Port Curtis post oil spill seagrass assessment
Gladstone - February 2006

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EXECUTIVE SUMMARY

This report details results of a seagrass assessment conducted in February 2006 to determine the potential impacts of the oil spill resulting from the collision of the tug boat "Tom Tough" and the bulk carrier "Global Peace" on the 24th of January 2006. The survey was conducted using standard methodology established for the annual long-term seagrass monitoring program for the port. Results were compared to the most recent of the long-term monitoring surveys conducted in October 2005.

The post spill seagrass assessment indicated that intertidal seagrass meadows in Port Curtis had not been significantly affected by the 'Global Peace' oil spill. Although most of the meadows showed a significant decline in biomass (density) and area, these changes were consistent with similar declines that occurred in meadows outside of the oil spill area. The declines in seagrass meadows were most likely attributable to natural seasonal variation, coupled with a combination of other climatic factors and anthropogenic impacts.

The longer term effects of the oil on seagrasses could not be determined from this assessment. At the time of the survey, some mangrove areas still contained oil amongst the roots and sediments with the possibility the oil may be released onto the seagrass beds in the months following our assessment. A second post-spill seagrass survey prior to the full seagrass monitoring event (scheduled for October 2006) may be warranted to ascertain if there has been any delayed effects of the oil spill to Gladstone's seagrasses.

INTRODUCTION

This report details the results of a post oil spill seagrass assessment that was conducted in February 2006. The seagrass assessment investigated the potential impacts of the oil spill associated with the collision of the tug boat "Tom Tough" and the bulk carrier "Global Peace" on the 24th of January 2006.

The survey was built on the established long term seagrass monitoring program for the Port of Gladstone (Rasheed *et al*. 2003; 2005 & 2006). As part of this program, large areas of seagrass have been mapped and monitored on the intertidal banks in the footprint of the oil spill. The most recent of these annual surveys was conducted in October 2005 and provided a good baseline to compare any post oil spill changes to seagrasses. In October 2005, the state of seagrass meadows indicated that the marine environment in Port Curtis was relatively healthy, however some localised declines in the Wiggins Island and Fishermans Landing area had occurred. Full background and details for the long term seagrass monitoring program can be found in Rasheed *et al*. (2003; 2005; 2006).

On the 24th of January 2006 the tug boat "Tom Tough" suffered engine failure and punctured the hull of the bulk carrier "Global Peace" during berthing operations at RG Tanna Coal Loading Facility in Port Curtis (see Map 1). The puncture occurred in the carrier's Deep Fuel Oil Tank, spilling approximately 25 tonnes of heavy fuel oil (bunker oil plus kerosene or diesel). The oil spill was contained to the area between South Trees Point and Grahams Creek (approximately 15km long by 4km wide), with the heaviest concentration of oil located around the wharf site, Mud & Wiggins Islands and the Calliope River mouth. The extent of the oil spill was controlled by tidal movement with the oil moving up and down the channel according to tidal flow.

Maritime Safety Queensland (MSQ) initiated its marine oil spill response arrangements immediately under its National Plan which resulted in the spill being contained to a relatively small area and a substantial amount of the oil being recovered. Despite this, oil was observed in the vicinity of several intertidal banks known to contain seagrass.

DPI&F and CQPA developed this survey to assess any changes to the seagrass monitoring meadows that may have been caused by the oil spill, and make recommendations on additional monitoring that may be required.

This report details the results of first post oil spill assessment, conducted in February 2006. The objectives of the survey were to:

1. Conduct an assessment of seagrass meadows that may have been affected by the oil spill of 24th January.
2. Compare and analyse changes in seagrass area, abundance and species composition for selected seagrass meadows with the most recent monitoring survey (October 2005) conducted as part of the established long term monitoring program.
3. Design an appropriate post oil spill seagrass monitoring strategy based on the findings of this survey.

METHODOLOGY

Seagrass surveys were conducted to assess the impact of the oil spill between the 27th of February and 1st of March 2006. We assessed five major intertidal meadows located between the Calliope River and Friend Point (north of Fishermans Landing). These meadows represented the major areas of seagrass that were most likely to have been impacted by the oil spill. As a control to measure any natural changes in seagrasses that had occurred since October 2005, we surveyed the intertidal seagrass meadow at Pelican Banks which was unlikely to have been affected by the spill. A reconnaissance of seagrass meadows in Rodds Bay (approximately 45 km from oil spill) was also conducted.

Sampling methodology was the same as that established for the long term monitoring program and is fully described in reports on the 2002 baseline survey (Rasheed *et al.* 2003) and the first monitoring survey (Rasheed *et al*. 2005).

Seagrass meadow characteristics were collected at seagrass habitat characterisation sites scattered randomly within seagrass meadows. The number of sites placed within each meadow was based on the results of the baseline surveys described in Rasheed *et al*. (2003). Seagrass habitat observations included species composition, above ground biomass, percent algal cover, sediment type, time and location. Sampling was conducted using a helicopter on the first spring low tide after the oil spill had occurred.

The boundaries of the seagrass meadows were recorded using a Global Positioning System (GPS) and digitised onto a Geographic Information System (GIS) basemap. The GIS basemap was constructed from a Landsat image, which was rectified and projected to Geodetic Datum of Australia (GDA 94) coordinates. Estimates of meadow boundary mapping reliability were calculated for each meadow area based on accuracy of site fixes and distances between mapping sites.

RESULTS

Seagrass species, distribution and abundance in February 2006

Two seagrass species (from two families) were identified in the five seagrass meadows assessed (Plate 1). For a complete list of species found within the port limits see Rasheed *et al.* (2003):

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

Family ZOSTERACEAE Drummortier:
Zostera capricorni Aschers.

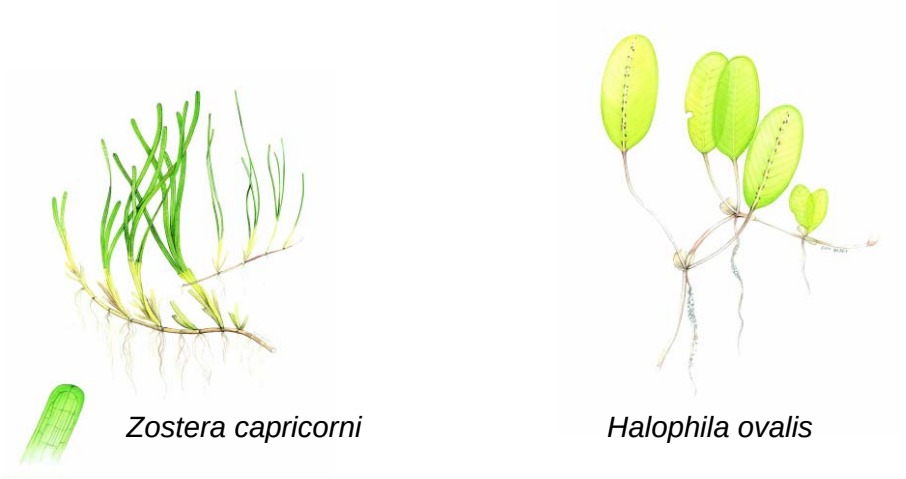


Plate 1 Seagrass species found in Port Curtis assessment meadows in February 2006 (seagrass illustrations by Ruth Berry - not to scale)

A total of 1229.9 ± 77 ha of seagrass habitat was mapped in the five seagrass meadows assessed in February 2006 (Table 1). Meadow area ranged from 24.3 ha to 499.0 ha with the smallest meadow situated at Wiggins Island (meadow 4) and largest meadow located at Pelican Banks (meadow 43) (Table 2). A total of 180 monitoring sites (excluding meadow boundary mapping sites) were surveyed, 68.3% (123 sites) of which had seagrass present (Map 1).

The five meadows included three different community types depending on species presence and dominance (Maps 2 & 3; Table 1). Three of the five meadow communities were dominated by *Halophila ovalis* with the remaining two meadows dominated by *Zostera capricorni*.

Seagrass cover in the assessed meadows comprised of isolated patches in the Fishermans Landing (meadows 6 & 8) and Wiggins Island East (meadow 4) meadows, continuous cover for Pelican Banks (meadow 43) and aggregated patches for Wiggins Island West (meadow 5). The meadows were located on sediments dominated by mud often combined with a

smaller component of sand and/or shell. The exception was Pelican Banks (meadow 43), which occurred on sediments dominated by sand.

Mean above ground biomass for the monitoring meadows ranged from 0.02 ± 0.02 g DW m^{-2} in the light *Zostera capricorni* meadow at North Fishermans Landing (meadow 8) to 5.86 ± 0.89 g DW m^{-2} for the large *Zostera capricorni* meadow on Pelican Banks (meadow 43) (Table 2).

An unidentified species of green filamentous algae was found in high abundances on the Wiggins Island east and west meadows (Map 4).

Evidence of dugong feeding activity was observed on seagrass meadows at Wiggins Island west and at Pelican Banks. The highest density of dugong feeding trails was recorded for the *Halophila ovalis* meadow at Wiggins Island west (meadow 5) with dugong feeding trails observed at 42.9% of sampling sites.

Comparison with October 2005

There were some significant declines to seagrass meadows both within and outside of the oil spill area (Table 2; Figure 1; Maps 2 & 3). In general, intertidal seagrass biomass and area had declined from the levels recorded in October 2005. Changes to meadows within the footprint of the oil spill were consistent with the declines that had occurred in the control meadows at Pelican Banks and losses in Rodds Bay.

The two *Halophila ovalis* meadows located near Wiggins Island (East - 4 & West - 5) that were most exposed to the oil spill showed no significant change in biomass from October 2005 (Table 2; Appendix 1). However, while not statistically significant, the East meadow had declined in biomass by 82%, with the opposite occurring for the West meadow which had increased by 51%. Seagrass cover had become patchier and total area substantially reduced for the meadow closest to Wiggins Island (East - 4 meadow). Area for the West meadow remained similar to that of October 2005 (Table 1; Figure 1). There was a marked increase in the presence of an unidentified green filamentous algae on these Wiggins Island meadows (meadows 4 & 5) (Map 4).

The *Zostera* meadows located north and south of Fishermans Landing (North - 8 & South - 6) had both significantly declined in biomass, with 200% and 73% declines respectively (Table 2, Figure 1; Appendix 1). In addition, substantial changes to the species composition of the South Fishermans meadow occurred with an increase in *Halophila ovalis* from 44% to 92% (Figure 1). The area of the South Fishermans meadow remained unchanged whilst the North Fishermans meadow decreased in area by 25% and had become extremely patchy (Table 2; Figure 1).

The *Zostera* meadow at Pelican Banks (located outside of the oil spill area) also showed a significant decline in biomass similar to the meadows within the oil spill area (79% reduction; Table 2; Figure 1; Appendix 1). The area of the meadow had also decreased by 19%. A reconnaissance of the *Zostera* seagrass meadows located in Rodds Bay also indicated they had declined substantially in biomass since October 2005.

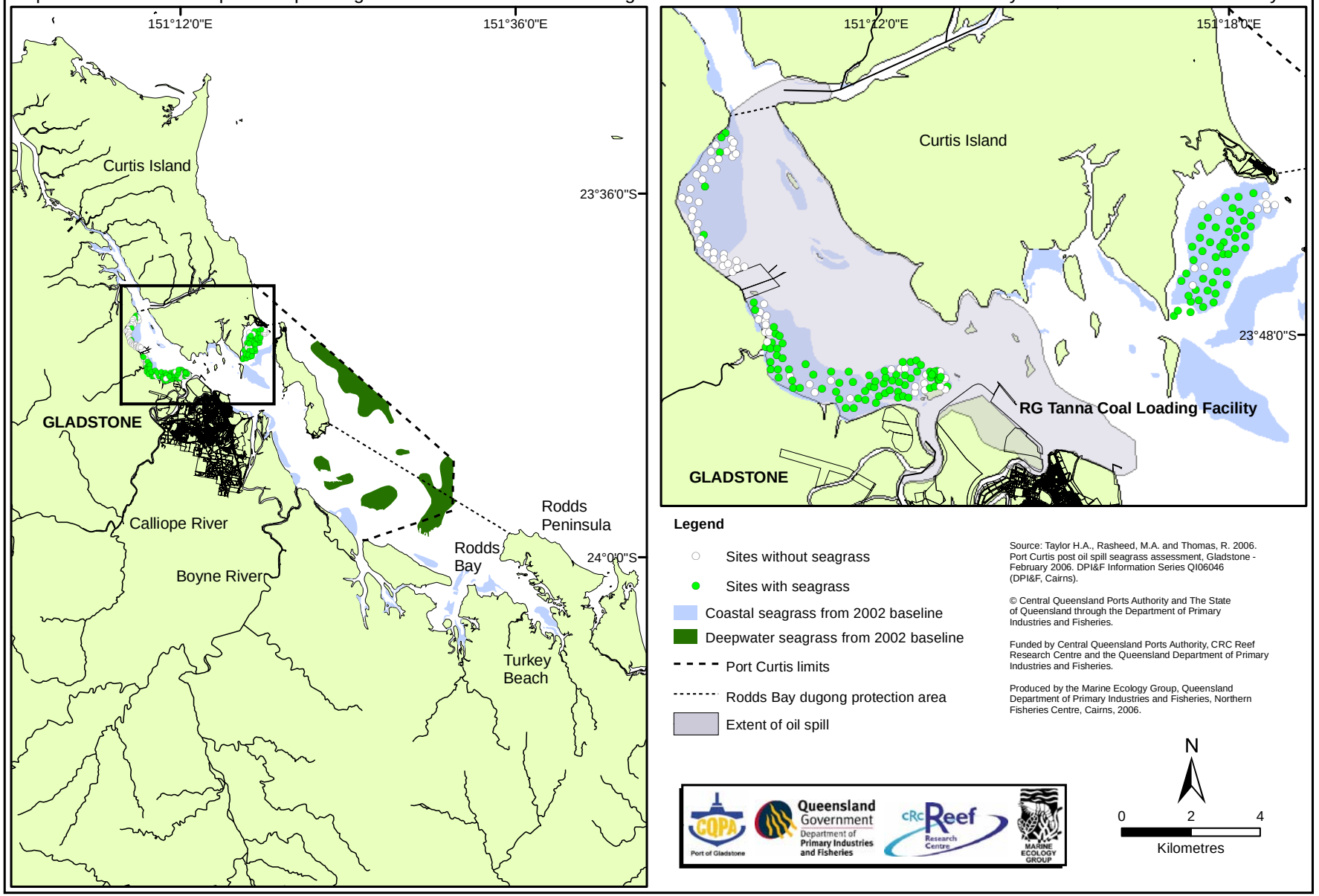
Table 1 Community type, seagrass cover and species present in the five post oil spill assessed meadows, February 2006.

Monitoring Meadow	Location	No. of sites	Community Type	Cover	Species Present
4	Wiggins Island	19	Light *H. ovalis*	Isolated patches	*H. ovalis, Z. capricorni*
5	Wiggins Island	29	Moderate *H. ovalis* with *Z. capricorni*	Aggregated patches	*H. ovalis, Z. capricorni*
6	South Fishermans	45	Light *H. ovalis*	Isolated patches	*H. ovalis, Z. capricorni*
8	North Fishermans	32	Light *Z. capricorni*	Isolated patches	*Z. capricorni, H. ovalis*
43	Pelican Banks	54	Light *Z. capricorni*	Continuous cover	*Z. capricorni, H. ovalis*

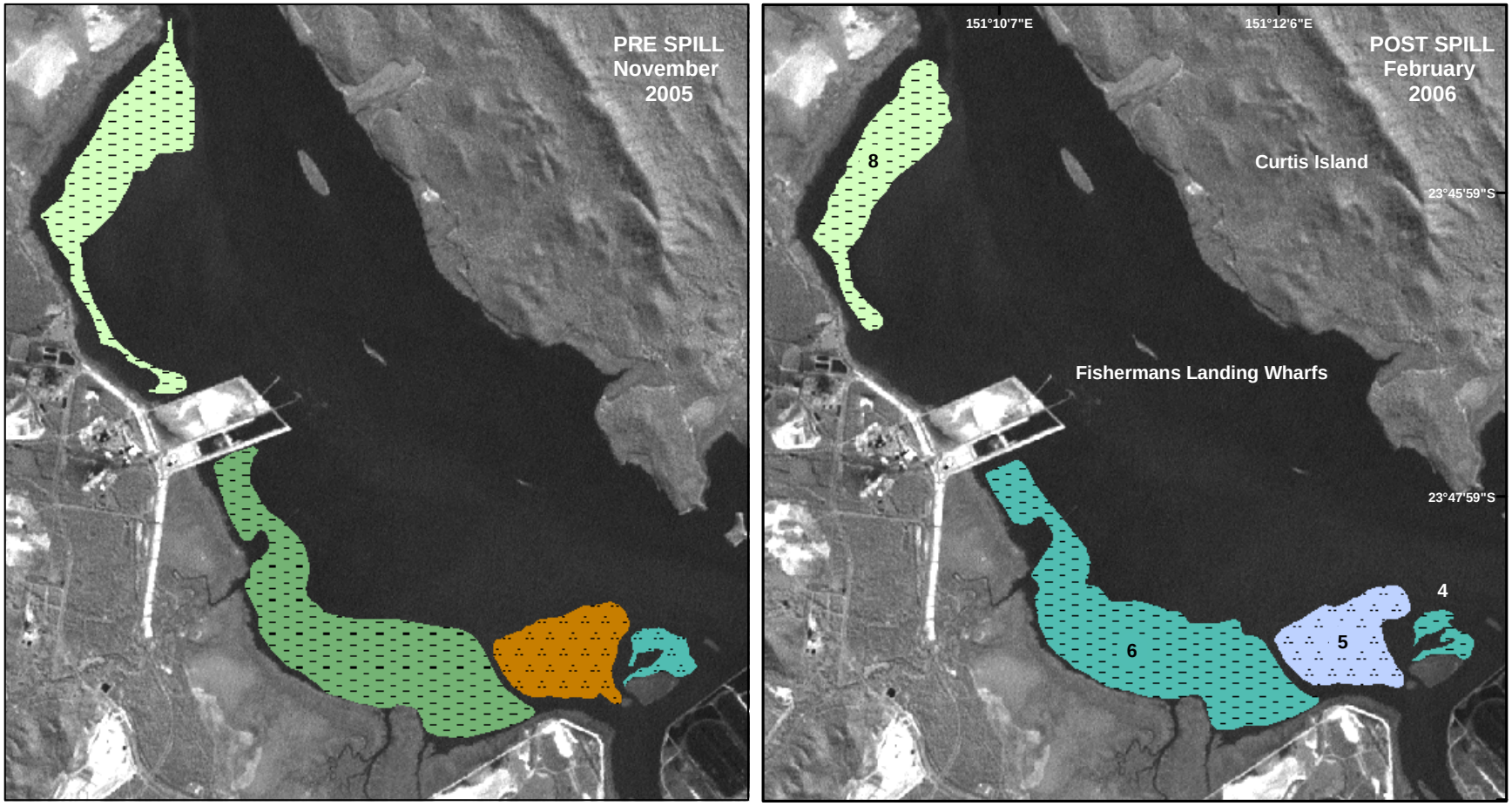
Table 2 Mean above ground biomass (g DW m^{-2}) and area (ha) for assessed meadows in Port Curtis pre oil spill – October 2005 and post oil spill – February 2006. *denotes significant difference (Appendix 1)

Meadow ID	See map	Location	Meadow depth	Mean biomass (g dw m^{-2})		Area ± R (ha)	
				2005	2006	2005	2006
4	**2**	Wiggins Island	intertidal	0.33 ± 0.15	0.06 ± 0.04 (-82%)	32.5 ± 1.9	24.3 ± 3.8 (-25%)
5	**2**	Wiggins Island	intertidal	0.86 ± 0.5	1.3 ± 0.42 (+51%)	140.11 ± 2.5	134.1 ± 2.6 (-4%)
6	**2**	South Fishermans	intertidal	0.94 ± 0.61	0.25 ± 0.15 (-73%*)	406.4 ± 12.7	398.3 ± 12.4 (-2%)
8	**2**	North Fishermans	intertidal	0.06 ± 0.04	0.02 ± 0.02 (-200%*)	231.1 ± 12.3	174.2 ± 41.9 (-25%)
43	**3**	Pelican Banks	intertidal	28.3 ± 3.3	5.86 ± 0.89 (-79%*)	614.55 ± 11.9	499.0 ± 16.3 (-19%)
Total						**1424.7 ± 41.3**	**1229.9 ± 77**

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



Map 2. Comparison of seagrass meadows pre & post oil spill in the Fishermans Landing region



Legend

Community type
- Light *Halophila ovalis*
- Light *Halophila ovalis* with *Zostera capricorni*
- Moderate *Halophila ovalis* with *Zostera Capricorni*
- Light *Zostera capricorni*
- Light *Zostera capricorni / Light Halophila ovalis*

Meadow Cover
- Isolated patches
- Aggregated patches
- Continuous cover
- 9 Meadow ID

N

0 0.9 1.8

Kilometres

Source: Taylor H.A., Rasheed, M.A. and Thomas, R. 2006. Port Curtis post oil spill seagrass assessment, Gladstone - February 2006. DPI&F Information Series QI06046 (DPI&F, Cairns).

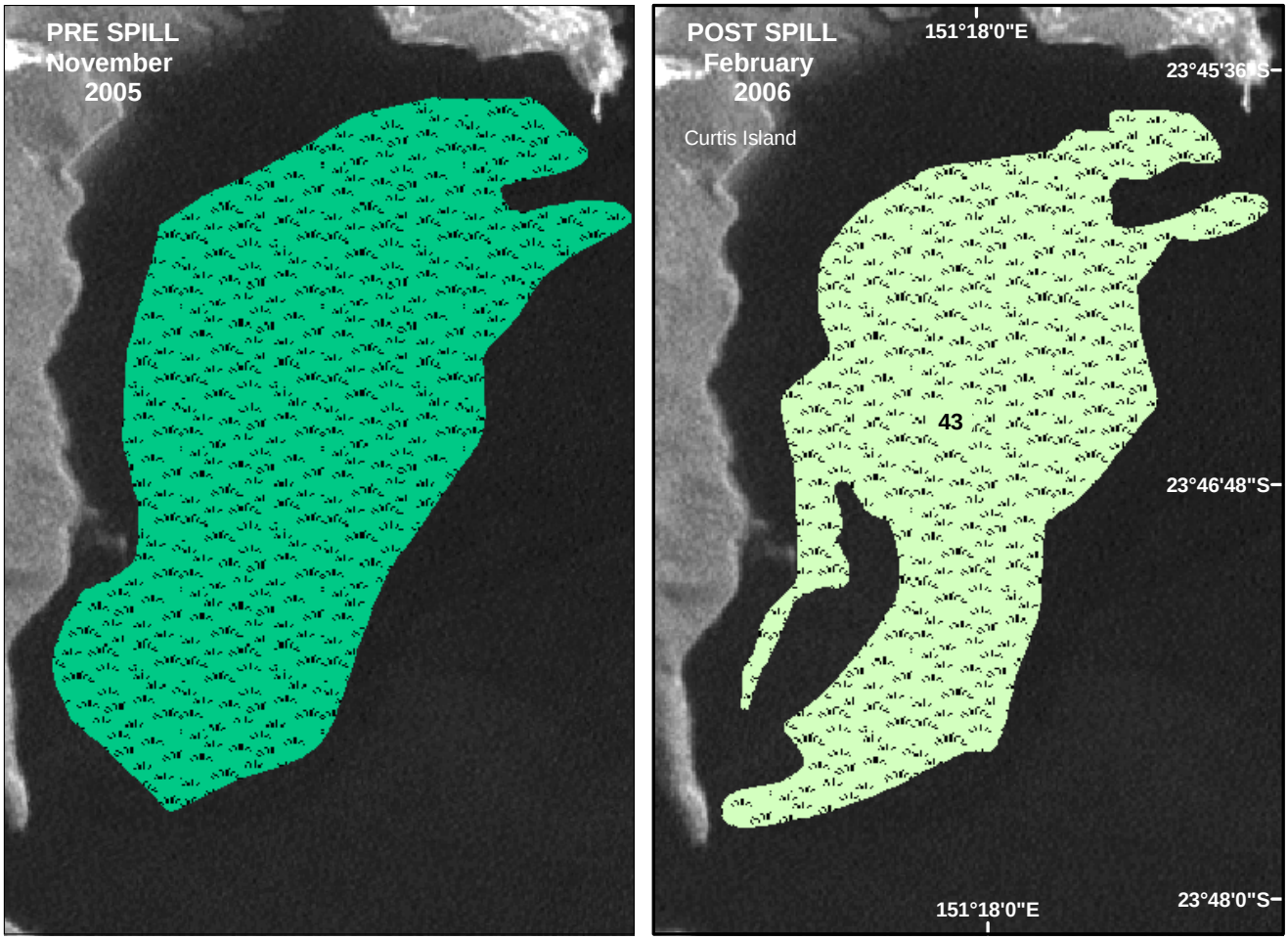
Funded by Central Queensland Ports Authority, CRC Reef Research Centre and the Queensland Department of Primary Industries and Fisheries.

Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2006.

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

Background: Landsat ETM + Panchromatic 24 July 2002

Map 3. Comparison of seagrass meadows pre & post oil spill at Pelican Banks



Legend

Community type
- Light *Zostera capricorni*
- Moderate *Zostera capricorni*

Meadow Cover
- Isolated patches
- Aggregated patches
- Continuous cover
- 43 Meadow ID

N

0 0.5 1

Kilometres

Source: Taylor H.A., Rasheed, M.A. and Thomas, R. 2006. Port Curtis post oil spill seagrass assessment, Gladstone - February 2006. DPI&F Information Series QI06046 (DPI&F, Cairns).

Funded by Central Queensland Ports Authority, CRC Reef Research Centre and the Queensland Department of Primary Industries and Fisheries.

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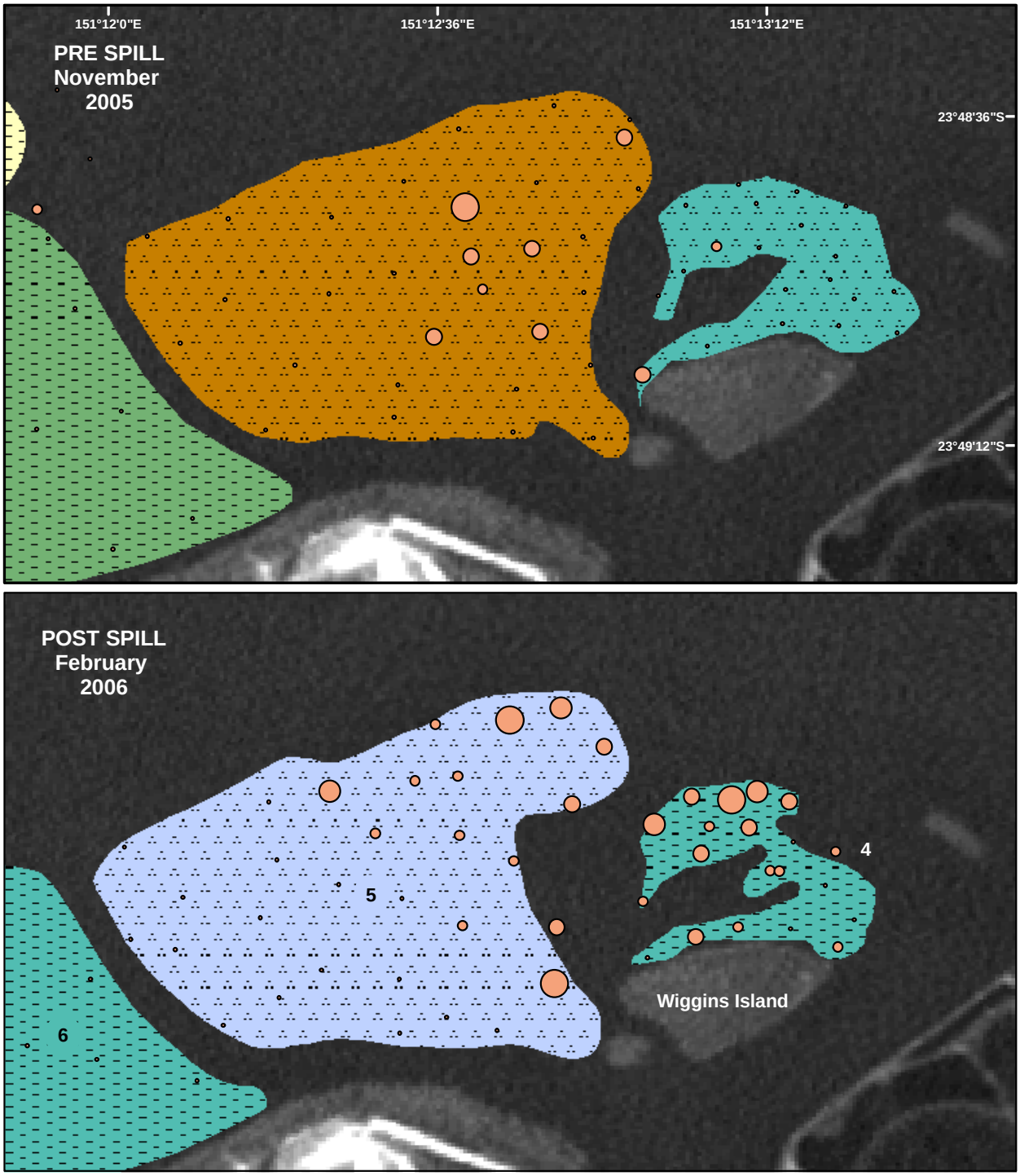
* This is not a complete seagrass distribution, only selected seagrass monitoring meadows displayed

Background: Landsat ETM + Panchromatic 24 July 2002

Map 4. Comparison of algal cover near Wiggins Island pre & post oil spill



Background: Landsat ETM + Panchromatic 24 July 2002

Legend

Percent algal cover*
- 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

* Algal cover recorded at seagrass characterisation sites

Community type
- Light *Halophila ovalis*
- Light Halophila ovalis with Zostera capricorni
- Light Zostera capricorni / Halophila ovalis
- Moderate *Halophila ovalis* with *Zostera capricorni*

Cover
- Isolated patches
- Aggregated patches

N

0 0.25 0.5
Kilometres

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

Source: Taylor, H.A., Rasheed, M.A. and Thomas, R. 2006. Port Curtis post oil spill seagrass assessment, Gladstone - February 2006. DPI&F Information Series QI06046 (DPI&F, Cairns).

Funded by Central Queensland Ports Authority, CRC Reef Research Centre and the Queensland Department of Primary Industries and Fisheries.

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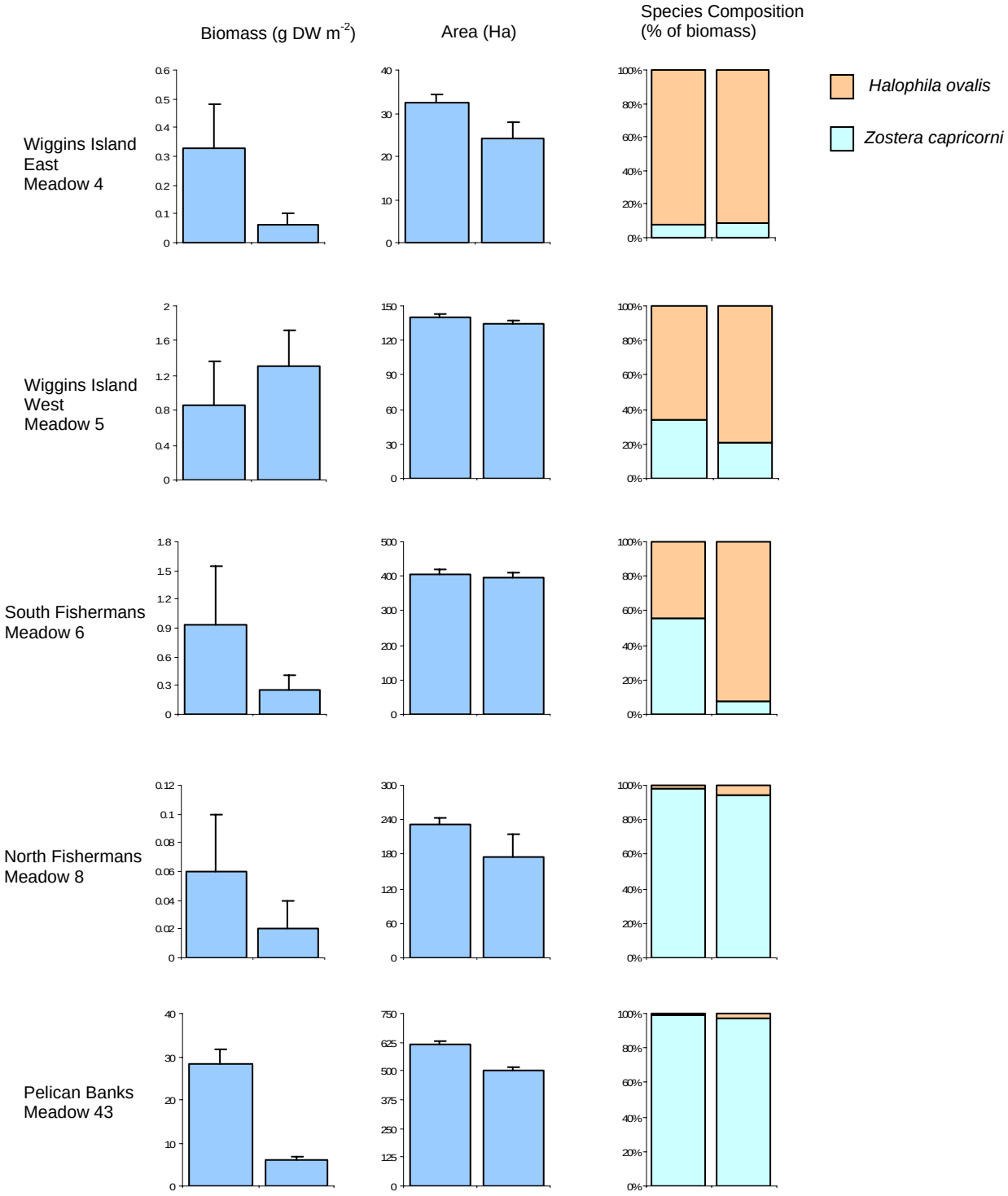

Figure 1 Changes in biomass, area and species composition for monitoring meadows in 2002, 2004 & 2005 (Biomass error bars = SE; Area error bars = "R" reliability estimate)

DISCUSSION

The February 2006 post-spill seagrass assessment indicated that intertidal seagrass meadows in Port Curtis had not been significantly affected by the 'Global Peace' oil spill that occurred on the 24th of January 2006. Although most of the meadows showed a significant decline in biomass and area, these changes were consistent with similar declines that occurred in meadows outside of the oil spill area. This suggests that there were other seasonal or climatic factors causing these declines.

While no major changes to seagrass seemed to have occurred as a result of the oil spill there may have been some minor impacts. Immediately following the oil spill, a team from Central Queensland University (CQU) undertook a reconnaissance of mangroves and seagrass beds located within the spill extent. They noted an area of seagrass on the Wiggins Island West meadow that contained oil from the spill, and seagrass leaves appeared to have had lost their pigmentation (Leonie Anderson, pers. com). The area where the oil was sited corresponded to a section on the eastern boundary of the meadow that was found to have contracted in our survey 4 weeks later. While it was possible that this minor loss of seagrass was due to the oil, the change in area was small and well within the normal expected range for the meadow.

It was likely that tidal conditions at the time of the oil spill may have protected seagrasses from the full effects of the spill. The most serious known effects of oil on seagrasses have been observed when leaves of intertidal plants have been exposed to direct contact with oil (Jacobs, 1980; Durako *et al*. 1993). The oil spill at Gladstone occurred on a high neap tide, and it is likely that the intertidal meadows were not exposed until 2-3 days after the spill. By this point in time, the oil would have approached its maximum spread, and evaporation and dissolution processes were likely to have reduced the quantity of remaining oil in the area to very low levels (Zieman *et al*. 1984).

The increased presence of macro-algae on the Wiggins Island East and West meadows was possibly related to the oil spill. These were the closest seagrass meadows to the site of the oil spill and were likely to have experienced the greatest concentrations of oil. A bloom of algae on intertidal seagrass beds has been documented in previous oil spill cases (e.g. Jacobs, 1980; Jackson *et al*. 1989; Ralph & Burchett, 1998). The algae bloom has been attributed to factors such as an increase in nutrients released from oil-killed organisms, stimulating compounds in oil, and a reduction in herbivore presence. Increased growth of algae can often lead to a smothering of seagrasses (e.g. Bulthuis & Woelkerling, 1983; Cambridge *et al*. 1986) and is often a sign of a reduction or change in water quality. Studies that have monitored oil impacted seagrass meadows have documented that algal levels may return to pre-spill levels approximately 12 months after the event. The increase in algae may also have been due to factors other than oil as algae had been increasing in sections of the Wiggins Island banks prior to the survey, possibly as a result of local anthropogenic inputs into the Calliope River and abnormally high water temperatures in the region (Rasheed *et al.* 2006).

The fact that losses of seagrass biomass in the spill area were consistent with changes at Pelican Banks and Rodds Bay (outside of the spill area) indicated that the oil spill was not responsible for the observed declines. It was most likely that the 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). This seasonal pattern is likely to be driven by a combination of climatic and environmental parameters, particularly rainfall, water and air temperature, and solar irradiance. While the

declines observed in Gladstone between October 2005 and February 2006 generally fit the accepted model of seasonal variation, the timing of the declines was on the early side. The early arrival of seasonal seagrass declines may not have been isolated to Gladstone with evidence with results from the Seagrass-Watch monitoring program indicating other central (eg Mackay) and southern (eg Hervey Bay) Queensland locations have experienced similar declines (McKenzie pers. com. , www.seagrasswatch.org). The un-expected severity of the declines in intertidal *Zostera* meadows in Gladstone and other central Queensland locations may be related to atypical climate conditions such as rainfall, wind and water temperature occurring in the region between October 2005 and February 2006.

Results of the 2005 annual long term monitoring survey in Gladstone indicated that factors other than regional and local climate may also have been affecting seagrass growth prior to the oil spill for some of the meadows that were assessed. For a detailed report see Rasheed *et al*. (2006). Some of the factors that were highlighted included anthropogenic inputs into the Calliope River and runoff from the Fishermans Landing reclamation.

The decline in density for the intertidal *Zostera capricorni* meadows may have implications to local and regional fisheries. *Zostera capricorni* communities 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). In addition, oil spills have been documented to cause a prominent decrease in the abundance of invertebrates, even when seagrass communities themselves have not been affected (Jacobs 1980; Zieman *et al.* 1984; Jackson *et al.* 1989; Baca *et al*. 1996). 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).

Results of the first post-spill seagrass assessment indicated that the ‘Global Peace’ oil spill did not have a significant impact on seagrasses in Gladstone. Declines in seagrass meadows that were recorded were most likely attributable to natural seasonal variation, coupled with a combination of other climatic factors and anthropogenic impacts. However, the long term effects of the oil on the seagrass community are not clear. Oil was seen coating mangroves and sediments south of Fishermans Landing and on Wiggins Island (Karen Danaher pers. com.). It is possible that this oil may be released onto the seagrass beds in the months following our assessment potentially impacting on the seagrass meadows. Delayed effects of the oil spill on seagrass may be detected in the next full seagrass monitoring event scheduled for October 2006.

REFERENCES

Baca, B.J., Snedaker, S.C., Dodge, R.E., Knap, A.H. & Sleeter, T.D. (1996). The effects of crude oil and dispersed crude oil on tropical ecosystems: Long-term seagrass, mangrove, and coral studies. *Oceans Conference Record (IEEE)* **1**:469-486.

Bulthuis, D.A. and Woelkerling, W.J. (1983). Biomass accumulation and the shading effects of epiphytes on leaves of the seagrass, *Heterozostera tasmanica*, in Victoria, Australia. *Aquatic Botany* **16**:137-148.

Cambridge, M.L., Chiffings, A.W., Brittan, C., Moore, L. and McComb, A.J. (1986). The loss of seagrass in Cockburn Sound, Western Australia. II. Possible causes of seagrass decline. *Aquatic Botany* **24**:269-285.

Durako, M.J., Kenworthy, W.J., Fatemy, S.M.R., Valavi, H. & Thayer, G.W. (1993). Assessment of the toxicity of Kuwait crude oil on the photosynthesis and respiration of seagrasses of the Northern Gulf. *Marine Pollution Bulletin* **27**:223-227.

Jackson, J.C.B., Cubit, J.D., Keller, B.D., Batista, V., Burns, K., Caffey, H.M., Caldwell, R.L., Garrity, S.D., Getter, C.D., Gonzalez, C., Guzman, H.M., Kaufmann, K.W., Knap, A.H., Levings, S.C., Marshall, M.J., Steger, R., Thompson, R.C. and Weil, E. (1989). Ecological effects of a major oil spill on Panamanian Coastal marine Communities. *Science* **243**:7-44.

Jacobs, R. P. W. M. (1980). Effects of the 'Amoco Cadiz' oil spill on the seagrass community at Roscoff with species reference to benthic infauna. *Marine Ecology Progress Series* **2**:207-212.

Lanyon, J.M. & Marsh, H. (1995). Temporal changes in the abundance of some tropical intertidal seagrasses in North Queensland. *Aquatic Botany* **49**:217-237.

McKenzie, L.J. (1994). Seasonal changes in biomass and shoot characteristics of a *Zostera capricorni* Aschers. dominant meadow in Cairns Harbour, North Queensland. *Australian Journal of Marine and Freshwater Research* **45**:1337-1352.

Ralph, P.J. & Burchett, M.D. (1998). Impact of the petrochemicals on the photosynthesis of *Halophila ovalis* using chlorophyll fluorescence. *Marine Pollution Bulletin* **36**:429-436.

Rasheed, M.A., McKenna, S.A. and Thomas, R. (2005). Long-term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone - October/October 2004. *DPI&F Information Series QI05032* (DPI&F, Cairns), 27 pp.

Rasheed, M.A., Taylor, H.A. and Thomas, R. (2006). Long-term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone - October 2005. *DPI&F Information Series QI06030* (DPI&F, Cairns), 30 pp.

Rasheed, M.A., Thomas, R., Roelofs, A.J. Neil, K.M. and Kerville, S.P. (2003). Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey, October/December 2002. *DPI Information Series QI03058* (DPI, Cairns), 47 pp.

Rasheed, M.A. and Thomas, R. (2002). Seagrass and marine resources of the Upstart Bay Dugong Protection Area. In 'Seagrass and the marine resources in the dugong protection areas of Upstart Bay, Newry Region, Sand Bay, Llewellyn Bay, Ince Bay and the Clareview Region: April/May 1999 and October 1999'. (Eds. Coles RG, Lee Long WJ, McKenzie LJ and Roder CA). Research Publication No. 72 (Great Barrier Reef Marine Park Authority, Townsville). pp 25-54.

Watson, R.A., Coles, R.G., and Lee Long, W.J. (1993). Simulation estimates of annual yield and landed value for commercial penaeid prawns from a tropical seagrass habitat, northern Queensland, Australia. *Australian Journal of Marine and Freshwater Research* **44**(1):211-220.

Zieman, J.C., Orth, R., Phillips, R.C., Thayer, G. & Thoraug, A. (1984). The effect of oil on seagrass ecosystems. In 'Restoration of habitats impacted by oil spills'. (Eds. Cairns Jr, J. & Buikema Jr, A.L.). Butterworth Publishers. pp 37-64.

APPENDIX 1

Results of one-way ANOVA for mean above ground biomass versus year for the five seagrass meadows assessed in Port Curtis (2005 and 2006) (* significant difference in biomass between years)

Meadow 4	**DF**	**SS**	**MS**	**F**	**P**
Between Years	1	0.25161	0.25161	1.57	0.218
Within Years	37	5.92745	0.1602		
Total	38	6.17906			
Meadow 5					
Between Years	1	0.24025	0.24025	0.39	0.5327
Within Years	57	34.7477	0.60961		
Total	58	34.9879			
Meadow 6					
Between Years	1	2.19956	2.19956	5.85	**0.0178***
Within Years	81	30.4432	0.37584		
Total	82	32.6427			
Meadow 8					
Between Years	1	0.17	0.17028	5.23	**0.0256***
Within Years	63	2.05081	0.03255		
Total	64	2.22109			
Meadow 43					
Between Years	1	208.605	208.605	43.07	**<0.0001***
Within Years	107	518.209	4.84308		
Total	108	726.814			

NB: All data was square root transformed

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

Meadow 4	
Year	**Mean Biomass**
2005	0.33 a
2006	0.06 a

Meadow 5	
Year	**Mean Biomass**
2005	0.86 a
2006	1.3 a

Meadow 6	
Year	**Mean Biomass**
2005	0.94 a
2006	0.25 b

Meadow 8	
Year	**Mean Biomass**
2005	0.06 a
2006	0.02 b

Meadow 43	
Year	**Mean Biomass**
2005	28.3 a
2006	5.86 b