^{-2} for the large *Zostera capricorni* meadow on Pelican Banks (meadow 43) (Table 5).

The majority of the monitoring meadows were intertidal with only the two *Halophila decipiens* dominated meadows near Fishermans Landing being completely subtidal and the Quoin Island *Halodule uninervis* meadow being partially sub-tidal(meadows 7 and 9; Map 2).

A species of green macro-algae was found in high abundances in the subtidal areas offshore from the Fishermans Landing area, particularly in the meadows to the north (Map 5). An unidentified species of filamentous green algae was also common on the banks adjacent to Wiggins Island (Map 5).

Evidence of heavy dugong feeding activity was observed on the majority of intertidal seagrass meadows surveyed. The highest density of dugong feeding trails was observed at the *Zostera capricorni / Halophila ovalis* meadow at Wiggins Island west (meadow 5; Map 2) with dugong feeding trails recorded at 81% of sampling sites. Dugong feeding trails were also observed at Rodds Bay (meadows 94 and 104), Quoin Island (meadow 48), Wiggins Island (meadow 4), Pelican Banks (meadow 43) and the intertidal meadow at South Fishermans Landing (meadow 6).

Map 1. Location of 2006 seagrass monitoring sites and seagrass meadows from the 2002 baseline survey in Ports Curtis and Rodds Bay

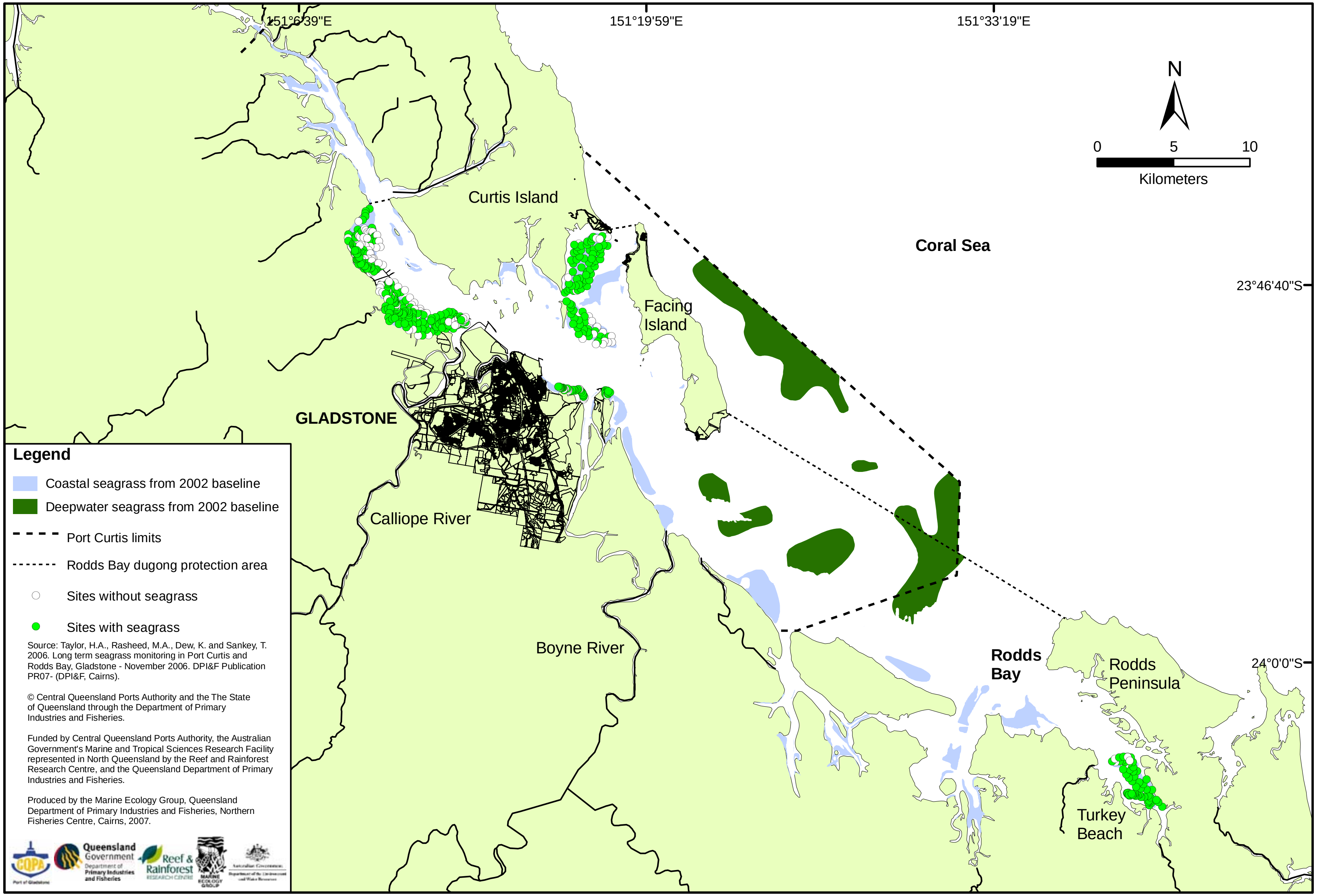
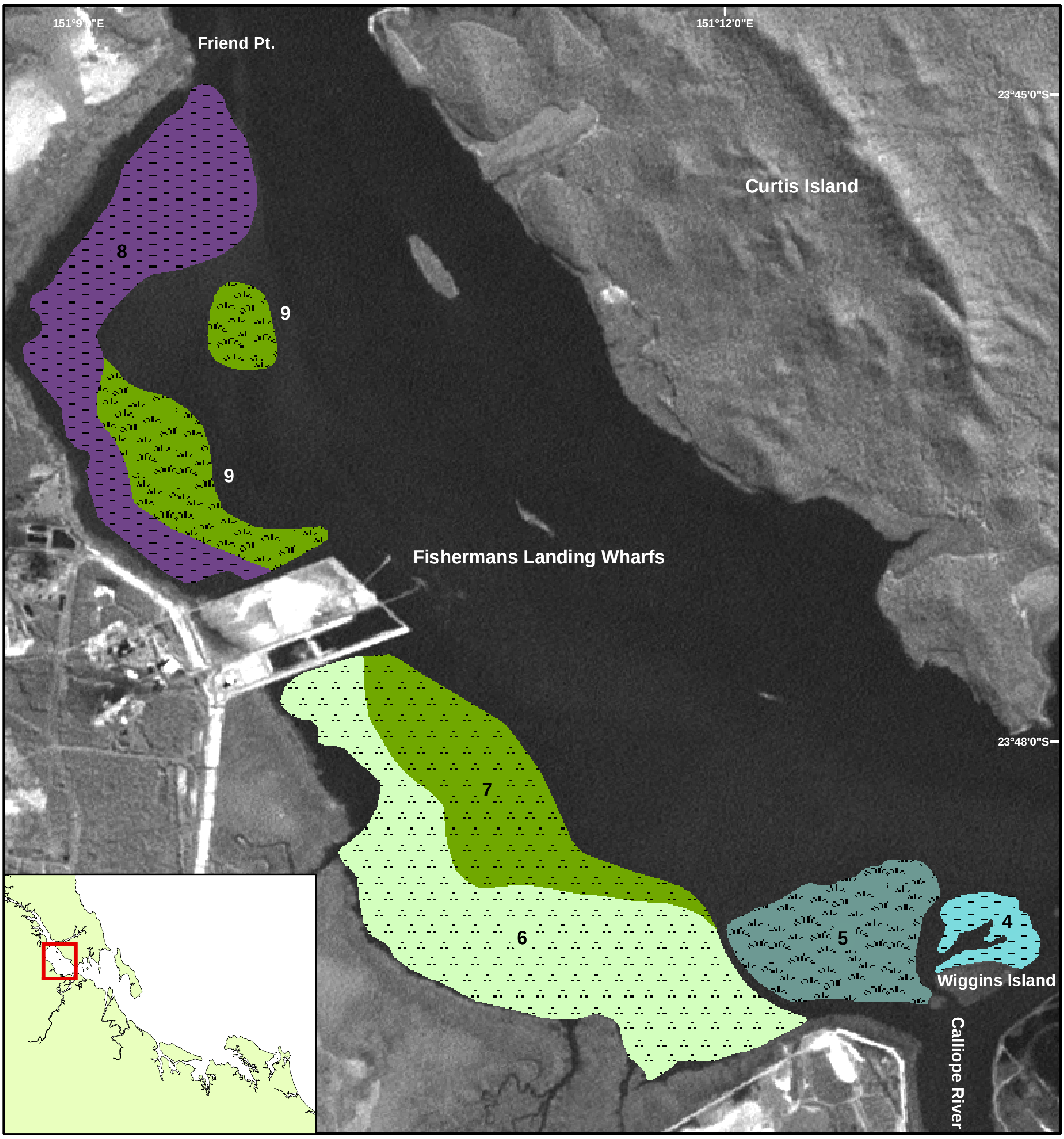


Table 4 Community type, seagrass cover and species present in the thirteen Gladstone monitoring meadows, November 2006

Monitoring Meadow	Location	No. of sites	Community Type	Cover	Species Present
4	Wiggins Island	27	Light *H. ovalis / Z. capricorni*	Aggregated patches	*H. ovalis, Z. capricorni, H. decipiens*
5	Wiggins Island	34	Light *Z. capricorni* with *H. ovalis*	Aggregated patches	*Z. capricorni, H. ovalis*
6	South Fishermans	59	Moderate *H. ovalis* with *Z. capricorni*	Isolated patches	*H. ovalis, Z. capricorni, H. decipiens*
7	South Fishermans	34	Moderate *H. decipiens*	Isolated patches	*H. decipiens, H. ovalis*
8	North Fishermans	40	Light *Z. capricorni* / mixed *Halophila* species	Isolated patches	*Z. capricorni, H. ovalis, H. decipiens, H. spinulosa*
9	North Fishermans	30	Moderate *H. decipiens*	Isolated patches	*H. decipiens, H. spinulosa, Z. capricorni*
43	Pelican Banks	60	Light *Z. capricorni*	Continuous cover	*Z. capricorni, H. ovalis*
48	Quoin Island	27	Moderate *H. uninervis* (wide) with *H. ovalis* / *H.uninervis* (thin)	Aggregated patches	*H. uninervis* (wide), *H. ovalis, H. uninervis* (thin)
58	South Trees	30	Light *H. ovalis* with *Z. capricorni*	Isolated patches	*H. ovalis, Z. capricorni*
60	South Trees	11	Light *Z. capricorni*	Aggregated patches	*Z. capricorni, H. ovalis*
94	Rodds Bay	11	Light *Z. capricorni*	Continuous cover	*Z. capricorni, H. ovalis*
96	Rodds Bay	34	Light *Z. capricorni*	Continuous cover	*Z. capricorni, H. ovalis*
104	Rodds Bay	17	Light *Z. capricorni*	Continuous cover	*Z. capricorni, H. ovalis*

Map 2. Monitoring meadows in the Fishermans Landing region, 2006



Legend

Community type

- Light *Halophila ovalis / Zostera capricorni*
- Moderate *Halophila ovalis* with *Zostera capricorni*
- Moderate *Halophila decipiens*
- Light *Zostera capricorni* with *Halophila ovalis*
- Light *Zostera capricorni* / mixed *Halophila species*

* This is not a complete seagrass distribution, only selected seagrass monitoring meadows displayed

Background: Landsat ETM + Panchromatic 24 July 1994

Meadow cover

- Continuous cover
- Aggregated patches
- Isolated patches

N

0 1 2

Kilometres

Source: Taylor, H.A., Rasheed, M.A., Dew, K. and Sankey, T.L. 2007. Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone - November 2006. DPI&F Publication PR07- 2774 (DPI&F, Cairns).

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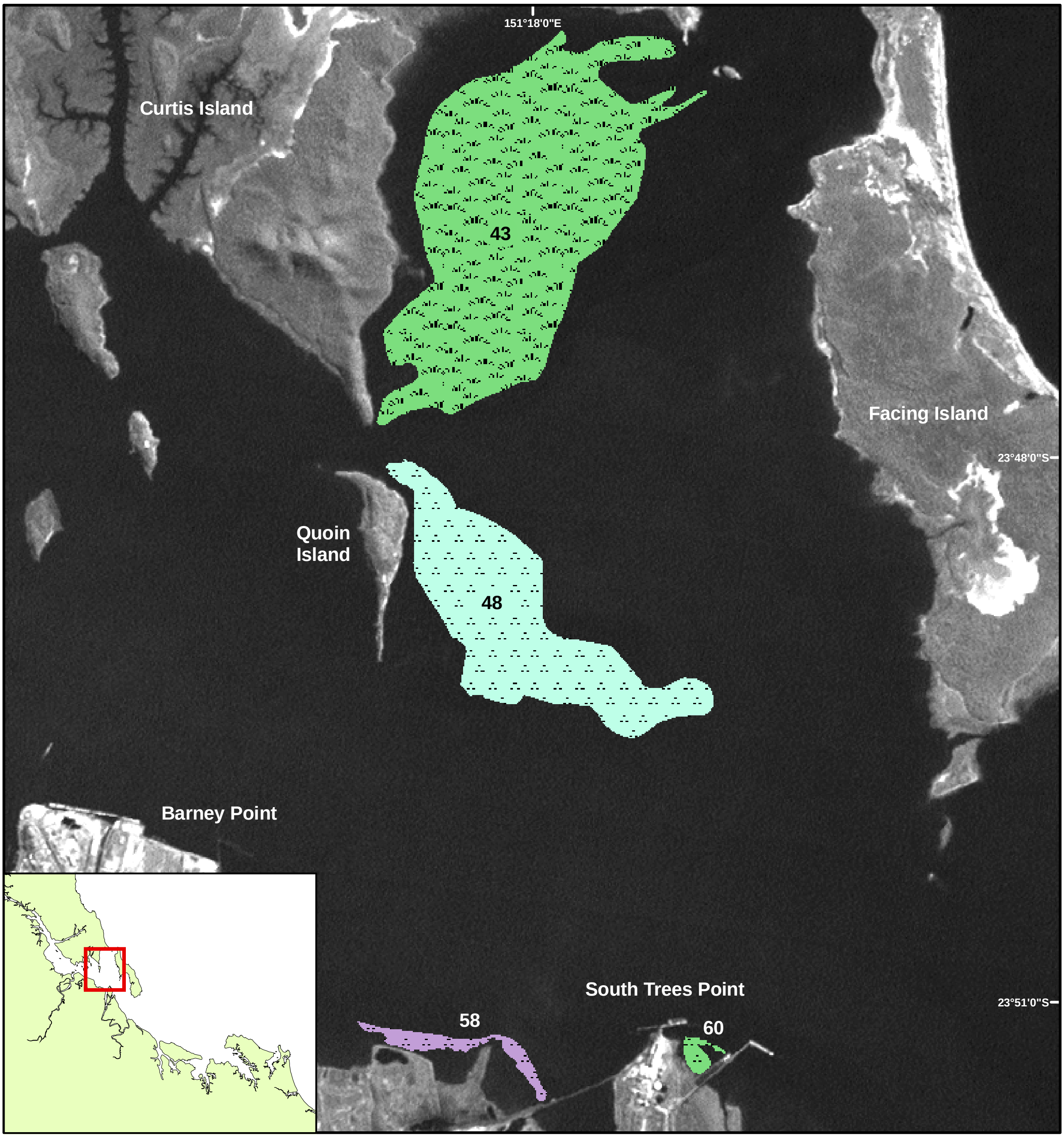
Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2007.

Map 3. Monitoring meadows in the Quoin Island and South Trees region, 2006



Legend

Community type

- Light *Halophila ovalis* with *Zostera capricorni*
- Light *Zostera capricorni*
- Moderate *Halodule uninervis* (wide) with *Halophila ovalis / Halodule uninervis* (thin)

* This is not a complete seagrass distribution, only selected seagrass monitoring meadows displayed

Background: Landsat ETM + Panchromatic 24 July 1994

Meadow cover

- Continuous cover
- Aggregated patches
- Isolated patches

N

0 1 2

Kilometres

Source: Taylor, H.A., Rasheed, M.A., Dew, K. and Sankey, T.L. 2007. Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone - November 2006. DPI&F Publication PR07-2774 (DPI&F, Cairns).

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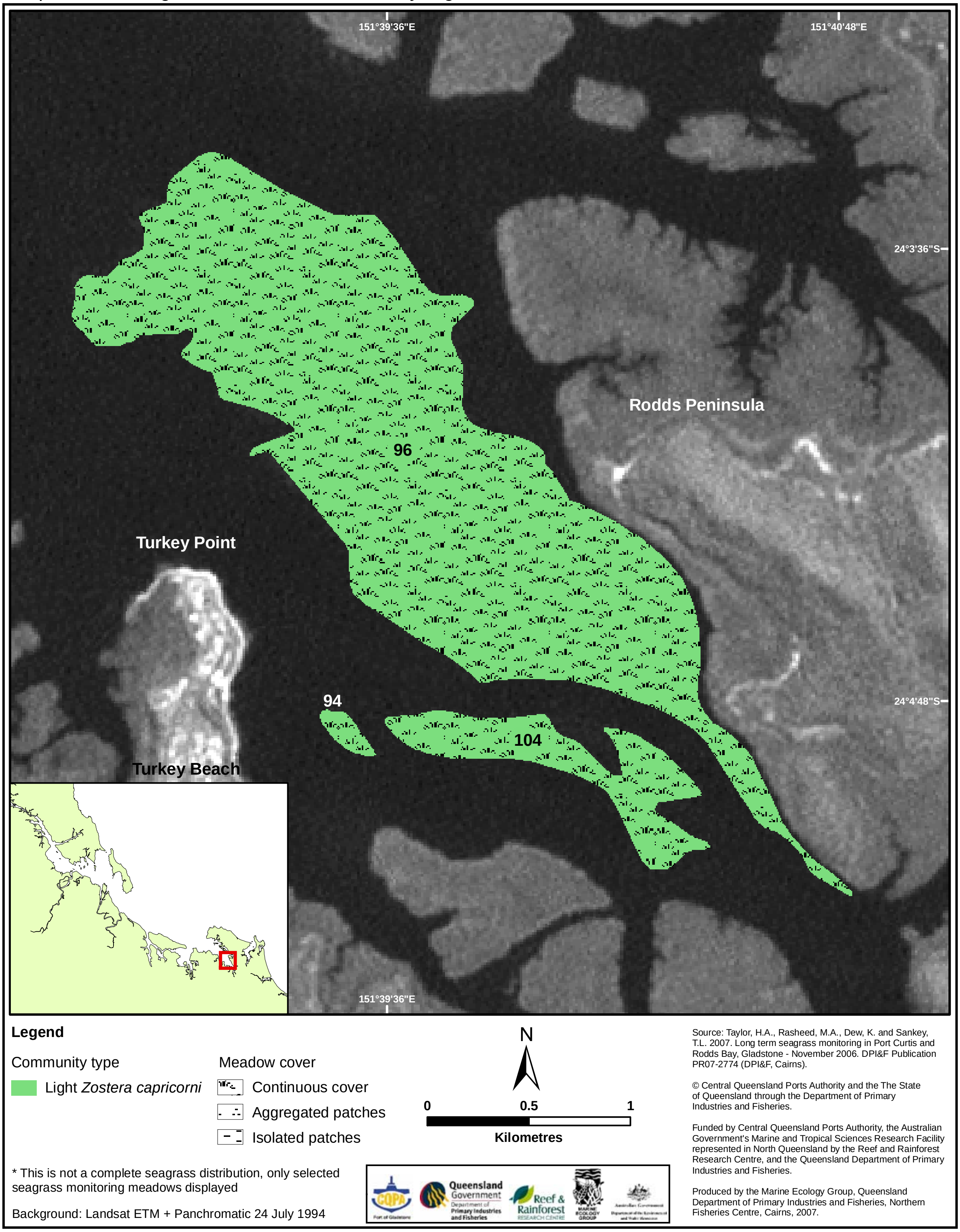
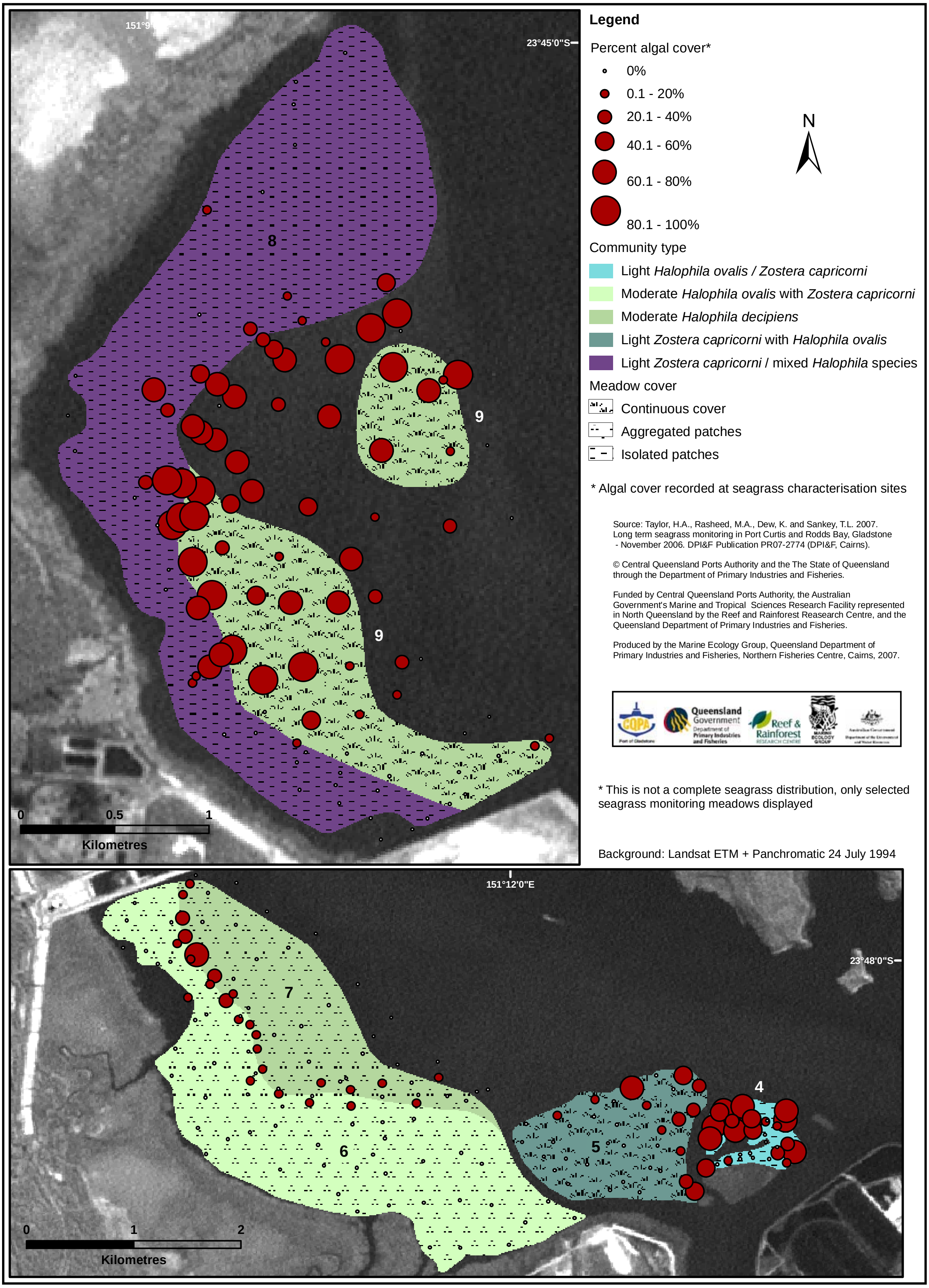
Map 4. Monitoring meadows in the Rodds Bay region, 2006



Map 5. Algal cover in the Fishermans Landing region, 2006



COMPARISON WITH PREVIOUS MONITORING SURVEYS

There have been significant changes to some of the monitoring meadows between the 2002 baseline survey, and the subsequent monitoring surveys in 2004, 2005 and 2006. Overall, intertidal seagrass meadows had either remained at the same biomass (density) from 2005 to 2006 or had increased. During the same period, all of the subtidal monitoring meadows had significantly increased in density (Table 5; Maps 6-8; Appendix 1).

Monitoring meadows located in the Wiggins Island and Fishermans Landing region had all shown significant increases in biomass from the extremely low levels recorded in 2005 (meadows 5, 6, 7, 8 & 9; Table 5; Map 6; Figure 1; Appendix 1). In particular, the two subtidal *Halophila decipiens* dominated meadows had recovered from near disappearance in 2005 to be at densities equal to or higher than those previously recorded in the program (Table 5). In addition, four of the five meadows located in this region also showed a substantial increase in area from 2005 to 2006, recovering to be similar in area to values recorded prior to 2005. The species composition of these meadows changed very little from 2005 to 2006. The most notable change was in the intertidal *Zostera capricorni* dominated meadow at North Fishermans Landing (meadow 8), in which a mix of *Halophila* species were present in higher abundances than in previous years.

The intertidal meadows located at South Trees Point (meadows 58 & 60) have shown many changes since the 2002 baseline. Biomass of the *Zostera capricorni* dominated meadow 60 was at its peak in 2002, but had reduced to very low levels in 2004. Since this time, the biomass of the meadow has been recovering but still remains below that of the baseline in 2006 (Table 5; Figure 1). Meadow 58 has been fluctuating in biomass since the program began, with low levels recorded in both 2004 and 2006, and highs in 2002 and 2005 (Table 5; Figure 1). The species composition of this meadow has fluctuated correspondingly with *Halophila ovalis* dominating in the low biomass years, and *Zostera capricorni* dominating in the high biomass years (Map 7; Figure 1).

In Rodds Bay seagrass biomass of the intertidal *Zostera capricorni* meadows remained similar to that of 2005. These meadows had significantly recovered in 2005 from dramatic declines that were recorded in 2004 (Table 5; Map 8; Figure 1). The largest meadow (meadow 96) was the only one of these control meadows to show a change, increasing significantly in biomass to be at a similar high level recorded in 2002, prior to the declines (Table 5; Figure 1; Appendix 1).

The *Halodule uninervis* monitoring meadow at Quoin Island (meadow 48) showed a significant increase in biomass from 2005 to be at its highest recorded biomass in the program to date (Table 5; Figure 1; Map 7; Appendix 1). In the baseline survey in 2002, this meadow was dominated by the narrow leaf form of *Halodule uninervis*, however in each subsequent survey there has been a shift in species composition with the heavier wide leaf form of the species becoming dominant (Figure 1). In 2006 this increase in density was particularly notable in the sub tidal sections of the meadow. Despite the large increase in biomass, the meadow had decreased in area by 10% (Table 5; Figure 1).

The only monitoring meadow to decline in biomass from 2005 to 2006 was the intertidal *Zostera capricorni* dominated meadow at Pelican Banks (meadow 43) (Table 5; Figure 1). In 2005 this meadow had peaked in density and was significantly higher than all previous monitoring results (Appendix 1). In 2006 this meadow had returned to be similar in biomass to surveys prior to the 2005 peak.

Table 5 Mean above ground biomass (g DW m^{-2}) and area (ha) for monitoring meadows in Port Curtis and Rodds Bay, November 2002, November 2004, October 2005 and November 2006.

Meadow ID	See map	Location	Meadow depth	Mean biomass (g dw m^{-2})				Area ± R (ha)			
				2002	2004	2005	2006	2002	2004	2005	2006
4	**6**	Wiggins Island	intertidal	0.8 ± 0.4	0.74 ± 0.36	0.33 ± 0.15	0.74 ± 0.26	35.8 ± 1.7	35.6 ± 1.7	32.5 ± 1.9	35.9 ± 2.1
5	**6**	Wiggins Island	intertidal	1.4 ± 0.3	0.57 ± 0.19	0.86 ± 0.5	3.73 ± 0.77	149.8 ± 2.5	143.6 ± 2.5	140.11 ± 2.5	147.4 ± 2.5
6	**6**	South Fishermans	intertidal	1.1 ± 0.1	0.24 ± 0.09	0.94 ± 0.61	2.65 ± 0.66	464.0 ± 12.9	373.5 ± 11.9	406.4 ± 12.7	428.8 ± 13.0
7	**6**	South Fishermans	subtidal	0.9 ± 0.2	1.91 ± 0.36	0.03 ± 0.02	3.7 ± 0.95	72.6 ± 11.4	185.6 ± 8.7	112.08 ± 12.3	203.1 ± 8.2
8	**6**	North Fishermans	intertidal	2.1 ± 0.3	0.14 ± 0.08	0.06 ± 0.04	1.28 ± 0.49	269.1 ± 11.3	268.3 ± 12.5	231.1 ± 12.3	275.2 ± 12.0
9	**6**	North Fishermans	subtidal	0.9 ± 0.3	1.93 ± 0.27	0.001 ± 0.001	4.98 ± 0.72	268.3 ± 14.9	284.4 ± 7.1	7.00 ± 1.1	143.9 ± 8.0
43	**7**	Pelican Banks	intertidal	20.8 ± 3.1	18.71 ± 2.13	28.3 ± 3.3	14.17 ± 1.07	624.8 ± 12.3	592.8 ± 12.4	614.55 ± 11.9	606.8 ± 14.5
48	**7**	Quoin Island	intertidal/subtidal	1.8 ± 0.2	1.11 ± 0.2	2.12 ± 1.01	9.52 ± 1.85	421.4 ± 10.2	285.8 ± 21.8	316.55 ± 18.7	285.1 ± 19.9
58	**7**	South Trees	intertidal	1.8 ± 0.5	0.47 ± 0.12	1.19 ± 0.35	0.44 ± 0.34	71.9 ± 3.9	11.2 ± 2.3	23.7 ± 2.4	24.0 ± 2.4
60	**7**	South Trees	intertidal	9.4 ± 3.3	0.08 ± 0.01	0.09 ± 0.03	4.23 ± 0.58	11.1 ± 0.7	0.8 ± 0.4	7.74 ± 0.6	7.5 ± 0.8
94	**8**	Rodds Bay	intertidal	15.1 ± 11.8	2.3 ± 0.51	17.11 ± 3.02	10.54 ± 1.38	3.4 ± 0.4	2.7 ± 0.8	3.09 ± 0.8	2.9 ± 0.8
96	**8**	Rodds Bay	intertidal	6.4 ± 3.1	0.9 ± 0.5	3.62 ± 1.41	7.7 ± 1.58	321.9 ± 10.6	303.5 ± 10.3	314.8 ± 10.6	324.4 ± 11.9
104	**8**	Rodds Bay	intertidal	8.4 ± 3.7	1.26 ± 0.43	10.73 ± 2.62	10.76 ± 1.81	47.7 ± 4.3	38.9 ± 3.8	41.94 ± 3.8	35.6 ± 4.5
Total								**2755.3 ± 96.6**	**2526.7 ± 96.1**	**2251.56 ± 91.6**	**2520.6 ± 100.8**

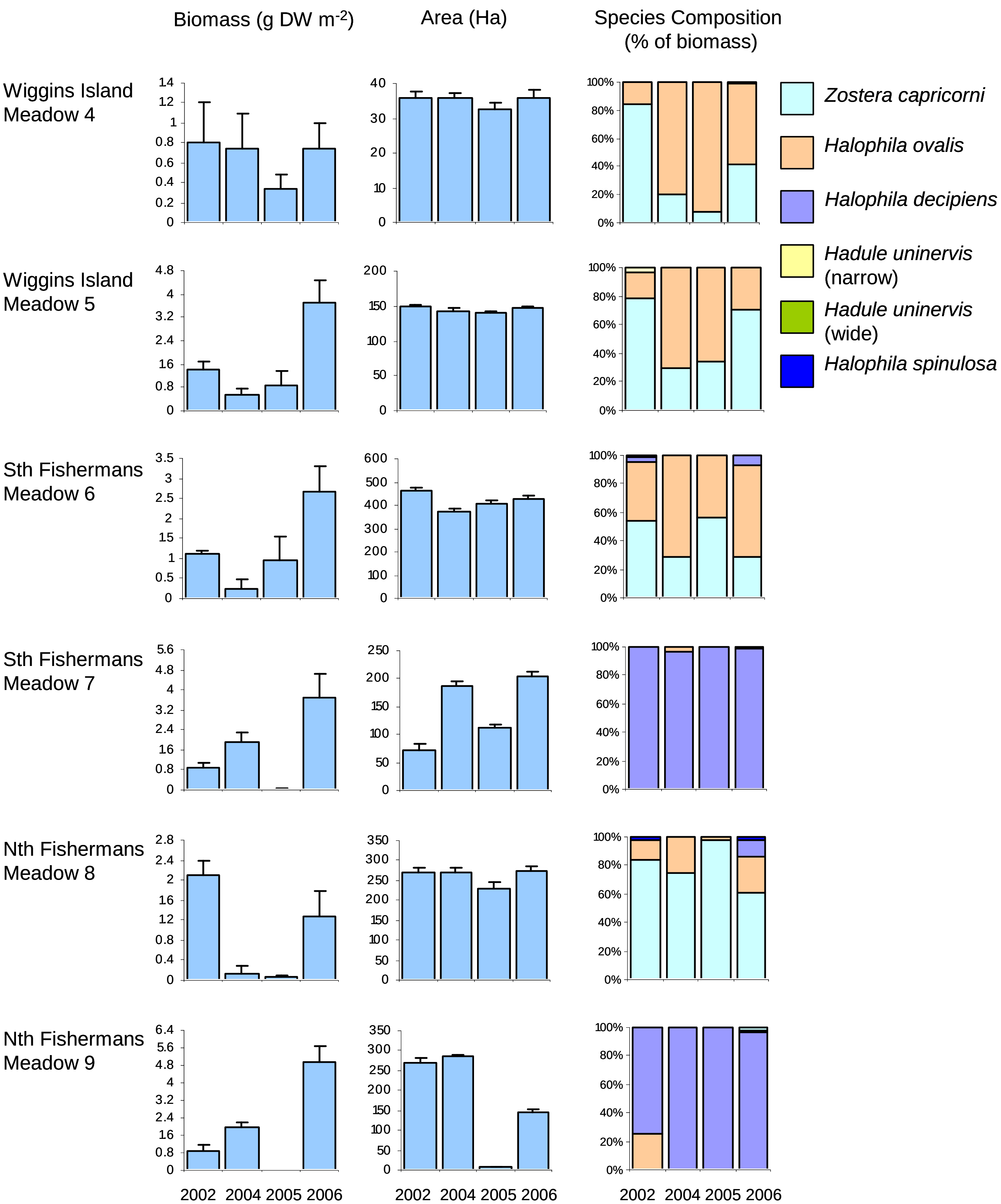


Figure 1(a) Changes in biomass, area and species composition for monitoring meadows in 2002, 2004, 2005 & 2006 (Biomass error bars = SE; Area error bars = "R" reliability estimate)

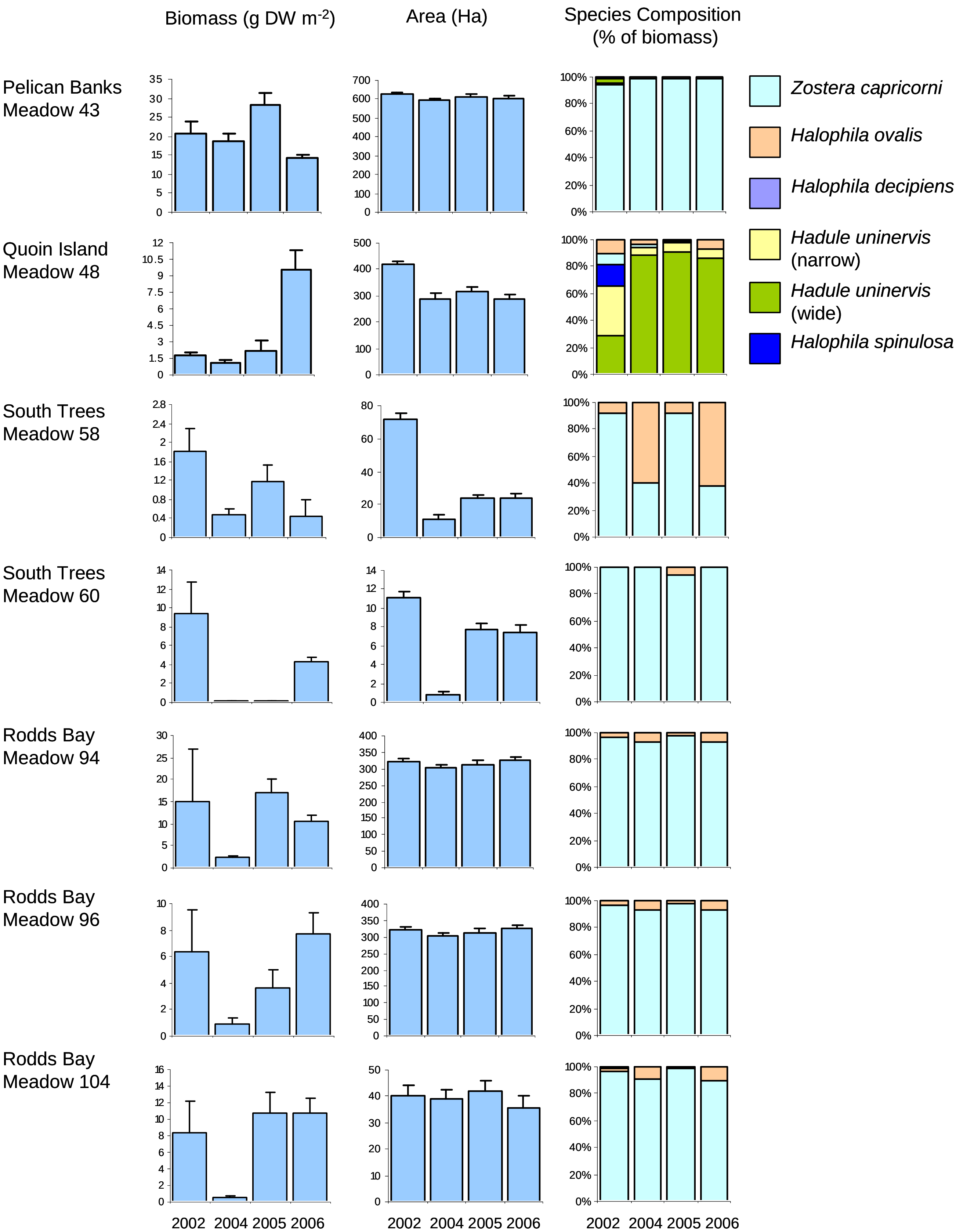
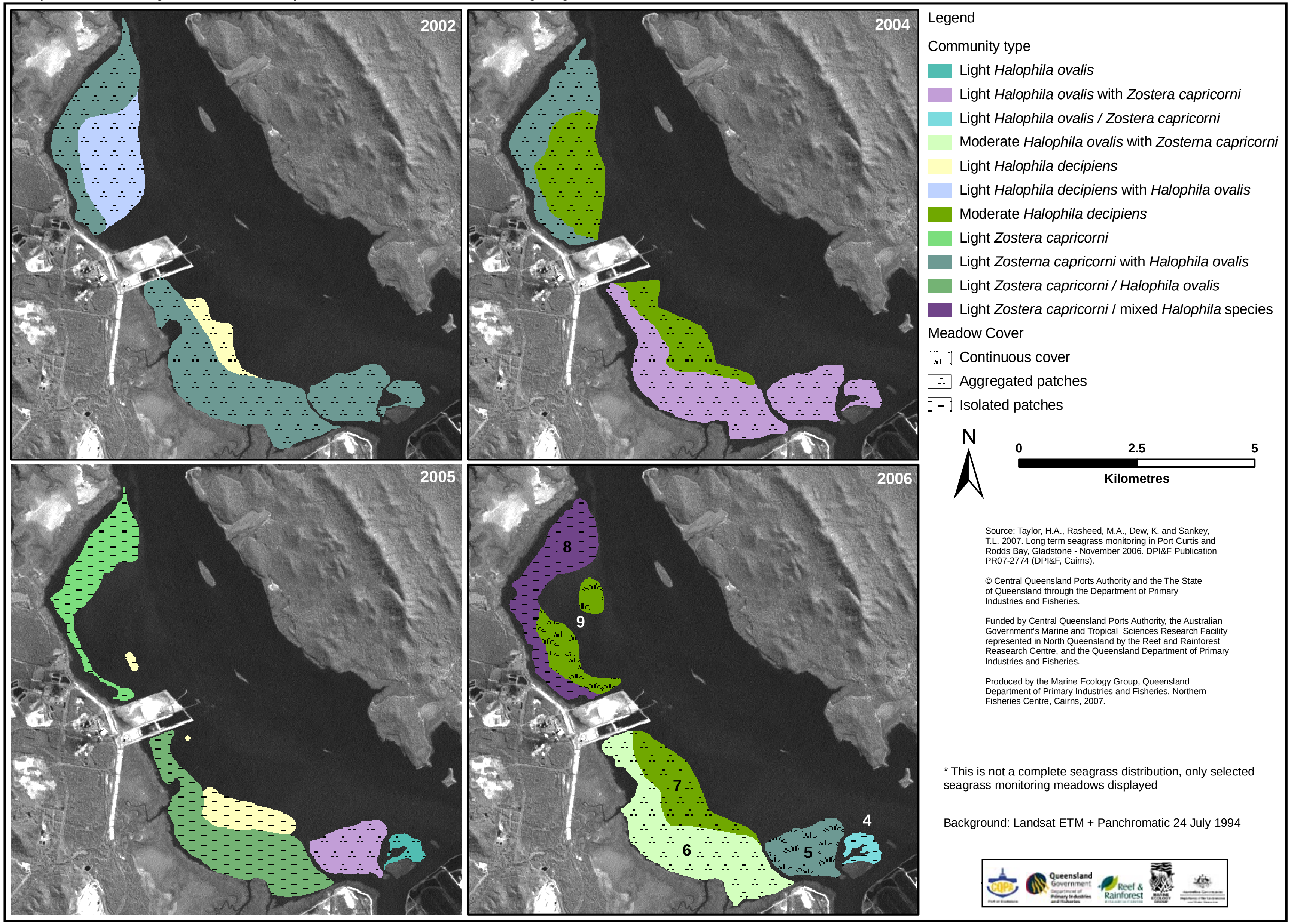
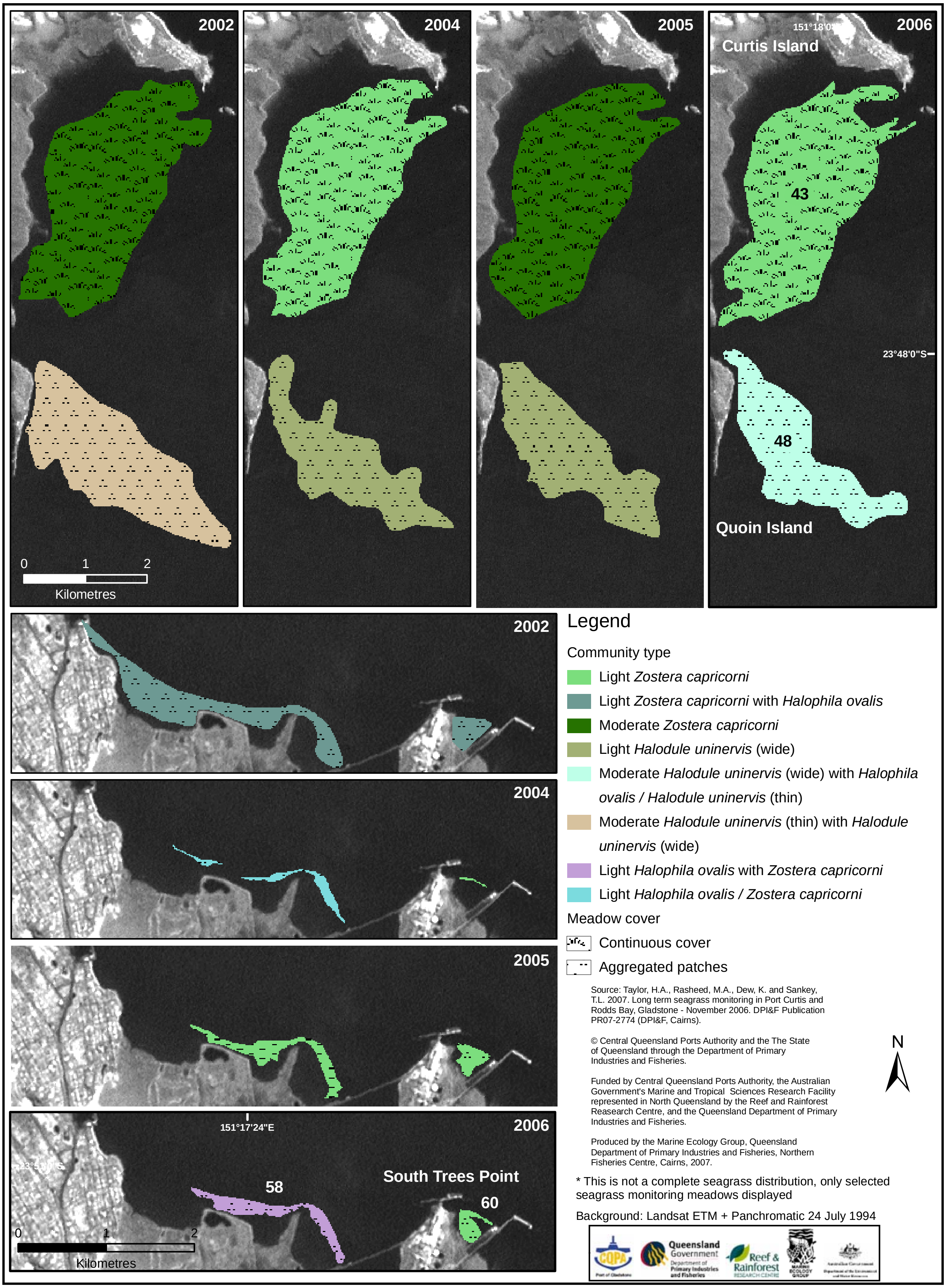


Figure 1(b) Changes in biomass, area and species composition for monitoring meadows in 2002, 2004, 2005, 2006 (Biomass error bars = SE; Area error bars = "R" reliability estimate)

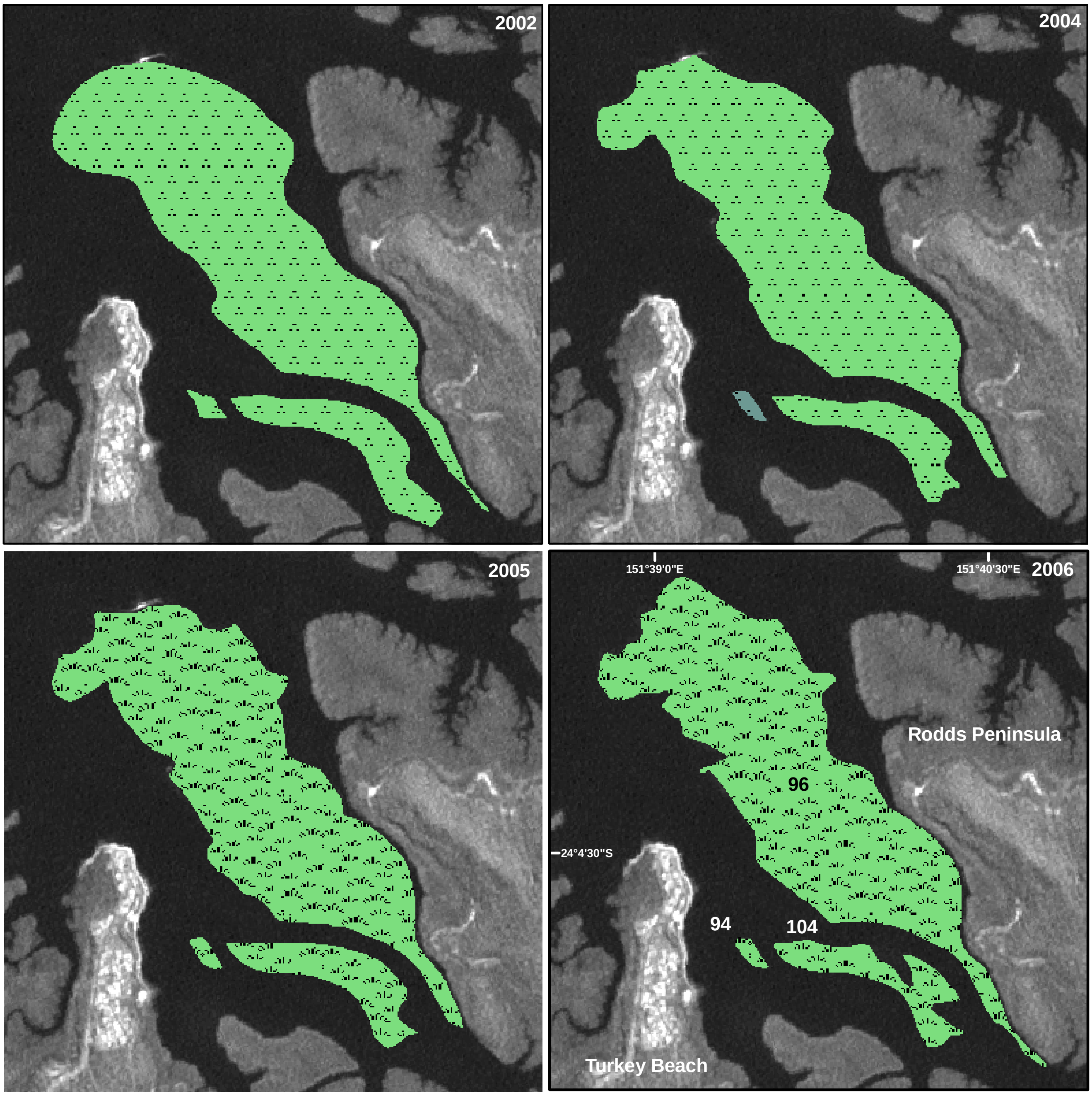
Map 6. Monitoring meadows comparison, Fishermans Landing region, 2002, 2004, 2005 & 2006



Map 7. Monitoring meadows comparison in the Quoin Island and South Trees region, 2002, 2004, 2005 & 2006



Map 8. Comparison of monitoring meadows in the Rodds Bay region, 2002, 2004, 2005 & 2006



Legend

Community type

Light *Zostera capricorni*

Light *Zostera capricorni* with *Halophila ovalis*

Meadow cover

Continuous cover

Aggregated patches

* This is not a complete seagrass distribution, only selected seagrass monitoring meadows displayed

N

0 1 2

Kilometres

Background: Landsat ETM + Panchromatic 24 July 1994

Source: Taylor, H.A., Rasheed, M.A., Dew, K. and Sankey, T.L. 2007. Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone - November 2006. DPI&F Publication PR07-2774 (DPI&F, Cairns).

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Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2007.

DISCUSSION

Results of the 2006 monitoring indicate that both intertidal and subtidal seagrasses in Port Curtis and Rodds Bay were healthy. Subtidal meadows had recovered substantially from 2005 and many intertidal meadows had increased to record high densities. The changes observed in the monitoring program appear to be strongly linked to climate and tidal exposure rather than recent port or other anthropogenic activities.

The factors driving seagrass changes have had different effects on intertidal and subtidal seagrass meadows. Generally, intertidal meadows declined and subtidal meadows increased from 2002 to 2004 and the reverse was true from 2004 to 2005. In 2006 there was substantial recovery of subtidal meadows with intertidal meadows remaining unchanged or increasing.

The most likely cause of the declines in intertidal seagrass between 2002 and 2004 were linked to tidal exposure and regional and local climate conditions. In 2004, daytime exposure of the intertidal seagrass banks in the months prior to the survey was higher than other years, with up to 30 hours of exposure recorded a month (Figure 2). This increased exposure, combined with the drought conditions of high solar irradiance and temperature, was likely to have lead to thermal stress and desiccation of the seagrasses when exposed (Rasheed *et al.* 2005). Evidence of this was observed during the 2004 survey with many meadows containing areas of “burnt” seagrass leaves. In 2005, many intertidal seagrass meadows showed signs of recovery (Rasheed *et al*. 2006). Climate conditions leading up to the 2005 survey had remained similar, however the number of hours the intertidal banks were exposed was greatly reduced from the highs of 2004, with solar irradiance also being lower (Figure 2). These conditions were likely to have placed less stress on the seagrasses and provided favourable conditions for growth. Similar conditions prevailed leading up to the 2006 survey with intertidal seagrass meadows remaining at the high densities recorded in 2005.

Substantial recovery of intertidal seagrass meadows in the Wiggins Island and Fishermans Landing region in 2006 reversed the recent trends for these meadows. These meadows had continued to decline in 2005 unlike the other monitoring meadows where recovery had begun. In 2005 it was thought that factors other than climate and exposure were also affecting the meadows in this area including the influence of the nearby Calliope River, increased abundance of algae and low resilience of the seagrass communities (see Rasheed *et al*. 2006). The continuation of low rainfall conditions in 2006 has resulted in the Calliope River having a minimal flow since the major flushing event that occurred in February 2003 (Figure 2). This meant that the seagrass meadows near the mouth of the river were unlikely to have been exposed to significant inputs of nutrients, sediments, herbicides, low salinity water or other inputs associated with flooding that can have negative impacts on seagrass growth. The fact that these meadows have taken longer to recover from the 2004 declines may reflect that they have a lower resilience and capacity to recover than other seagrass meadows in the survey area. These meadows were low biomass and highly patchy in nature with no evidence of a substantial seed bank from which recovery could occur (Rasheed *et al.* 2006). The observed recovery therefore relied on the vegetative expansion of the remaining isolated patches of seagrass and recruitment from outside of the meadow. Recovery therefore would take substantially longer than in other meadows where a consistent cover of seagrass plants remained from which recovery could occur after the 2004 decline (Rasheed 1999; 2004).

The continuation of drought conditions in 2006 was also likely to benefit the growth of subtidal seagrass meadows. The prevailing conditions of low rainfall resulting in lower levels of turbid runoff combined with high solar irradiance were likely to lead to more light reaching seagrasses growing in deeper areas. The rapid recovery of the subtidal *Halophila decipiens* meadows around Fishermans Landing under these conditions was not surprising despite these meadows almost completely disappearing in 2005. *Halophila decipiens* is known to be a rapid colonising species when conditions are favourable and is capable of producing relatively long lived seeds that can lay dormant in the sediment for at least 2 years (Hammerstrom *et al*. 2005; McMillan 1991). Once established the species is capable of rapid spread through vegetative expansion.

Similar patterns of change have been found in other Queensland locations where seagrasses are monitored, with changes to intertidal and subtidal seagrass meadows strongly linked to exposure and climate conditions. Recent surveys in Cairns and Mourilyan have seen intertidal *Zostera capricorni* meadows increase substantially in abundance over the past two years (Rasheed *et al.* 2007; McKenna *et al.* 2007). However unlike Port Curtis, subtidal meadows at these locations had declined from 2005 to 2006 following a return to more normal climate conditions in the wet tropics region.

In January 2006 there was an oil spill in Port Curtis with 25 tonnes of heavy fuel oil (bunker oil plus kerosene or diesel) spilled potentially affecting seagrasses in the area between Wiggins Island and Friend Point. A post-spill assessment was conducted in February 2006 which indicated that there had been no discernable effect of the oil spill on seagrass meadows (Taylor *et al*. 2006). However, meadows located at Pelican Banks and also in Rodds Bay (outside of the spill area) recorded significant declines in biomass. It was likely that these changes were related to natural seasonal variation. Studies of tropical and subtropical seagrass communities have found distinct seasonal patterns with maximum abundance usually occurring in spring/summer and minima in winter (McKenzie, 1994; Lanyon & Marsh, 1995). The patterns observed in Gladstone between October 2005, February 2006 and October 2006 generally fit this accepted model of seasonal variation. The *Zostera capricorni* meadow at Pelican Banks had reduced in biomass by 79% from October 2005 to February 2006 (see Taylor *et al*. 2006). In October 2006, biomass had recovered to be within the range of previously recorded densities for that meadow.

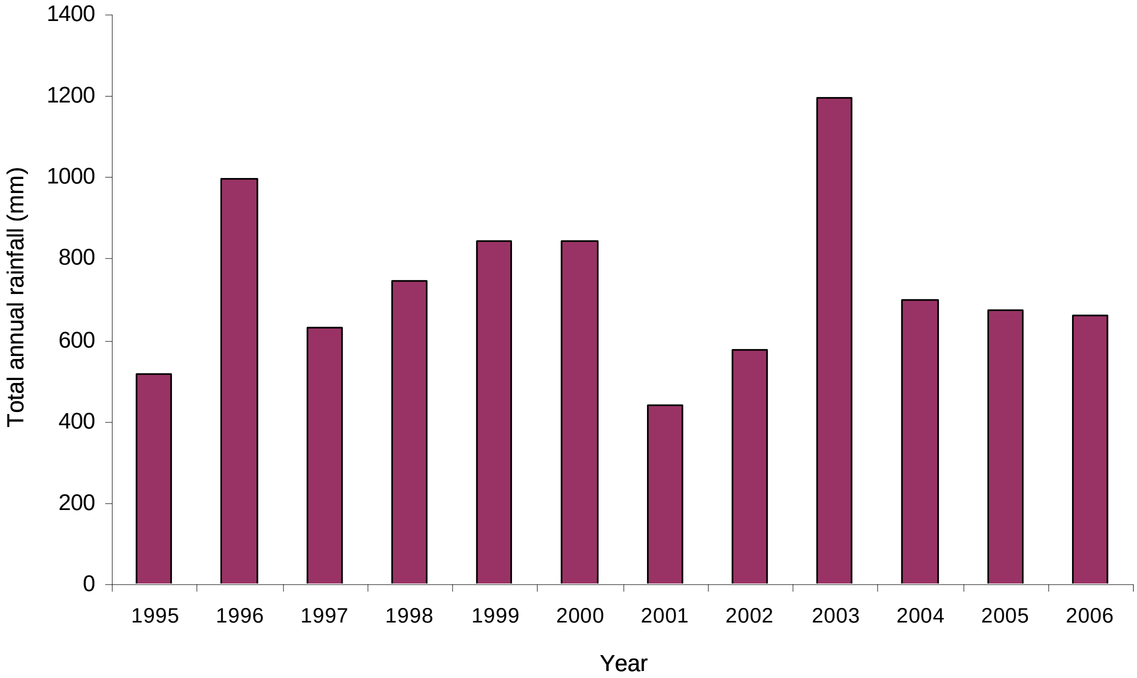
The healthy *Zostera capricorni* communities identified in the 2006 monitoring are likely to provide an important refuge for fish and crustacean species and are recognized as key nursery areas for many commercial species (Rasheed and Thomas 2002; McKenzie *et al.* 1996; Watson *et al.* 1993). Healthy *Zostera capricorni* meadows in Cairns Harbour have been demonstrated to be important habitat for juvenile tiger prawns and were estimated to be worth over AUD $3,687 per hectare per year in total landed value (1992 value) (Watson *et al.* 1993).

Evidence of dugong activity in the Port Curtis seagrass meadows has been consistently observed throughout the monitoring program. In 2006 dugong feeding activity was observed both within and outside of the port area. The seagrass meadows around Wiggins Island in particular appear to be heavily utilised by dugong, as feeding trails were found at a majority of sites sampled in 2006, and have been recorded in all previous surveys. Further evidence of feeding activity was observed in Rodds Bay, Quoin Island and Fishermans Landing. Green sea turtles were regularly observed within the seagrass meadows particularly on Pelican Banks where they were often 'stranded' at low tide.

The presence of seagrass meadows and dugong activity in intertidal areas adjacent to port facilities and infrastructure has implications for port management. Future port infrastructure developments such as wharves, breakwaters and reclamations would require careful management to ensure minimal impacts on these communities. The fact that "healthy" seagrass meadows and dugong activity have continued to exist within the port indicates that these important habitats can co-exist with well managed port activities and development.

The 2006 annual survey indicated that seagrasses in Port Curtis were healthy, and changes to meadows were likely related to climatic and environmental factors, rather than port related activities. This was the third survey in the established annual monitoring program and while still in the early stages of establishing the ranges of natural change, the program has already identified the major climate related drivers of seagrass change. As the program matures, future monitoring will help to strengthen these links and identify other potential drivers of change for Port Curtis seagrasses. The development of these links is placing us in a stronger position to assess any anthropogenic (human induced) impacts to seagrass meadows that may arise in the future.

A



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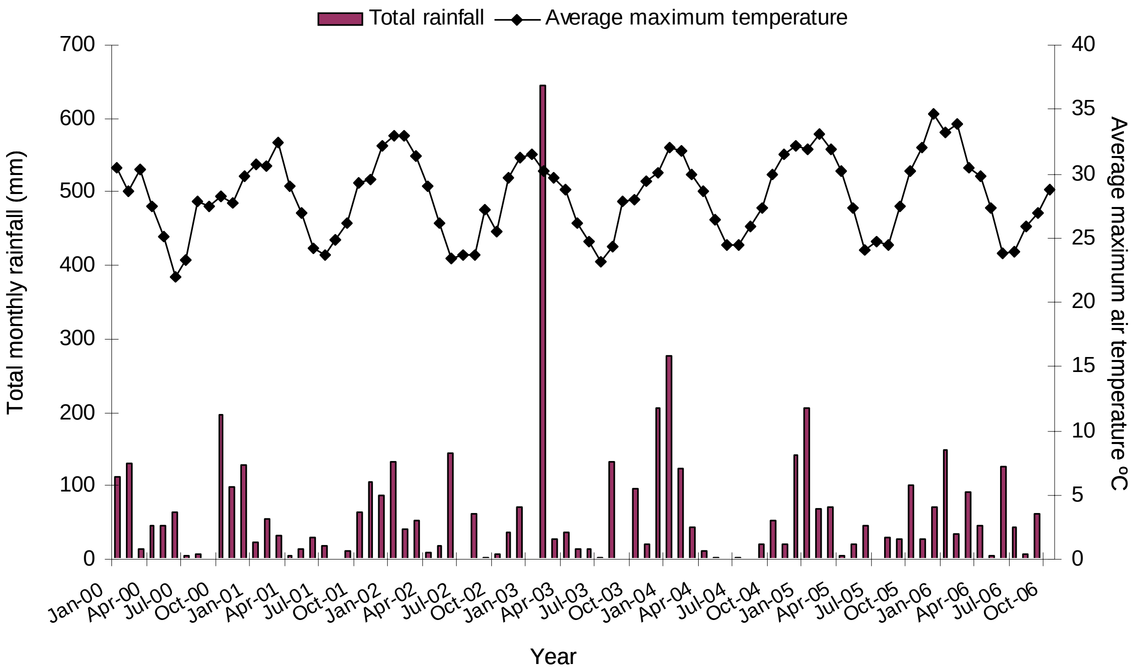
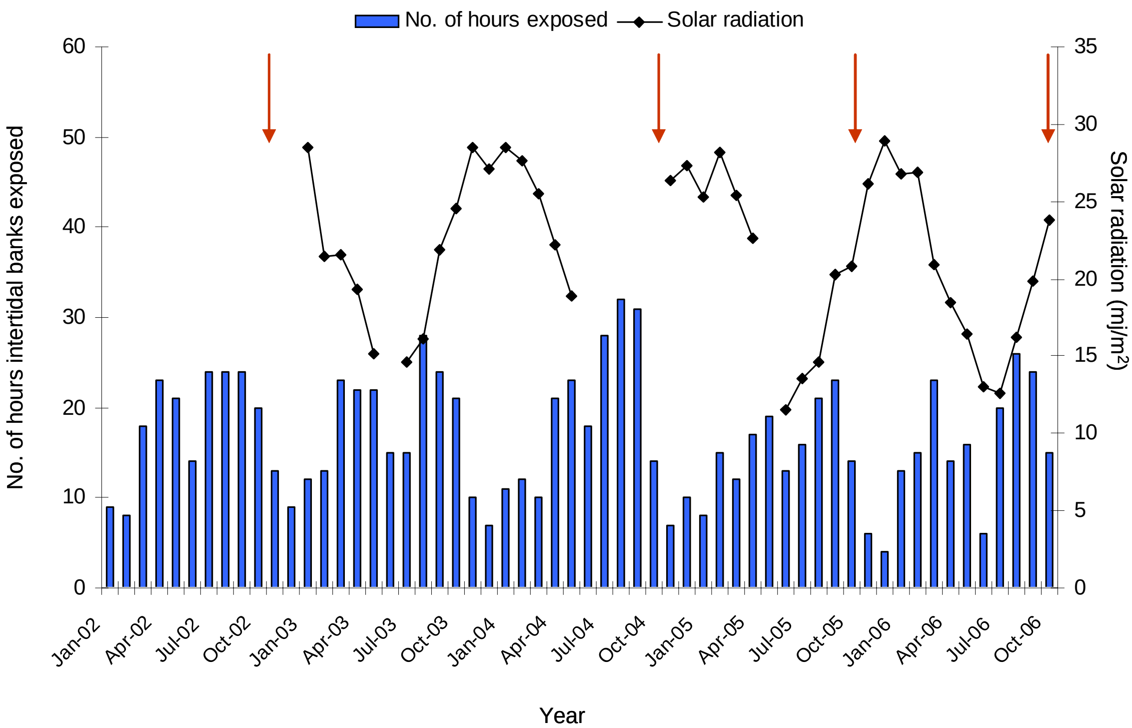


Figure 2a (A) Total annual rainfall recorded at Gladstone from 1995 to 2006 (Bureau of Meteorology); (B) Gladstone mean monthly maximum temperature and total monthly rainfall (Bureau of Meteorology).

C



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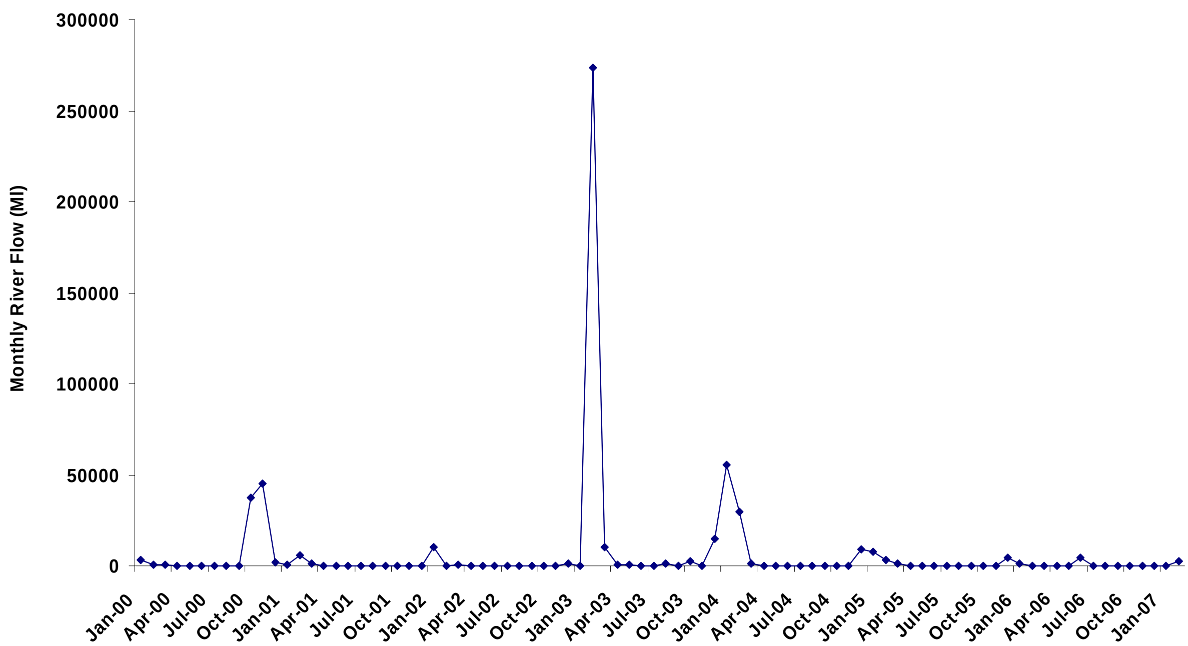

Figure 2b (C) The monthly total number of daylight hours that intertidal banks are exposed and solar radiation (megajoules/metre^2) recorded from 2002 to 2006 (red arrows indicate times of seagrass monitoring surveys)(Bureau of Meteorology and Maritime Safety Queensland) and (C) Total monthly river flow for the Calliope River between 2000 and 2006 (Queensland Department of Natural Resources and Mines).

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APPENDIX 1

Results of one-way ANOVA for mean above ground biomass versus year for the thirteen seagrass monitoring meadows in Port Curtis and Rodds Bay (2002, 2004, 2005 and 2006) (* significant difference in biomass between years)

Meadow 4	**DF**	**SS**	**MS**	**F**	**P**
Between Years	3	3.04646	1.0149	0.59	0.6304
Within Years	71	123.143	1.73441		
Total	74	126.189			
Meadow 5[#]					
Between Years	3	26.6439	8.8813	15.01	**<0.0001***
Within Years	121	71.5932	0.59168		
Total	124	98.2371			
Meadow 6[#]					
Between Years	3	145.707	48.5689	18.29	**<0.0001***
Within Years	156	414.268	2.65557		
Total	159	559.975			
Meadow 7^					
Between Years	3	17067.5	5689.17	16.41	**<0.0001***
Within Years	78	27043	346.705		
Total	81	44110.5			
Meadow 8^					
Between Years	3	84419.1	28139.7	23.69	**<0.0001***
Within Years	144	171034	1187.74		
Total	147	255453			
Meadow 9					
Between Years	3	405.349	135.116	16.98	**<0.0001***
Within Years	82	652.678	7.95949		
Total	85	1058.03			
Meadow 43					
Between Years	3	5953.93	1984.64	5.31	**0.0016***
Within Years	232	86765.2	373.988		
Total	235	92717.1			
Meadow 48[~]					
Between Years	3	8.02764	2.67588	25.07	**<0.0001***
Within Years	167	17.8269	0.10675		
Total	170	25.8545			
Meadow 58[~]					
Between Years	3	0.71114	0.23705	4.08	**0.0088***
Within Years	108	6.27081	0.05806		
Total	111	6.98194			
Meadow 60[#]					
Between Years	3	35.8947	11.9649	16.43	**<0.0001***
Within Years	34	24.7566	0.72814		
Total	37	60.6513			
Meadow 94[~]					
Between Years	2	1.91201	0.956	5.38	**0.0103***
Within Years	29	5.15034	0.1776		
Total	31	7.06234			
Meadow 96[#]					
Between Years	3	63.939	21.313	9.88	**<0.0001***
Within Years	112	241.61	2.15723		
Total	115	305.549			
Meadow 104[~]					
Between Years	3	1128.63	376.21	3.7	**0.0160***
Within Years	65	6617.92	101.814		
Total	68	7746.55			

^ Kruskal-Wallis ANOVA; [#] One-way ANOVA using square root transformed data [~]One-way ANOVA using log+1 transformed data

Results of Least Significant Difference (LSD) pair-wise comparisons of mean above-ground biomass (g DW m-2) for the Gladstone monitoring meadows. Means that share a common letter for each meadow are not significantly different (p>0.05).

Meadow 4	
Year	**Mean Biomass**
2002	0.8 a
2004	0.74 a
2005	0.33 a
2006	0.79 a

Meadow 5	
Year	**Mean Biomass**
2002	1.4 b
2004	0.57 c
2005	0.86 bc
2006	3.73 a

Meadow 6	
Year	**Mean Biomass**
2002	1.1 b
2004	0.24 c
2005	0.94 c
2006	2.65 a

Meadow 7#	
Year	**Mean Biomass**
2002	0.9 ab
2004	1.91 a
2005	0.03 b
2006	1.9 a

Meadow 8#	
Year	**Mean Biomass**
2002	2.1 a
2004	0.14 b
2005	0.06 b
2006	1.28 a

Meadow 9	
Year	**Mean Biomass**
2002	0.9 bc
2004	1.93 b
2005	0.0008 c
2006	4.98 a

Meadow 43	
Year	**Mean Biomass**
2002	20.8 b
2004	18.71 b
2005	28.3 a
2006	14.17 b

Meadow 48	
Year	**Mean Biomass**
2002	1.8 b
2004	1.11 b
2005	2.12 b
2006	9.52 a

Meadow 58	
Year	**Mean Biomass**
2002	1.8 a
2004	0.47 b
2005	1.19 ab
2006	0.44 b

Meadow 60	
Year	**Mean Biomass**
2002	9.4 a
2004	0.08 c
2005	0.09 c
2006	4.23 b

Meadow 94	
Year	**Mean Biomass**
2002	15.1 n/a
2004	2.3 b
2005	17.11 a
2006	10.54 a

Meadow 96	
Year	**Mean Biomass**
2002	6.4 ab
2004	0.9 c
2005	3.62 b
2006	7.7 a

Meadow 104	
Year	**Mean Biomass**
2002	8.4 a
2004	1.26 b
2005	10.73 a
2006	10.75 a

Kruskal-Wallis pair-wise comparisons