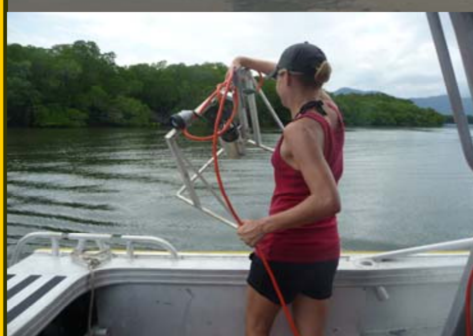
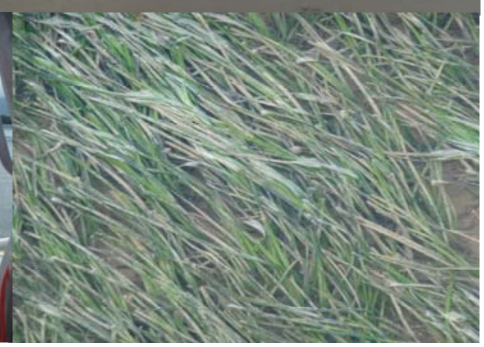
Long term seagrass monitoring in Cairns Harbour and Trinity Inlet – October/December 2008





Skye McKenna
Michael Rasheed
Richard Unsworth
Helen Taylor
Kathryn Chartrand
Tonia Sankey

Department of Employment, Economic Development and Innovation

Queensland Primary Industries and Fisheries
Marine Ecology Group
Northern Fisheries Centre

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McKenna, S.A., Rasheed, M.A., Unsworth, R.K.F, Taylor, H.A., Chartrand, K.M., and Sankey, T.L.

Department of Employment, Economic Development and Innovation
PO Box 5396 Cairns Qld 4870

Queensland Primary Industries and Fisheries
Marine Ecology Group
Northern Fisheries Centre

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Seagrass illustrations are by Ruth Berry.

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EXECUTIVE SUMMARY

This report details results from the October/December 2008 seagrass monitoring survey for Cairns Harbour and Trinity Inlet and discusses changes in inter-annual seagrass meadow dynamics. Following a baseline survey of Cairns Harbour and Trinity Inlet, a monitoring program was established in December 2001 that annually examines selected representative seagrass meadows in the area. Results of the program are used to ensure port and other human activities are having a minimal impact on the marine environment by using seagrasses as a key indicator of marine environmental health. The program is also used to assess the status of these important fisheries habitats and forms part of a network of seagrass assessment established throughout Queensland.

Results of the 2008 monitoring survey indicate that seagrass habitat in Cairns Harbour and Trinity Inlet was in a fair condition. The density of intertidal monitoring meadows had either increased significantly or remained relatively stable compared to the previous year of monitoring, a positive change from three consecutive years of biomass decline. Meadow area remained at similar levels to the previous year for the intertidal meadows. The opposite was true for the small subtidal monitoring meadows within Trinity Inlet where some significant declines in both biomass and area were recorded. Density and distribution of these small Inlet meadows has been highly variable over the past few years and they are particularly vulnerable to additional stresses in the future.

The observed changes in biomass and distribution of the Cairns monitoring meadows have been linked to regional and local climate conditions. However the current lack of marine environmental data at the meadow level makes interpretation of the observed changes in Cairns Harbour and Trinity Inlet seagrass difficult. Several enhancements to the monitoring program are suggested that would strengthen the ability to separate out the causes of seagrass change and better inform the management and protection of seagrasses in the future. These include:

- Assessing light and temperature at the meadow level (in situ loggers)
- Examining reproductive and recovery capacity of the meadows
- Expanding the geographic scope of the area examined to a broader region and incorporating additional monitoring meadows
- Linking water quality assessment with seagrass condition

The seagrass meadows of Cairns Harbour and Trinity Inlet have been identified as one of four regions in the Great Barrier Reef World Heritage Area (GBRWHA) facing the highest level of risk from anthropogenic impacts. Continued impacts from natural events have the capacity to reduce the resilience of seagrasses in the region due to compounding effects of current human activities such as urbanisation and coastal and port development. The vulnerable state of some seagrasses in Trinity Inlet underscores the value of continued monitoring to ensure the long term viability of these marine habitats.

INTRODUCTION

Background

Seagrass forms a key ecological habitat in Cairns Harbour and Trinity Inlet and represents a significant component of the region's seagrass resources (Trinity Inlet Management Plan 1999). The seagrass meadows are mostly within the Trinity Inlet Fish Habitat Area, which encompasses 1200 ha of tidal waters including seagrass, mangrove and salt marsh habitats. The State of Trinity Inlet Report and Ecological Overview (1997) recognised seagrass as crucial to maintaining biodiversity and fisheries productivity in the inlet and identified it as a key habitat type for monitoring. The first surveys of seagrass distribution, species diversity and abundance in Cairns Harbour were undertaken as part of a broad-scale survey in February 1988 (Coles *et al.* 1993). In December 1993, the Cairns Harbour and Trinity Inlet region was re-surveyed (Lee Long *et al.* 1996) and subsequent detailed mapping of Ellie Point seagrasses occurred in December 1996 (Rasheed and Roelofs 1996).

The importance of seagrass as a structural component of coastal ecosystems is well established (Hemminga and Duarte 2000). On a global scale, seagrass/algal beds have been rated the third most valuable ecosystem (on a per hectare bases) for their efficiency in nutrient trapping and cycling, preceded only by estuaries and swamps/flood plains (Constanza *et al*. 1997). Seagrass meadows are also vital nursery habitat for commercial and recreational fisheries species, provide food for dugong and turtle and provide a significant component of the primary productivity that underpins the coastal marine ecosystem. In recognition of their value and the potential threats in the region, Trinity Inlet Waterways (TIW) and Cairns Ports (now Far North Queensland Ports Corporation Limited (FNQPCL)) in partnership with Queensland Primary Industries and Fisheries (QPIF) established an annual long term seagrass monitoring program in 2001. The goals of the program were to use seagrass condition as an indicator of the health of Cairns Port and Trinity Inlets' marine environment and as a tool to ensure that port activities and development were having a minimal impact on these habitats.

The wide distribution of seagrasses in Queensland and their capacity to show measurable, short-term responses to changes in water quality make them ideal candidates for monitoring the health of marine and coastal environments. In December 2001, a baseline survey of all seagrasses in Cairns Harbour and Trinity Inlet was conducted (Campbell *et al.* 2002). From this baseline survey, five seagrass meadows were initially identified as suitable for a long term seagrass monitoring program with a sixth meadow added in 2006. The six meadows selected were representative of the range of seagrass species and habitat types (intertidal and subtidal) that occur within the Cairns Harbour and Trinity Inlet monitoring area. These meadows also encompassed the seagrass meadows most likely to be impacted from port and other anthropogenic impacts.

Annual monitoring conducted from 2002 to 2007 has revealed some significant changes in seagrasses from the baseline survey. Generally, climatic factors as well as the local characteristics of the seagrass population, and physical characteristics of Cairns Harbour and Trinity Inlet were the most likely causes of change. The long term monitoring program has begun to reveal the ranges of natural variability for these seagrasses as well as some of the associations between seagrass abundance and changes in climate.

The collaborative monitoring program between TIW, FNQPCL and QPIF continued in 2008. Results of the long term seagrass monitoring surveys are used by FNQPCL to assess and demonstrate the marine environmental health of the port and to satisfy environmental monitoring requirements as part of the port's long term dredge management plan and by management agencies to assess the status and condition of seagrass resources in the region.

Objectives

This report presents the results of the annual long term monitoring survey conducted in October & December 2008. The objectives of the 2008 long term seagrass monitoring of Cairns Harbour and Trinity Inlet were to:

1. Map the distribution and abundance of selected seagrass monitoring meadows;
2. Compare results of monitoring with previous seagrass surveys and assess any changes in seagrass distribution and abundance in relation to natural events or anthropogenic port and catchment activities
3. Place observed changes within a regional and state-wide context
4. Discuss the implications of monitoring results for the overall health of Cairns Harbour and Trinity Inlet's marine environment and port and dredging activity.

METHODOLOGY

Sampling Methods

Surveys of the monitoring meadows in Cairns Harbour and Trinity Inlet were conducted in October and December 2008. Intertidal areas were surveyed from helicopter on the 15th October 2008 and subtidal areas were surveyed by boat on the 1st and 2nd December 2008. Five core seagrass meadows from the 2001 baseline and 2002 monitoring surveys (Campbell *et al*. 2002; 2003) were selected for long term monitoring. These meadows represented the range of seagrass community types found in the area and also captured areas of interest and likely impact.

At each survey site within the monitoring meadows, seagrass meadow characteristics, including seagrass species composition, above-ground biomass, percent algal cover, depth below mean sea level (MSL; for subtidal meadows), sediment type, time and position fixes (GPS; ±5m) were recorded. A detailed description of the methods used to characterize the monitoring meadows is provided in Campbell *et al*. (2002; 2003).

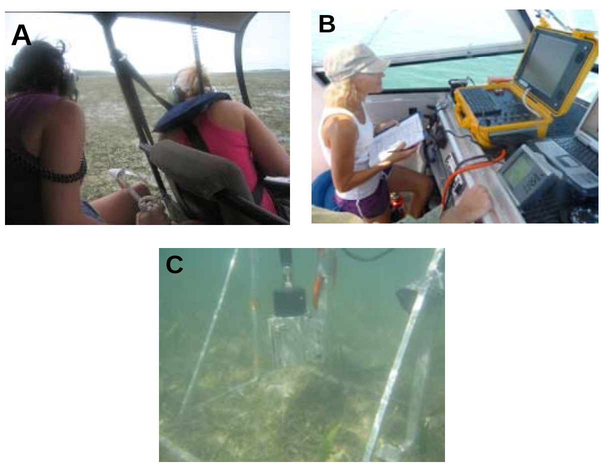


Plate 1. Seagrass methodology utilising (A) helicopter aerial surveillance and (B & C) boat based CCTV surveillance

Habitat Mapping and Geographic Information System

All survey data was incorporated into the Cairns Harbour Geographic Information System (GIS). Three seagrass GIS layers were created in ArcGIS:

- **Habitat characterisation sites** – point data containing above-ground biomass (for each species), dbMSL, sediment type, time, latitude and longitude from GPS fixes, sampling method and any comments.
- **Seagrass meadow biomass and community types** – area data for seagrass meadows with summary information on meadow characteristics. Seagrass community types were determined according to species composition from nomenclature

developed for seagrass meadows of Queensland (Table 1). Abundance categories (light, moderate, dense) were assigned to community types according to above-ground biomass of the dominant species (Table 2).

Table 1. Nomenclature for seagrass community types in Cairns Harbour and Trinity Inlet, October/December 2008

Community type	Species composition
Species A	Species A is 90-100% of composition
Species A with Species B	Species A is 60-90% of composition
Species A with Species B/Species C	Species A is 50% of composition
Species A/Species B	Species A is 40-60% of composition

Table 2. Density categories and mean above-ground biomass ranges for each species used in determining seagrass community density in Cairns Harbour and Trinity Inlet, October/December 2008.

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

- **Seagrass landscape category** – area data showing the seagrass landscape category determined for each meadow :

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

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

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

Each seagrass meadow was assigned a mapping precision estimate (±m) based on the mapping methodology utilised for that meadow (Table 3). Mapping precision estimates ranged from 5m for isolated subtidal seagrass meadows to 15-20m for larger intertidal 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 aerial photographs onto basemaps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 3. Mapping precision for seagrass meadow boundaries in Cairns Harbour and Trinity Inlet, October/December 2008

Mapping precision	Mapping methodology
5m	Small meadows in Trinity Inlet Meadow boundary interpreted from camera/grab sites; Recent aerial photography aided in mapping.
15-20m	Meadow boundaries determined from a combination of helicopter and camera/grab and/or diver surveys; Inshore boundaries mapped from helicopter; Offshore boundaries interpreted from survey sites and aerial photography; Relatively high density of mapping and survey sites;

RESULTS

Seagrass species, distribution and abundance in October/December 2008

A total of 369 habitat characterisation sites were surveyed of which 67% (247 sites) had seagrass present. Five seagrass species (from three families) were identified in the six monitoring meadows (for a complete list of species found in the survey area see Campbell *et al*. (2002)):

Family CYMODOCEACEAE Taylor:
Halodule uninervis (wide and thin leaf morphology) (Forsk.) Aschers. in Boissier
Cymodocea serrulata (R. Br.) Aschers and Magnus

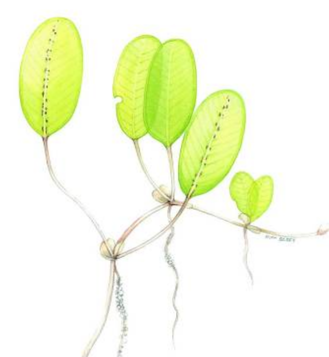
Family HYDROCHARITACEAE Jussieu:
Halophila ovalis (R.Br) Hook. F.
Halophila decipiens Ostenfeld

Family ZOSTERACEAE Drummortier:
Zostera capricorni Aschers.

Halodule uninervis


Cymodocea serrulata


Zostera capricorni


Halophila ovalis


Halophila decipiens

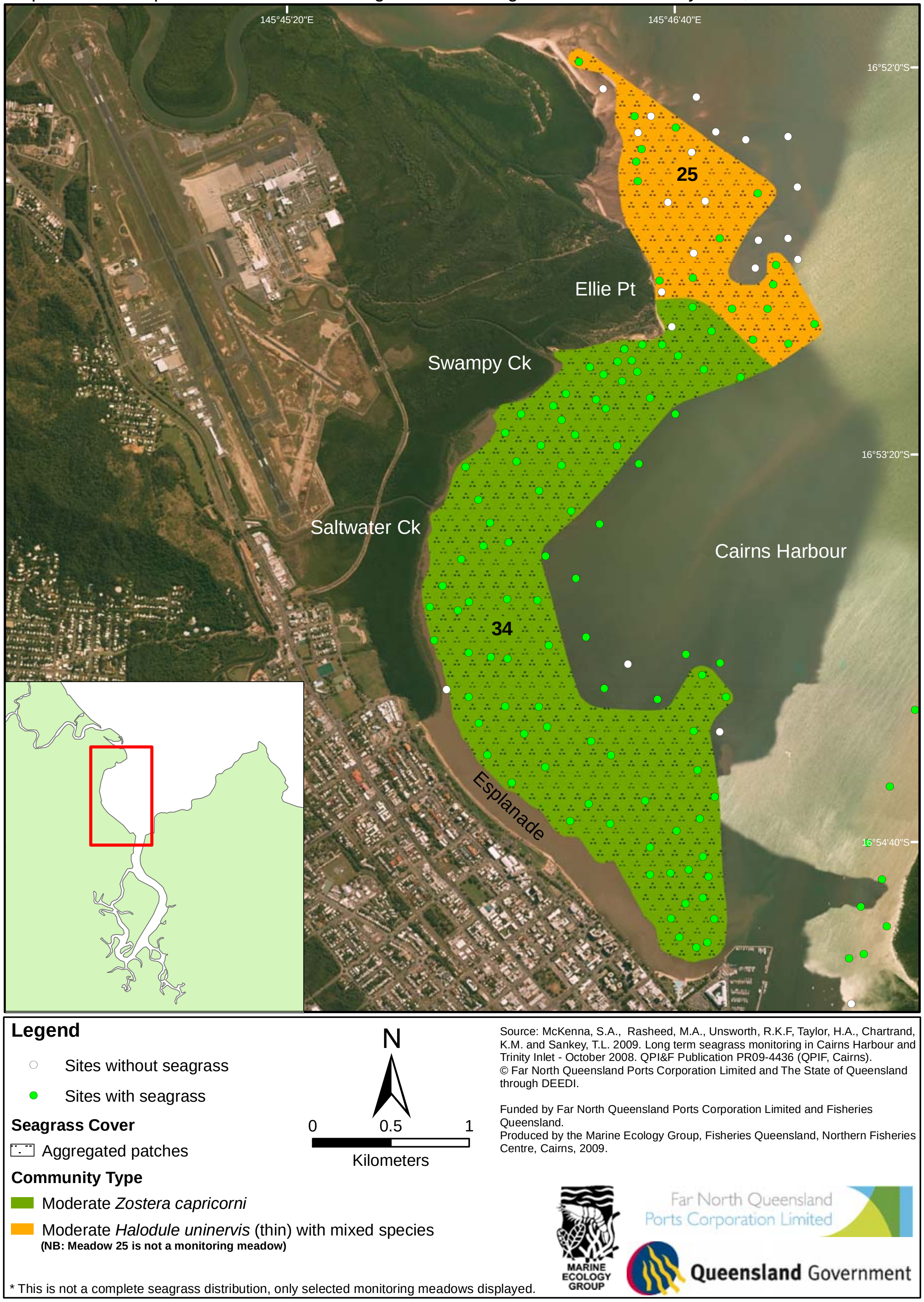
A total of 1382.9 ± 60.8 hectares of seagrass habitat was mapped in the six monitoring meadows (Maps 1, 2 & 3; Table 4). Meadow areas ranged from 0.6 ha to 803 ha (Table 4) with the smallest meadows located in Trinity Inlet (Inlet and Redbank meadows) and the largest meadows in Cairns Harbour (Esplanade and Bessie Point meadows).

Mean above-ground biomass for the six monitoring meadows ranged from 0.4 to 48.4g DW m^{-2} and was largely dependent on the mix of species present (Table 4). Meadows dominated by *Zostera capricorni* and *Halodule uninervis* were higher in above-ground biomass than *Halophila ovalis/Halophila decipiens* dominated meadows (Table 4).

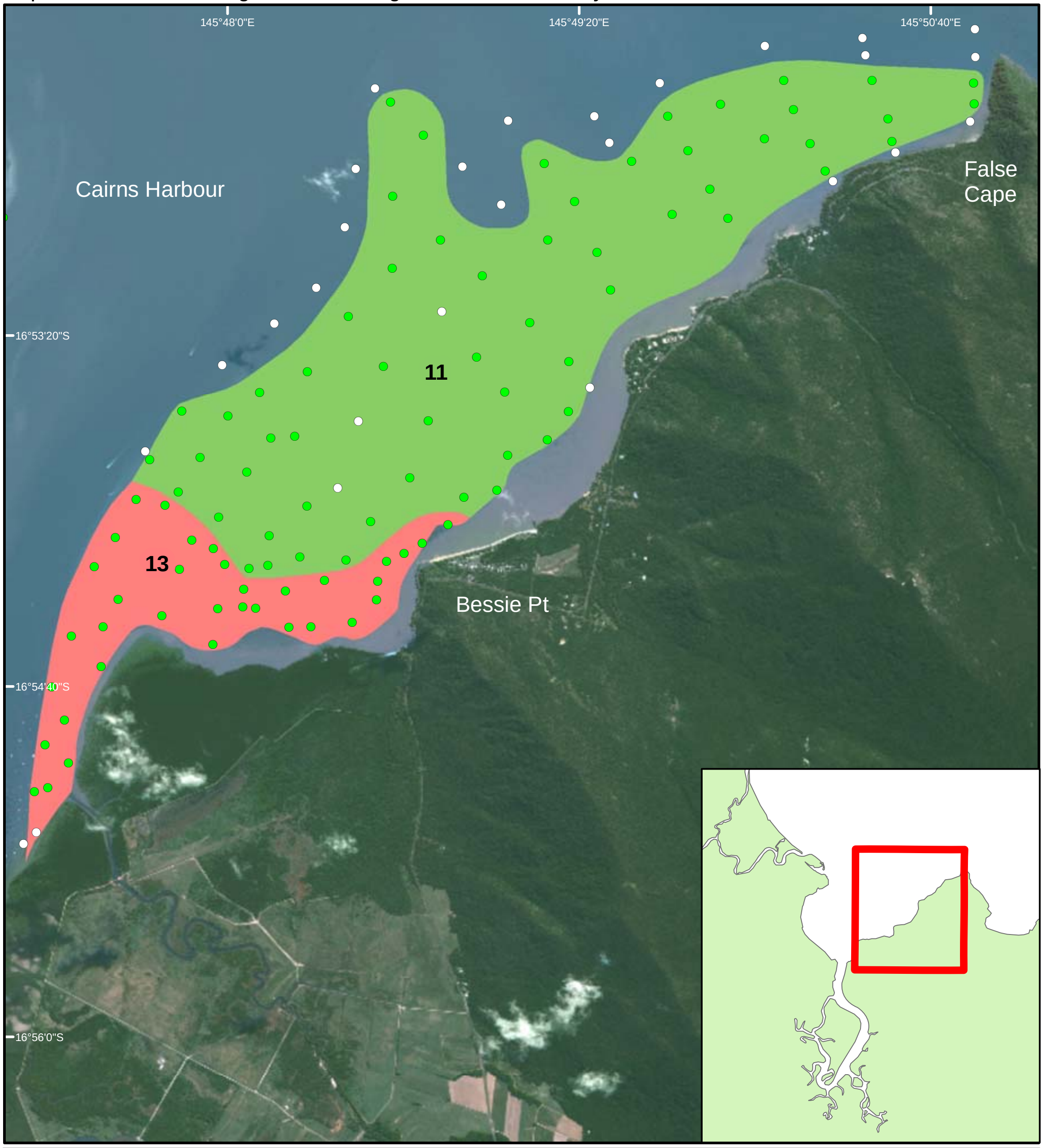
The seagrass landscape within the monitoring meadows varied. The Bessie Point and Redbank (*Zostera capricorni*) meadows had a continuous cover of seagrass, while the Esplanade-Ellie Point and the Redbank (*Halophila ovalis*) meadow were comprised of aggregated patches of seagrass (Maps 1, 2 & 3; Table 5). The Inlet (*Halophila ovalis*) meadow was extremely patchy with only isolated patches of seagrass present (Map 3; Table 5).

Seagrass density in the Bessie Point meadow was classified as “dense” cover for the species while the Esplanade-Ellie Point and both Redbank meadows were classified as having a “moderate” density of seagrass. The patchy Inlet (*Ho*) meadow had a “light” cover of seagrass (Table 5).

Map 1. Cairns Esplanade to Ellie Point seagrass monitoring meadow and survey sites, October 2008



Map 2. Bessie Point seagrass monitoring meadow and survey sites, October/December 2008



Legend

Sites without seagrass

Sites with seagrass

Seagrass Cover

Continuous cover

Community Type

Dense *Halodule uninervis* (thin)

Light *Zostera capricorni* with mixed species

(NB: Meadow 13 is not a monitoring meadow)

N

0 0.5 1

Kilometers

Source: McKenna, S.A., Rasheed, M.A., Unsworth, R.K.F, Taylor, H.A., Chartrand, K.M. and Sankey, T.L. 2009. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - October 2008. QPI&F Publication PR09-4436 (QPIF, Cairns).

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

Map 3. Trinity Inlet and Redbank Creek seagrass monitoring meadow and survey sites, December 2008

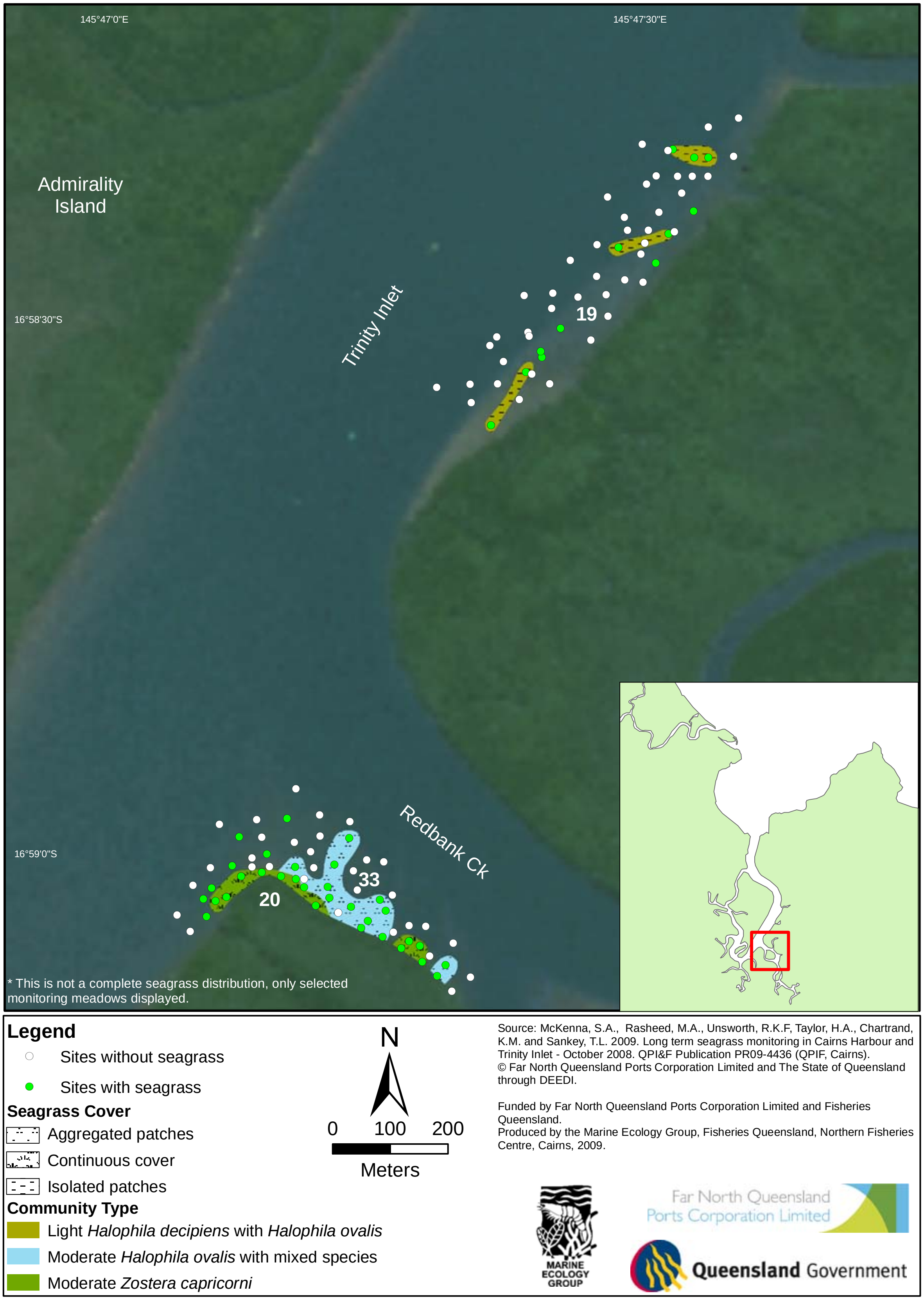

Table 4. Seagrass mean above-ground biomass (g DW m^{-2}) and area (ha) for monitoring meadows in Cairns Harbour and Trinity Inlet, 2001-2008 (% values indicate change in area from previous survey; ± R = reliability estimate).
Meadows indicated by a * were found to show significant differences in biomass between years (see Appendix 1).

Meadow	Area (ha) (R)							
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Esplanade to Ellie Pt. (34)	307.3 ± 10.0	258.5 ± 12.2 (-16%)	280.4 ± 11.7 (+8%)	300.8 ± 12.3 (+7%)	328.91 ± 6.47 (+9%)	370.8 ± 6.5 (+13%)	418.9 ± 6.4 (+13%)	379.3 ± 19.2 (-9.5%)
Bessie Pt. * (11)	351.8 ± 133.9	451.2 ± 137.3 (+28%)	473.5 ± 148.8 (+5%)	659.3 ± 158.5 (+39%)	820.4 ± 86.6 (+24%)	868.1 ± 81.6 (+6%)	899.7 ± 81.3 (+4%)	803.3 ± 25 (-11%)
South Bessie Pt. Meadow (13)	NP	NP	NP	Included in Meadow 11	Included in Meadow 11	73.0 ± 6.3	162.8 ± 8.4 (+123%)	197.7 ± 15.4 (+21%)
Inlet (Ho) (19)	1.7 ± 0.6	4.9 ± 1.6 (+195%)	6.9 ± 1.7 (+4%)	5.2 ± 1.5 (-25%)	2.3 ± 1.3 (-56%)	1. 8 ± 1.3 (-23%)	2.9 ± 1.4 (+60%)	0.6 ± 0.4 (-79%)
Redbank (Zc) (20)	1.7 ± 1.1	0.1 ± 0.05 (-94%)	0.7 ± 0.4 (+600%)	0.8 ± 0.4 (+14%)	0.4 ± 0.1 (-50%)	0.5 ± 0.2 (+20%)	0.8 ± 0.2 (+60%)	0.6 ± 0.4 (-25%)
Redbank (Ho) (33)	NP	4.0 ± 1.4[+]	4.4 ± 1.3 (+9%)	3.9 ± 1.2 (-11%)	2.8 ± 1.0 (-28%)	1.4 ± 1.1 (-50%)	2.4 ± 1.2 (+71%)	1.4 ± 0.4 (-42%)
TOTAL (monitoring meadows only)	**662.5 ± 145.7**	**718.9 ± 152.6**	**765 ±163.9**	**970 ± 173.9**	**1154.8 ± 95.5**	**1315.5 ± 96.9**	**1487.5 ± 98.9**	**1382.9 ± 60.8**
Meadow	**Mean biomass ± SE (g DW m^{-2})**							
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Esplanade to Ellie Pt.* (34)	36 ± 3.2	18 ± 1.7	46.2 ± 4.1	81.6 ± 6.7	71.6 ± 5.3	47.4 ± 3.4	33.2 ± 2.9	48.4 ± 4
Bessie Pt.* (11)	2.0 ± 0.4	6.4 ± 0.8	4.4 ± 0.4	5.8 ± 0.3^	15.6 ± 1.5	12.7 ± 1.7	6.9 ± 0.5	7.5 ± 0.4
South Bessie Pt. Meadow (13)	NP	NP	NP	Included in Meadow 11	Included in Meadow 11	46.3 ± 9.0	50.9 ± 10.4	24 ± 4
Inlet (Ho)* (19)	6.6 ± 2.1	0.4 ± 0.1	3 ± 0.5	1.8 ± 0.3	3.6 ± 1.2	0.1 ± 0.0	2.3 ± 0.3	0.4 ± 0.2
Redbank (Zc) * (20)	4.5 ± 4.1	3.1 ± 0.6	50.1 ± 9.4	61.5 ± 12.1	15.1 ± 7.4	11.9 ± 2.9	14.1 ± 3.5	37.5 ± 6.8
Redbank (Ho) * (33)	NP	0.8 ± 0.1	5.2 ± 1.1	1.3 ± 0.2	2.2 ± 0.4	0.3 ± 0.0	2.1± 0.3	2.1 ± 0.4

[+] Percent change not shown because of insufficient biomass samples in 2001 for statistical analyses
^ The one site containing *Cymodocea serrulata* was omitted from Bessie Point biomass analyses
NP = meadow not present
(Ho = *Halophila ovalis*; Zc = *Zostera capricorni*)

Table 5. Description of Cairns Harbour and Trinity Inlet seagrass monitoring meadows from the October/December 2008 monitoring survey.

	Meadow	Location	Meadow ID	Number of Sites	Habitat Type	Meadow Cover	Meadow Description
Cairns Harbour	**Esplanade-Ellie Pt.**	Cairns Harbour	34	72	Intertidal	Aggregated patches	Moderate *Zostera capricorni*
	Bessie Point	Cairns Harbour	11	50	Subtidal to intertidal	Continuous	Dense *Halodule uninervis* (thin)
	South Bessie Point	Cairns Harbour	13	36	Intertidal	Continuous	Light *Zostera capricorni* with mixed species
Trinity Inlet	**Inlet (Ho)**	Trinity Inlet	19	16	Subtidal	Isolated patches	Light *Halophila decipiens* with *Halophila ovalis*
	Redbank (Zc)	Trinity Inlet	20	16	Intertidal	Continuous	Moderate *Zostera capricorni*
	Redbank (Ho)	Trinity Inlet	33	26	Subtidal	Aggregated patches	Moderate *Halophila ovalis* with mixed species

(Ho = *Halophila ovalis*; Zc = *Zostera capricorni*)

COMPARISON WITH PREVIOUS MONITORING SURVEYS

In 2008, seagrass biomass remained below historical peak densities (2001 to present) but was generally similar to 2007 values (Table 4; Figure 1). There were substantial declines in area of the small subtidal *Halophila* meadows in Trinity Inlet (Maps 4-6; Table 4; Figure 1). These meadows have continued to decline since 2003 with the Inlet (*Ho*) meadow recording its smallest distribution in 2008 since monitoring began (Maps 4-6; Table 4; Figure 1). The area of all other monitoring meadows generally remained within the range of previously recorded values (2001 to present).

The small monitoring meadows in Trinity Inlet, particularly the two subtidal *Halophila* meadows (meadows 19 & 33) have been highly variable in both density and distribution throughout the monitoring program. In 2006 the biomass and area of these meadows reached the lowest levels recorded in the monitoring program (Table 4; Figure 1). By 2007 these meadows showed signs of recovery increasing in area and significantly increasing in biomass (Table 4; Figure 1). In the current survey, the Inlet (*Ho*) meadow significantly declined again in biomass to densities similar to those that were observed in 2002 & 2006 (Table 4; Figure 1; Appendix 1). The meadow had also substantially contracted in area in 2008 to such an extent that it was only a collection of small isolated patches of seagrass. This decline in size resulted in the lowest recorded area since monitoring began in 2001 (Maps 3 & 6; Table 4; Figure 1).

In 2007, the Inlet (*Ho*) meadow underwent a species shift from *Halophila ovalis* to *Halophila decipiens*, a species that typically dominates in deeper areas and in low light conditions (Ralph *et al*. 2007; Figure 1). *Halophila decipiens* continued to dominate this meadow in 2008 when despite the record decline in area, the depth penetration of this meadow was at its deepest since monitoring began (4.4m below MSL; Table 6).

The other *Halophila* dominated meadow in Trinity Inlet (Redbank (*Ho*) meadow) did not change in biomass from 2007 to 2008, although loss in area did occur (Table 4; Figure 1). The loss of area in this subtidal meadow generally occurred at the deepest margins of the meadow, resulting in the depth penetration decreasing from 3.0m to 1.8m below MSL (Table 6). In addition, the Redbank (*Ho*) meadow fragmented into two separate areas, a trend that was noted in 2006 when biomass and area of this meadow was also low. This meadow has been the most naturally variable of all the monitoring meadows in the program and was not present in 2001 when monitoring began (Map 6).

In contrast to the subtidal Inlet meadows, the biomass of the intertidal Redbank (*Zc*) meadow increased in 2008 (Table 4; Figure 1). The density of this meadow significantly increased in 2008 compared to the previous three years of monitoring surveys (Table 4; Figure 1; Appendix 1). This meadow forms a narrow fringe along Redbank Creek that although similar in area to previous surveys it had fragmented into two separate areas in 2007 and 2008 (Map 6).

In 2008, the distribution of the much larger Cairns Harbour monitoring meadows (Esplanade-Ellie Point (34) and Bessie Point (11) meadows) remained within the upper-range of previous peak monitoring values, even though declines in area from the previous year were observed (Table 4; Figure 1). In 2007 these meadows recorded their highest total area since monitoring began in 2001 (Table 4; Figure 1).

Density of the Esplanade-Ellie Point (34) meadow was significantly higher in 2008 than in 2007 and similar to levels observed in 2006 and 2003 (Table 4; Figure 1; Appendix 1). The biomass of the Bessie Point (11) meadow had also increased slightly in 2008 from 2007 and remained well within the range of previous monitoring results (Table 4; Figure 1).

In 2006 the southern section of the large Bessie Point meadow was separated and reclassified based on a substantial change in species composition. This area was dominated by *Zostera capricorni* and *Cymodocea Serrulata* and was named the South Bessie Point meadow (13). In 2008 this meadow expanded in area by 35 ha (Table 4; Map 5), the largest area since the meadow was reclassified. The density of this meadow however declined in 2008 to the lowest density observed since first recorded in 2006 (Table 4).

Plate 2. New high biomass *Zostera* and *Cymodocea* meadow south of Bessie Point

Table 6. Maximum depth of monitoring meadows at Cairns Harbour and Trinity Inlet, 2001 – 2008.

Meadow location and ID number	Maximum Depth (depth below mean sea level (m))							
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Esplanade to Ellie Pt. (34)	na	na	na	0.9	na	na	na	1.7
Bessie Pt. (11)	3.7	3.7	4.0	4.1	4.0	4.3	4.2	4.2
Inlet (Ho) (19)	na	3.2	3.4	3.8	2.9	3.3	3.3	4.4
Redbank (Zc) (20)	1.3	1.1	1.5	1.6	1.2	1.1	2.0	1.6
Redbank (Ho) (33)	na	3.4	3.2	3.2	2.9	2.4	3.0	1.8

(na = insufficient depth measurements, or sites were surveyed using helicopter not boat)

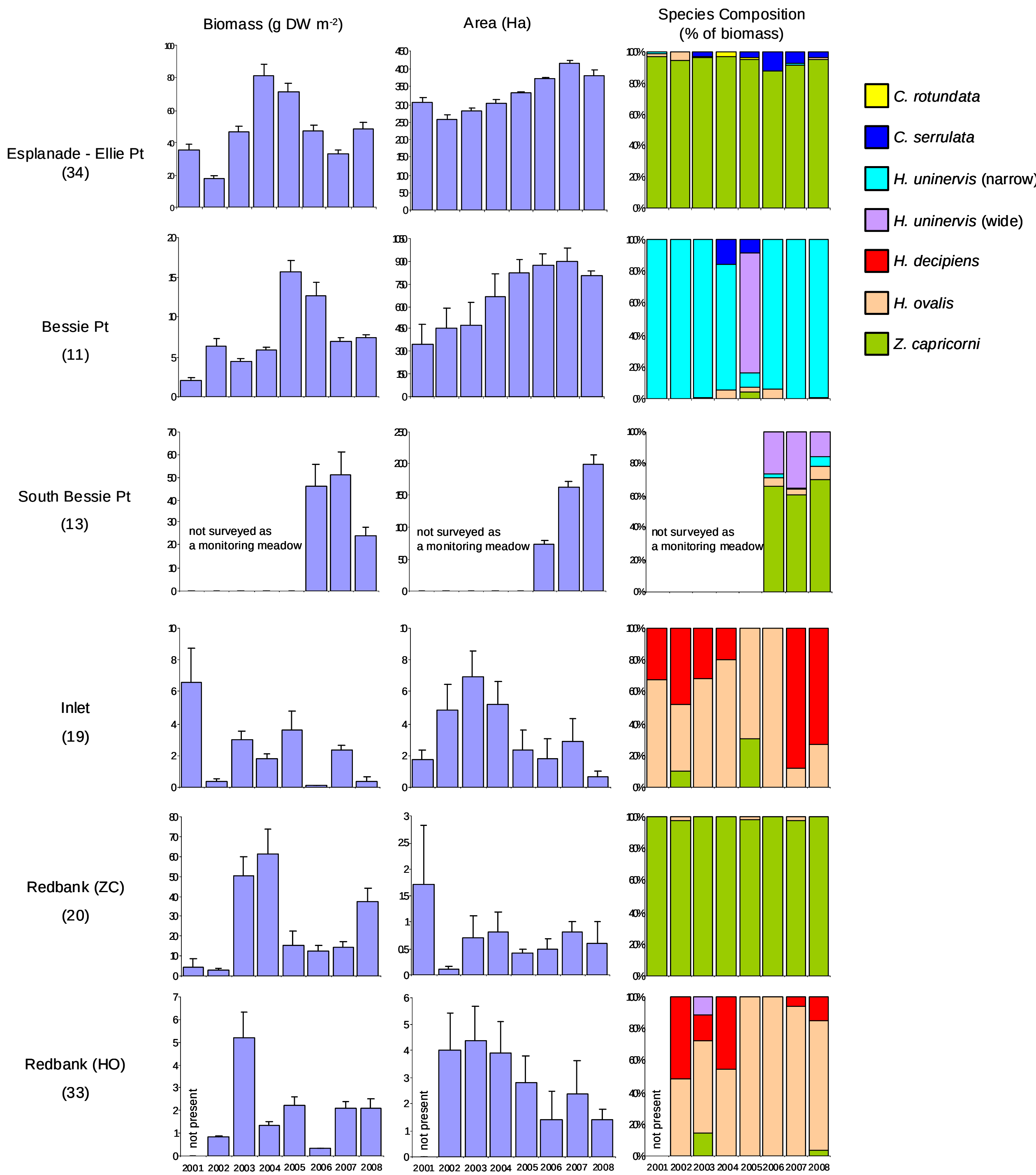

Figure 1. Mean biomass (g DW m^{-2}) area ± R (ha) and species composition (%) of monitoring meadows at Cairns Harbour and Trinity Inlet from 2001-2008.

Map 4. Esplanade to Ellie Point seagrass monitoring meadows from 2001 to 2008

Legend

Monitoring Meadow 34

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

Source: McKenna, S.A., Rasheed, M.A., Unsworth, R.K.F, Taylor, H.A., Chartrand, K.M. and Sankey, T.L. 2009. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - October 2008. QPI&F Publication PR09-4436 (QPIF, Cairns).

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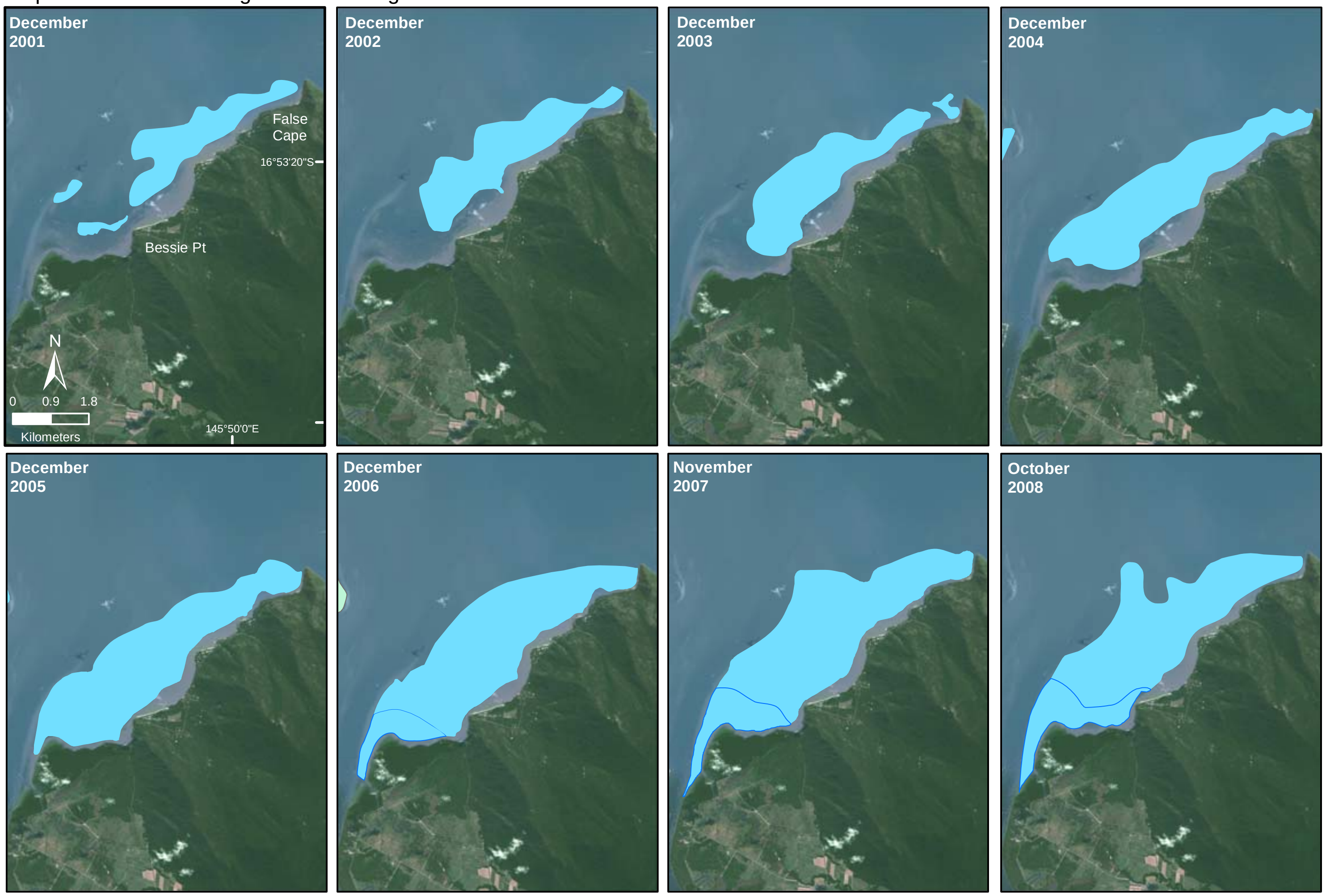
Map 5. Bessie Point seagrass monitoring meadow from 2001 to 2008



Legend

Monitoring Meadow 11

Monitoring Meadow 13

Source: McKenna, S.A., Rasheed, M.A., Unsworth, R.K.F, Taylor, H.A., Chartrand, K.M. and Sankey, T.L. 2009. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - October 2008. QPI&F Publication PR09-4436 (QPIF, Cairns).

Funded by Far North Queensland Ports Corporation Limited and Fisheries Queensland.
Produced by the Marine Ecology Group, Fisheries Queensland, Northern Fisheries Centre, Cairns, 2009.

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

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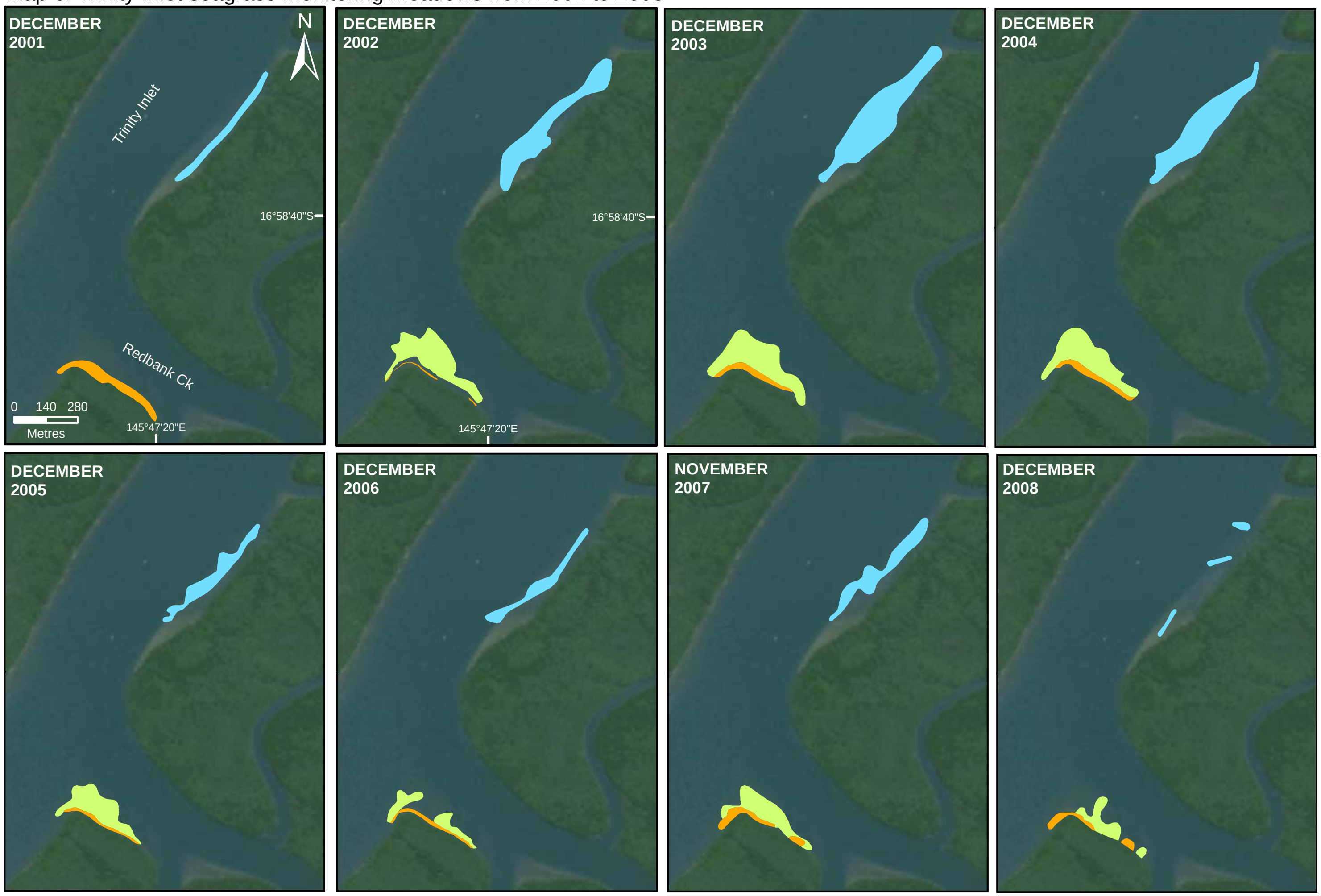
Map 6. Trinity Inlet seagrass monitoring meadows from 2001 to 2008



Legend

- Monitoring Meadow 19
- Monitoring Meadow 20
- Monitoring Meadow 33

Source: McKenna, S.A., Rasheed, M.A., Unsworth, R.K.F, Taylor, H.A., Chartrand, K.M. and Sankey, T.L. 2009. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - October 2008. QPI&F Publication PR09-4436 (QPIF, Cairns).

Funded by Far North Queensland Ports Corporation Limited and Fisheries Queensland.
Produced by the Marine Ecology Group, Fisheries Queensland, Northern Fisheries Centre, Cairns, 2009.

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

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CLIMATE DATA

Total annual rainfall in Cairns was above the 66 year average in 2008 (Figure 2). Between 2001 and 2007, Cairns generally received below average rainfall. Rainfall is highly seasonal with the majority of rainfall typically occurring from December to March/April. In 2008 flooding associated with seasonal rainfall also occurred in March/April (Figure 2). This high rainfall coincided with high flows of the major catchment for the Cairns area, the Barron River (Figure 3). The Barron River catchment flows out of the Barron mouth sub-catchment and empties into the marine waters approximately 2.5km north of Ellie Point.

Total daytime tidal exposure for intertidal seagrass meadows has been below average for the past three years (Figure 4) and in 2008 the total number of hours that intertidal banks were exposed in the month before the survey was lower compared to 2007 (Figure 4).

The total number of cloudy days was well below average (134.6 days) from 2001 to 2005 (Figure 4). In contrast, the last three years have seen a greater number of cloudy days (Figure 4). In 2008, there was a consistent number of ‘high cloudy day months’ prior to the monitoring survey compared to 2007 (Figure 4).

The mean annual daily maximum temperature was 29.6°C in 2008 which was only slightly above the 66 year average of 29°C and only 0.46°C above the 2007 average (Figure 5).

Low tidal exposure combined with high cloud cover and average temperatures suggest that intertidal seagrasses were subjected to reduced thermal and desiccation stress during 2008. While higher rainfall and associated flooding were likely to place subtidal seagrasses in Trinity Inlet under increased light stress.

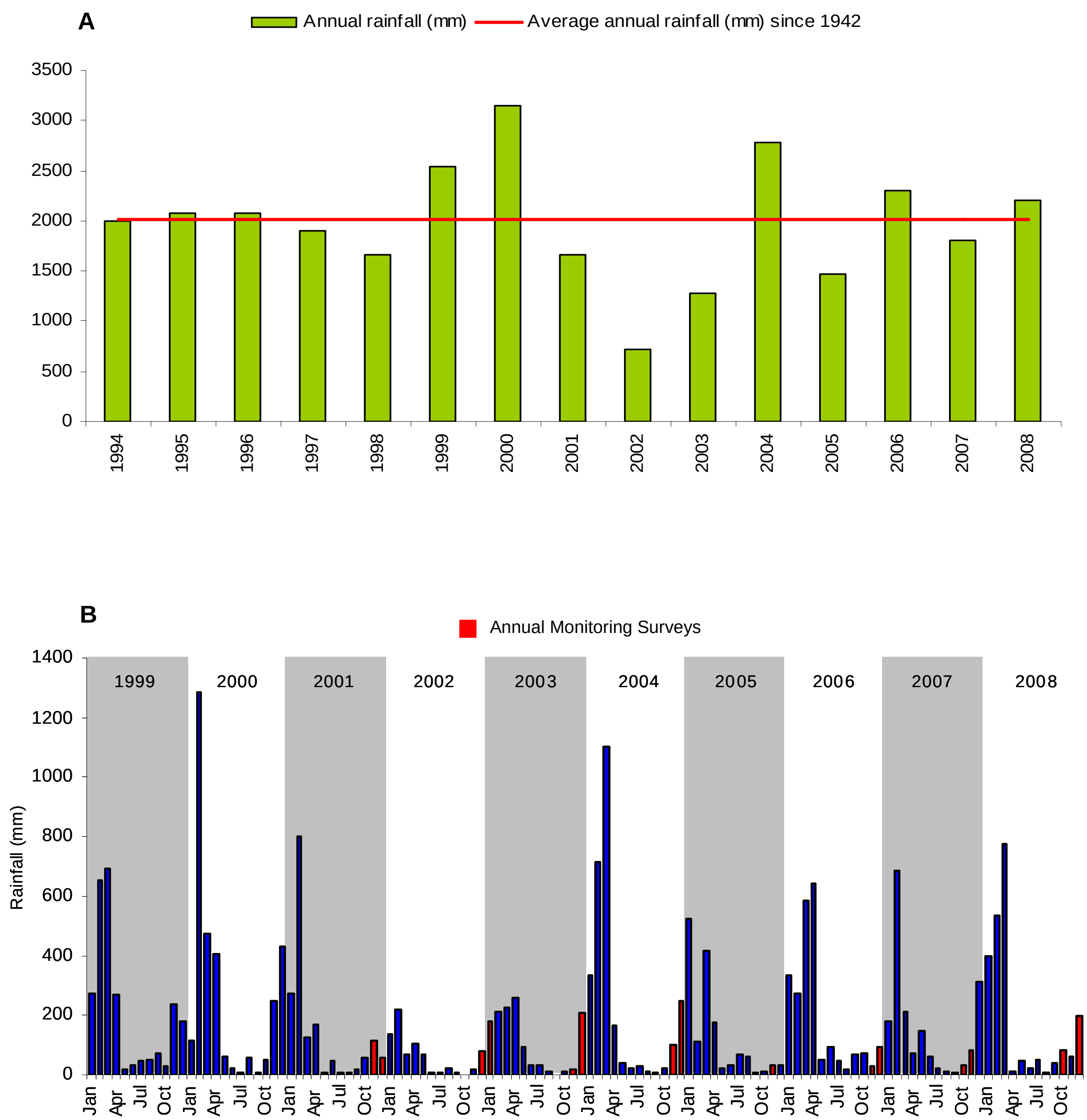

Figure 2. (A) Total annual rainfall (mm) for the Cairns area from 1994 to 2008. (B) Total monthly rainfall (mm) for the Cairns area from 1999 to 2008 (Bureau of Meteorology 2009).

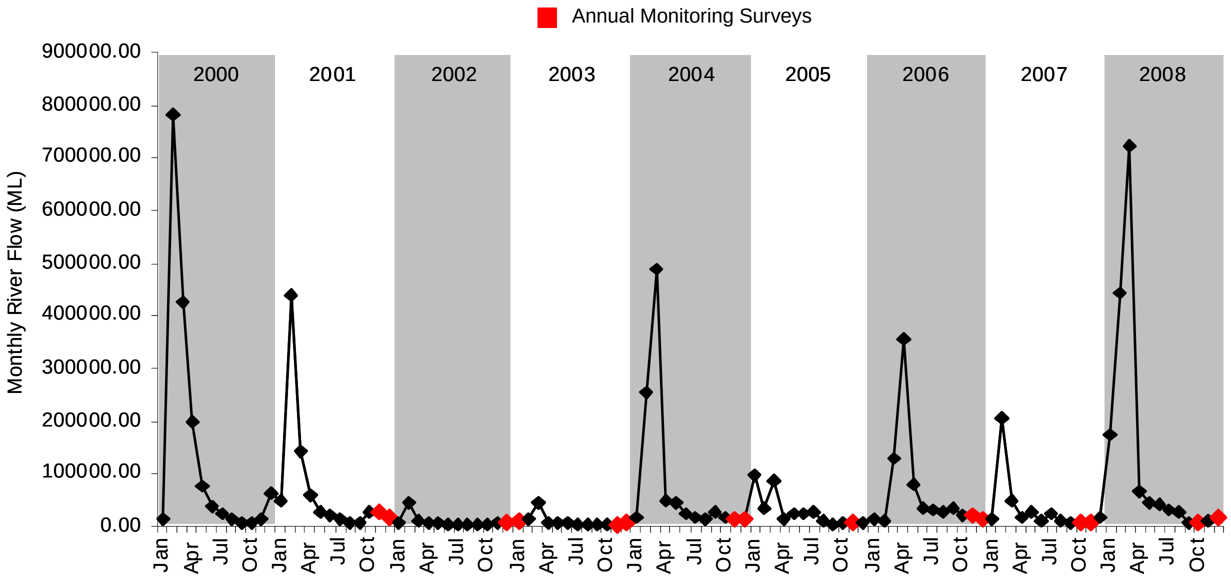

Figure 3. Total monthly river flow for the Barron River between 2000 and 2008

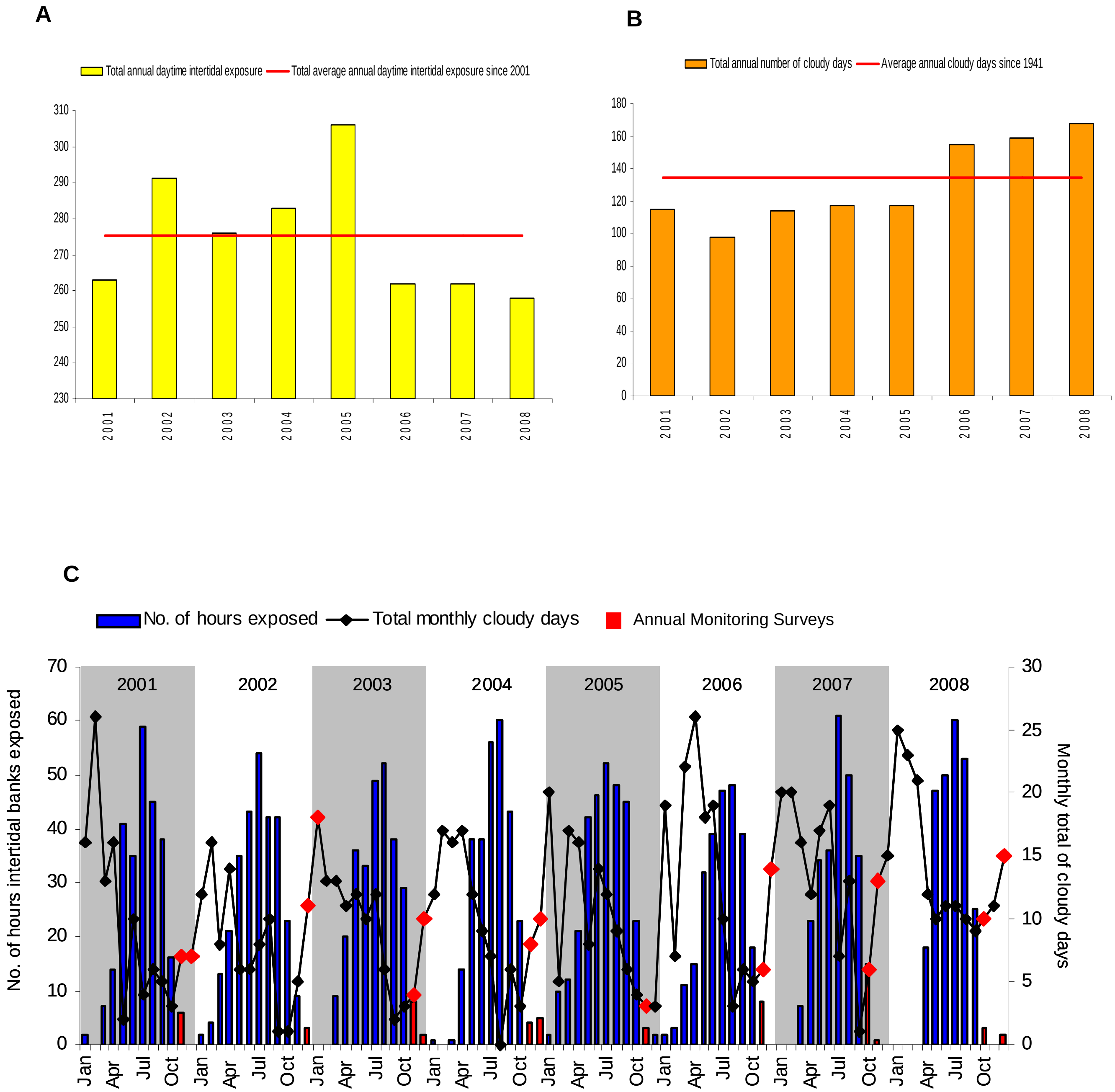

Figure 4. (A) Total annual hours of daytime intertidal exposure (<0.8m tidal height) in Cairns Harbour and Trinity Inlet. (B) Total annual daily number of cloudy days recorded at Cairns airport 2001 to 2008. (C) Mean number of daylight hours per month intertidal seagrasses are exposed and number of cloudy days per month for Cairns from 2001-2008 (Bureau of Meteorology, 2009).

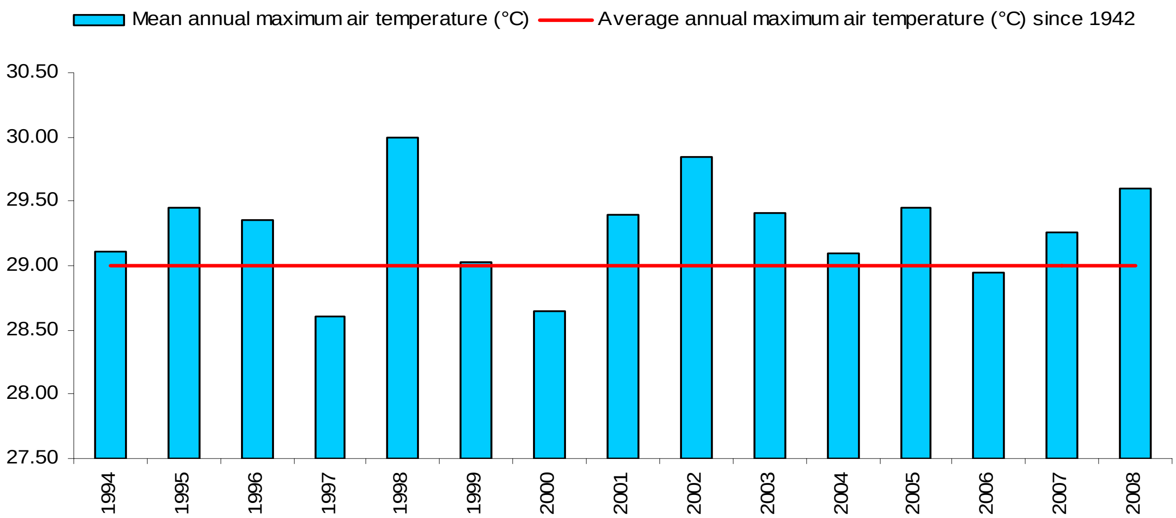

Figure 5. Mean annual daily maximum air temperature recorded at Cairns airport 1994 to 2008 (Bureau of Meteorology, 2009).

DISCUSSION

The 2008 Cairns Harbour and Trinity Inlet survey found that seagrass was generally healthy. The biomass within the intertidal monitoring meadows had either increased or remained relatively stable compared to the previous year of monitoring, reversing three consecutive years of biomass decline. The area of these meadows was also similar to previously recorded values. The opposite was true for the small subtidal meadows within Trinity Inlet where some significant declines in both biomass and area were recorded in 2008. These meadows had become fragmented and were likely to be in a highly vulnerable state in the event of future impacts, or stress. Changes to seagrass meadow composition continued to occur in the south Bessie meadow, an area which appears to be highly dynamic and subject to changes in bank topography.

The drivers of seagrass change in Cairns Harbour and Trinity Inlet have been linked to local and regional climate conditions with differences between meadow responses associated with differences in species and the physical setting of the meadows. In general terms the intertidal meadows in Cairns Harbour seem to be strongly affected by the degree and severity of exposure related stress, while changes to subtidal meadows are associated with turbidity and other factors linked with high rainfall and runoff. Subtidal meadows in Trinity Inlet appear to be particularly vulnerable compared to those between Bessie Point and False Cape, where regular mixing of clearer oceanic water occurs, potentially buffering these areas from flood and turbidity related impacts.

Previously in the monitoring program the reduction of biomass and area in the intertidal meadows has been linked to higher air temperatures, lower numbers of cloudy days (i.e. higher irradiance) and increased amounts of daytime exposure of intertidal banks in the months prior to the survey (Rasheed *et al*. 2008). These conditions are thought to have led to thermal stress and exposure related desiccation of intertidal meadows (Erftemeijer & Herman 1994; Rasheed *et al*. 2006; 2008). In 2008, there was an increase in number of cloudy days (i.e. lower irradiance) in the months previous to the October intertidal survey and a decrease in the number of hours that intertidal meadows were exposed. These mild conditions were likely to have protected intertidal seagrasses from the effects of thermal stress and desiccation providing more favourable growing conditions for the intertidal meadows in Cairns Harbour and Trinity Inlet (Redbank *Zc* meadow).

In contrast, the newly established intertidal south Bessie Point meadow decreased in biomass and increased in area in 2008. The expansion of this meadow in area may have contributed to an overall reduction in biomass. Seagrass in the newly-colonised sections of the meadow tended to be less dense as they were likely only recently recruited, with these areas bringing the overall mean meadow biomass to a lower level. The formation of this meadow in 2006 (species changes first noted in 2004) was thought to be associated with a shallowing of the sand /mud bank making conditions more suitable for the growth of *Zostera* and *Cymodocea* species. It appears that this area is highly dynamic with shifts in bank topography likely to play a major role in shaping seagrass density and distribution.

In addition to the natural changes in bank topography, the South Bessie bank and meadow are immediately adjacent to the section of the dredged shipping channel that requires the most regular maintenance dredging due to high siltation rates (Adam Fletcher, FNQPCL pers. comm.). Maintenance dredging that occurred in September 2008, one month prior to the survey, had the potential to impact this meadow. Dredging operations have been demonstrated to negatively affect seagrass meadows through burial and reduced light attenuation as a result of sedimentation and high turbidity in other locations (Chartrand *et al*. 2008). The duration of the dredging operation in Cairns however, was relatively short (14 days) and the species in the meadow are capable of tolerating short-term reductions in light in other areas of Queensland (Bite *et al*. 2007).

Above average rainfall and flooding of the Barron River early in 2008 (Figure 3) were likely to have had an impact on seagrasses in the region. High catchment rainfall and runoff can result in sediment loading leading to burial, high nutrient doses, herbicides, large freshwater pulses and periods of high turbidity and associated light reduction which can all negatively affect seagrasses (Campbell and McKenzie 2004, Waycott *et al*. 2007). These effects would be particularly strong for subtidal meadows that may already be at the limits of their light requirements such as the subtidal *Halophila* meadows in Trinity Inlet. The Trinity Inlet meadows were also likely to be subjected to prolonged exposure to these effects compared with subtidal meadows in Cairns Harbour. Hydrodynamic modelling has shown that flow in Trinity Inlet tends to circulate around Admiralty Island with the potential to trap turbid water in the area of the subtidal meadows for extended periods (Lou Mason, JCU pers. comm.). In contrast the meadows in Cairns Harbour undergo regular tidal flushing of oceanic water which would potentially have a buffering effect against increased turbidity and sediment associated with flooding. The small losses of meadow area that did occur for both the Cairns Harbour meadows (Esplanade-Ellie Point and Bessie Point) were at the deeper margins of the meadows, consistent with impacts from a reduction in light availability.

In recent years of the monitoring program the sub-tidal *Halophila* dominated meadows in Trinity Inlet have undergone cycles of decline and recovery. This cycle may have resulted in an overall lowering of resilience for the meadows and a reduced capacity for recovery from impacts (Mckenna *et al*. 2007). *Halophila* species have the capacity to colonise quickly and have the ability to form large seed bank reserves which forms the basis of their resilience (Birch & Birch 1984; Preen *et al*. 1995; McMillan 1991; Rasheed 2004; Hammerstrom *et al*. 2005). The repeated declines of the subtidal Inlet meadows may have substantially reduced this capacity and source for recovery and growth. As a consequence these meadows may be in a vulnerable state with reduced resilience to further natural or human impacts.

Although sedimentation and turbidity plumes associated with flooding may have had a short-term detrimental impact on intertidal seagrasses, their daytime exposure during low tide periods was likely to have ensured that seagrasses receive sufficient light to continue productive growth (Pollard and Greenway 1993).

The changes in Cairns Harbour and Trinity Inlet seagrass meadows in 2008 were similar to changes in other areas of north Queensland where monitoring is being conducted. The majority of intertidal *Zostera* meadows in Mourilyan and Gladstone either increased in biomass or remained stable, while in Karumba in the Gulf of Carpentaria increases in biomass and area were observed in the intertidal *Halodule* meadows (Chartrand *et al*. 2009; Sankey *et al*. 2009; Unsworth *et al*. 2009a). Monitoring in Townsville in 2008 revealed that there were declines in subtidal *Halophila* and *Halodule* meadows and these declines were likely linked to turbidity and low light availability (Unsworth *et al*. 2009b).

Intertidal *Halodule* meadows at Yule Point north of Cairns (approximately 45km north of Ellie Point) also recorded high abundances in 2008 (Seagrass Watch 2009). These meadows have been monitored by Seagrass Watch since 2000 and have been increasing in cover and abundance since 2000. Although similar in trend between 2007 and 2008 with intertidal meadows in Cairns, previous changes have not always been the same between the two locations. The differences may be due to their locations. Cairns Harbour meadows form part of an estuarine environment and would be strongly influenced by rainfall and flooding whereas the Yule Point meadows are part of a coastal system with no major estuary or freshwater influence and were therefore generally exposed to 'cleaner' oceanic water.

The seagrass meadows of Cairns Harbour and Trinity Inlet have been identified as one of four regions in the Great Barrier Reef World Heritage Area (GBRWHA) facing the highest level of risk from anthropogenic impacts (Rasheed *et al.* 2007). Continued impacts from natural events have the capacity to reduce the resilience of seagrasses in the region due to compounding effects of current human activities such as urbanisation and coastal and port development. The vulnerable state of some seagrasses in Trinity Inlet underscores the value of continued monitoring to ensure the long term viability of these marine habitats.

Although we have been able to place some of the major changes that have occurred to Cairns seagrasses into a regional climate perspective it is difficult to conclusively establish the links between change and natural or human induced causes. This is particularly the case at the scale of the meadow were more localised factors are often highly important in determining meadow responses to impacts. There are several enhancements to the existing monitoring program that would significantly strengthen the ability to separate out the causes of seagrass change and to better inform the management and protection of seagrasses in the future. These include:

1. *Assessing light and temperature at the meadow level (in situ loggers)*

   Light and temperature are two of the major factors that have been linked to changes in seagrasses. The use of light and temperature data loggers within monitoring meadows at other monitoring locations has enabled an evaluation of changes occurring at the meadow scale (Chartrand *et al*. 2009). This provides direct information on what conditions seagrasses are experiencing rather than inferring them from regional climate information. Where installed, these loggers have shown that meadows of similar species composition and location may experience different physical conditions and different outcomes in density and distribution over time (Chartrand *et al*. 2009).

2. *Examining reproductive and recovery capacity of the meadows*

   The capacity for meadows to reproduce, including the density of seeds stored as a "seed-bank" are critical components of the resilience of seagrass meadows and their ability to recover from impacts. Assessments of seed bank status have been used in other monitoring locations such (e.g. Karumba) to assess meadow vulnerability (Unsworth et al. 2009a).

3. *Expanding the geographic scope of the area examined to a broader region and incorporating additional monitoring meadows*
   Expanding the geographic scope of the Cairns program to include more seagrass areas such as those in Mission Bay and seagrasses to the north of the Barron River may assist in placing changes observed in the port and city area in a better local perspective.

4. *Linking water quality assessment with seagrass condition*

   FNQPCL has a quarterly water quality monitoring program in Trinity Inlet incorporating three primary sampling sites and six sites that are sampled on an ad hoc basis. (Cairns Ports Limited Annual Report 2008). However location of the water quality monitoring sites and timing of sampling does not necessarily tie in with the location of seagrass monitoring. Enhancing the existing program to tie in with the seagrass assessments and the addition of more water quality parameters would enhance the assessment of seagrass changes and their causes.

Overall, results of the 2008 monitoring program indicate that seagrasses within Cairns Harbour and Trinity Inlet are in a fair condition while vulnerable to environmental change and anthropogenic disturbances that may detrimentally affect water quality. It is unlikely that operations within the port were the main cause of changes in seagrass biomass and area in 2008, as there have been no major changes in port activity. However, determining causes of change are difficult and port and other anthropogenic activities cannot be ruled out as contributing factors. Enhancements proposed to the monitoring program would greatly assist in isolating the causes of seagrass change and in developing effective plans for managing seagrass resources in the region.

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APPENDIX 1 – STATISTICAL ANALYSIS

Results of one-way ANOVA for mean above-ground biomass versus year for the Cairns Harbour and Trinity Inlet monitoring meadows 2001 to 2008.

Esplanade to Ellie Pt. Meadow (34)	DF	MS	F	P
Between Years	7	34886.8	23.24	< 0.0001
Within Years	623	1501.43		
Total	630			
Redbank (Zc) Meadow (20)	**DF**	**MS**	**F**	**P**
Between Years	7	5675.87	10.39	< 0.0001
Within Years	86	546.121		
Total	93			
Inlet (Ho) Meadow (19) ^	**DF**	**MS**	**F**	**P**
Between Years	7	2.24309	9.74	< 0.0001
Within Years	89	0.23021		
Total	96			
Redbank (Ho) Meadow (33) *	**DF**	**MS**	**F**	**P**
Between Years	6	4.57264	13.38	< 0.0001
Within Years	148	0.34172		
Total	154			
Bessie Pt Meadow (11) *	**DF**	**MS**	**F**	**P**
Between Years	7	30.7389	22.13	< 0.0001
Within Years	453	1.38904		
Total	460			

* Data was square root transformed
^ Data was log+1 transformed

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Results of Least Significant Difference (LSD) pairwise comparisons of mean above-ground biomass (g DW m^{-2}) for the Cairns Harbour and Trinity Inlet monitoring meadows. Means that share the same letter group within each meadow are not significantly different ($P<0.05$).

Meadow	Year	Mean biomass
Esplanade to Ellie Pt (34)	2001	36 cd
	2002	18 e
	2003	46.2 bc
	2004	81.6 a
	2005	71.6 a
	2006	47.4 bc
	2007	33.2 d
	2008	48.4b
Redbank (Zc) (20)	2001	4.5 c
	2002	3.1 c
	2003	50.1 ab
	2004	61.5 a
	2005	15.1 c
	2006	11.9 c
	2007	14.1 c
	2008	37.5 b
Inlet (Ho) (19)	2001	6.6 a
	2002	0.4 c
	2003	3 b
	2004	1.8 b
	2005	3.6 b
	2006	0.1 d
	2007	2.3 b
	2008	0.4 bc
Redbank (Ho) (33)	2001	not sampled
	2002	0.8 cd
	2003	5.2 a
	2004	1.3 bc
	2005	2.2 b
	2006	0.3 d
	2007	2.1 b
	2008	2.1 b
Bessie Point (11)	2001	2.0 d
	2002	6.4 bc
	2003	4.4 c
	2004	5.8 b
	2005	15.6 a
	2006	12.7 a
	2007	6.9 b
	2008	7.5 b