Department of **Employment, Economic Development and Innovation**

Long-term seagrass monitoring in Cairns Harbour and Trinity Inlet

December 2009 and 2010

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Toward Q2 Tomorrow's Queensland

MARINE ECOLOGY GROUP

Ports North

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EXECUTIVE SUMMARY

This report details results from the October 2009 and October/December 2010 seagrass monitoring surveys 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 examines selected representative seagrass meadows in the area annually. Results of the program are used to ensure port and other human activities are having a minimal impact on the marine environment by using seagrasses as a key indicator of marine environmental health. The program is also used to assess the status of these important fisheries habitats and forms part of a network of seagrass assessment established throughout Queensland.

Results of the 2009 and 2010 monitoring surveys indicate that seagrass habitat in Cairns Harbour and Trinity Inlet was in a poor condition. Seagrasses were in a highly vulnerable state with meadows reduced to their smallest area and density recorded in the monitoring program. The large seagrass meadows adjacent to the Esplanade and on the opposite of the Inlet between Bessie Point and False Cape suffered major declines in seagrass, becoming patchy and fragmented with only light cover of seagrass within remaining patches. Density and distribution of other small monitoring meadows in the inlet was less affected.

The large declines in seagrasses were likely associated with local and regional climate conditions of high rainfall, flooding of local catchments and low light conditions creating unfavourable conditions for seagrass growth. Such changes in Cairns were consistent with similar trends noted at other seagrass monitoring locations on the east coast of North Queensland over the same time period. While these climate conditions provide the likely explanation for seagrass declines, 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 such as those that have occurred over the last two years may have had the capacity to reduce the resilience of seagrasses in the region due to compounding effects of current human activities such as urbanisation, coastal and port development. The vulnerable state of some seagrasses in Cairns underscores the value of continued monitoring to ensure the long-term viability of these marine habitats. While port activities during 2010 were unlikely to have had a major impact on seagrass condition, the current state of low resilience may mean that the seagrass is increasingly vulnerable to impacts to which they have previously been resilient and that there is a greater potential for activities within the Trinity Inlet catchment to influence seagrass condition. Extra vigilance should be maintained for any activity such as maintenance dredging, coastal development, land use change or runoff water quality that has the capacity to impact on water quality and seagrass condition, until these meadows have recovered.

INTRODUCTION

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 vital nursery habitat for commercial and recreational fisheries species, they provide food for dugong and turtle and provide a significant component of the primary productivity that underpins the coastal marine ecosystem.

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 broadscale 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 wide distribution of seagrasses in Queensland and their capacity to show measurable responses to changes in water quality make them ideal candidates for monitoring the health of marine and coastal environments. Trinity Inlet Waterways (TIW) and Ports North (the port authority for the Port of Cairns) have recognised the importance of seagrasses in the region and in partnership with Fisheries Queensland, 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 Harbour and Trinity Inlet's marine environment and as a tool to ensure that port activities and development were having a minimal impact on these habitats.

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. Monitoring has been conducted annually since 2002. This report provides the findings of the 2009 and 2010 annual monitoring surveys.

This report discusses the implications of monitoring results on the overall health of Cairns Harbour and Trinity Inlet's marine environment, the implications of port and dredging activity and places observed changes within a regional and statewide context. The objectives of the 2009 and 2010 long-term seagrass monitoring in Cairns Harbour and Trinity Inlet were to:

1. Map and measure 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.

METHODOLOGY

Sampling Methods

Surveys of the six monitoring meadows in Cairns Harbour and Trinity Inlet were conducted in October and December 2009 and 2010. In 2009 the intertidal areas were surveyed from helicopter on the 15th and 16th October and subtidal areas were surveyed by boat on the 26th and 27th December. In 2010 the intertidal areas were surveyed from helicopter on 7th October and subtidal areas were surveyed by boat on the 29th October, 2nd November and 14th December.

At each survey site within the monitoring meadows, seagrass meadow characteristics including seagrass species composition, above-ground biomass, per cent 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 characterise the monitoring meadows is provided in Campbell et al. (2002; 2003).

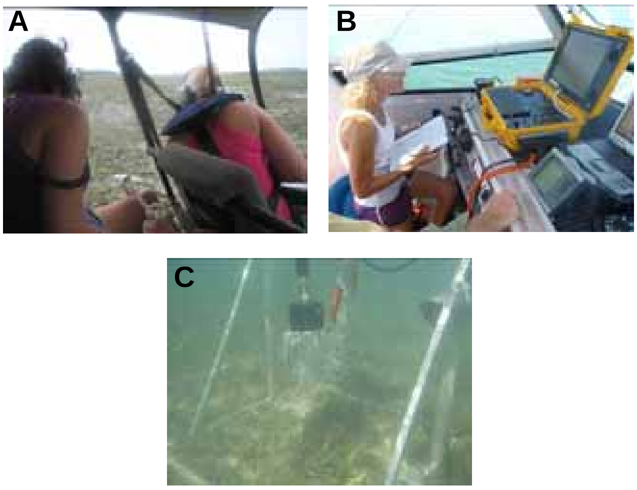


Plate 1. Seagrass methodology utilising (A) helicopter aerial surveillance and (B & C) boat based CCTV surveillance

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 2009 and 2010

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 2009 and 2010.

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 :

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.

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 10m for isolated subtidal seagrass meadows to 15m 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 2009 and 2010

Mapping precision	Mapping methodology
10m	Small meadows in Trinity Inlet Meadow boundary interpreted from camera/grab sites; Recent aerial photography aided in mapping.
15m	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

2009

In October 2009 a total of 359 habitat characterisation sites were surveyed of which 56% (201 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)).

A total of 1,303 ± 60.52 hectares of seagrass habitat was mapped in the six monitoring meadows (Maps 1a-4a; Table 4). Meadow area ranged from 0.6 ha to 766 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 0.1 to 36.1 g 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 1; Figure 1).

The Bessie Point meadow was characterised as dense cover based on the mean biomass of the dominant species while the Redbank (*Zostera capricorni* dominated), Inlet and South Bessie Point meadows had moderate density of seagrass. The Redbank (*Halophila ovalis* dominated) and Esplanade to Ellie Point meadow had a light cover of seagrass (Table 5a).

The seagrass landscape within the monitoring meadows varied. The South Bessie Point and Redbank (*Zc*) meadows had a continuous cover of seagrass, while the Redbank (*Ho*), Esplanade and Bessie Point meadows were comprised of aggregated patches of seagrass in 2009 (Maps 2a-4a; Table 5a). The Trinity Inlet meadow was highly patchy with only isolated patches of seagrass present (Map 4; Table 5a).

2010

In 2010 a total of 320 habitat characterisation sites were surveyed, 34% (108 sites) of which had seagrass present. Five seagrass species (from three families) were identified in the six monitoring meadows. In 2010 *Cymodocea rotunda* was present in the South Bessie Pt meadow; a species that has not been detected in the monitoring meadows since 2005 (in the Esplanade meadow).

A total of 254 ± 33.15 hectares of seagrass habitat was mapped in the six monitoring meadows (Maps 1b-4b; Table 4b). Meadow area ranged from 0.37 ha in the Redbank (*Zc*) meadow to 101.4 ha in the Bessie Point meadow (Table 4b). The smallest meadows were located in Trinity Inlet while the larger meadows were in the harbour along the Esplanade and the eastern side of the channel at Bessie Point.

Mean above-ground biomass for the six monitoring meadows ranged from 0.22 to1.74 g DW m^{-2}. Meadows dominated by *Zostera capricorni* and *Halodule uninervis* were higher in above-ground biomass than *Halophila ovalis/Halophila decipiens* dominated meadows (Table 4b; Figure 1).

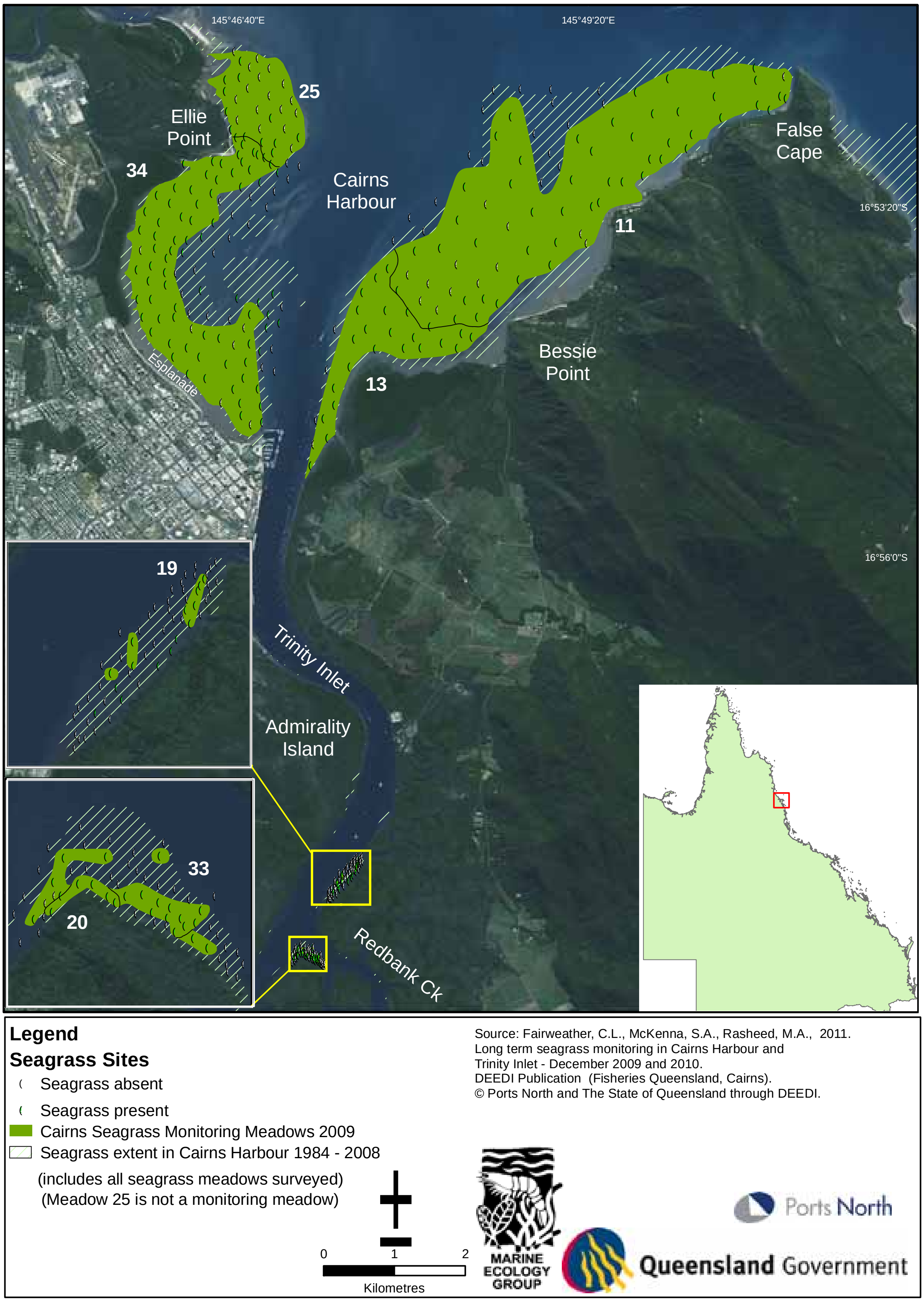
The seagrass landscape category was similar for all monitoring meadows. The Inlet, Redbank and both Bessie Point meadows were comprised of aggregated patches of seagrass (Maps 3b-4b; Table 5b). The Esplanade meadow was highly patchy with only isolated patches of seagrass present (Map 2b; Table 5b).

All six meadows were characterised as having a light density of seagrass based on the mean biomass of the dominant species (Table 2 & 5b).

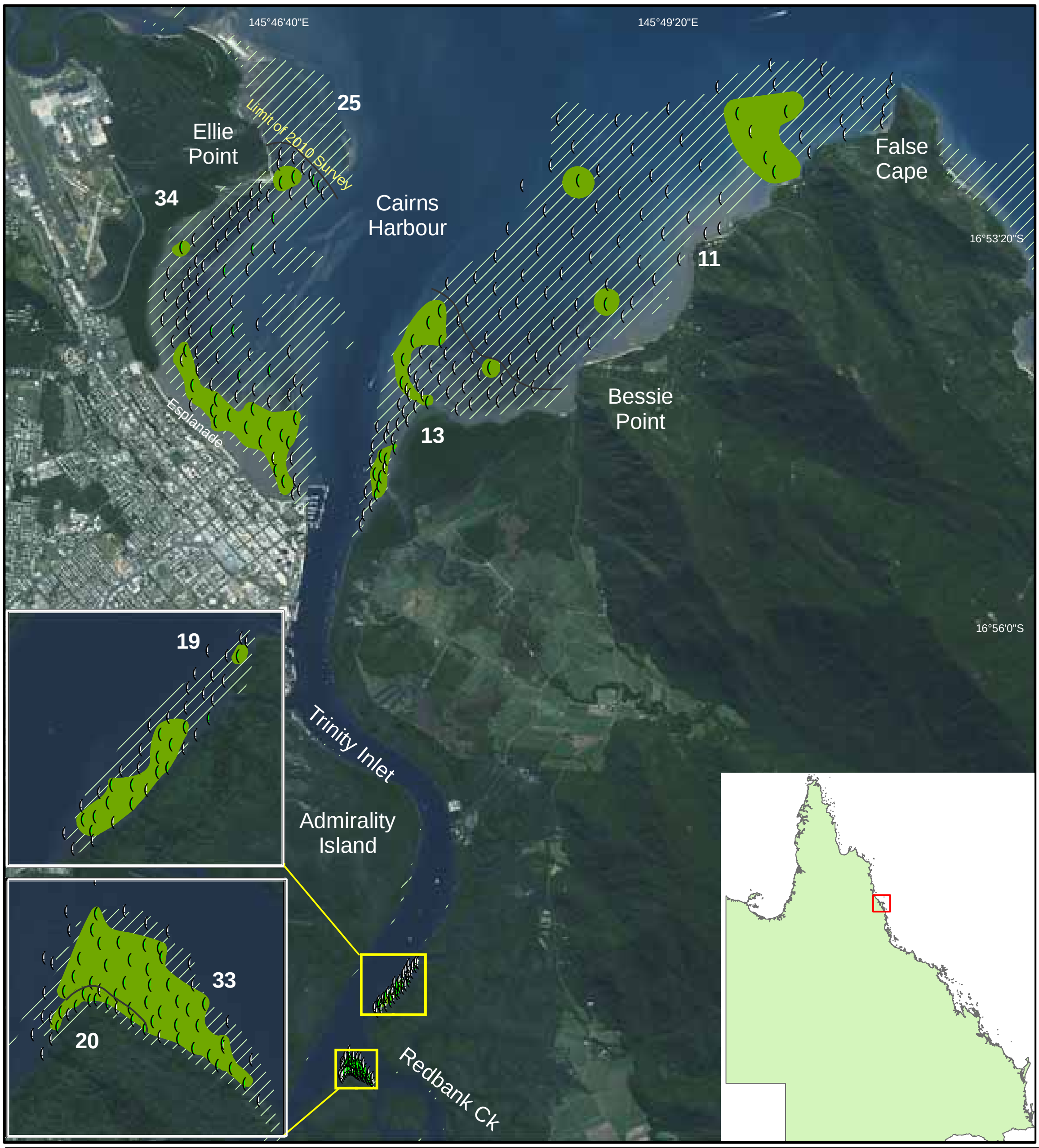
The depth penetration of Inlet *Ho* meadow (19) was at it's shallowest since monitoring began, while in the Redbank *Ho* meadow (33), depth penetration had decreased in 2010 from 2009 (Table 6).

Family	**Species**			
CYMODOCEACEAE Taylor	*Cymodocea serrulata* (R.Br.) Aschers and Magnus (present in 2009, not present in 2010)		*Halodule uninervis* (wide and narrow leaf morphology) (Forsk.) Aschers. in Boissier	
	Cymodocea rotundata (present in 2010, not present in 2009)			
ZOSTERACEAE Drummortier	*Zostera capricorni* Aschers.		* Note *Zostera capricorni* has been re-classified as a sub-species of *Zostera mulleri* however for consistency purposes we will continue to name the seagrass as *capricorni*	
HYDROCHARITACEAE Jussieu	*Halophila decipiens* Ostenfield		*Halophila ovalis* (R. Br.) Hook. F.	
	Halophila spinulosa (R. Br.) Aschers. in Neumayer		*Thalassia hemprichii* (Ehrenb.) Aschers. in Petermann	

Map 1a. Location of baseline seagrass meadows and monitoring meadows in Cairns Harbour, October 2009.



Map 1b. Location of baseline seagrass meadows and monitoring meadows in Cairns Harbour, December 2010.



Legend

Seagrass Sites

- Seagrass absent
- Seagrass present
- Cairns Seagrass Monitoring Meadows 2010
- Total Seagrass extent in Cairns Harbour 1984 - 2008 (includes all seagrass meadows surveyed) (Meadow 25 is not a monitoring meadow)

0 0.4 0.8
Kilometres

Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010. DEEDI Publication (Fisheries Queensland, Cairns).

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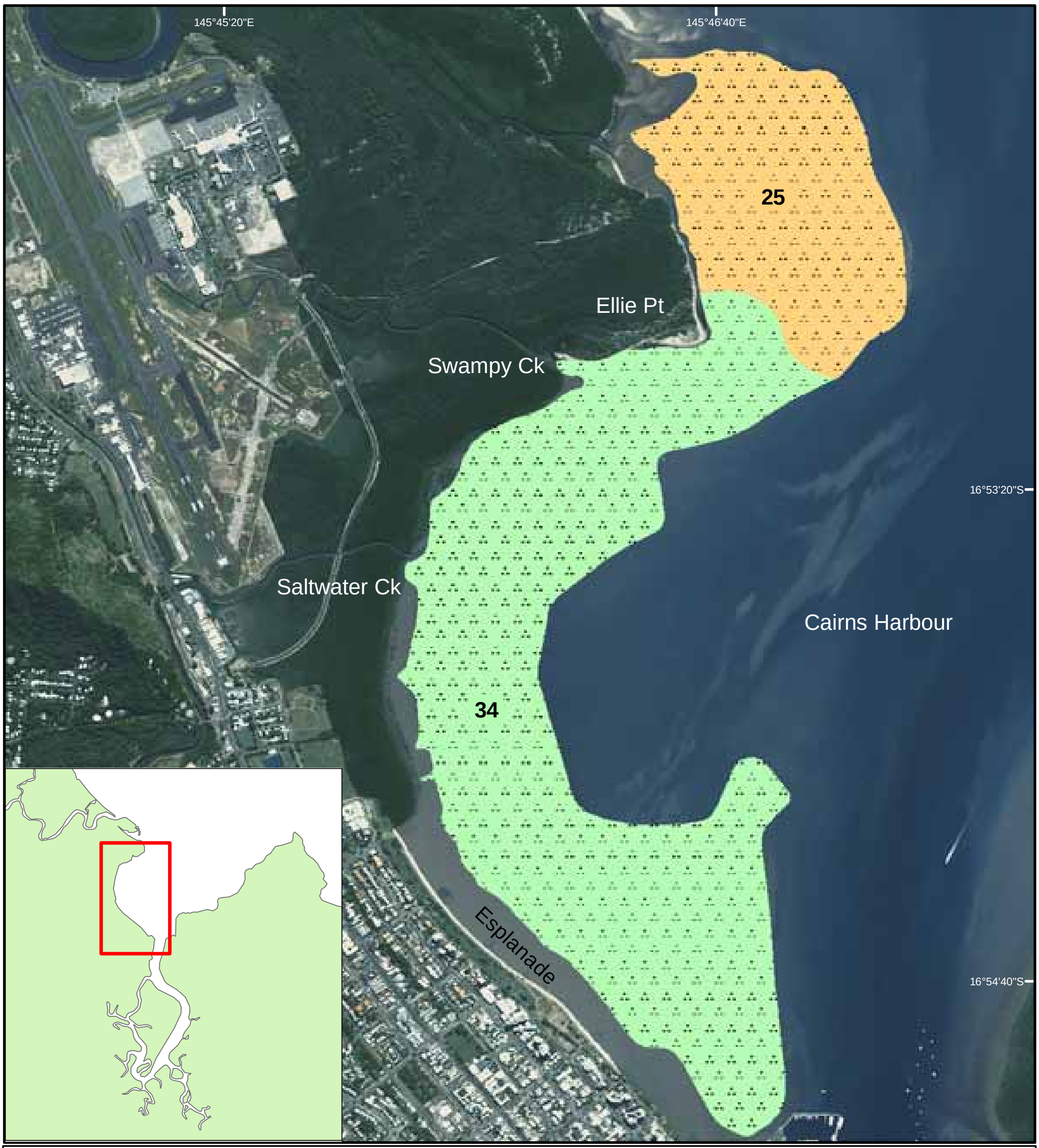
Map 2a. Cairns Esplanade to Ellie Point seagrass monitoring meadow October 2009.



Legend

Cover type

Aggregated patches

Community type

Light *Zostera capricorni*

Light *Zostera capricorni/Halodule uninervis* (thin)

(NB: Meadow 25 is not a monitoring meadow)

0 0.5 1

Kilometres

Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010.
DEEDI Publication (Fisheries Queensland, Cairns).

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Map 2b. Cairns Esplanade to Ellie Point seagrass monitoring meadows December 2010.

Legend

Cover type

Isolated patches

Community type

Light *Zostera capricorni/Halophila ovalis*

(NB: Meadow 25 is not a monitoring meadow)

0 0.5 1

Kilometres

Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010. DEEDI Publication (Fisheries Queensland, Cairns).

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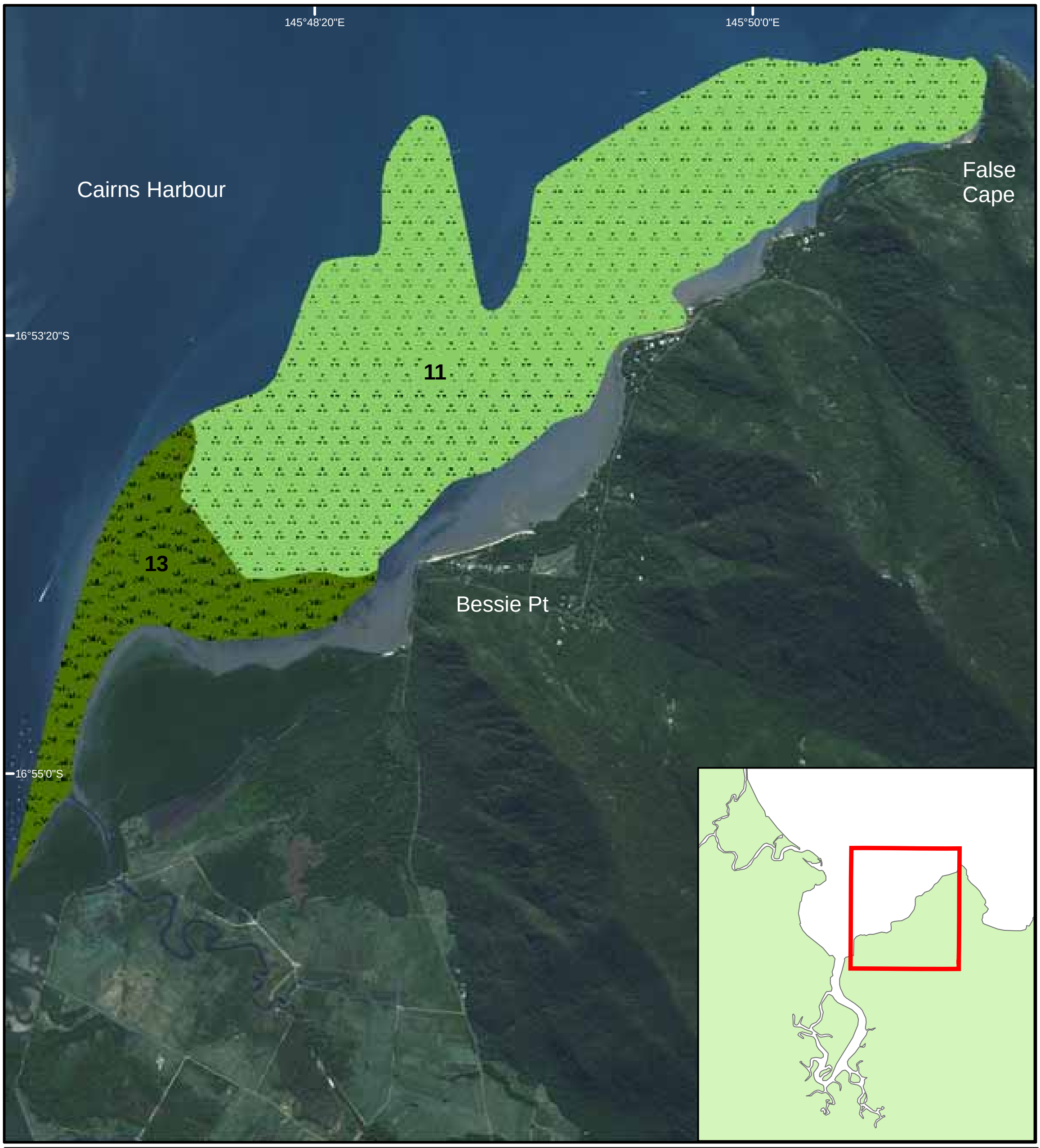
Map 3a. Bessie Point and South Bessie Point seagrass monitoring meadows October 2009.



Legend

Cover type

- Continuous cover
- Aggregated patches

Community type

- Moderate *Zostera capricorni*
- Dense *Halodule uninervis* (thin)

0 0.5 1
Kilometres

Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010. DEEDI Publication (Fisheries Queensland, Cairns).

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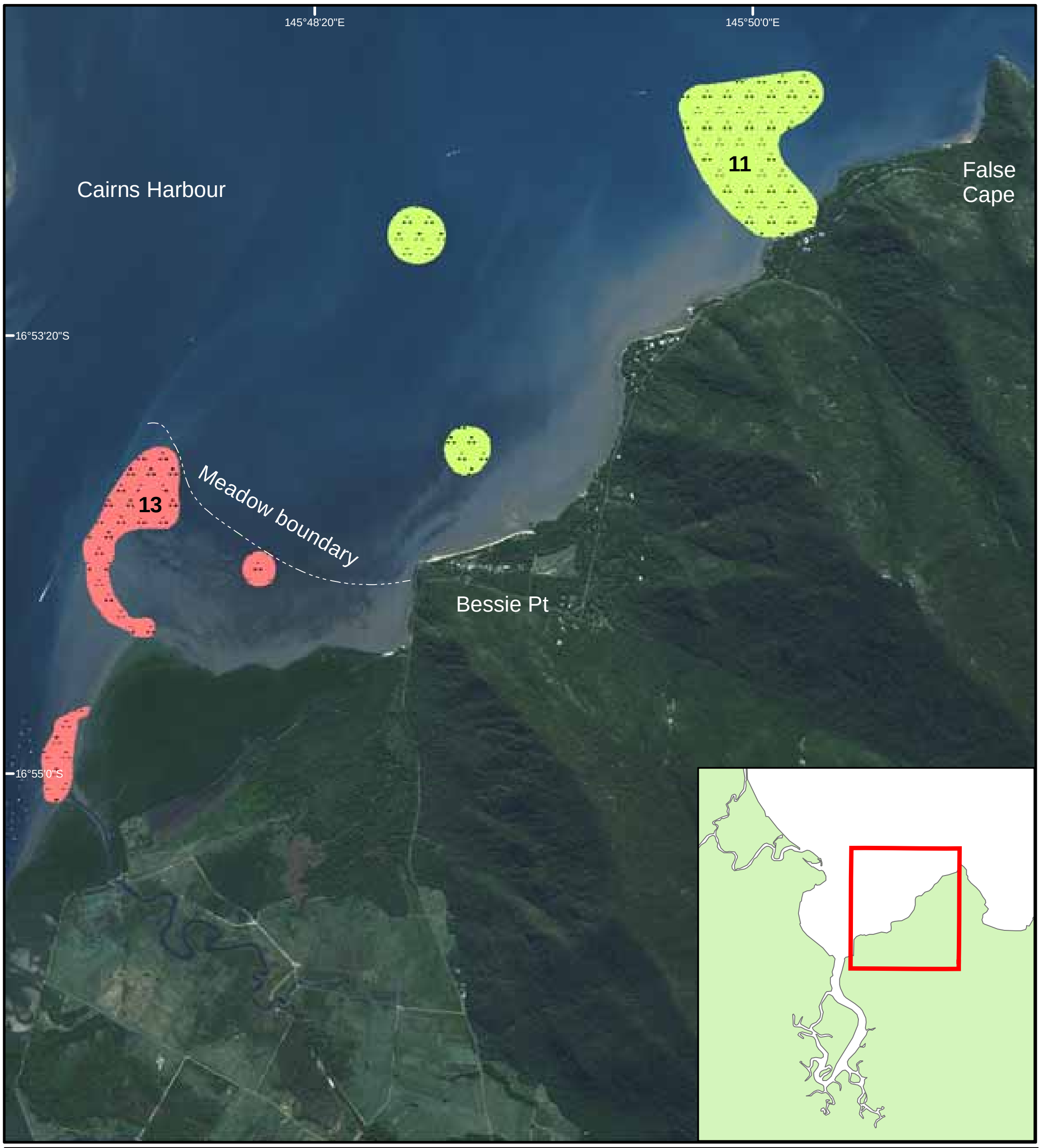
Map 3b. Bessie Point and South Bessie Point seagrass monitoring meadows December 2010.



Legend

Cover type

Aggregated patches

Community Type

Light *Halodule uninervis* (thin)

Light *Zostera capricorni* with mixed species

0 0.5 1

Kilometres

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Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010. DEEDI Publication (Fisheries Queensland, Cairns).

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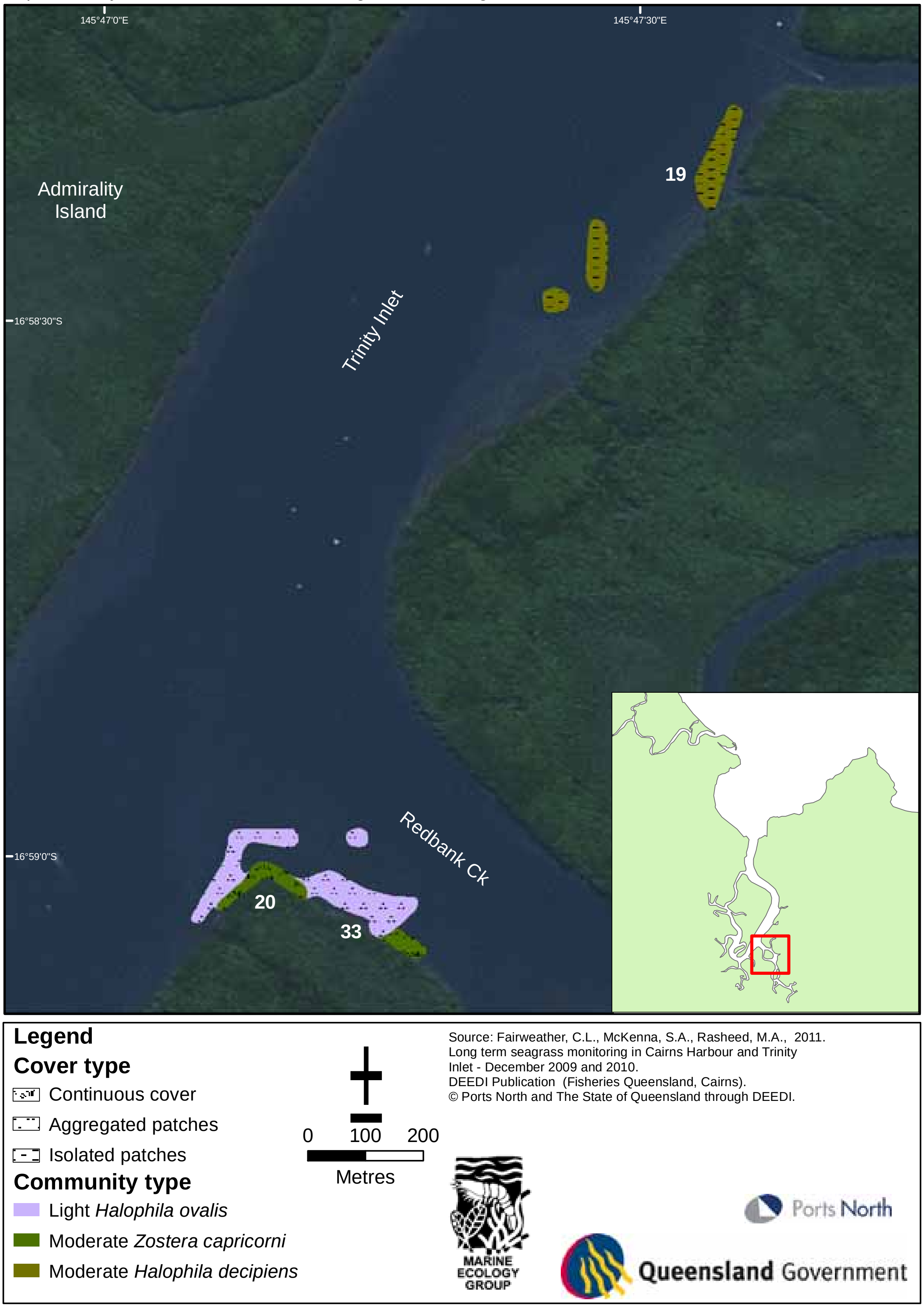
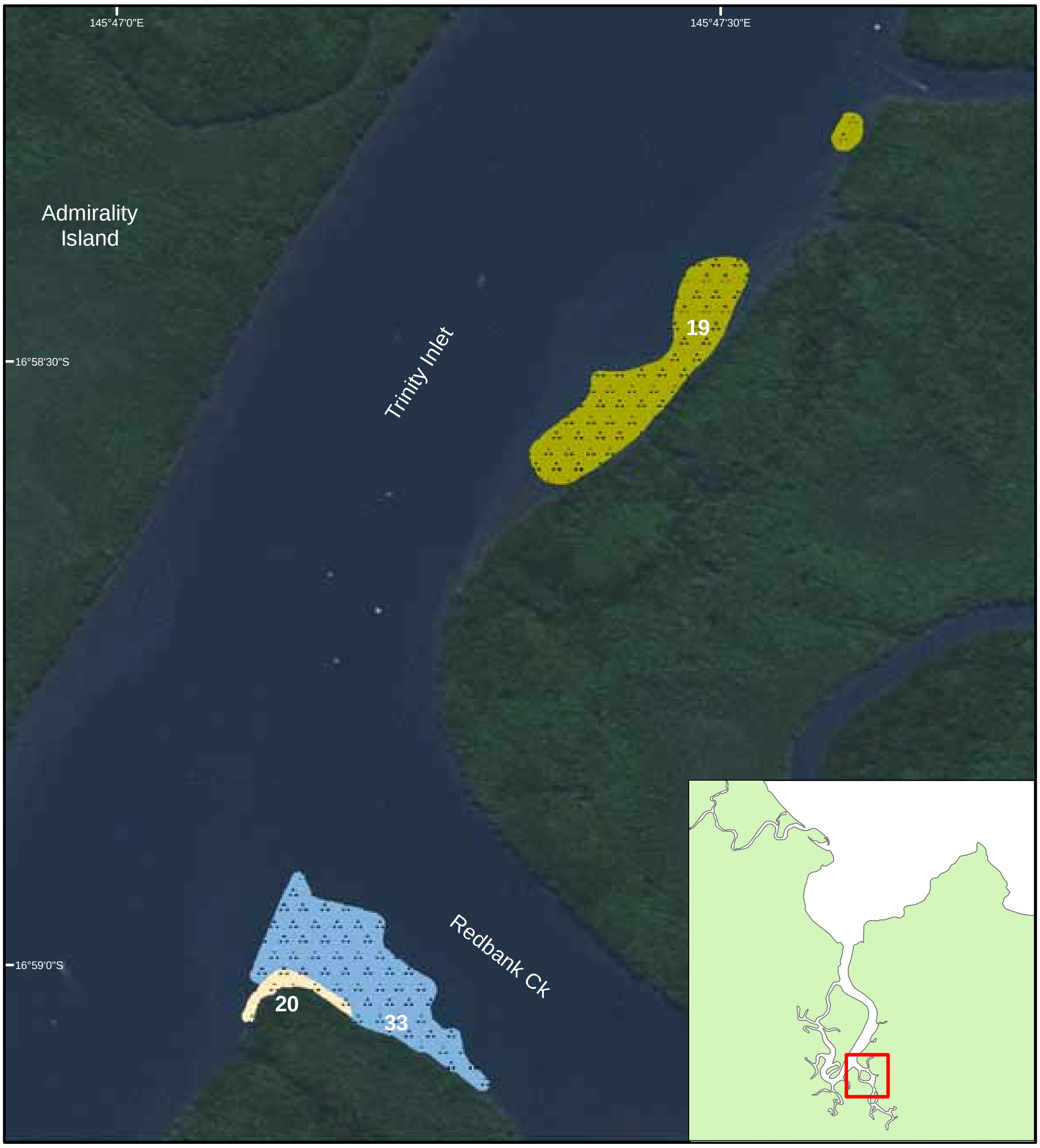
Map 4a. Trinity Inlet and Redbank Creek seagrass monitoring meadows October 2009.



Map 4b. Trinity Inlet and Redbank Creek seagrass monitoring meadows December 2010.



Legend

Aggregated patches

Cover type

- Light *Halophila decipiens* with *Halphila ovalis*
- Light *Halophila ovalis* with mixed species
- Light *Zostera capricorni* with *Halophilia ovalis*

0 100 200

Metres

Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011. Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010. DEEDI Publication (Fisheries Queensland, Cairns).

Table 4a. Seagrass monitoring meadow area (ha) in Cairns Harbour and Trinity Inlet, 2001-2010 (% values indicate change in area from previous survey; ± R = reliability estimate).

Meadow	Area (ha) (R)									
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
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%)	362.8 ± 13.37 (-4.3%)	92.1 ± 11.51 (-74%)
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%)	766.2 ± 34.06 (-4.6%)	97.2 ± 9.33 (-87%)
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%)	170.3 ± 9.63 (-13.8%)	54.2 ± 9.41 (-68%)
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%)	1.2 ± 1.46 (+100%)	3.68 ± 1.26 (+206%)
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%)	0.6 ± 0.68	0.37 ± 0.47 (-38%)
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%)	1.9 ± 1.32 (+35.7%)	3.84 ± 1.13 (+102%)
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**	**1303 ± 60.52**	**254 ± 33.11**

+ Percent change not shown because of insufficient biomass samples in 2001

NP = meadow not present

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

Table 4b. Mean above-ground biomass (g DW m^{-2}) of seagrass for monitoring meadows in Cairns Harbour and Trinity Inlet, 2001-2010.

Meadows indicated by an * were found to show significant differences in biomass between years (see Appendix 1).

Meadow	Mean biomass ± SE (g DW m^{-2})									
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
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	10.2 ± 3.3	1.07 ± 0.73
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	7.3 ± 1.1	0.54 ± 0.23
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	36.1 ± 7.6	1.74 ± 1.18^
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	1.6 ± 0.3	0.31 ± 0.19
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	30.4 ± 10.8	0.22 ± 0.17
Redbank (Ho) * (33)	NP	0.8 ± 0.1	6.6 ± 1.1	1.3 ± 0.2	2.2 ± 0.4	0.3 ± 0.0	2.1± 0.3	2.1 ± 0.4	0.1 ± 0.04	0.40 ± 0.24

^ The one site containing *Cymodocea serrulata* was omitted from Bessie Point biomass analysis and *Cymodocea rotunda* was omitted from South Bessie Point biomass analysis.

NP = meadow not present

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

Table 5a. Description of Cairns Harbour and Trinity Inlet seagrass monitoring meadows from the October 2009 monitoring survey.

Meadow	Location	Meadow ID	Number of Sites	Habitat Type	Meadow Cover	Meadow Description
Esplanade-Ellie Pt.	Cairns Harbour	34	69	Intertidal	Aggregated patches	Light *Zostera capricorni*
Bessie Point	Cairns Harbour	11	63	Subtidal to intertidal	Aggregated patches	Dense *Halodule uninervis* (thin)
South Bessie Point	Cairns Harbour	13	24	Intertidal	Continuous	Moderate *Zostera capricorni*
Inlet (Ho)	Trinity Inlet	19	9	Subtidal	Isolated patches	Moderate *Halophila decipiens*
Redbank (Zc)	Trinity Inlet	20	7	Intertidal	Continuous	Moderate *Zostera capricorni*
Redbank (Ho)	Trinity Inlet	33	19	Subtidal	Aggregated patches	Light *Halophila ovalis*

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

Table 5b. Description of Cairns Harbour and Trinity Inlet seagrass monitoring meadows from the October 2010 monitoring survey.

Meadow	Location	Meadow ID	Number of Sites	Habitat Type	Meadow Cover	Meadow Description
Esplanade-Ellie Pt.	Cairns Harbour	34	20	Intertidal	Isolated patches	Light *Zostera capricorni* with *Halophila ovalis*
Bessie Point	Cairns Harbour	11	7	Subtidal to intertidal	Aggregated patches	Light *Halodule uninervis* (thin)
South Bessie Point	Cairns Harbour	13	17	Intertidal	Aggregated patches	Light *Zostera capricorni* with *mixed species*
Inlet (Ho)	Trinity Inlet	19	16	Subtidal	Aggregated patches	Light *Halophila decipiens* with *Halophila ovalis*
Redbank (Zc)	Trinity Inlet	20	9	Intertidal	Aggregated patches	Light *Zostera capricorni* with *Halphila ovalis*
Redbank (Ho)	Trinity Inlet	33	37	Subtidal	Aggregated patches	Light *Halophila ovalis* with mixed species

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

Comparison with previous monitoring surveys

In 2009, the total seagrass meadow area in Cairns harbour and Trinity Inlet was largely unchanged from 2008 and within ranges recorded since 2001. However in 2010, the total seagrass meadow area declined dramatically in all meadows except the two subtidal Trinity Inlet meadows (Table 4a). Additionally, the area of the Cairns harbour meadows; Esplanade to Ellie Point, Bessie Point and South Bessie Point, were all well below the ranges previously recorded since monitoring began (Table 4a).

While there were some small fluctuations in meadow biomass in 2009, only two meadows showed significant change from 2008 (meadows 33 and 34) (see Appendix 1a; 1c). In 2010 meadow biomass showed declines compared to 2009, with significant declines occurring in meadows 20, 11 and 13 (see Appendix 1b; 1c). Seagrass meadow biomass remained below historical peak densities (2001 to present) for both 2009 and 2010 (Table 4b; Figure 1).

The three monitoring meadows in Cairns Harbour remained generally stable in biomass and area between 2008 and 2009, however significant declines in both biomass and area for all three meadows were seen in 2010. These declines are well below the range that has previously been recorded for these meadows since monitoring began in 2001 (Table 4 & 5; Figure 1; Appendix 1). All three Cairns Harbour meadows have been exhibiting a general downward trend in biomass and area for the last 4-6 years (Figure 1).

While the distribution of the Esplanade to Ellie Point meadow (34) remained unchanged in 2009 compared to the previous year, in 2010 the meadow was highly fragmented with only isolated patches of seagrass present, thus reducing the overall area of the meadow. Similarly, the South Bessie Point (13) meadow remained relatively unchanged in 2009 compared to 2008, however it also showed a change in landscape category from a continuous cover of seagrass to fragmented aggregated patches of seagrass in 2010.

Species composition in the Cairns Harbour meadows over 2009 and 2010 have generally followed similar trends to those seen since at least 2006 (Figure 1). There was however, a small notable shift in species composition in two of the Cairns Harbour meadows from 2009 to 2010. In the *Zostera* dominated Esplanade to Ellie Point meadow (34), *Halophila ovalis* comprised 11.5% of the meadow; the highest presence it has had in this meadow since monitoring began. While *Cymodocea serrulata* has been present in the Esplanade to Ellie Point (34) and South Bessie Point (13) meadows for at least the last four years, it was not recorded in 2010 in either meadow. Interestingly, *Cymodocea rotundata* was present in small quantities in the South Bessie Point meadow (13) in 2010, which has not been recorded at this site in previous monitoring surveys.

The small monitoring meadows in Trinity Inlet have been highly variable in both density and distribution throughout the monitoring program. Increases and decreases in meadow biomass between years have occurred mainly in the subtidal *Halophila* dominated meadows (meadows 19 and 33) with the Redbank *Ho* meadow (33) showing a significant decline in biomass in 2009 compared with 2008. A slight, but not significant increase in biomass from 2009 was evident in this meadow in 2010. The intertidal *Zostera* dominated meadow on Redbank (20) has declined in biomass for two consecutive years since 2008. From 2009 to 2010 the biomass of this meadow had declined significantly by 92% (Maps 4-7; Figure 1; Appendix 1).

The small isolated patches of seagrass in the Inlet (19) meadow had increased in area in 2009 from 2008, however not enough to again form one whole meadow as it was in 2007 (Map 7). The Redbank *Ho* (33) meadow had also fragmented into three separate areas in 2009, a pattern that was first noted in 2006 when biomass of this area was similarly low. By 2010 the distribution of this meadow had expanded again to form one whole meadow, increasing in distribution to values that were seen in the peak years of monitoring: 2002-2004 (Maps 4-7; Table 4; Figure 1; Appendix 1). The Redbank *Zc* (20) meadow has remained relatively stable in distribution over the past eight years.

Species composition has remained relatively unchanged in the Inlet meadow (19) for the last four years, however changes have occurred in both Redbank meadows (20 & 33) (Figure 1). In 2010, a higher component of *Halophila ovalis* (20%) was found in the *Zostera* dominated meadow of Redbank (20) compared with 2008 and 2009 (Figure 1). In the Redbank *Ho* meadow (33), *Halophila decipiens* was absent in 2009, but had returned in 2010 making up 25% of the species composition. *Zostera capricorni* was also present in the Redbank *Ho* meadow (33).

Table 6. Maximum depth of monitoring meadows at Cairns Harbour and Trinity Inlet, 2001 – 2010.

Meadow location and ID number	Maximum Depth (depth below mean sea level (m))									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Esplanade to Ellie Pt. (34)	na	na	na	0.9	na	na	na	1.7	1.5	na
Bessie Pt. (11)	3.7	3.7	4.0	4.1	4.0	4.3	4.2	4.2	3.1	4.2
Inlet (Ho) (19)	na	3.2	3.4	3.8	2.9	3.3	3.3	4.4	3.8	2.6
Redbank (Zc) (20)	1.3	1.1	1.5	1.6	1.2	1.1	2.0	1.6	2.4	1.5
Redbank (Ho) (33)	na	3.4	3.2	3.2	2.9	2.4	3.0	1.8	4.8	3.8

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

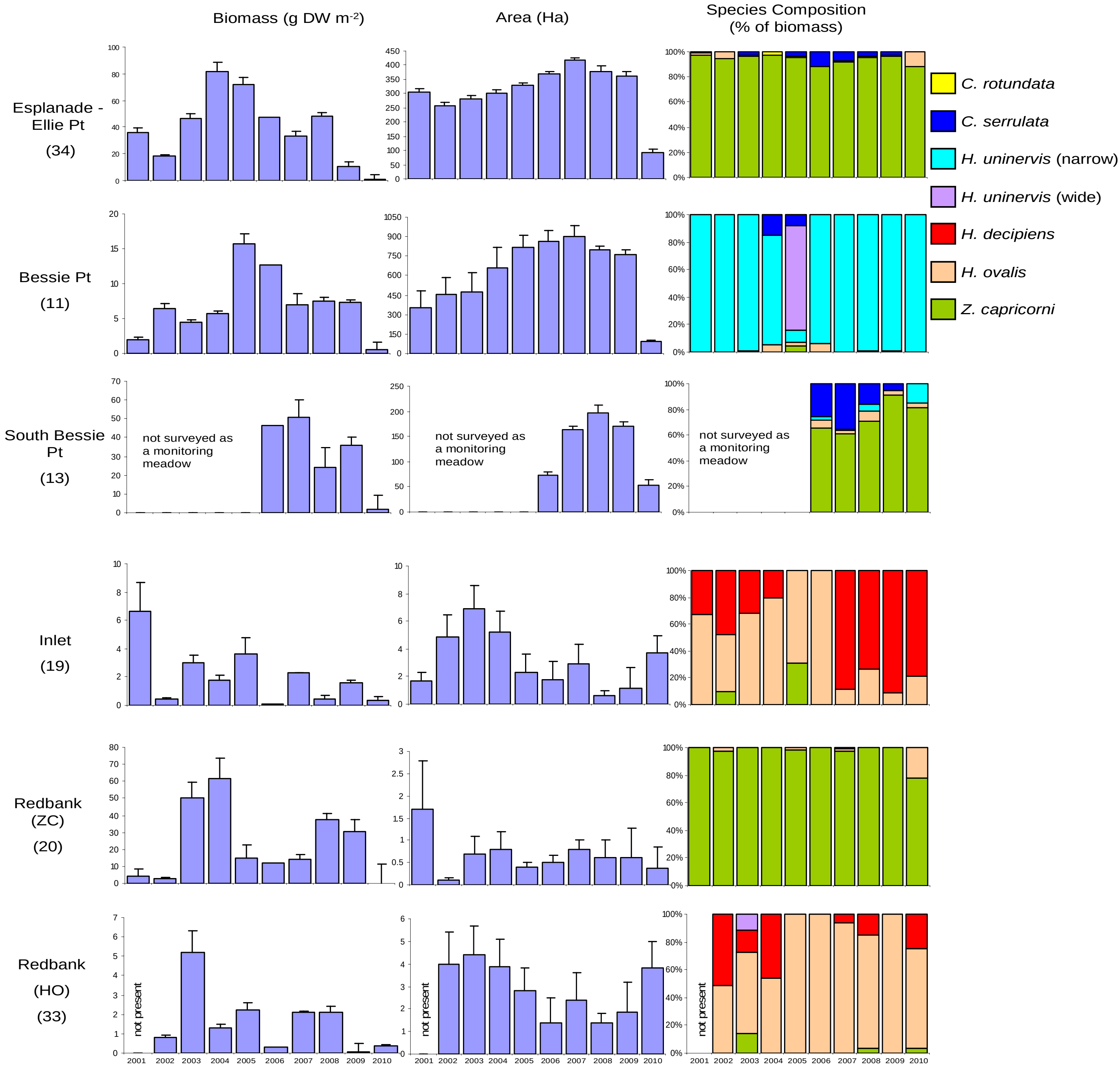
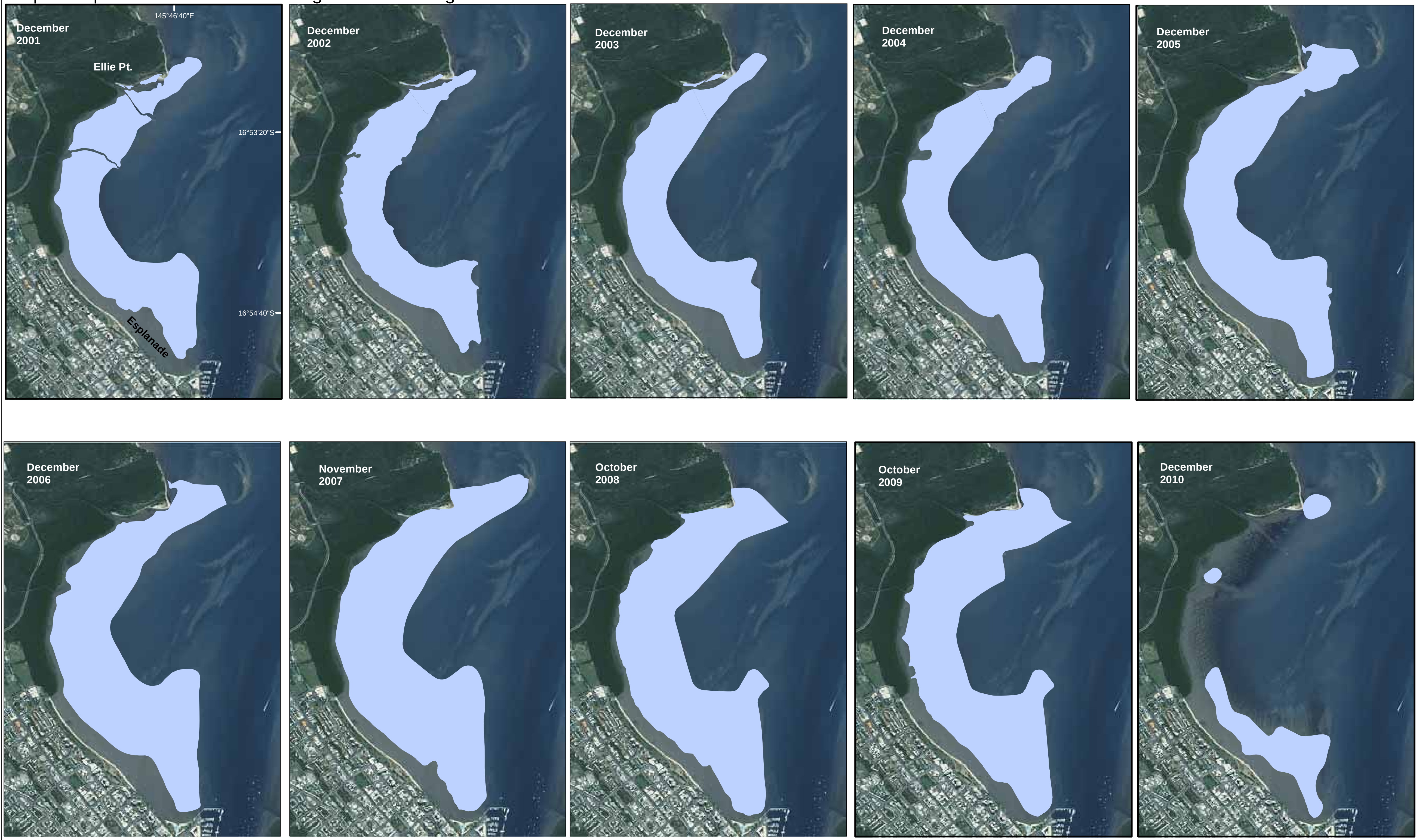


Figure 1. Mean biomass (g DW m^{-2}) area ± R (ha) and species composition (%) of monitoring meadows at Cairns Harbour and Trinity Inlet from 2001-2010.

Map 5. Esplanade to Ellie Point seagrass monitoring meadows from 2001 to 2010.



Legend

Esplanade - Ellie Point Meadow (34)

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

0 0.5 1
Kilometres

Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011.
Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010.
DEEDI Publication (Fisheries Queensland, Cairns).

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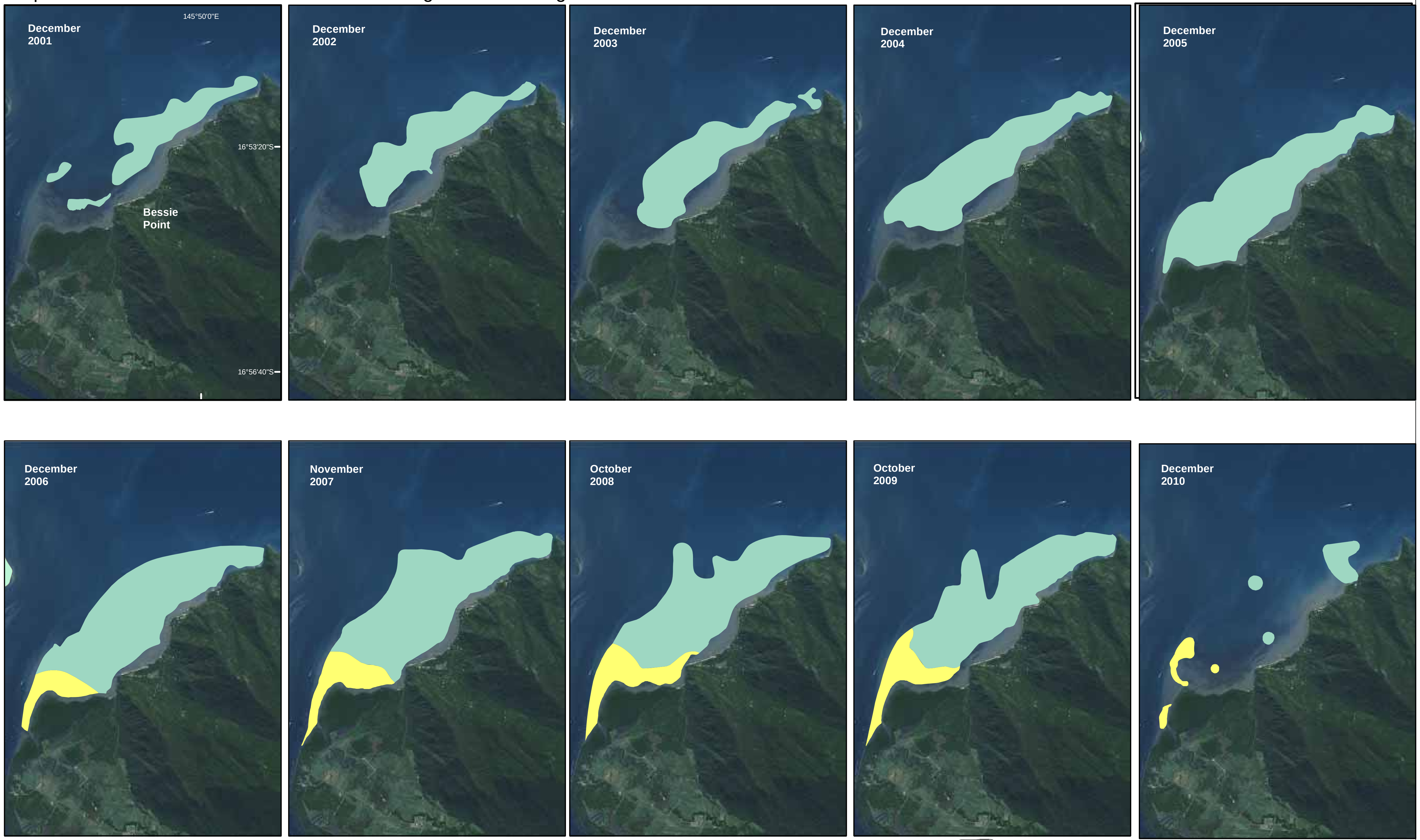
Map 6. Bessie Point and South Bessie Point seagrass monitoring meadows from 2001 to 2010.



Legend

Bessie Point Meadow (11)

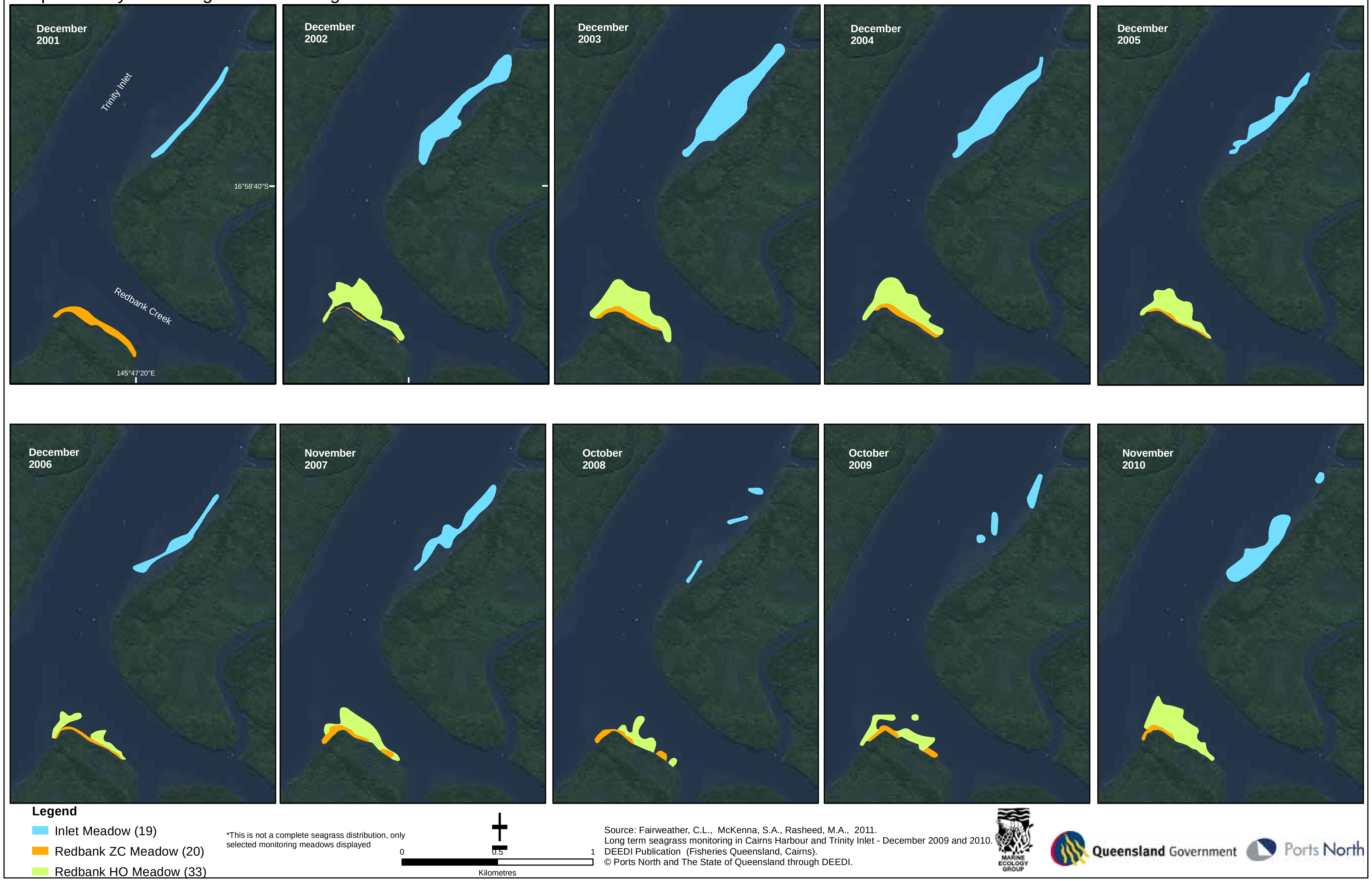
South Bessie Point Meadow (13)

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

0 0.5 1
Kilometres

Source: Fairweather, C.L., McKenna, S.A., Rasheed, M.A., 2011.
Long term seagrass monitoring in Cairns Harbour and Trinity Inlet - December 2009 and 2010.
DEEDI Publication (Fisheries Queensland, Cairns).

Map 7. Trinity Inlet seagrass monitoring meadows from 2001 to 2010.



CLIMATE DATA

Total annual rainfall in Cairns was above the 68 year average in 2009 and 2010 (Figure 2a). Rainfall is highly seasonal with the majority of rainfall typically occurring from December to March/April. 2009 experienced four months of low rainfall over the typical dry season, while in 2010 the seasonal trend was not so obvious with every month except June experiencing high levels of rainfall (Figure 2b). In 2009 and 2010 flooding associated with seasonal rainfall occurred from January to March (Figure 2b). This high rainfall coincided with high flows of the major catchment for the Cairns area, the Barron River (Figure 3). High flows were recorded between January and April in 2009 and almost half the year in 2010, from January to May (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 and was the lowest on record in 2010 (Figure 4a). Intertidal banks in 2010 experienced substantially lower amounts of tidal exposure for all months compared to 2009 (Figure 4b). No day time exposure occurred in January, February or November in 2009 and none in November and December in 2010 (Figure 4b). Coinciding with low tidal exposure in 2010 was a higher amount of cloudy days in the three months prior to the survey in 2010 compared to 2009 (Figure 5). In the three months prior to the 2009 survey 3-25% of days were considered cloudy. In contrast, 40-80% of days in the three months prior to the surveys were considered cloudy in 2010 (Figure 5).

Solar irradiance has varied over the past decade, however, the trend indicates a slight increase in solar radiation from 2000 to 2010 (Figure 6a). The solar radiation in the months leading up to the survey were higher in 2009 compared with 2010 (Figure 6b). 2010 showed the lowest solar radiation in the past three years (Figure 6b).

The mean annual daily maximum temperature was 29.68°C in 2009 and 29.82°C in 2010 which was only slightly above the 68 year average of 29°C and at most 0.22°C above the 2008 average (Figure 7).

Low tidal exposure combined with high cloud cover, low solar irradiance and average temperatures suggest that intertidal seagrasses were protected from thermal and desiccation stress that can be experienced during tidal exposure in 2010. While this may have been of some benefit the sustained higher rainfall and associated flooding experienced in 2009 and 2010 were likely to place seagrasses in Cairns Harbour and Trinity Inlet under increased stress due to high levels of freshwater input and a substantial reduction in light available for photosynthesis and plant growth.

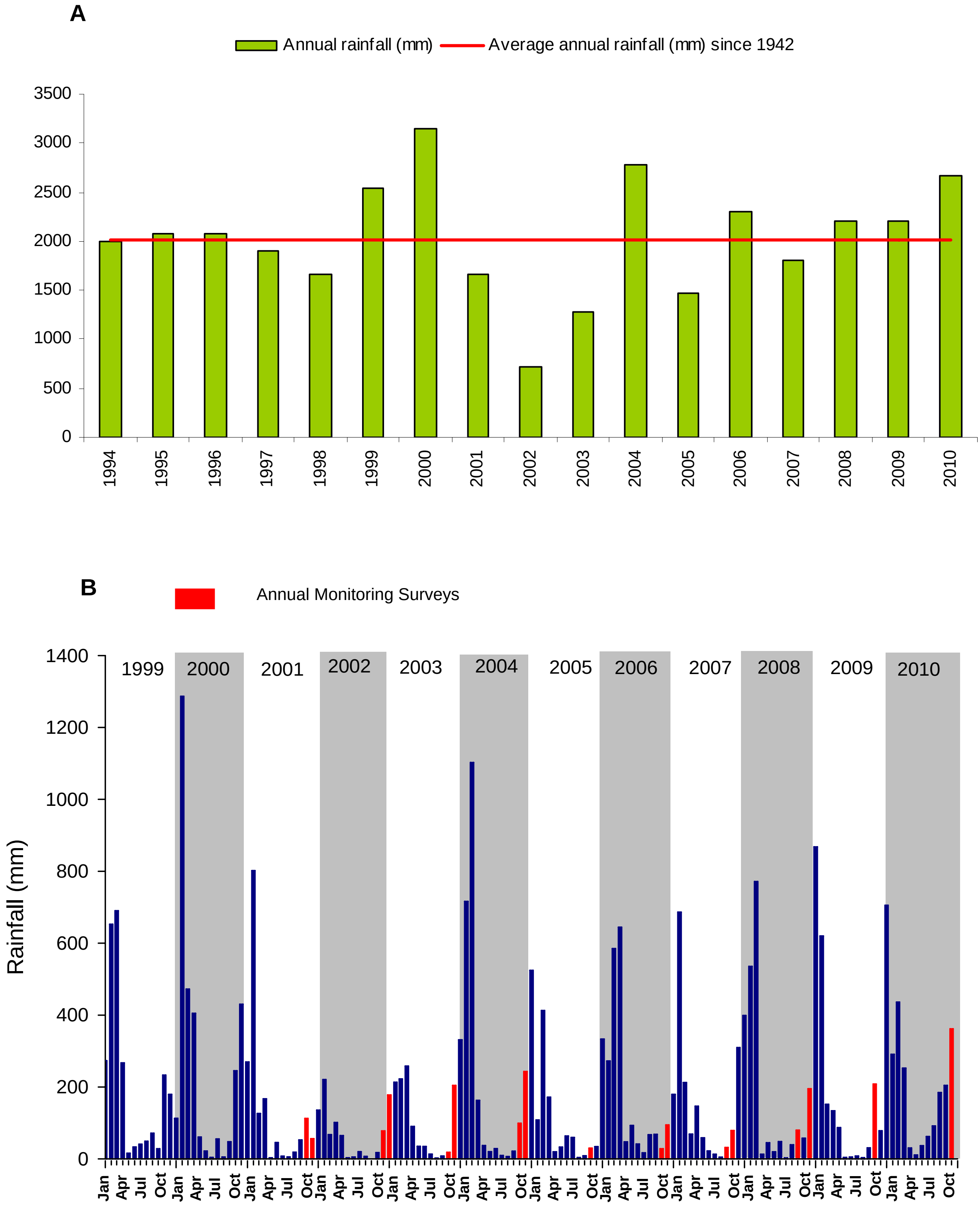


Figure 2. (A) Total annual rainfall (mm) for the Cairns area from 1994 to 2010. (B) Total monthly rainfall (mm) for the Cairns area from 1999 to 2010 (Bureau of Meteorology 2010).

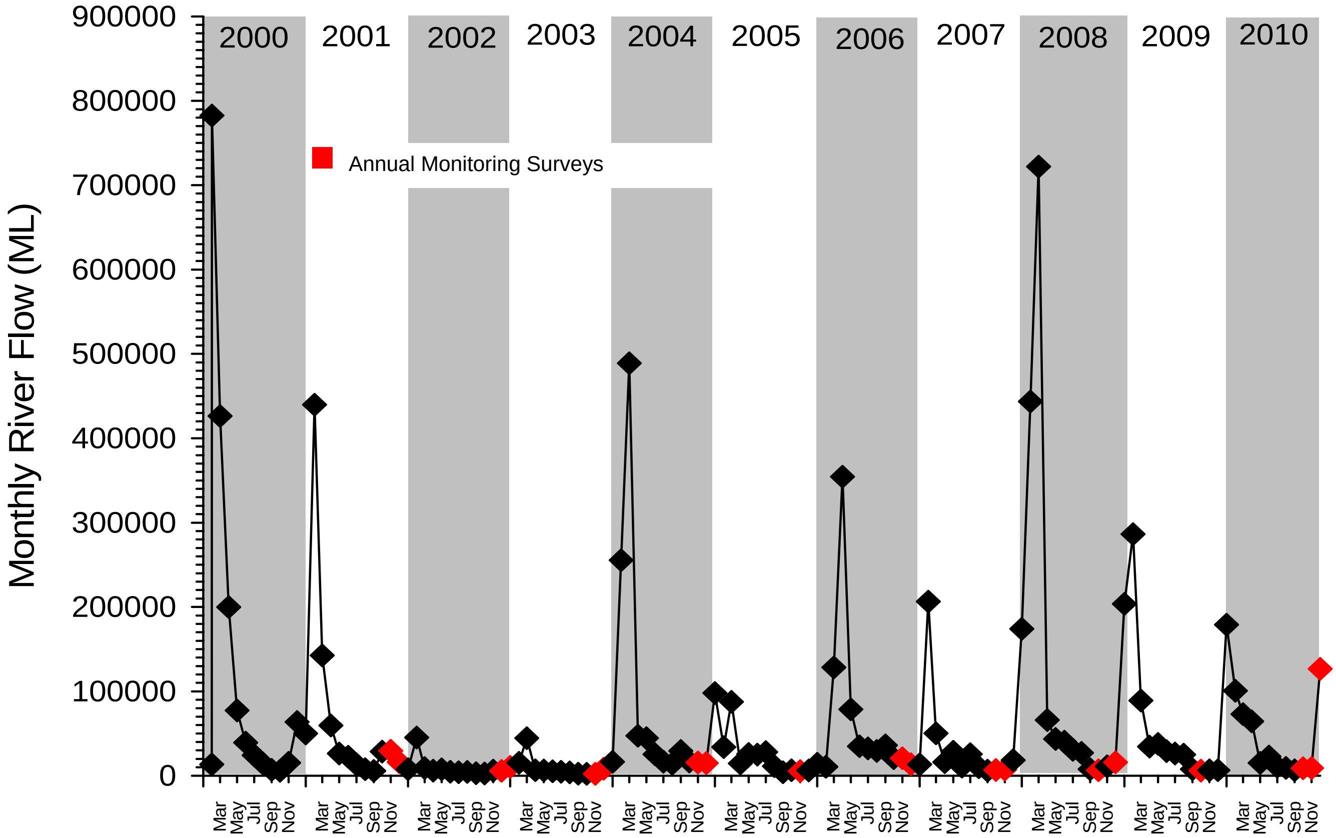
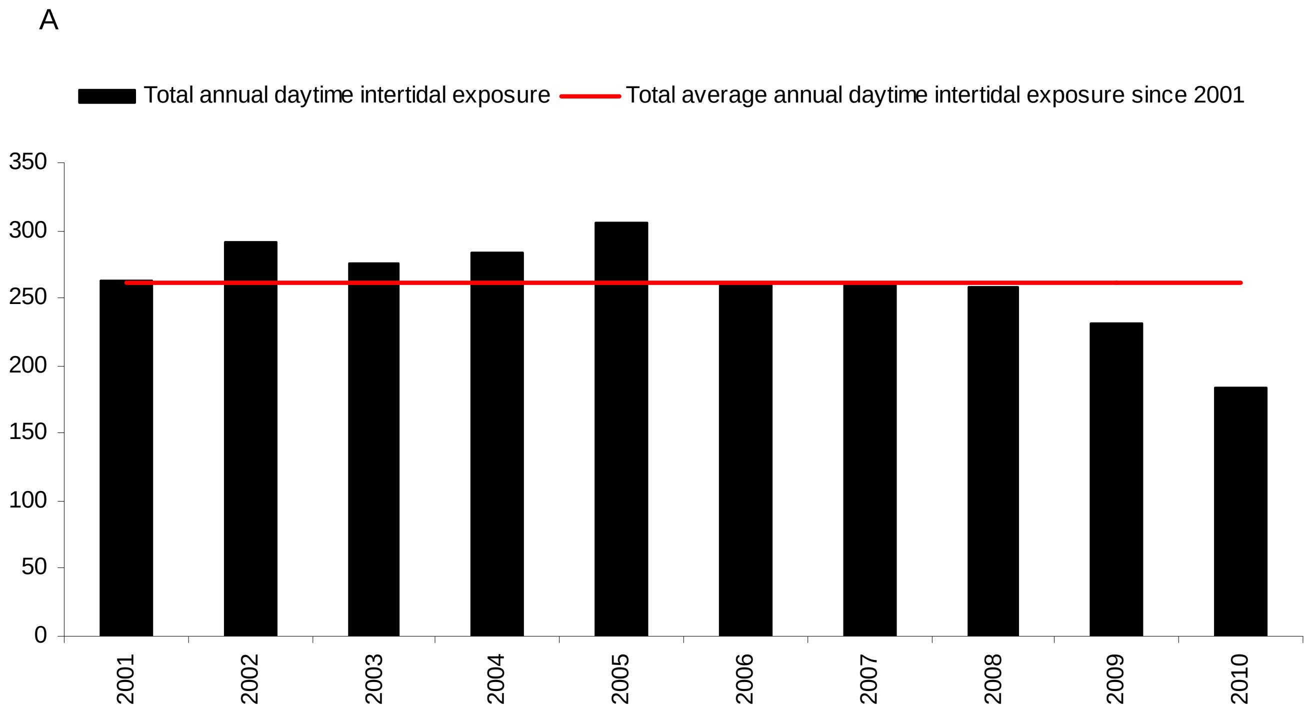


Figure 3. Total monthly river flow for the Barron River between 2000 and 2010 (© The State of Queensland (Department of Environment and Resource Management) 2011.)



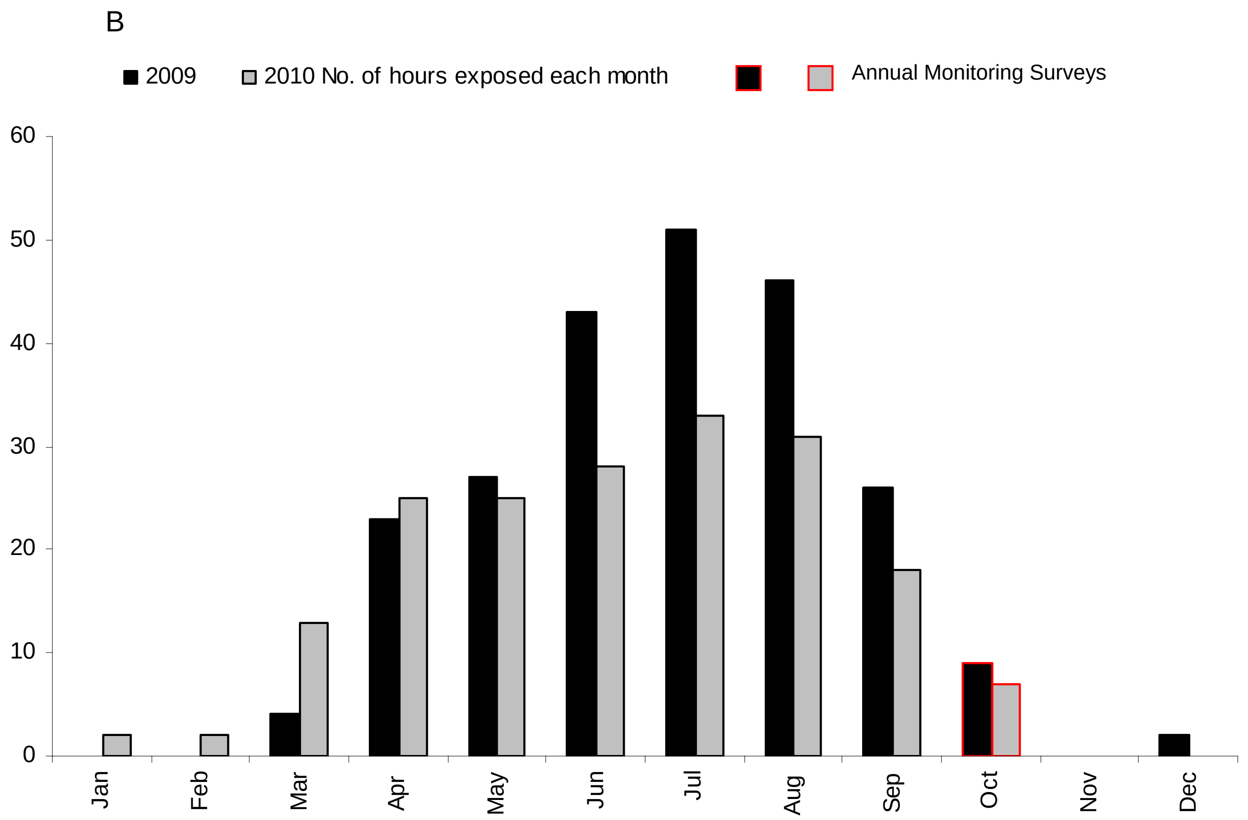


Figure 4. (A) Total annual hours of daytime intertidal exposure (<0.8m tidal height) in Cairns Harbour and Trinity Inlet. (B) Total number of daytime hours intertidal banks exposed for each month in 2009 and 2010 (Bureau of Meteorology, 2010).

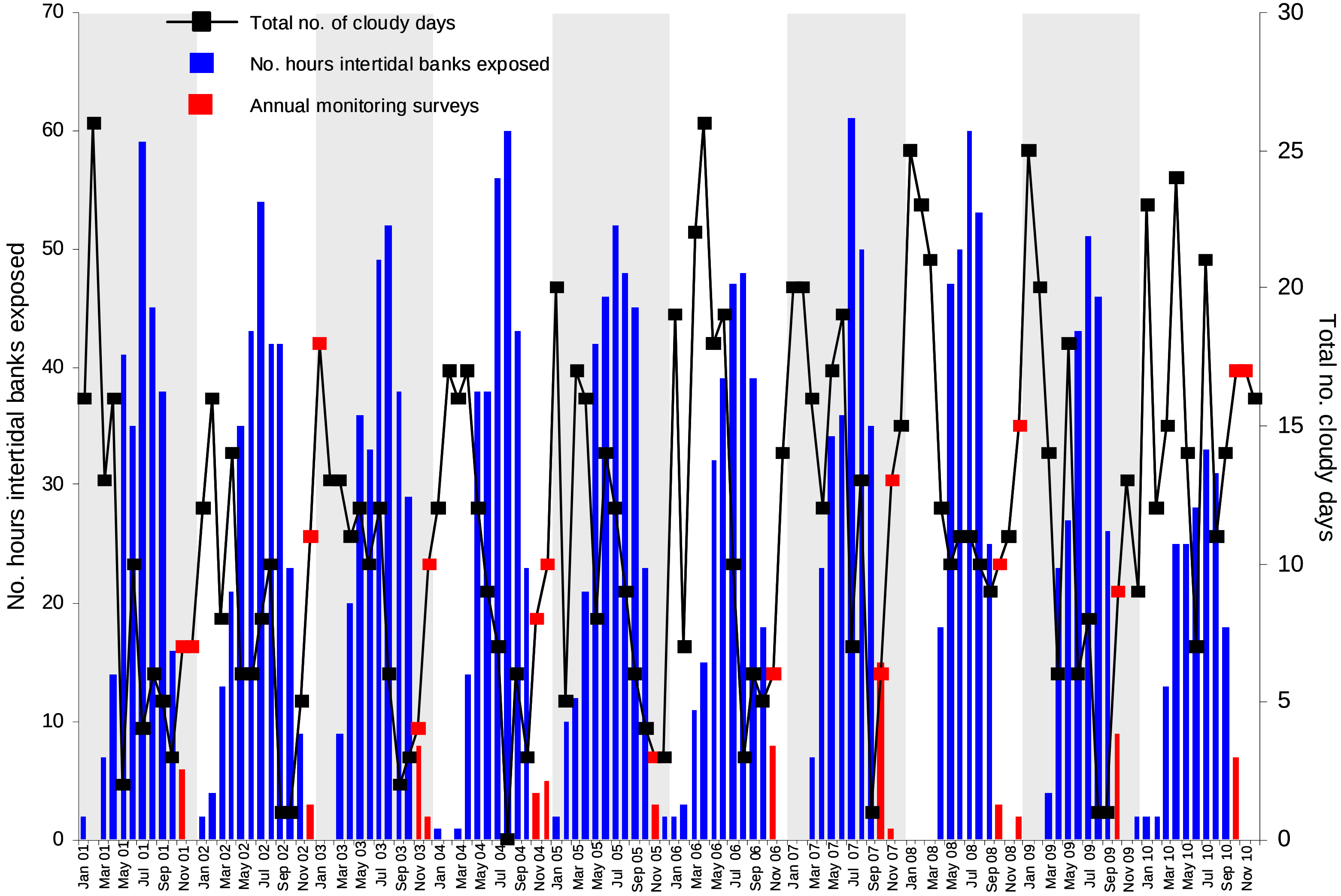
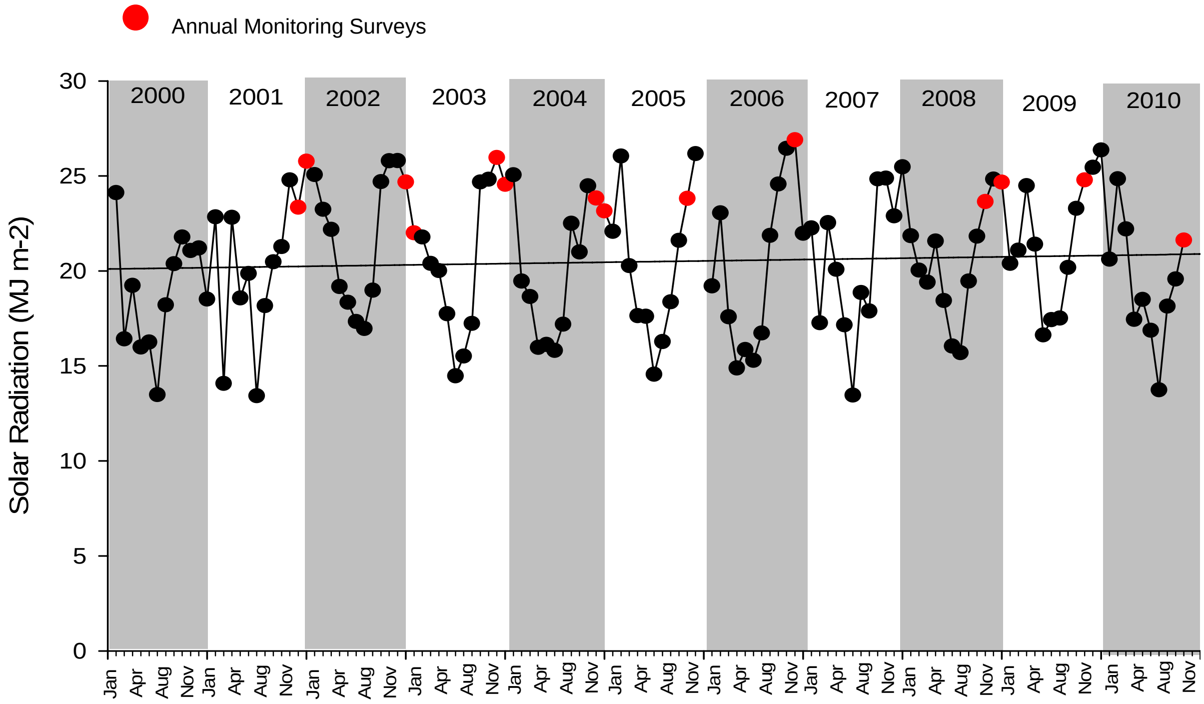


Figure 5. Mean number of daylight hours per month intertidal seagrasses are exposed and number of cloudy days per month for Cairns from 2001-2010 (Bureau of Meteorology 2010)

A



B

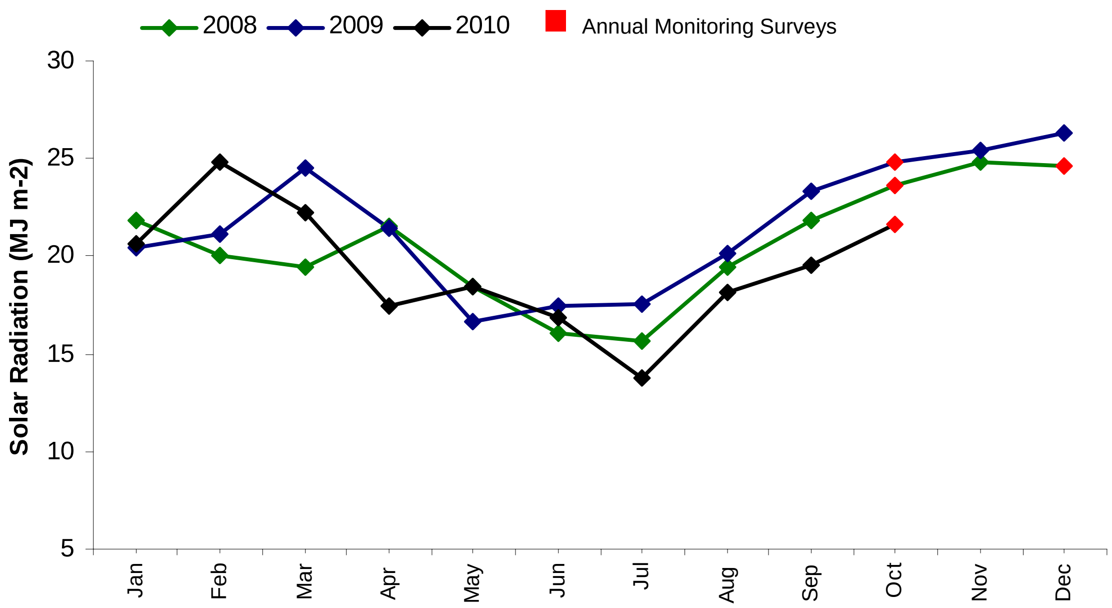


Figure 6. (A) Mean monthly solar radiation recorded in Cairns Harbour and Trinity Inlet. (B) Mean monthly solar radiation for each month in 2008 to 2010 (Note: data current at time of analysis until 27.10.2010)(Bureau of Meteorology 2010).

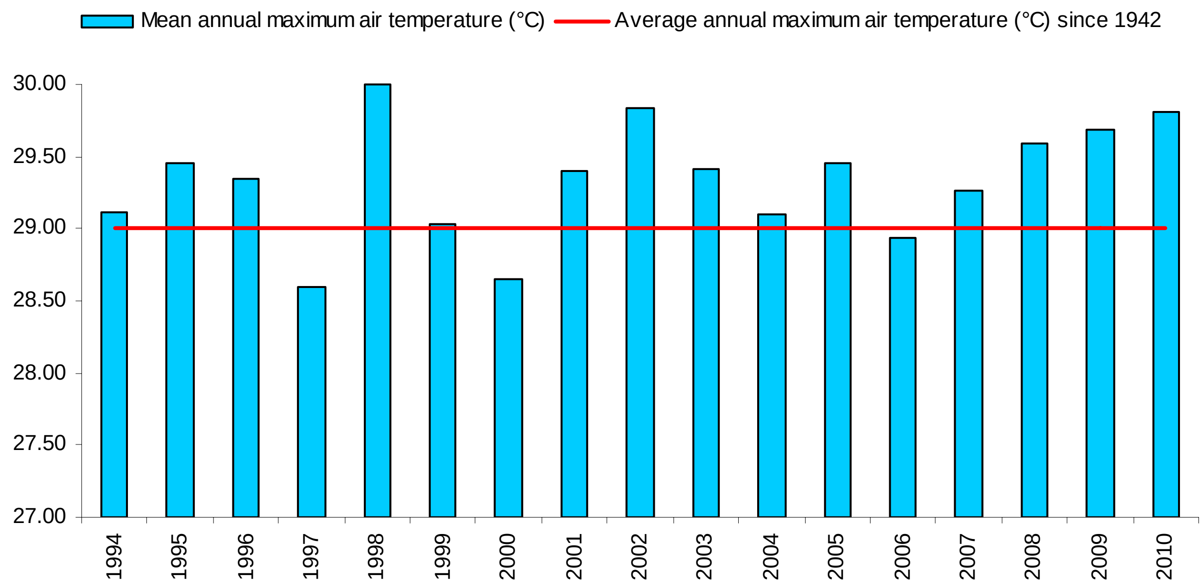


Figure 7. Mean annual daily maximum air temperature recorded at Cairns airport 1994 to 2010 (Bureau of Meteorology 2010).

Discussion

Results from the most recent seagrass monitoring have found that seagrasses in Cairns Harbour are in a highly vulnerable state with meadows reduced to their smallest area and density recorded in the program. The large seagrass meadows adjacent to the Esplanade and on the opposite side of the Inlet between Bessie Point and False Cape suffered major declines, becoming patchy and fragmented with only a light cover of seagrass within remaining patches.

While seagrasses were in a fair condition in 2009 with a small decline from the previous year, there was a dramatic decline between 2009 and 2010. In 2010 the biomass and distribution of most meadows in Cairns Harbour and Trinity Inlet declined to record low values since monitoring began in 2001. Overall, these meadows are likely to be highly vulnerable in the event of future impacts or stress.

The cause of this large decline in seagrass was highly likely to be linked to a range of climate conditions resulting in unfavourable conditions for seagrass growth in 2010. Higher than average rainfall across both the wet and dry seasons, flooding from local catchments and a reduction in solar irradiation would have all resulted in a substantial reduction in the light available to seagrasses for growth and photosynthesis. Many seagrasses in Cairns under “normal” climate conditions are likely to be growing at their lower limits of light requirements and are reliant on a narrow window of opportunity around low tide for effective photosynthesis (Pollard & Greenway 1993). Climate conditions experienced during 2010 combined with a reduced tidal window of opportunity due to natural cycles in daytime low tides would have substantially reduced the effective window of opportunity for seagrass growth.

Above average rainfall and flooding of the Barron River early in 2009 and most of 2010 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 from 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, Chartrand et al. 2010).

Seagrass meadows in Cairns Harbour and Trinity Inlet are highly dynamic, responding to a range of environmental stressors such as seasonal cycles that impact upon light availability and nutrient dynamics. The differences between meadow responses may be associated with differences in species and the physical setting of the meadows. Previous changes in intertidal meadows of Cairns Harbour and Trinity Inlet were linked to the degree and severity of exposure related stress (McKenna et al. 2009). Higher air temperatures, lower numbers of cloudy days/higher irradiance and high hours of intertidal daytime exposure are thought to lead to thermal stress and desiccation (Erftemeijer and Herman 1994; Rasheed et al. 2008). In contrast changes to subtidal meadows that had occurred were linked with turbidity and other factors associated with high rainfall and runoff (McKenna et al. 2009). In 2010 the number of hours of daytime exposure were substantially lower than in previous years along with an increased number of cloudy days, and a decrease in solar radiation. While these conditions were likely to benefit seagrasses by protection from the effects of thermal stress and desiccation, the lower light conditions caused by increased rainfall, turbidity and catchment runoff and reduced tidal window for effective photosynthesis were likely to have contributed to the observed decline in seagrasses.

Similar large scale declines of seagrass occurred during 2010 in other north-eastern Queensland coastal locations where the team conducts similar monitoring programs indicating a regional, rather than local, driver of seagrass change. Large declines occurred in Mourilyan Harbour, Townsville and Gladstone over the same period. The majority of intertidal *Zostera* meadows in Mourilyan and Gladstone decreased in biomass in November 2010 (Fairweather et al. 2010; Chartrand et al. 2010), while monitoring in Townsville revealed that there were similar declines in intertidal and subtidal meadows (Taylor & Rasheed In press). These declines corresponded with major rainfall events and severe episodic flooding that occurred across the state in 2010 related to the strong La Nina weather patterns in the Pacific Ocean.

In contrast, seagrasses in the Gulf of Carpentaria and Torres Strait have generally increased in biomass and distribution (McCormack et al. 2011, McKenna & Rasheed 2011; Fisheries Queensland unpublished data). In 2010 the Gulf of Carpentaria was not subjected to the same La Nina conditions and levels of flooding that the east coast experienced which may explain the different responses of seagrass populations in these areas.

Although there was a small increase in area for the subtidal meadows in Trinity Inlet from 2008 to 2010, the depth penetration of Inlet *Halophila* meadow was at its shallowest since monitoring began, and the Redbank Creek *Halophila* meadow's depth penetration had decreased in 2010 from 2009. The growth, survival and depth penetration of seagrass is directly related to the availability of light (Dennison and Alberte 1985; Dennison 1987), which is influenced by turbidity associated with high rainfall and runoff. The reduced depth penetration of the inlet seagrass meadows is a further indication of a reduced light environment.

The major declines in the Cairns Harbour seagrass meadows have likely left them with a low resilience to further impacts and a reduced capacity for recovery. 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). The cumulative impacts of natural stressors, combined with a potential increased level of impact from future port activities, places these seagrasses at a heightened risk. The health of these seagrasses needs to be carefully monitored in the future as their reduced resilience may mean that they are more vulnerable to impacts that in the past they have been able to withstand.

If these meadows are completely lost the time for recovery could be substantial. While some seagrass meadows in Queensland can have established seed banks from which recovery can occur (Inglis 2000; McKenzie and Unsworth 2009), this is not always the case. Studies on *Zostera capricorni* at Ellie Point in Cairns Harbour found that recovery was almost exclusively reliant on asexual colonisation through rhizome extension from nearby plants with the seed bank being absent and playing no role in recovery (Rasheed 1999). Under these conditions if all of the adult plants were lost from the meadow then recovery could only occur through dispersal from elsewhere (Rasheed 1999; Rasheed 2004; Unsworth et al. 2010; Chartrand et al. 2010).

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 where more localised factors are often highly important in determining meadow responses to impacts. There are several enhancements to the existing monitoring program that were first discussed in the 2008 long-term seagrass monitoring report. These enhancements would still 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; 2010). 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; 2010).

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 (e.g. Karumba) to assess meadow vulnerability (Unsworth et al. 2009).

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*

   Location of the existing water quality monitoring sites maintained by Ports North and Cairns Regional Council 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.

While port activities during 2010 were unlikely to have had a major impact on seagrass condition, the current state of low resilience of the seagrass means they are increasingly vulnerable to impacts to which they have previously been resilient. Extra vigilance should be maintained for any activity such as maintenance dredging, coastal development, land use change or runoff water quality, that has the capacity to impact on water quality and seagrass condition, until these meadows have recovered.

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Appendix 1 – STATISTICAL ANALYSIS

A. Results of one-way ANOVA for mean above-ground biomass versus year for the Cairns Harbour and Trinity Inlet monitoring meadows 2001 to 2009.

Esplanade to Ellie Pt. Meadow (34)	DF	MS	F	P
Between Years	8	42068.4	30.53	< 0.0001
Within Years	691	1378.15		
Total	699			
Redbank (Zc) Meadow (20)	**DF**	**MS**	**F**	**P**
Between Years	8	4987.87	8.86	< 0.0001
Within Years	92	562.853		
Total	100			
Inlet (Ho) Meadow (19)*	**DF**	**MS**	**F**	**P**
Between Years	8	0.56434	8.99	< 0.0001
Within Years	113	0.06280		
Total	121			
Redbank (Ho) Meadow (33)*	**DF**	**MS**	**F**	**P**
Between Years	7	0.86806	21.26	< 0.0001
Within Years	166	0.04083		
Total	173			
Bessie Pt Meadow (11)	**DF**	**MS**	**F**	**P**
Between Years	8	852.69	16.3	< 0.0001
Within Years	515	52.32		
Total	523			
South Bessie Pt Meadow (13)	**DF**	**MS**	**F**	**P**
Between Years	3	3308.49	3.21	< 0.0001
Within Years	82	1029.65		
Total	85			

* Data was log+1 transformed

B. Results of one-way ANOVA for mean above-ground biomass versus year for the Cairns Harbour and Trinity Inlet monitoring meadows 2001 to 2010.

Esplanade to Ellie Pt. Meadow (34)	DF	MS	F	P
Between Years	9	41556.3	30.98	< 0.0001
Within Years	710	1341.37		
Total	719			
Redbank (Zc) Meadow (20)	**DF**	**MS**	**F**	**P**
Between Years	9	5027.95	9.71	< 0.0001
Within Years	100	517.83		
Total	109			
Inlet (Ho) Meadow (19)*	**DF**	**MS**	**F**	**P**
Between Years	9	34.87	6.49	< 0.0001
Within Years	128	5.37		
Total	137			
Redbank (Ho) Meadow (33)	**DF**	**MS**	**F**	**P**
Between Years	8	44.69	30.78	< 0.0001
Within Years	202	1.45		
Total	210			
Bessie Pt Meadow (11)	**DF**	**MS**	**F**	**P**
Between Years	9	795.79	15.39	< 0.0001
Within Years	521	51.72		
Total	530			
South Bessie Pt Meadow (13)	**DF**	**MS**	**F**	**P**
Between Years	4	6318.16	7.32	< 0.0001
Within Years	98	863.55		
Total	102			

C. 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 2009	Mean biomass 2010
Esplanade to Ellie Pt (34)	2001	36 cd	36 cd
	2002	18 e	18 e
	2003	46.2 bc	46.2 bc
	2004	81.6 a	81.6 a
	2005	71.6 a	71.6 a
	2006	47.4 bc	47.4 bc
	2007	33.2 d	33.2 d
	2008	48.4b	48.4b
	2009	10.2e	10.2e
	2010		1.07e
Redbank (Zc) (20)	2001	4.5 cd	4.5 d
	2002	3.1 d	3.1 d
	2003	50.1 ab	50.1 ab
	2004	61.5 a	61.5 a
	2005	15.1 cd	15.1 cd
	2006	11.9 cd	11.9 cd
	2007	14.1 cd	14.1 cd
	2008	37.5 b	37.5 b
	2009	30.4 bc	30.4 bc
	2010		0.22d
Inlet (Ho) (19)	2001	6.6 a	6.6 a
	2002	0.4 d	0.4 ef
	2003	3 b	3 bc
	2004	1.8 bc	1.8 cde
	2005	3.6 b	3.6 b
	2006	0.1 d	0.1 f
	2007	2.3 b	2.3 bcd
	2008	0.4 d	0.4 def
	2009	1.6 cd	1.6 cdef
	2010		0.7f
Redbank (Ho) (33)	2001	not sampled	not sampled
	2002	0.8 cd	0.8 cd
	2003	5.2 a	5.2 a
	2004	1.3 bc	1.3 c
	2005	2.2 b	2.2 b
	2006	0.4 de	0.4 d
	2007	2.0 b	2.0 b
	2008	2.1 b	2.1 b
	2009	0.1 e	0.1 d
	2010		0.07d
Bessie Point (11)	2001	2.0 f	2.0 f
	2002	6.4 bd	6.4 bd
	2003	4.4 df	4.4 df
	2004	5.8 bde	5.8 bde
	2005	14.4 a	14.4 a
	2006	12.7 a	12.7 a
	2007	6.9 bd	6.9 bd
	2008	7.6 b	7.6 b
	2009	7.34 b	7.34 b
	2010		0.54 ef
South Bessie Point (13)	2001 – 2005	NA	NA
	2006	46.3 a	46.3 a
	2007	50.9 a	50.9 a
	2008	23.3 b	23.3 b
	2009	36.5 ab	36.5 ab
	2010		1.7c