Reef Rescue

Marine Monitoring Program
Intertidal Seagrass

ANNUAL REPORT

For the sampling period 1st September 2009 – 31st May 2010

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Acronyms Used In This Report

DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts
DEEDI	The Department of Employment, Economic Development and Innovation Queensland
Fisheries QLD	Fisheries Queensland (DEEDI)
GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
JCU	James Cook University
MMP	Marine Monitoring Program
NRM	Natural Resource Management
Paddock to Reef	Paddock to Reef Integrated Monitoring, Modelling and Reporting Program

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Executive summary

Overall there are indications that seagrass meadows along the GBR are in a state of decline. The indicators of this decline are; 67% of sites with reduced seagrass abundance (below the seagrass guidelines), 50% sites exhibiting shrinking meadow area, many sites have limited or are not producing seeds that would enable rapid recovery, indications of light limitation at 63% of sites, nutrient enrichment at 33% sites and 90% of sites with either high or elevated nitrogen. There is also evidence of long term increases of seagrass nutrient content (in tissues) in coastal and reef seagrasses, particularly in the Wet Tropics and Burdekin regions. Elemental ratios of tissue nutrients indicate some locations in the Wet Tropics and Mackay Whitsunday have degraded water quality with an excess of nutrients compared to light availability. Increased epiphyte loads, possibly stimulated by nutrient loading, further exacerbate light limitation on the surfaces of slower-growing seagrass leaves in coastal and estuarine habitats. It is not clear if this decline will be reversed with a shift in climatic factors.

Other interactions will also be important to consider. Under limiting light levels, elevated nutrient levels will saturate the seagrass more rapidly. As seagrass reproduction is positively correlated with nutrient saturation in some circumstances seagrasses experiencing low light but elevated nutrients may be expected to have increased reproductive effort – until light levels result in compromised survival due to respiration demands being greater than photosynthesis. We observe this association at Bushland Beach and Shelley Beach sites in the Burdekin region. The capacity of seagrass meadows to naturally recover community structure following disturbance will involve the interaction between light availability, nutrient loads and the availability of seeds to form the foundation of new populations. At present, GBR seagrass meadows appear the have variable recovery potential due to changeable light levels and seed availability both spatially and temporally.

Report card for seagrass status *(community & environment)* for the GBR and each NRM region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100. Green = good, yellow = moderate, gold = fair, red = poor.

Region	Seagrass Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index**
Cape York	58	67	33	33	**48**
Wet Tropics	50	0	33	33	**29**
Burdekin	12	33	67	33	**36**
Mackay Whitsunday	31	0	33	33	**24**
Fitzroy	52	33	33	67	**46**
Burnett Mary	31	0	33	33	**24**
GBR	**39**	**38**	**38**	**35**	**37**

Summary of seagrass condition and overall trend at each NRM region habitat, values are Sep09 – Apr10 with the long term average in parentheses and 4 year trajectory in bold. Plant C:N is a surrogate for light where moderate = adequate light availability on average required for growth (C:N>20:1), low = less available light on average than required for growth (C:N<20:1); C:P is a surrogate for nutrient status of the habitat where, rich = relatively large P pool (C:P <500:1), poor = relatively small P pool (C:P >500:1); N:P is the overall nutrient availability to the plant, where N limited = N:P <25, replete N:P = 25 to 30; P limited = N:P >30. Percent cover = mean percent cover for sampling period ± SE. Repro health = repro structures per node x103.

Parameter	Period	Unit	Region					
			Cape York	Wet Tropics	Burdekin	Mackay Whitsunday	Fitzroy	Burnett Mary
community status								
Abundance	Late dry & late Wet Seasons	Cover (%)	Reef: 16.0±1.7 *(18)* ***stable***	Coast: 11.2±0.8 *(12)* Reef: 20.6±1.2 *(28)* ***variable***	Coast : 7.3±1.0 *(16)* Reef: 8.7±1.2 *(32)* ***declining***	Estuary: 4.8±0.6 (12) Reef: 3.5±0.7 (6) Coast: 20.1±1.5 (21) ***declining***	Estuary: 29.9±2.1 (20) Reef: 1.4±0.2*(2)* Coast: 26.1±0.8 *(22)* ***variable***	Estuary: 4.7±0.5 (10) ***increasing***
Reproduction		Seed reserve (per m^2)	Reef: 311±87 *(163)* ***increasing***	Coast: 270±65 *(272)* Reef: 2 *(1)* ***increasing***	Coast: 615±213 *(2004)* Reef: 0 *(16)* ***declining***	Estuary: 0 *(31)* Reef: nil Coast: 105±38 *(208)* ***declining***	Estuary: nil Reef: nil Coast: nil ***absent***	Estuary: nil *(0)* ***decreasing***
		Repro effort (structures per core)	Reef: 4.3±1.5 *(2.1)* ***increasing***	Coast: 3.7±0.8 *(1.6)* Reef: 0.9±0.3 *(0.8)* ***variable***	Coast: 23.3±8.3 *(24.0)* Reef: 1.7±0.6 *(1.8)* ***stable***	Estuary: 1.3±0.4 *(3.9)* Reef: 0.1±0.05 *(0.7)* Coast: 8.3±1.4 *(5.7)* ***declining***	Estuary: 3±0.7 *(8.3)* Reef: 3.3±0.9 *(1.3)* Coast: 6.3±1.2 *(6.2)* ***stable***	Estuary: 1.4±0.6 *(4)* ***declining***
environment status								
Light availability	Late dry Season	Leaf tissue C:N	Reef: low ***low light & stable***	Coast : low Reef: low ***low light & stable***	Coast : Low Reef: Moderate ***low light & decreasing***	Estuary: low Reef: low Coast: low ***low light & increasing***	Estuary: moderate Reef: low Coast: moderate ***moderate light & increasing***	Estuary: low ***low light & increasing***
Nutrient status (enrichment)	Late dry Season	Leaf tissue C:P	Reef: poor ***small P pool & variable***	Coast : rich Reef: poor ***moderate nutrients & variable***	Coast: Rich Reef: poor ***high nutrients & variable***	Estuary: rich Reef: poor Coast: poor ***moderate nutrients & stable***	Estuary: poor Reef: poor Coast: poor ***small P pool & decreasing***	Estuary: poor ***small P pool & decreasing***
	Late dry Season	Leaf tissue N:P	Reef: P limited ***nitrogen full & increasing***	Coast: P limited Reef: replete ***nitrogen elevated & increasing***	Coast: replete Reef: P limited ***nitrogen full & variable***	Estuary: P limited Reef: P limited Coast: replete ***nitrogen full & variable***	Estuary: P limited Reef: P limited Coast: replete ***nitrogen full & increasing***	Estuary: P limited ***nitrogen full & variable***
	Late dry & late Wet Seasons	Epiphytes (%)	Reef: 33.1±3.1 *(22)* ***increasing***	Coast : 11.5±1.2 *(12)* Reef: 14.5±1.2 *(20)* ***increasing***	Coast: 11.6±2.0 *(17)* Reef: 26.3±3.4 *(34)* ***declining***	Estuary: 11.1±1.2 *(12)* Reef: 14.4±1.2 *(20)* Coast: 2.7±0.3 *(15)* ***variable***	Estuary: 9.8±1.6 *(23)* Reef: 15.1±2.4 *(26)* Coast: 9.4±0.8 *(12)* ***declining***	Estuary: 12.4±1.5 *(12)* ***increasing***

1. Introduction

A key component of Reef Rescue is the implementation of a long-term water quality and ecosystem monitoring program in the Great Barrier Reef lagoon. The Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) has responsibility for implementation of this program. Fisheries Queensland (Fisheries QLD) and James Cook University (JCU) were contracted to provide the intertidal seagrass monitoring component. The key aims of this component of the programme were to:

a. Understand the status and trend of GBR intertidal seagrass *(detect long-term trends in seagrass abundance, community structure, distribution, reproductive health, and nutrient status from representative intertidal seagrass meadows)*,

b. Identify response of seagrass to environmental drivers of change,

c. Integrated reporting on GBR seagrass status including production of seagrass report card metrics for use in an annual Paddock to Reef Report Card.

Background

Seagrass are considered coastal canaries or coastal sentinels that can be monitored to detect human influences to coastal ecosystems (Orth *et al*., 2006). Since 1990, seagrasses globally have been declining at a rate of 7% per year (Waycott *et al*., 2009). Multiple stressors are the cause of this decline, the most significant being degraded water quality. In the GBR system, seagrasses are at risk from a wide diversity of impacts, in particular where coastal developments occur (Grech 2010; Grech *et al.,* 2010). Healthy seagrass meadows in the GBR act as important resources as the primary food for dugong, green turtles, numerous commercially important fish species and as habitat for large number of invertebrates, fish and algal species (Carruthers *et al.,* 2002). Much of the connectivity in reef ecosystems depends on intact and healthy non-reef habitats, such as seagrass meadows. These non-reef habitats are particularly important to the maintenance and regeneration of populations. Therefore, monitoring changes in seagrasses meadows can provide an indication of coastal ecosystem health and be used to improve our capacity to predict expected changes to reefs, mangroves and associated resources upon which coastal communities depend (Heck *et al*., 2008).

There is in excess of 5,000 km^2 of coastal seagrass meadows in eastern Queensland waters shallower than 15 metres, relatively close to the coast, and in locations that can potentially be influenced by adjacent land use practices (Coles *et al.,* 2007). Statistical modeling of the seagrass distribution suggests 40,000km^2 of the seafloor in the GBR deeper than 15 metres has a probability of some seagrass being present (Coles *et al.,* 2003; Coles *et al.,* 2009). This represents about 36% of the total recorded area of seagrass in Australia. Monitoring of the major marine ecosystem types most at risk from land based sources of pollutants is being conducted to ensure that any change in their status is identified. Seagrass monitoring sites have been located as close as practically possible (dependent on historical monitoring and location of existing meadows) to river mouth and inshore marine water quality monitoring programs to enable correlation and concurrently collected water quality information.

The Reef Water Quality Protection Plan (Reef Plan) brings together people and projects to help improve the quality of water entering the Great Barrier Reef (the Reef) lagoon (http://www.reefplan.qld.gov.au/about/rwqpp.shtm, accessed 28 September 2010). The Reef Plan builds on existing government policies, and government, industry and community initiatives that assist in halting and reversing the decline in the quality of water entering the Reef lagoon. It was identified very early in development of the Reef Water Quality Protection Plan (Reef Plan), that the existing Seagrass-Watch program was an excellent opportunity on which the inshore seagrass monitoring component could be based. It was designed such that the ongoing monitoring activities were enhanced through; value adding by collecting other information by scientists in the field, and where stakeholder/community groups can not monitor, Fisheries QLD staff collects the data.

There are 15 species of seagrass in the GBR. A high diversity of seagrass habitats is provided by extensive bays, estuaries, rivers and the 2600 km length of the Great Barrier Reef with its reef platforms and inshore lagoon. They can be found on sand or muddy beaches, on reef platforms and in reef lagoons, and on sandy and muddy bottoms down to 60 metres or more below Mean Sea Level (MSL). Seagrasses in the GBR can be separated into four major habitat types: estuary/inlet, coastal, reef and deepwater (Carruthers *et al.,* 2002) (Figure 1). All but the outer reef habitats are significantly influenced by seasonal and episodic pulses of sediment laden, nutrient rich river flows, resulting from high volume summer rainfall. Cyclones, severe storms, wind and waves as well as macro grazers (fish, dugongs and turtles) influence all habitats in this region to varying degrees. The result is a series of dynamic, spatially and temporally variable seagrass meadows.

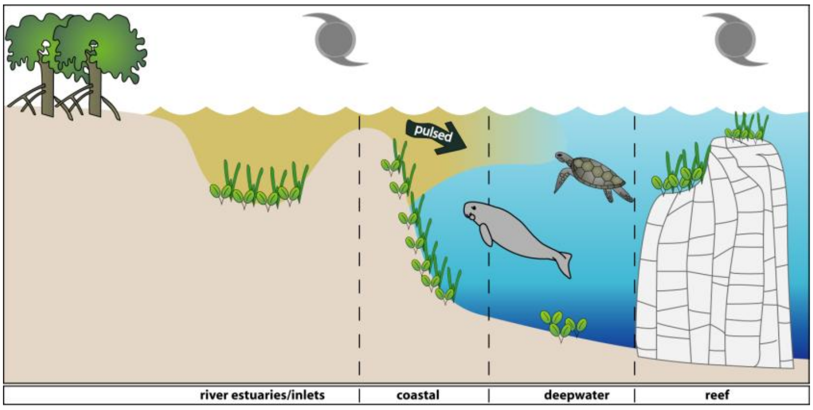


Figure 1*. General conceptual model of seagrass habitats in north east Australia (from Carruthers et al., 2002)*

The requirements for formation of healthy seagrass meadows are relatively clear as they are photosynthetic plants occupying a marine habitat. They require adequate light, nutrients, carbon dioxide, suitable substrate for anchoring along with tolerable salinity, temperature and *p*H (Waycott and McKenzie, 2010). A number of indicators and thresholds of some of these requirements have been established for seagrass communities that are relevant to the GBR, and are monitored as part of the Reef Rescue Marine Monitoring Program.

2. Methodolgy

Intertidal seagrass monitoring methods were conducted as per McKenzie *et al.* (2010). Thirty sites were monitored during the 2009/10 monitoring period (Table 1). This included nine inshore (intertidal coastal and estuarine) and six offshore reef intertidal locations. A description of all the data collected during the sampling period under the monitoring contract has been collated by Natural Resource Management (NRM) region, site, parameter, and the number of samples collected per sampling period is listed in Table 2. The presence of the targeted and foundation seagrass species at monitoring sites is listed in Table 3.

The different measures and analysis reported in this document were conducted in collaboration between Fisheries Queensland, James Cook University Townsville, and the Seagrass-Watch program with each contributing the following:

- seagrass % cover & species composition (Seagrass-Watch & Fisheries QLD)
- seed banks (Seagrass-Watch & Fisheries QLD)
- epiphytes & macro-algae (Seagrass-Watch & Fisheries QLD)
- meadow edge mapping (late dry Season, late monsoon Season) (Fisheries QLD)
- reproductive health (Fisheries QLD with reporting by JCU)
- seagrass tissue elements (C:N:P) (late dry Season) (Fisheries QLD)
- *in-situ* within canopy temperature (Fisheries QLD)
- *in-situ* canopy light (JCU with field assistance by Fisheries QLD)

Inter-tidal seagrass abundance, composition and distribution

Survey methodology followed Seagrass-Watch standard methodology (McKenzie *et al.*, 2007; see also www.seagrasswatch.org). At each location, sampling included two sites nested in a location and three 50m transects nested in each site. A site was defined as a 50m x 50m area within a relatively homogenous section of a representative seagrass community/meadow (McKenzie *et al.,* 2000). Monitoring at the sites identified for the Reef Rescue MMP long-term intertidal monitoring in late dry (September/October 2009) and late monsoon (March/April 2010) of each year was conducted by a qualified and trained scientist. Monitoring conducted outside these periods, was conducted at some locations by trained/certified local stakeholders/community volunteers. Sites were monitored for seagrass cover and species composition. Additional information was collected on canopy height, macro-algae cover, epiphyte cover and macro-faunal abundance. An assessment of reproductive health was also conducted via seed bank monitoring (predominately *Halodule uninervis*). Monitoring of within canopy temperatures was also recorded at all established sites. Mapping the edge of the seagrass meadow within 100m of each monitoring site was conducted at all sites in the late dry and late monsoon monitoring periods. Edge mapping is used to determine if changes in seagrass abundance are the result of the meadow shrinking/increasing in distribution or the plant increasing/decreasing in density, or both. Extent of seagrass within the mapping area is compared against each sites baseline (first measure). As most distributional changes occur at either the shoreward or seaward extents of seagrass meadows, a description of the type of change is provided. The shoreward extent is primarily controlled by exposure at low tide, wave action and associated turbidity and low salinity from fresh water inflow, while the seaward extent is most likely to be controlled by the availability of light for photosynthesis.

Table 1. *Reef Rescue MMP intertidal seagrass (Seagrass-Watch) long-term monitoring sites. NRM region from www.nrm.gov.au.*

GBR region	NRM region (*Board*)	Catchment	Monitoring location	Site		Latitude		Longitude		Seagrass community type
Far Northern	Cape York	Endeavour	Cooktown *Intertidal fringing reef*	AP1	Archer Point	15°	36.5	145°	19.143	*H. univervis/ H. ovalis* with *Cymodocea/T. hemprichii*
				AP2	Archer Point	15°	36.525	145°	19.108	*H. univervis/H. ovalis* with *C. rotundata*
Northern	Wet Tropics (*Terrain NRM*)	Barron Russell - Mulgrave Johnstone	Green Island *intertidal offshore reef*	GI1	Green Island	16°	45.789	145°	58.31	*C. rotundata/T. hemprichii* with *H. uninervis/H. ovalis*
				GI2	Green Island	16°	45.776	145°	58.501	*C. rotundata/T. hemprichii* with *H. uninervis/H. ovalis*
			Cairns *Coastal intertidal*	YP1	Yule Point	16°	34.159	145°	30.744	*H. uninervis* with *H. ovalis*
				YP2	Yule Point	16°	33.832	145°	30.555	*H. uninervis* with *H. ovalis*
		Tully	Mission Beach *Coastal intertidal*	LB1	Lugger Bay	17°	57.645	146°	5.61	*H. uninervis*
				LB2	Lugger Bay	17°	57.674	146°	5.612	*H. uninervis*
			Dunk Island *intertidal offshore reef*	DI1	Dunk Island	17°	56.6496	146°	8.4654	*H. uninervis* with *T. hemprichii/ C. rotundata*
				DI2	Dunk Island	17°	56.7396	146°	8.4624	*H. uninervis* with *T. hemprichii/ C. rotundata*
Central	Burdekin (*NQ Dry Tropics*)	Burdekin	Magnetic island *intertidal offshore reef*	MI1	Picnic Bay	19°	10.734	146°	50.468	*H. uninervis* with *H. ovalis & Zostera/T. hemprichii*
				MI2	Cockle Bay	19°	10.612	146°	49.737	*C. serrulata/ H. uninervis* with *T. hemprichii/H. ovalis*
			Townsville *Coastal intertidal*	SB1	Shelley Beach	19°	11.046	146°	45.697	*H. uninervis* with *H. ovalis*
				BB1	Bushland Beach	19°	11.028	146°	40.951	*H. uninervis* with *H. ovalis*
	Mackay Whitsunday (*Reef Catchments*)	Proserpine	Whitsundays *Coastal intertidal*	PI2	Pioneer Bay	20°	16.176	148°	41.586	*H. uninervis/ Zostera* with *H. ovalis*
				PI3	Pioneer Bay	20°	16.248	148°	41.844	*H. uninervis* with *Zostera/H. ovalis*
			Whitsundays *intertidal offshore reef*	HM1	Hamilton Island	20°	20.7396	148°	57.5658	*H. uninervis* with *H. ovalis*
				HM2	Hamilton Island	20°	20.802	148°	58.246	*Z. capricorni* with *H. ovalis/H. uninervis*
		Pioneer	Mackay *estuarine intertidal*	SI1	Sarina Inlet	21°	23.76	149°	18.2	*Z. capricorni* with *H. ovalis (H. uninervis)*
				SI2	Sarina Inlet	21°	23.712	149°	18.276	*Z. capricorni* with *H. ovalis (H. uninervis)*
Southern	Fitzroy (*Fitzroy Basin Association*)	Fitzroy	Shoalwater Bay *Coastal intertidal*	RC1	Ross Creek	22°	22.953	150°	12.685	*Zostera capricorni* with *H. ovalis*
				WH1	Wheelans Hut	22°	23.926	150°	16.366	*Zostera capricorni* with *H. ovalis*
			Keppel Islands *intertidal offshore reef*	GK1	Great Keppel Is.	23°	11.7834	150°	56.3682	*H. uninervis* with *H. ovalis*
				GK2	Great Keppel Is.	23°	11.637	150°	56.3778	*H. uninervis* with *H. ovalis*
		Boyne	Gladstone Harbour *estuarine intertidal*	GH1	Gladstone Hbr	23°	46.005	151°	18.052	*Zostera capricorni* with *H. ovalis*
				GH2	Gladstone Hbr	23°	45.874	151°	18.224	*Zostera capricorni* with *H. ovalis*
	Burnett Mary (*Burnett Mary Regional Group*)	Burnett	Rodds Bay *estuarine intertidal*	RD1	Rodds Bay	24°	3.4812	151°	39.3288	*Zostera capricorni* with *H. ovalis*
				RD2	Rodds Bay	24°	4.866	151°	39.7584	*Zostera capricorni* with *H. ovalis*
		Mary	Hervey Bay *estuarine intertidal*	UG1	Urangan	25°	18.053	152°	54.409	*Zostera capricorni* with *H. ovalis*
				UG2	Urangan	25°	18.197	152°	54.364	*Zostera capricorni* with *H. ovalis*

Table 2. *Samples collected at each monitoring site per parameter for each season. Activities include: SG = seagrass cover & composition, SM=seed monitoring, TN=tissue nutrients, EM=edge mapping, RH=reproductive health, TL=temperature loggers, LL=light loggers.*=additional activity funded by Fisheries QLD. Greyed cells indicate no longer supported by RRMMP but covered by other sources.*

Sector	Region	Catchment	Monitoring location		late dry Season (2009)							late monsoon Season (2010)					
					SG	SM	TN	EM	RH	TL	LL	SG	SM	EM	RH	TL	LL
Far Northern	Cape York	Endeavour	Cooktown	AP1	33	30	3	✓	15	✓		33	30			✓	
				AP2	33	30	3	✓	15	✓							
Northern	Wet Tropics	Russell - Mulgrave Johnstone	Green Island	GI1	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
				GI2	33	30	3	✓	15	✓		33	30	✓	15*	✓	
			Cairns	YP1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				YP2	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
		Tully	Mission Beach	LB1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				LB2	33	30	3	✓	15	✓		33	30	✓	15*	✓	
			Dunk Island	DI1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				DI2	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
Central	Burdekin	Burdekin	Magnetic Island	MI1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				MI2	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
			Townsville	SB1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				BB1	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
	Mackay Whitsunday	Proserpine	Whitsundays	PI2	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
				PI3	33	30	3	✓	15	✓		33	30	✓	15*	✓	
			Hamilton Is.	HM1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				HM2	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
		Pioneer	Mackay	SI1	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
				SI2	33	30	3	✓	15	✓		33	30	✓	15*	✓	
Southern	Fitzroy	Fitzroy	Shoalwater Bay	RC1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				WH1	33	30	3	✓	15	✓	✓	33	30	✓	15*	✓	✓
			Great Keppel Is.	GK1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				GK2	33	30	3	✓	15	✓		33	30	✓	15*	✓	
		Boyne	Gladstone	GH1*	33*	30*		✓*		✓*		33*	30*	✓*		✓*	
				GH2*	33*	30*		✓*		✓*		33*	30*	✓*			
	Burnett Mary	Burnett	Rodds Bay	RD1	33	30	3	✓		✓		33	30	✓	15*	✓	
				RD2	33	30	3	✓		✓		33	30	✓	15*	✓	
		Mary	Hervey Bay	UG1	33	30	3	✓	15	✓		33	30	✓	15*	✓	
				UG2	33	30	3	✓	15	✓		33	30	✓	15*	✓	

Table 3. *Presence (■) of targeted and foundation seagrasses (Cymodocea rotundata, Halophila ovalis, Halodule uninervis, Thalassia hemprichii and Zostera capricorni) in monitoring locations sampled in Reef Rescue MMP for plant tissue and reproductive health. Habitat type is classified as Reef=reef intertidal, Coast=coastal intertidal, Estuary=Estuarine intertidal following the classification of Carruthers et al. (2002).*

Zostera capricroni = Zostera muelleri subsp. *capricorni*

^ *foundation seagrass species*
* *indicates presence adjacent, but not within, 50m x 50m site.*
+ *only found at Picnic Bay*

GBR region	NRM Region	Catchment	Seagrass monitoring location	Habitat type	*C. rotundata^*	*H. ovalis*	*H. uninervis^*	*T. hemprichii^*	*Z. capricorni^*
Far Northern	Cape York	Endeavour	Cooktown	Reef	■	■	■		■*
Northern	Wet Tropics	Daintree	*NA*						
		Russell - Mulgrave Johnstone	Green Island	Reef	■	■	■	■	
			Yule Point	Coast		■	■		■*
		Tully	Lugger Bay	Coast		■*	■		
			Dunk Island	Reef	■	■*	■	■	
Central	Burdekin	Herbert	*NA*						
		Burdekin	Magnetic Island	Reef		■	■	■	■+
			Townsville	Coast		■	■		
	Mackay Whitsunday	Proserpine	Whitsundays	Coast		■	■		■
			Whitsunday Islands	Reef		■	■		■
		Pioneer	Mackay	Estuary		■			■
Southern	Fitzroy	Fitzroy	Shoalwater Bay	Coast		■*	■*		■
			Keppel Islands	Reef		■	■		
		Boyne	Gladstone	Estuary		■	■*		■
	Burnett Mary	Burnett	Rodds Bay	Estuary					■
		Mary	Hervey Bay	Estuary		■*			■

Seagrass reproductive health

Seagrass reproductive health was assessed from samples collected in the late dry 2009 and late monsoon 2010 at locations identified in Table 2. Samples were processed according to standard methodologies (McKenzie *et al.,* 2010).

In the field, 15 haphazardly placed cores of seagrass were collected from an area adjacent (of similar cover and species composition) to each monitoring site. In the laboratory, reproductive structures (spathes, fruits, female and male flowers) of plants from each core were identified and counted for each samples and species. Reproductive effort was calculated as number of reproductive structures (fruits, flowers, spathes) per core for analysis.

Seeds banks and abundance of germinated seeds were measured according to standard Seagrass-Watch methods (McKenzie *et al.,* 2010). Seed banks were compared against the GBR long-term average calculated for each habitat. Townsville coastal sites were removed from the calculation of the long-term average due to their exceptionally high abundances of seeds.

Seagrass tissue nutrients

In late dry season (October) 2009, foundation seagrass species tissue nutrient samples were collected from the monitoring sites, as indicated in Table 3. Plants from three haphazardly placed 0.25m^2 quadrats were collected from an area adjacent (of similar cover and species composition) to each monitoring site. Leaves were separated from the below ground material in the laboratory and epiphytic algae removed by gently scraping. Dried and milled samples were analysed according to McKenzie *et al.* (2010). Elemental ratios (C:N:P) were calculated on a mole:mole basis using atomic weights (i.e., C=12, N=14, P=31).

Analysis of tissue nutrient data was based upon the calculation of the atomic ratios of C:N:P. The magnitude of these ratios and their temporal changes allow for a broad level understanding of the physical environment of seagrass meadows. Changing C:N ratios have been found in a number of experiments and field surveys to be related to light levels (Abal *et al.,* 1994; Grice *et al.,* 1996; Cabaço and Santos 2007; Collier *et al.,* 2009). Experiments on seagrasses in Queensland have suggested that at an atomic C:N ratio of less than 20, seagrass may suggest reduced light availability (Abal *et al.,* 1994; Grice *et al.,* 1996).

The ratio of N:P is also a useful indicator as it is a reflection of the *"Redfield"* ratios (Redfield *et al.,* 1963), and seagrass with an atomic N:P ratio of 25 to 30 can be determined to be 'replete' (Atkinson and Smith 1983; Fouqurean *et al.,* 1997; Fourqurean and Cai 2001). N:P values in excess of 30 may potentially indicate P-limitation. The median seagrass tissue ratios of C:P is approximately 500 (Atkinson and Smith 1983), therefore deviation from this value is also likely to be indicative of some level of nutrient enriched or nutrient limited conditions.

Within seagrass canopy temperature

Autonomous iBTag™ submersible temperature loggers were deployed at all sites identified in Table 1. The loggers recorded temperature (degrees Celsius) within the seagrass canopy every 90 minutes. iBCod 22L submersible temperature loggers were attached to the permanent marker at each Seagrass-Watch site above the sediment-water interface.

Autonomous iBTag™ submersible temperature loggers attached to permanent site marker at Green Island (GI1)

Seagrass canopy light

Submersible Odyssey™ photosynthetic irradiance autonomous loggers were attached to permanent station markers at inshore and offshore seagrass locations from the Wet Tropics region to the Fitzroy region (Table 2). Measurements were recorded by the logger every 30 minutes. Automatic wiper brushes cleaned the optical surface of the sensor every 15 minutes to prevent marine organisms fouling.

Submersible Odyssey™ photosynthetic irradiance autonomous loggers deployed at Dunk Island (left) and Cockle Bay (right).

Loggers were calibrated against a certified reference Photosynthetically Active Radiation (PAR) sensor (LI-COR™ LI-192SB Underwater Quantum Sensor) in full direct sunlight conditions.

Reporting Approach

Results and discussion of monitoring is presented firstly in a GBR general overview and then by the NRM regions identified in the GBR area. These discrete regions have been used for stratifying issues of land and catchment based resource management and used to report downstream impacts on the reef environment such as from the affect of water quality. There are 56 NRM regions identified in Australia, 15 are in Queensland and six are part of the coastal processes of the GBR. These regions are mostly based on catchments or bioregions using assessments from the National Land and Water Resources Audit. Regional plans have been developed for each of these setting out the means for identifying and achieving natural resource management targets and detailing catchment-wide activities addressing natural resource management issues including land and water management, biodiversity and agricultural practices. Seagrass habitat data forms part of these targets and activities.

Within each region, estuarine and coastal habitat boundaries were delineated based on the Queensland coastal waterways geomorphic habitat mapping, Version 2 (1:100 000 scale digital data) (Heap *et al* 2001). Reef habitat boundaries were determined using the AUSLIG (now the National Mapping Division of Geosciences Australia) geodata topographic basemap (1:100 000 scale digital data).

Conceptual diagrams have been used to illustrate the general seagrass habitats type in each region. Symbols/icons have been used in the conceptual diagrams to illustrate major controls, processes and threats/impacts (Figure 2).

Report card

Four indicators (presented as indexed scores) were chosen as components of the seagrass report card, and these were divided into community and environment status in recognition of the role of seagrass as a bioindicator:

Seagrass community status

1. Seagrass abundance
2. Reproductive effort

Seagrass environment status

3. Light availability (seagrass tissue C:N ratio)
4. Nutrient status (seagrass tissue N:P and C:P ratios, and epiphyte abundance)

Seagrass abundance

The status of seagrass abundance was determined using the seagrass abundance guidelines developed by McKenzie (2009). Subregional seagrass abundance guidelines were developed based on the 50th and 20th percentiles (as recommended for water quality guidelines) of abundance data collected from reference sites (McKenzie 2009). For the 50th and 20th percentiles, error values were found to level off at around 15–20 samples, suggesting this number of samples was sufficient to provide a reasonable estimate of the true percentile value. Based on the analyses it was recommended that estimates of the 20th percentile at a reference site should be based on a minimum of 18 samples collected over at least three years. For the 50th percentile a smaller minimum number of samples (approximately 10–12) would be adequate but in most situations it would be necessary to collect sufficient data for the 20th percentile anyway. For seagrass habitats with high variability, primarily the result of seasonal fluctuations, a more appropriate guideline may however be the 10th percentile (similar to highly disturbed systems).

Using the recommended approach, subregional seagrass abundance guidelines (here after known as "the seagrass guidelines") were developed for each seagrass habitat types where possible (Table 4). If an individual site had 18 or more sampling events and no identified impacts (e.g., major loss from cyclone), abundance guideline was determined at the site or location level and used for the specific site.

Table 4. *Subregional seagrass percentage cover guidelines ("the seagrass guidelines").*

NRM Region	habitat	percentile guideline (% cover) 10th	20th	50th
Cape York	*estuarine*			
	coast			
	reef	11	16.8	18.9
Wet Tropics	*estuarine*			
	coast	5	6.6	12.9
	reef	27.5	31.9^	37.7
Burdekin Dry Tropics	*estuarine*			
	coast	11.9	15.7	21.1
	reef	22.15	26.25	34.5
Mackay Whitsunday	*estuarine*		18*	34.1*
	coast	12.1	13.15	19.1
	reef	22.2*		34.5*
Fitzroy	*estuarine*		18*	34.1*
	coast	15.85	17.5	21.6
	reef	22.2*		34.5*
Burnett Mary	*estuarine*	10.8	18	34.1
	coast			

**from nearest adjacent region*

Using the seagrass guidelines, seagrass state was determined for each monitoring event at each site and allocated as poor (median abundance below 20th or 10th percentile), fair (median abundance below 50th and above 20th percentile) or good (median abundance above 50th percentile) state. Seagrass state was then scored on a scale of 0 to 3 against the seagrass guidelines and relative to the previous sampling event (Table 5).

Table 5. *Scores against the guidelines adjusting for trends.*

		Trend from previous event	
		>20% increase	**>20% decrease**
	>50th percentile	3	2
median	**>20<50th percentile**	2	1
	<20th percentile	1	0

Scores were then rescaled from 0 to 100 to allow integration with other components of the report card (Table 6).

Table 6. *Rescaled scores to determine seagrass abundance status.*

score	0-100 score	status
3	>67 - 100	*good*
2	>33.3 - 67	*fair*
≤1	0 -33.3	*poor*

Seagrass reproductive effort

The reproductive effort of seagrasses provides an indication of the capacity of seagrasses to recover from the loss of an area of seagrass through the recruitment of new plants, i.e. the resilience of the population (Collier and Waycott 2009). Given the high diversity of seagrass species that occur in the GBR coastal zone (Waycott *et al.,* 2007), their variability in production of reproductive structures (e.g. Orth *et al.* 2006b), a metric that incorporates all available information on the production of flowers and fruits per node is the most useful.

The production of seeds also reflects a simple measure of the capacity of a seagrass meadow to recover following large scale impacts (Collier and Waycott 2009). As it is well recognized that coastal seagrasses are prone to small scale disturbances that cause local losses (Collier and Waycott 2009) and then recover in relatively short periods of time, the need for a local seed source is considerable. In the GBR, the production of seeds comes in numerous forms and assessments must capture these forms in sampling. Unfortunately, seed banks examined at Seagrass-Watch and Reef Rescue MMP sites are limited to seagrass species with larger seeds or seeds which are not targeted by consumers. As a result, seed banks have not been included in the metric for reproductive effort at this time, but methods for future incorporation are currently being explored.

Using the annual mean of all species pooled in the late dry and comparing with the long-term (2005-2010) average for GBR habitat, the reproductive effort was scored as the number of reproductive structures per core and the overall status determined (Table 7).

Table 7. *Scores for monitoring period reproductive effort average against long-term (2005-2010) GBR habitat average.*

Reproductive Effort monitoring period / long-term	**score**	**0-100 score**	**status**
4.0	3	>67 - 100	*good*
2.0	2	>33.3 - 67	*moderate*
1.0	1	>0 -33.3	*fair*
<1.0	0	0.0	*poor*

Seagrass environment nutrient status

The ratios of the most common macronutrients required for plant growth has been used widely as an indicator of growth status, in phytoplankton cultures this known as the familiar *"Redfield"* ratio of 106C:16N:P (Redfield *et al.,* 1963). Seagrass and other benthic marine plants possess large quantities of structural carbon, resulting in ''seagrass Redfield ratios'' estimated to be between 550:30:1 (Atkinson and Smith 1983) and 474:24:1 (Duarte 1990). Like phytoplankton, seagrasses growing in eutrophic waters have C:N:P ratios that reflect elevated nitrogen and phosphorus levels (Duarte 1990). Plants residing in nutrient poor waters show significantly lower N:P and/or higher C:P ratios than those from nutrient rich conditions (Atkinson and Smith 1983). Comparing deviations in the ratios of carbon, nitrogen and phosphorous (C:N:P) retained within plant tissue has been used extensively as an alternative mean of evaluating the nutrient status of coastal waters (Duarte, 1990).

Seagrass with an atomic N:P ratio of 25 to 30 can be determined to be 'replete'(Atkinson and Smith 1983; Fouqurean *et al.,* 1997; Fourqurean and Cai 2001). N:P values in excess of 30 may potentially indicate P-limitation and less than 25 are considered to show N limitation (Atkinson and Smith 1983; Duarte 1990; Fourqurean et al. 1992; Fourqurean and Cai 2001). The median seagrass tissue ratios of C:P is approximately 500 (Atkinson and Smith 1983), therefore deviation from this value is also likely to be indicative of some level of nutrient enriched or nutrient limited conditions. A combination of these ratios can indicate seagrass environments which are impacted by nutrient enrichment. Plant tissue which has a high N:P and low C:P indicates an environment of elevated (saturated) nitrogen.

Using the guideline ratios of C:P and N:P for the foundation seagrass species (excluding *Halophila ovalis*), nutrient status was scored on a scale of 0 to 3 scale and then rescaled from 0 to 100 to allow integration with other components of the report card (Table 8).

Table 8. *Scores for leaf tissue N:P + C:P ratios against guideline to determine nutrient status (enrichment).*

N:P ratio	**score**	**C:P ratio**	**score**
> 30	0	> 500	1
25-30	1	<= 500	0
<25	2		

FINAL score (N:P score + C:P score)	**0-100 score**	**status**
3	>67 - 100	*good*
2	>33.3 - 67	*moderate*
1	>0 -33.3	*fair*
0	0.0	*poor*

Increased epiphyte (the plants growing on the surfaces of slower-growing seagrass leaves (Borowitzka *et al.,* 2006)) loads may result in shading of seagrass leaves by up to 65%, reducing photosynthetic rate and leaf densities of the seagrasses (Sand-Jensen 1977; Tomasko and Lapointe 1991; Walker and McComb 1992; Tomasko et al. 1996; Frankovich and Fourqurean 1997; Ralph and Gademann 1999; Touchette, 2000). In seagrass meadows, increases in the abundance of epiphytes are stimulated by nutrient loading (e.g. Borum, 1985; Silberstein *et al.,* 1986; Neckles *et al.,* 1994;

Balata *et al.,* 2008) and these increases in abundance have been implicated as the cause for declines of seagrasses during eutrophication (e.g. Orth and Moore, 1983; Cambridge *et al.,* 1986).

Given the observed relationships between nutrient loading and the abundance of epiphytes observed in seagrass ecosystems from around the world, and the perceived threat to water quality owing to human population, the abundance of epiphytes in seagrass meadows may prove to be a valuable indicator for assessing both the current status and trends of the GBR seagrass meadows. However, preliminary analysis of the relationship between seagrass abundance and epiphyte cover collected by the RRMMP and Seagrass-Watch were inconclusive (McKenzie 2008) and further research and analysis is recommended before threshold levels for epiphyte abundances can be used as an indicator.

Seagrass environment light availability.

As changing leaf C:N ratios have been found in a number of experiments and field surveys to be related to light levels (Abal *et al.,* 1994; Grice *et al.,* 1996; Cabaço and Santos 2007; Collier *et al.,* 2009) they can be used as an indicator of the light that the plant is receiving. With light limitation, seagrass plants are unable to grow (take up carbon), hence the proportion of carbon decreases relative to nitrogen. Experiments on seagrasses in Queensland have reported that at an atomic C:N ratio of less than 20, may suggest reduced light availability (Abal *et al.,* 1994; Grice *et al.,* 1996). The light availability to seagrass is not necessarily an indicator of light in the water column, but an indicator of the light that the plant is receiving. This available light can be highly impacted by epiphytic growth or sediment smothering photosynthetic leaf tissue.

Using the guideline ratio of 20:1 for the foundation seagrass species (excluding *Halophila ovalis*), light status was scored on a scale of 0 to 3 scale and then rescaled from 0 to 100 to allow integration with other components of the report card (Table 9).

Table 9. *Scores for leaf tissue C:N against guideline to determine light availability.*

C:N ratio	Score	0-100 score	status
> 25	3	>67 - 100	*good*
20-25	2	>33.3 - 67	*moderate*
15-20	1	>0 -33.3	*fair*
<15	0	0.0	*poor*

Seagrass index

The seagrass index is average score (0-100) of the four seagrass status indicators chosen for the Reef Rescue MMP. Each indicator is equally weighted as we have no preconception that it should be otherwise. The overall index is rated and coloured according to the standard scheme adopted by the Paddock to Reef reporting (Table 10).

Table 10. *Paddock to Reef index rating scheme.*

80 - 100	*excellent*
60 - < 80	*good*
40 - < 60	*moderate*
20 - < 40	*fair*
0 - <20	*poor*

Figure 2. *Key to symbols used for conceptual diagrams detailing impacts to seagrasses.*

3. Results

GBR Summary

Seagrass meadows are an important component of the GBR nearshore ecosystems. Seagrass species diversity differs between locations and habitats in the GBR Region, with inshore reef habitats tending to be more diverse than meadows at coastal or estuarine habitats. Intertidal seagrass meadow cover (as a percentage of the substrate covered by plant material) also varies between locations along the length of the GBR.

The average seagrass percent cover (over the past 11 years) at each of the intertidal seagrass habitats within the GBR are relatively similar: 18% for estuarine, 18% for coastal, and 21% for reef. Seagrass abundance has declined across half of the NRM regions monitored, and were in a poor state at locations south of Cairns. Findings from the 2009/10 monitoring period indicate that the overall status of intertidal seagrass meadows within the GBR were in a fair state (Table 11). The regions of greatest concern for seagrass are the Mackay Whitsunday and Burnett Mary where not only has seagrass abundance declined, but very poor seed banks and reproductive effort have raised concerns about the ability of local seagrass meadows to recover from environmental disturbances. As bioindicators of the environmental status of the inshore GBR, seagrass at the intertidal sites manifested a trend of nutrient enrichment with plants growing in reducing light levels. Importantly, seagrass monitoring data from the Wet Tropics and Mackay Whitsunday regions suggests that coastal and estuarine habitats are showing increasing signs of poor water quality conditions, as seagrass tissue indicates light limited, nutrient rich environments with elevated nitrogen levels.

Table 11. *Report card for seagrass status (community & environment) for the GBR and each NRM region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100. Green = good, yellow = moderate, gold = fair, red = poor.*

Region	Seagrass Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index**
Cape York	58	67	33	33	**48**
Wet Tropics	50	0	33	33	**29**
Burdekin	12	33	67	33	**36**
Mackay Whitsunday	31	0	33	33	**24**
Fitzroy	52	33	33	67	**46**
Burnett Mary	31	0	33	33	**24**
GBR	**39**	**38**	**38**	**35**	**37**

Status of the seagrass community

Seagrass abundance and composition

Of the 30 sites examined across the GBR in 2009/10, 67% were classified as poor in abundance (below the seagrass guidelines) in late monsoon 2010 and only 20% were classified as good. Based on the average score against the seagrass guidelines (all sites and seasons pooled), the abundance of seagrass in the GBR over the 2009/10 period was classified as fair (average score = 1.23). The overall trend in seagrass abundance of the same 30 sites since they were established indicates a significant decline (ANOVA, d.f.=10, F=3.78, p<0.001) over the last 4 monitoring periods (Figure 3).

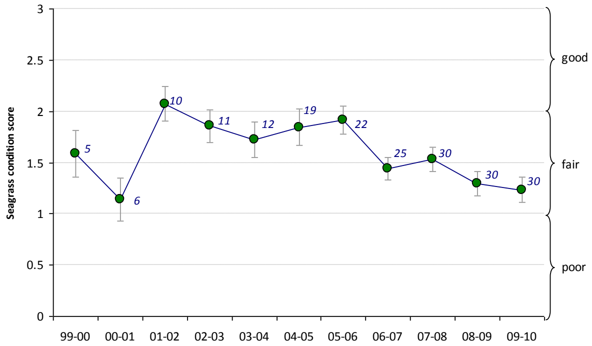


Figure 3. *Average abundance score (all sites and seasons pooled) for each monitoring period in the GBR (±Standard Error).*

Over the past decade, the patterns of seagrass abundance at each GBR habitat type have differed (Figure 4). Seagrass abundance has fluctuated greatly in estuarine habitats; most often as a response to climate (eg rainfall, temperature and desiccation) and at smaller localized scales there have been some acute event related changes. Seagrass meadows in coastal habitats have changed over periods of three to five years, however the decadal trend is relatively stable. Inshore reef seagrass meadows appear to have declined in abundance over the last four to five years.

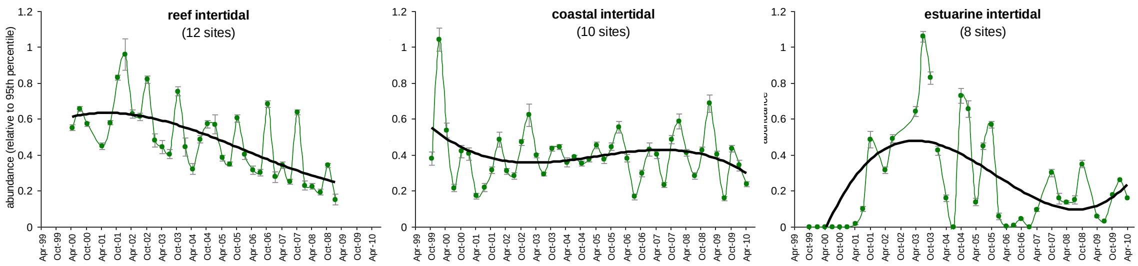


Figure 4. *Generalised trends in seagrass abundance for each habitat type (sites pooled) relative to the 95th percentile (equally scaled). The 95th percentile is calculated for each site across all data.*

Abundance of inter-tidal seagrasses at locations in Cape York region and the northern section of the Wet Tropics region were stable or increasing; however most locations from Cairns to the southern GBR were either variable or have declined over the past 12 months. The only exceptions within the southern GBR region were Shoalwater Bay and Gladstone Harbour which increased in abundance. Locations which had severe losses in 2006 (eg Gladstone and Urangan) have either fully or significantly recovered (>70% of long-term average) by the late monsoon 2010 (Table 12).

Most of these declining locations have poor seed reserves (Table 12). In addition, many of these sites have low or below average reproductive effort in general and as a result recovery time may take longer, between 18 months and three years as it will be dependent on vegetative growth and/or translocation of vegetative fragments, or arrival of seeds from outside the area that has experienced loss.

Intertidal estuarine locations were only monitored in the Mackay Whitsunday, Fitzroy and Burnett Mary regions over the past 12 months. Seagrass abundance at estuarine monitoring sites continues to vary greatly seasonally (Figure 4). Abundances declined in late monsoon 2009, possibly a consequence of the flooding across the regions and have not shown any significant recovery at recovered at three of the 4 locations. Seed banks remain absent at estuarine intertidal sites (Table 12), indicating a relatively low capacity to recover. Recovery at Urangan in the 2009 growing season (August-November) would have been primarily the result of vegetative growth.

Intertidal coastal sites were monitored in the Wet Tropics, Burdekin, Mackay Whitsunday and Fitzroy regions over the past 12 months. Seagrass abundance at coastal intertidal seagrass meadows has remained relatively stable decadally (Figure 4, Table 12), however it declined over the last monitoring period. Seed banks continued to decline throughout the 2009/10 monitoring period.

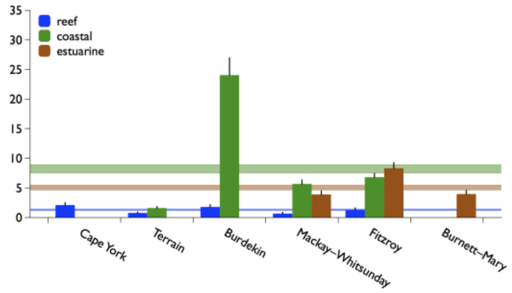
Six reef habitat locations were monitored by the Reef Rescue MMP within the GBR in the Cape York, Wet Tropics, Burdekin and Mackay Whitsunday regions over the past 12 months. Reef habitats are more seagrass species diverse. The more dominant seagrass species in reef habitats of the GBR include *Cymodocea rotundata*, *Thalassia hemprichii*, and the colonising species *Halophila ovalis* and *Halodule uninervis*. Although one location is on the mainland (Archer Point), most are located on near-shore reef-platforms associated with continental islands or coral cays. Seagrass abundance at intertidal reef-platform seagrass meadows were lower last five years than the previous five years (Figure 4). Within years, seagrass abundance fluctuates greatly between seasons. Seed banks are very low at reef habitats compared to both estuarine and coastal intertidal habitats (Table 12). Seed abundance also appears to fluctuate greatly both within and between years, which is possibly a consequence of the species diversity with relatively low occurrence of *Halodule uninervis*.

Table 12. *Summary of seagrass condition and overall trend at each monitoring location (sites pooled) for each Season. Cover = % seagrass cover, Seeds = seeds per m^2 sediment surface, meadow = edge mapping within 100m of monitoring sites, epiphytes = % cover on seagrass leaves, macro-algae = % cover. Trend data values presented as Oct09 – Apr010 (long-term average in parenthesis) and colours represent direction of trend, where red= declining, green = stable or increasing, yellow = variable.*

Region	Catchment	Location	% cover Long Term Average	% cover late dry		% cover late monsoon		Overall trend since late dry 2005				
				2009	% Difference 2008 to 2009	2010	% Difference 2009 to 2010	Seagrass Cover	Seagrass Seeds	Meadow	Epiphytes	Macro-Algae
Cape York	Endeavour	Archer Point	18.1 ±1.9	16.1 ±2.1	similar	15.2 ±3.1	>20% decrease	stable	187 - 288 (162) increase	variable	30 – 39 (27) increase	3 - 2 (9) decline
Wet Tropics	Barron Russell - Mulgrave Johnstone	Yule Point	15.7 ±1.3	20.1 ±1.4	similar	17.4 ±1.6	>20% decrease	increase	611 - 459 (386) decline	variable	16 -22 (21) increase	1 (2) decline
		Green Is	40.2 ±2.2	36.5 ±1.7	>20% increase	36.4 ±2.1	similar	stable	nil	stable	28 - 12 (27) increase	3 - 15 (4) increase
	Tully – Murray	Lugger Bay	4.3 ±0.6	6.6 ±0.8	similar	0.4 ±0.1	>20% decrease	variable	9 - 0 (4) variable	variable	8 - 1 (3) increase	0 (<1) stable
		Dunk Is	9.7 ±1.0	6.7 ±0.8	>20% decrease	2.9 ±0.3	>20% decrease	variable	8 - 0 (3) variable	stable	10 - 7 (16) decline	4 (6) variable
Burdekin	Burdekin	Townsville	16.9 ±2.1	7.7 ±1.0	similar	2.0 ±0.4	>20% decrease	decline	675 – 764 (2004) decline	decline	4 - 1 (15) decline	3 - 1 (4) decline
		Magnetic Is	30.8 ±2.5	11.0 ±2.2	>20% decrease	6.5 ±1.1	>20% decrease	decline	0 (16) decline	decline	43 - 6 (38) decline	8 - 9 (7) stable
Mackay Whitsunday	Proserpine	Pioneer Bay	20.2 ±1.6	29.4 ±2.3	similar	10.9 ±1.1	>20% decrease	variable	71 - 161 (208) stable	increase	4 - 2 (14) decline	2 - 1 (11) decline
		Hamilton Is*	6.3 ±1.1	1.6 ±1.5	>20% decrease	2.9 ±0.8	>20% increase	decline	nil	variable	14 - 4 (15) decline	1 - 3 (3) stable
	Pioneer	Sarina Inlet	13.8 ±1.5	7.6 ±1.1	>20% decrease	2.0 ±0.5	>20% decrease	decline	0 (31) stable	decline	22 - 0 (14) stable	<1 (2) variable
Fitzroy	Fitzroy	Shoalwater	22.9 ±1.4	29.2 ±1.1	similar	23.0 ±1.1	similar	increase	nil	stable	10 – 8 (12) decline	4 - 1 (5) decline
		Great Keppel	2.3 ±0.5	2.1 ±0.4	>20% increase	0.7 ±0.2	>20% decrease	decline	nil	variable	19 - 11 (27) decline	2 - 18 (8) stable
	Boyne	Gladstone	21.0 ±1.7	30.8 ±1.8	similar	28.9 ±4.0	>20% increase	increase	nil	variable	16 - 4 (22) decline	2 -<1 (12) decline
Burnett Mary	Burnett	Rodds Bay	11.6 ±1.4	1.3 ±0.5	>20% decrease	0	>20% decrease	decline	0 (1) stable	variable	5 - 0 (5) decline	1 - 6 (2) increase
	Mary	Urangan	15.0 ±1.0	6.5 ±1.3	>20% increase	11.0 ±1.2	>20% decrease	variable	nil	variable	5 - 39 (20) variable	4 - 0 (1) variable

Seagrass reproductive status

There is a difference in the observed reproductive effort in different habitats sampled across the GBR (Figure 5). Coastal habitats on average produce more flowers, fruits and seeds per sampled area than either estuarine or reefal seagrasses. However, the two coastal sites in the Burdekin region (Bushland Beach and Shelley Beach) dominate the results in this region and significantly alter the results. Without these two sites, coastal and estuarine sites produce similar numbers of reproductive structures. Reefal sites produce fewer reproductive structures, putatively because of lower nutrient availability although research is required to confirm this. As an indicator of the capacity of seagrass meadows to recover following major disturbance, reef sites in 2009 in all regions except Mackay Whitsunday were average or above average. The Mackay Whitsunday region were significantly below average corresponding with a decline in seagrass % cover. The Wet Tropics region coastal sites were below average and all estuarine sites were below average. These also corresponded to previous declines in seagrass cover in these regions.



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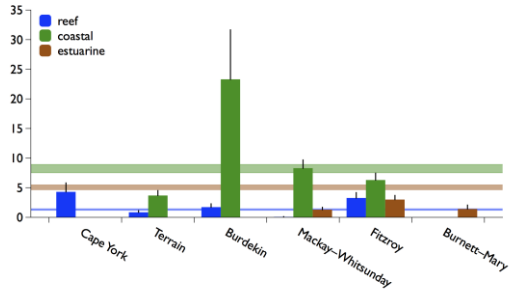


b.

Figure 5. *Reproductive effort (mean number reproductive structures per core ± s.e.) of intertidal seagrass meadows for each habitat type for NRM regions in the GBR sampled during dry seasons.* ***a.*** *reproductive effort across all years sampled (2005-2010) for each habitat type in each region. Horizontal lines depict the whole of GBR mean reproductive effort across all sampling years by way of reference.* ***b.*** *reproductive effort for the 2009 sample for each habitat type in each NRM. Horizontal lines depict the whole of GBR mean reproductive effort across all sampling years by way of reference.*

Status of the seagrass environment

Seagrass tissue nutrients

Tissue nutrient concentrations were variable between years, both across habitats and within habitats between years. By pooling across species and habitat types, some trends are apparent.

Tissue nitrogen concentrations (%N and %P) have increased since monitoring began across all habitats (species pooled), however the 2005 values may be unreliable due to contamination of the samples during the grinding phase (see McKenzie *et al.,* 2006a).

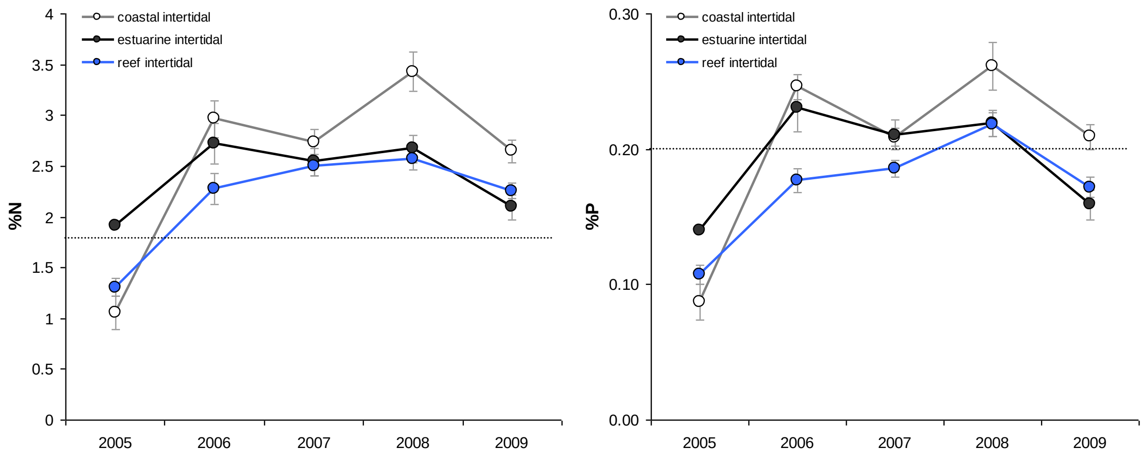


Figure 6. *Mean tissue nutrient concentrations (±Standard Error) in seagrass leaves for each habitat type (species pooled) over the entire monitoring program. Dashed lines indicate global threshold values of 1.8% and 0.2% for tissue nitrogen and phosphorus, respectively (Duarte 1990).*

In 2009, mean tissue nitrogen and phosphorus concentrations for all habitats declined (Figure 6). However, since 2005, mean tissue nitrogen concentrations for all habitats have exceeded the global threshold values of 1.8% (Duarte 1990; Schaffelke *et al.,* 2005) (Figure 6). Although mean tissue phosphorus concentrations for all habitats exceeded the global threshold values of 0.2% (Duarte 1990; Schaffelke *et al.,* 2005) in 2008, declines in 2009 resulted in concentrations for reef and estuarine habitats dropping back to below the global average (Figure 6). Although some concerns have been raised as to accuracy of the global tissue nutrient values (Schaffelke *et al.,* 2005), coastal tissue concentrations in 2009 remained similar to 2007 and higher than the 2005 baseline.

C:N ratios have been shown in a number of experiments and field surveys to be related to light levels (Abal *et al.,* 1994; Grice *et al.,* 1996; Cabaço and Santos 2007; Collier *et al.,* 2009). With increasing light availability, plants increase growth, thereby taking on more carbon relative to nitrogen. Experiments on seagrasses in Queensland have suggested that at an atomic C:N ratio <20, may suggest reduced light availability (Abal *et al.,* 1994; Grice *et al.,* 1996). In 2009, all three habitat types (coast, reef and estuary) had C:N ratios <20; these levels have mostly declined since 2005. These low C:N levels in 2009 potentially indicate reduced light availability (Figure 7).

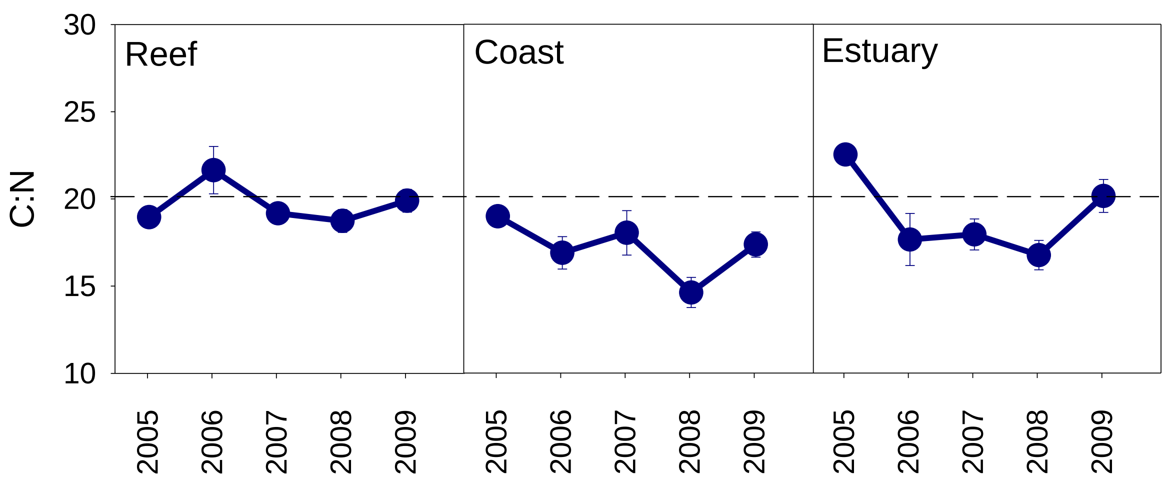


Figure 7. *Elemental ratios (atomic) of seagrass leaf tissue C:N for each habitat each year (foundation species pooled). Horizontal shaded band on the C:N ratio panel represents the accepted guideline seagrass "Redfield" ratio of 20:1 (Abal et al. 1994; Grice et al. 1996). C:N ratios below this line indicate reduced light availability.*

In 2009, all seagrass species within all habitat types of the Mackay Whitsunday region had C:N ratios <20. Similarly, all estuary seagrass species in the Burnett Mary region and all seagrass species in coastal habitats from the Wet Tropics region south to Mackay Whitsunday region, had C:N ratios <20.

Coastal habitats across the GBR were consistently rich in nutrients relative to carbon with C:P ratios below 500, indicating a relatively large P pool (Figure 8). Reef habitats became poorer in nutrients in 2009, indicating a relatively small P pool, which is expected for calcium carbonate dominated sediments which bind P to the $CaCO_3$ matrix, making it less available for plants. C:P ratios have fluctuated greatly in estuary habitats, and in 2009 were similar to 2006 levels where nutrients were much poorer (Figure 8).

In 2009, all seagrass species within the reef habitat of Cape York had N:P ratios >30, indicating P-limitation. Only *Halophila ovalis* and *Cymodocea serrulata* within coastal and reef habitats in the Wet Tropics and Burdekin regions had N:P ratios <30, indicating N-limitation. Within all other species and habitats levels of N:P were between 25 and 30 in 2009, indicating seagrass to be nutrient replete, and potentially nutrient saturated. Within coastal habitats these levels had consistently increased since 2005, until 2009 when they dropped slightly (Figure 8). In estuary habitats, N:P has remained mostly unchanged between years, however in reef habitats N:P significantly increased from 2008 to 2009, indicating increasing levels of nitrogen enrichment.

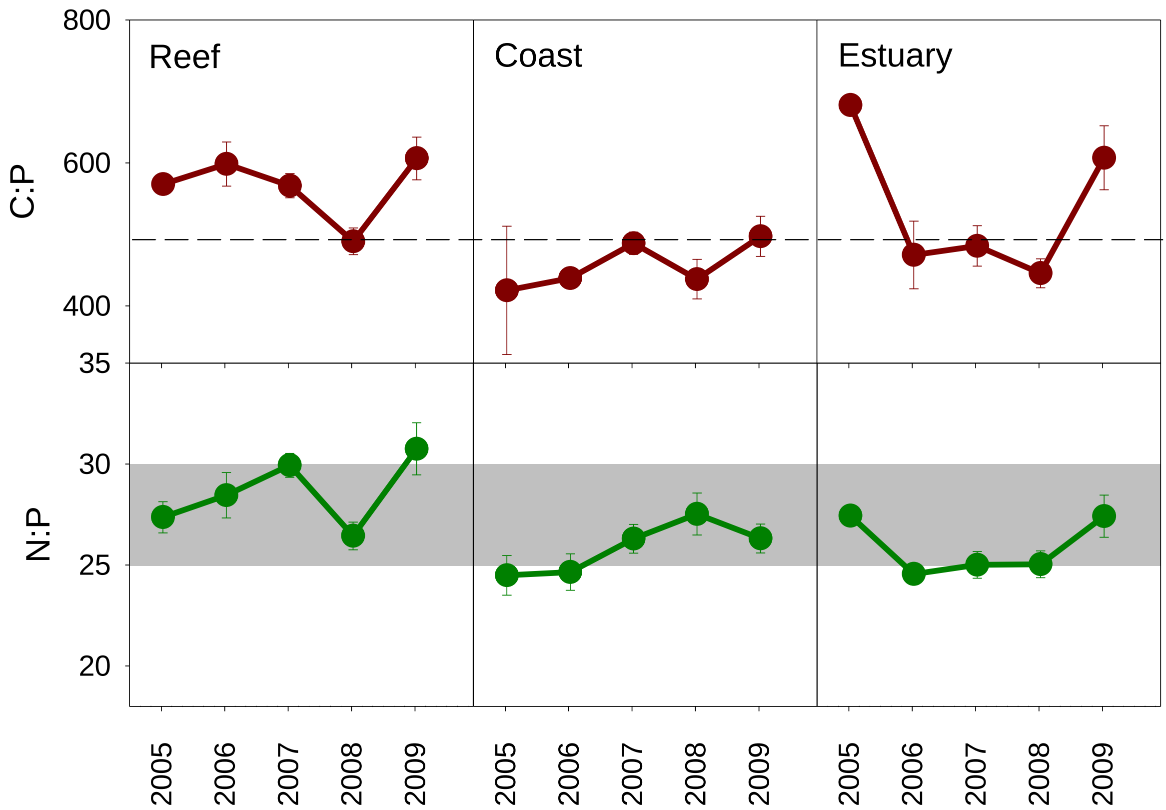


Figure 8. *Elemental ratios (atomic) of seagrass leaf tissue N:P and C:P for each habitat each year (foundation species pooled) (± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation, below indicates N limitation and within indicates replete. Horizontal dashed line on the C:P panel at 500 represents the value associated with C:P balance ratio in the plant tissues, C:P values <500 may indicate nutrient rich habitats (large P pool).*

Locations where seagrass are growing in low light environments (C:N is low), with a relatively large P pool (C:P is rich) and an even larger N pool (N:P is P limited) indicate relatively poor water quality. Two locations met these criteria in 2009: Sarina Inlet (Mackay Whitsunday region) and Yule Point (Wet Tropics region) (Table 13). Sarina Inlet and Yule Point were also identified as poor water quality locations in 2008, together with Lugger Bay (Wet Tropics region) and Townsville (Burdekin region). In 2009/10, with the exception of Yule Point, seagrass declined significantly in abundance at locations identified with relatively poor water quality in the previous monitoring period (Table 13). At Yule Point, however, seagrass abundance continued to increase in 2009 until the monsoon (Table 12).

Table 13. *Summary of elemental ratios (atomic) of seagrass leaf tissue condition at each seagrass monitoring location, values are Sep/Oct 2009 with the 2008 value in parentheses. Light orange = sites of concern with respect to water quality. Plant elemental C:N is a surrogate for light where moderate = adequate light availability on average required for growth (C:N>20:1), low = less available light on average than required for growth (C:N<20:1); C:P is a surrogate for nutrient status of the habitat where, rich = relatively large P pool (C:P <500:1), poor = relatively small P pool (C:P >500:1); N:P is the overall nutrient availability to the plant, where N-limited = N:P <25, replete N:P = 25 to 30; P-limited = N:P >30.*

Region	Catchment	Location *(habitat)*	$C:N_{plant}$ status	$C:P_{plant}$ status	$N:P_{plant}$ status
Cape York	Endeavour	Archer Pt *(reef)*	low *(low)*	poor *(rich)*	P-limited *(N-limited)*
Wet Tropics	Barron Russell - Mulgrave Johnstone	Yule Pt *(coast)*	low *(low)*	rich *(rich)*	P-limited *(P-limited)*
		Green Is *(reef)*	moderate *(moderate)*	poor *(poor)*	replete *(replete)*
	Tully – Murray	Lugger Bay *(coast)*	low *(low)*	rich *(rich)*	replete *(P-limited)*
		Dunk Is *(reef)*	moderate *(poor)*	poor *(poor)*	replete *(replete)*
Burdekin	Burdekin	Townsville *(coast)*	low *(low)*	rich *(rich)*	replete *(P-limited)*
		Magnetic Is *(reef)*	moderate *(moderate)*	poor *(poor)*	P-limited *(replete)*
Mackay Whitsunday	Proserpine	Pioneer Bay *(coast)*	low *(low)*	poor *(rich)*	replete *(N-limited)*
		Hamilton Is* *(reef)*	low *(low)*	poor *(rich)*	P-limited *(replete)*
	Pioneer	Sarina Inlet *(estuary)*	low *(low)*	rich *(rich)*	P-limited *(P-limited)*
Fitzroy	Fitzroy	Shoalwater *(coast)*	moderate *(moderate)*	poor *(rich)*	replete *(replete)*
		Great Keppel *(reef)*	low *(low)*	poor *(rich)*	P-limited *(replete)*
	Boyne	Gladstone *(estuary)*	moderate *(low)*	poor *(rich)*	P-limited *(replete)*
Burnett Mary	Burnett	Rodds Bay *(estuary)*	low *(moderate)*	poor *(rich)*	P-limited *(N-limited)*
	Mary	Urangan *(estuary)*	low *(low)*	poor *(rich)*	replete *(replete)*

Epiphytes and macro-algae

Epiphyte abundance was dependent on seagrass presence and for some habitats, time of year/season. In coastal habitats, epiphyte cover was significantly higher in the monsoon period (ANOVA, d.f.=3, F=5.12, p=0.006), however in estuarine habitats, epiphyte cover was significantly higher in the late dry (ANOVA, d.f.=3, F=3.58, p=0.03). At intertidal reef habitats, there was no difference in epiphyte abundance between seasons (ANOVA, d.f.=3, F=1.64, p=0.2). Generally trends in epiphyte cover are similar to seagrass abundance, however epiphyte cover appears to be increasing and remaining above the GBR long-term average at coastal habitats (Figure 9).

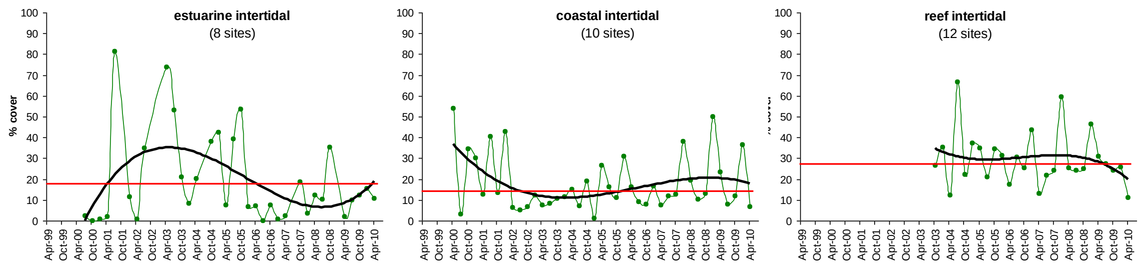


Figure 9. *Epiphyte abundance (% cover) at each seagrass habitat monitored (sites pooled) (±SE). Red line = GBR long-term average.*

Some macro-algal overgrowth was reported at monitoring sites, but abundance was not as high as epiphytes and apart from the reef habitats, was below the GBR long-term average during the 2009/10 monitoring period (Figure 10).

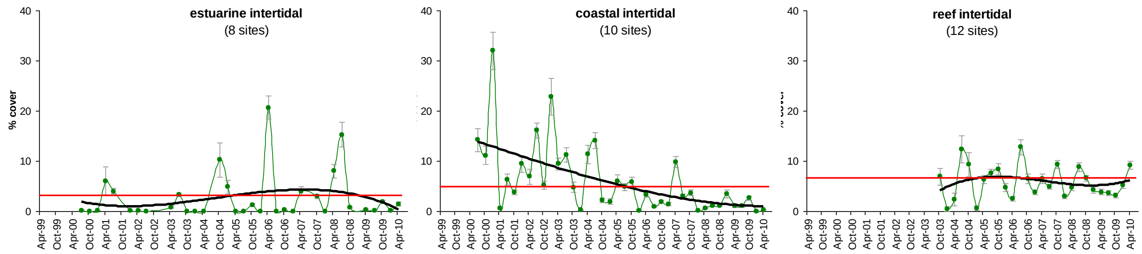


Figure 10. Macro-*algal abundance (% cover) at each seagrass habitat monitored (sites pooled) (±SE). Red line = GBR long-term average.*

Cape York

2009/10 Summary

The majority of the land in Cape York Peninsula is relatively undeveloped and waters entering the lagoon are perceived to be of a high quality. Only one seagrass location, Archer Point, is monitored in the Cape York region. It is a reef habitat, located in the southern section of the region and seagrass growth is primarily controlled by physical disturbance from waves and swell and associated sediment movement. Seagrass abundance in 2009/10 was relatively stable and seed banks increased above the GBR long-term average, indicating higher recovery potential to disturbances. Plant tissue nutrient ratios suggest the seagrass habitat had moderate/fair light availability, was nutrient poor and the plants N-limited. Epiphyte fouling of seagrass leaves increased above the GBR long-term average. Climate in the region (Cooktown) was warmer and drier over the monitoring period and within canopy temperatures in the 2009 calendar year were slightly higher than previous. Overall the status of seagrass condition in the region was rated as moderate.

Table 14. *Report card for seagrass status (community & environment) for the Cape York region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100. Yellow = moderate, gold = fair.*

Habitat	Abundance	Reproductive Effort	Nutrient status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index**
reef intertidal	58	67	33	33	**48**
coastal intertidal	*not monitored*				
estuarine intertidal	*not monitored*				
Cape York	58	67	33	33	**48**

Background

Cape York Peninsula is the northernmost extremity of Australia. From its tip at Cape York it extends southward in Queensland for about 800 km, widening to its base, which spans 650 km from Cairns (east) to the Gilbert River (west). The largest rivers empty into the gulf, however there are several significant catchments which empty into the GBR. The region has a monsoonal climate with distinct wet and dry seasons with mean annual rainfall ranging from 1715 mm (Starke region) to 2159 mm (Lockhart River airport). Most rain falls between December and April. Mean daily air temperatures in the area range from 19.2 – 32.1°C. The prevailing winds are from the south east and persist throughout the year (EarthTech, 2005).

Cape York Peninsula is an area of exceptional conservation value and has cultural value of great significance to both Indigenous and non-Indigenous communities. The majority of the land is relatively undeveloped, therefore water entering the lagoon is perceived to be of a high quality. Mining, agriculture, shipping tourism and commercial and recreational fishing are the major economic activities. All have potential to expand in this region and with this expansion the possible increase in pollutants.

Of the seagrass habitats types identified for the GBR (Figure 1), Reef Rescue MMP monitoring of intertidal seagrass meadows within this region is on a fringing reef platform. These habitats in the Cape York region support diverse seagrass assemblages. Approximately 3% of all mapped seagrass meadows in the Cape York region are located on fringing-reefs (Coles *et al.,* 2007). On fringing-reefs, physical disturbance from waves and swell and associated sediment movement primarily control seagrass growing in these habitats (Figure 11). Shallow unstable sediment, fluctuating temperature, and variable salinity in intertidal regions characterize these habitats. Sediment movement due to bioturbation and prevalent wave exposure creates an unstable environment where it is difficult for seagrass seedlings to establish or persist.

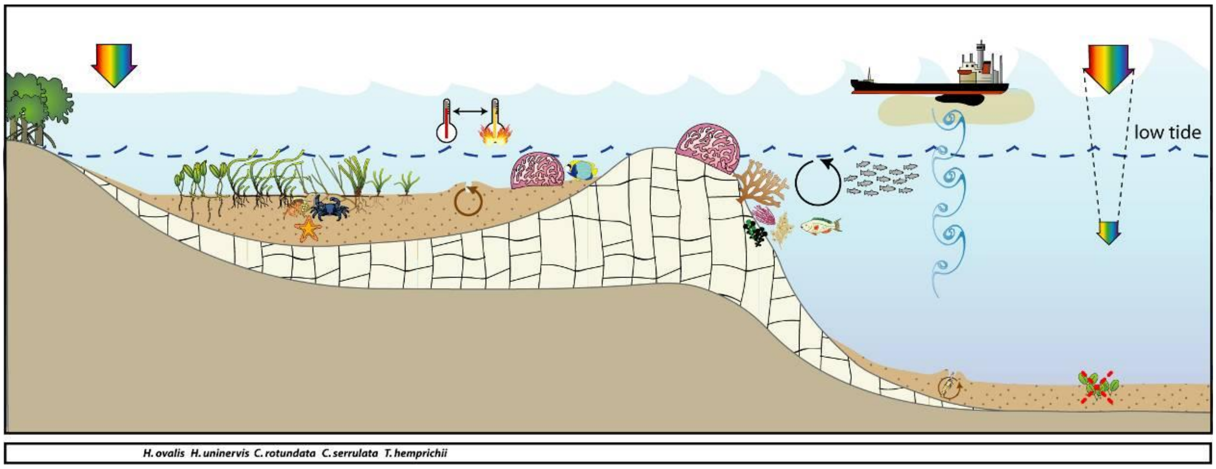


Figure 11. *Conceptual diagram of reef-platform habitat in the Cape York region – major control is pulsed physical disturbance, salinity and temperature extremes: general habitat and seagrass meadow processes (see Figure 2 for icon explanation).*

The monitoring sites at Archer Point were located in a protected section of bay adjacent to Archer Point, fringed by mangroves, approximately 15km south of Cooktown. There are two major rivers within the immediate region: the Endeavour and the Annan River. The Endeavour River is the larger of the two river systems and has a catchment area of approximately 992 km^2. The Annan River is located approximately 5 km south of Cooktown and extends inland from Walker Bay. The Annan River catchment area is approximately 850 km^2 (Hortle and Pearson 1990). The Kuku Yalanji bama are the traditional people connected to country between Mowbray River (Port Douglas) and the Annan River.

Status of the seagrass community

Seagrass abundance and composition

Cape York region reef habitat seagrass cover long-term average was between 16% in the dry and 19% in late dry season (Figure 12). Sampling was discontinued at Archer Point site AP2 after late dry 2009, however Seagrass-Watch volunteers continued to monitor Archer Point site AP1. Seagrass abundance, although below the GBR long-term average, remained stable over the past 12 months at AP1 and decreased at AP2 in the late dry (Figure 12).

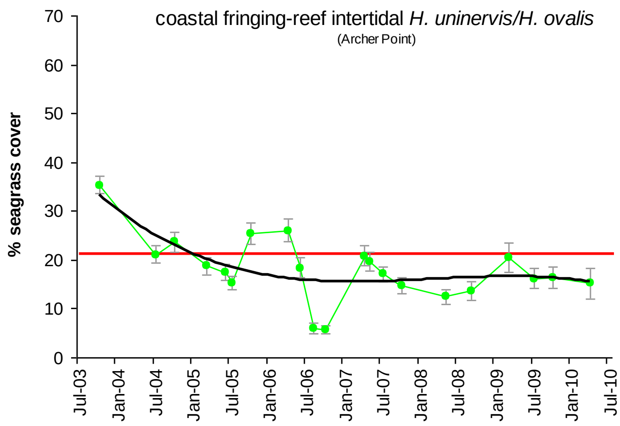
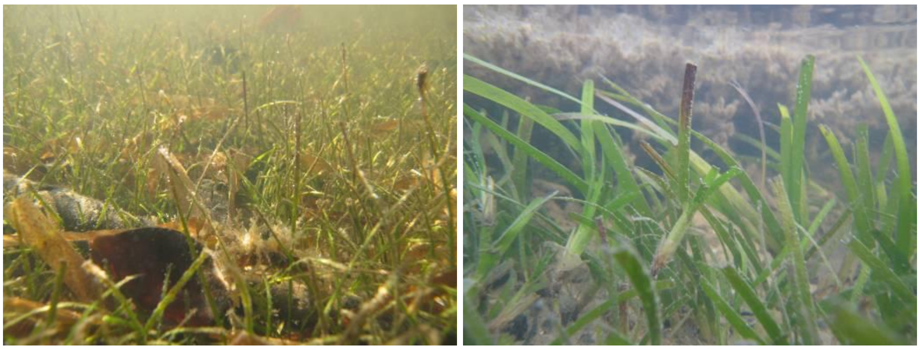


Figure 12. *Seagrass abundance (% cover, ± Standard Error) at Archer Point, inshore intertidal fringing-reef habitat (sites pooled). Red line = GBR long-term average for reef habitats.*

The Cape York region reef sites were dominated by *Halodule uninervis* and *Halophila ovalis* with varying amounts of *Cymodocea rotundata* (Figure 13). Although sites were only 50m apart, AP2 had slightly more *Cymodocea* and *Thalassia* present. Species composition has varied since sampling began in 2003 with the composition of *Halophila ovalis* increasing in 2006/07; coinciding with significant losses in abundance. Since then, the composition of *Halophila ovalis* has fluctuated seasonally with increases in the late monsoon following disturbance followed by deceases when the foundation species (*Halodule* and *Cymodocea*) increase.



Monospecific H. uninervis (AP1) and mixed H. uninervis/C. rotundata (AP2).

Quadrat at 5m on transect 3 at AP1 on 27 March 2009 (left) and 1 October 2009 (right)

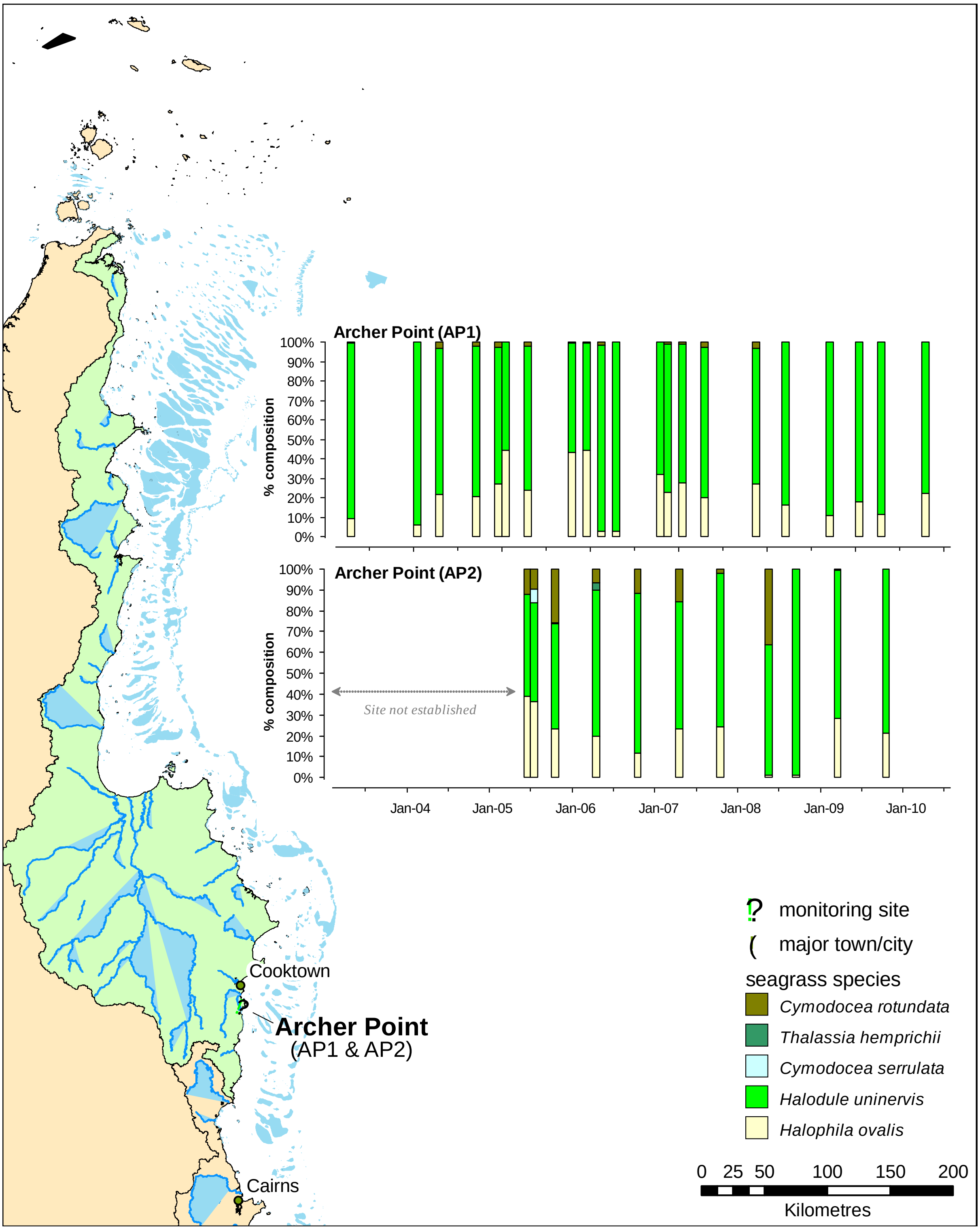


Figure 13. *Location of the Cape York region monitoring sites and seagrass species percent composition at each site since 2003. Please note: replicate sites within 500m of each other.*

Since monitoring was established at Archer Point site 1 (AP1) in 2003, seagrass cover has generally followed a seasonal trend with higher abundance in late dry to monsoon period (Figure 14). The seasonal trend at Archer Point site 2 (AP2) is less apparent.

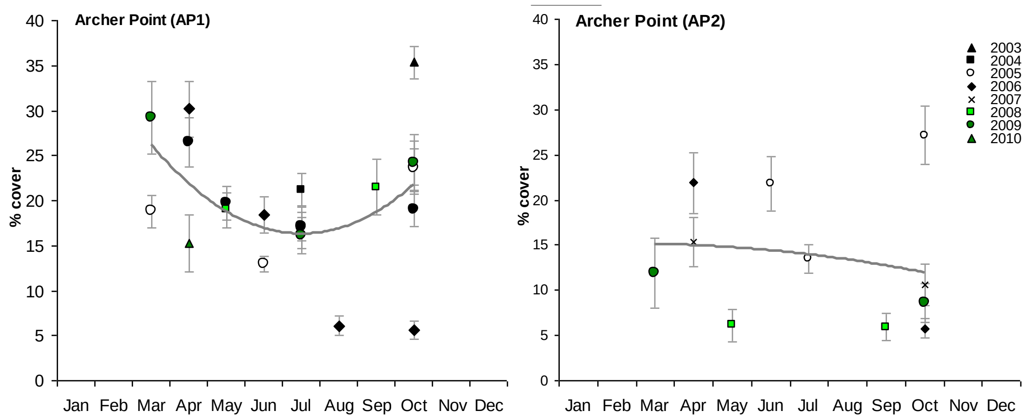


Figure 14. *Mean percentage seagrass cover (all species pooled) (± Standard Error) for inshore fringing-reef long-term monitoring sites in Cape York region at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass abundance relative to the seagrass guidelines indicates that Archer Point site AP1 was good during the 2009/10 monitoring period, however the AP2 site fell back to poor in the late dry season (*Figure 15*).

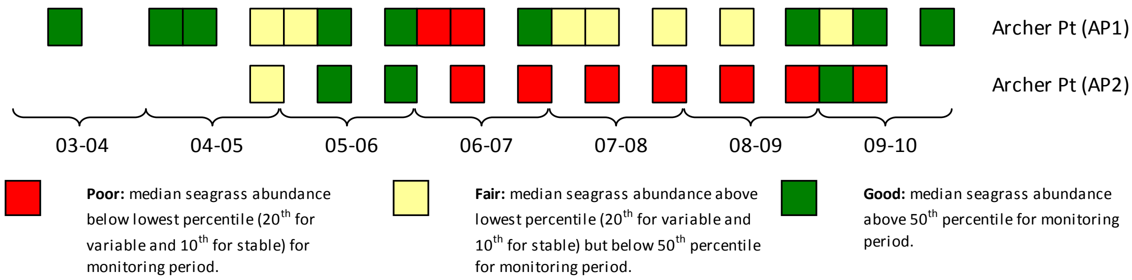


Figure 15. Status of seagrass abundance relative to the seagrass guidelines since monitoring was established in 2003. Each block represents the seasonal monitoring event (dry, late dry, monsoon, late monsoon), with time along the x-axis from left to right.

Seagrass meadow edge mapping was conducted within a 100m radius of both Archer Point monitoring sites in October 2009 to determine if changes in abundance were a consequence of the meadow edges changing. Up until October 2009, both meadow boundaries increased shoreward, increasing the overall area of seagrass present within the mapping boundaries (Figure 16, Table 4). Unfortunately, the extent of the meadow within the mapping area remained lower than the 2005 baseline for AP2. This indicates that improvements in abundance were aided by the expansion/recovery of the meadows.

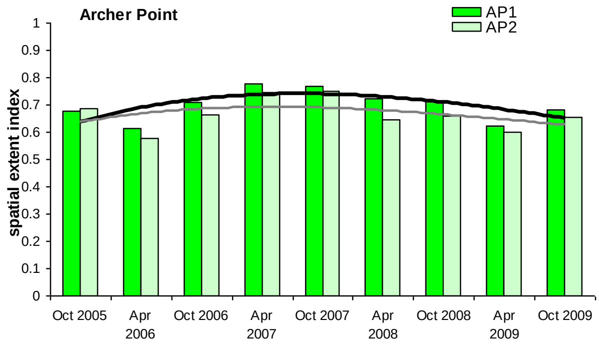


Figure 16. *Extent of area (100m radius of monitoring site) covered by seagrass at each monitoring site.*

Table 15. *Area (ha) of seagrass meadow being monitored within 100m radius of each Archer Point site (AP1 and AP2). Value in parenthesis is % change from October 2005 baseline (bold) and description of change from previous mapping. Shading indicates decrease in meadow area since baseline.*

Site	October 2005	April 2006	October 2006	April 2007	October 2007	April 2008	October 2008	April 2009	October 2009
AP1	**3.667**	3.330 *(-9.2%, decrease seaward)*	3.843 *(4.8%, increase shoreward)*	4.212 *(14.9%, increase shoreward)*	4.173 *(13.8%, decrease seaward)*	3.905 *(6.5%, decrease seaward)*	3.88 *(5.7%, decrease seaward)*	3.36 *(-8.3%, decrease seaward)*	3.70 *(-1%, increase shoreward)*
AP2	**3.710**	3.139 *(-15.4%, decrease seaward)*	3.5865 *(-3.3%, increase shoreward)*	4.0367 *(8.8%, decrease seaward)*	4.053 *(9.28%, decrease seaward)*	3.489 *(-5.98%, decrease seaward)*	3.57 *(-3.73%, increase shoreward)*	3.26 *(-12.14%, decrease seaward)*	3.55 *(-4.2%, increase shoreward)*

Seagrass reproductive status

Reproductive effort at the two Archer Point sites was above average in 2009 compared with other years at these sites (Figure 17) and was high (1.3 ± 0.14) compared to the GBR long-term average for reef habitats.

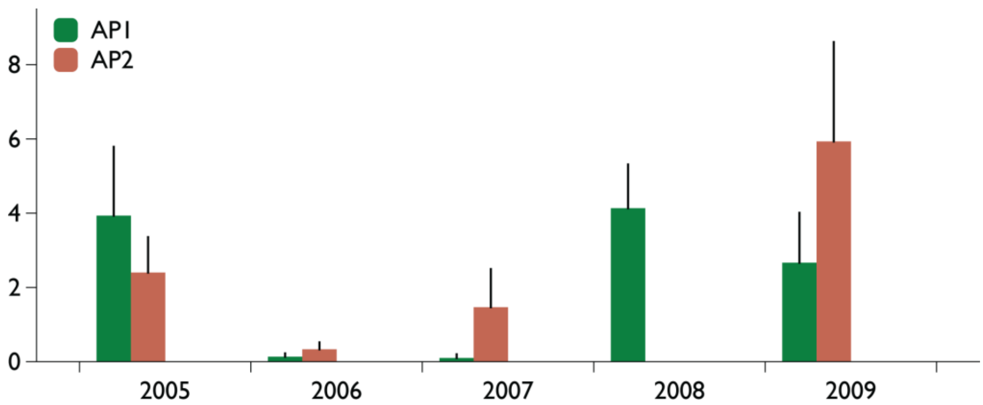


Figure 17. *Mean reproductive effort (number of reproductive structures per core ± SE) during dry season sampling from 2005–2009 for Cape York region sites (AP1 and AP2).*

A persistent and increasing *Halodule uninervis* seed bank has been present at the Archer Point monitoring sites (Figure 18). The seed bank is above the GBR long-term average, and abundances in 2009/10 were higher in the late dry 2009 than the previous year. The abundance of germinated seeds fluctuates from year to year, but is generally higher in the late monsoon (Figure 18).

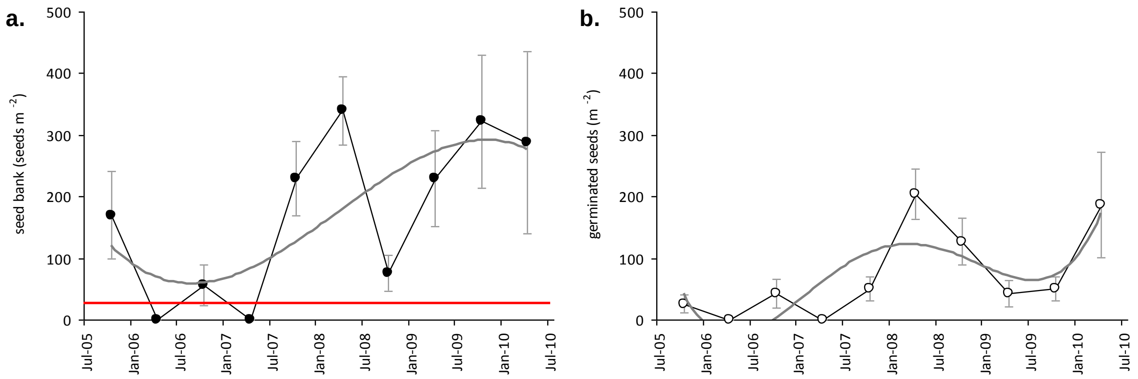


Figure 18. *Halodule uninervis seed bank (a) and germinated seed abundance (b) at Archer Point (seed bank is represented as the total number of seeds per m^2 sediment surface). Red line = GBR long-term average for reef habitats.*

The Cape York region sites, although reefal, are also strongly influenced by coastal processes and have experienced perturbations in recent years. The ongoing presence of reproductive structures indicates a good capacity to recover following disturbance.

Status of the seagrass environment

Seagrass tissue nutrients

Seagrass species in Archer Point in late dry season 2009 all had low molar C:N ratios, where values of 20 or less indicated low light availability (Figure 20). There was little change in C:N values in 2009 compared to 2008, with the average of foundation species remaining just below 20.

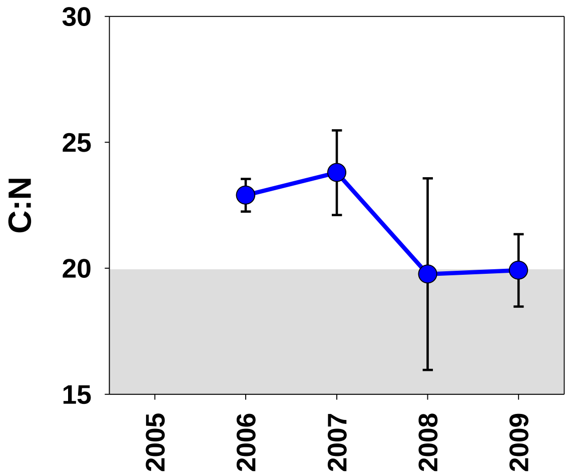


Figure 19. *Elemental ratios (atomic) of seagrass leaf tissue C:N for the foundation species in Cape York region at Archer Point each year (species pooled) (mean and SE displayed). Horizontal shaded band on the C:N ratio panel represents the accepted guideline seagrass "Redfield" ratio of 20:1 (Abal et al. 1994; Grice et al. 1996). C:N ratios below this line indicate reduced light availability.*

C:P ratios in 2009 were significantly >500, indicating that the plants (*Cymodocea rotundata* and *Halodule uninervis*) were growing in an environment with a relatively small P pool, suggesting the habitat to be nutrient poor (Figure 20).

N:P ratios for all species were the highest since the commencement of Reef Rescue MMP. N:P ratios for the foundation species were all above 30, indicating the plants were P-limited (Figure 20). Ratios suggest the habitat to be moderate/fair light availability, nutrient poor and plants N-limited.

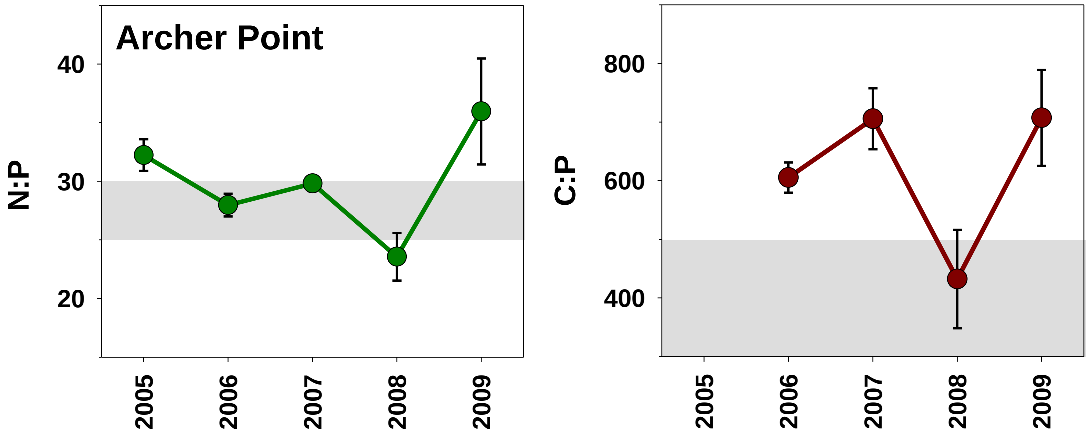


Figure 20. *Elemental ratios (atomic) of seagrass leaf tissue N:P and C:P for the foundation species in Cape York region at Archer Point each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation, below indicates N limitation and within indicates replete. Shaded portion on the C:P panel ≤500 represents the value associated with C:P balance ratio in the plant tissues, C:P values <500 may indicate nutrient rich habitats (large P pool).*

Epiphytes and macro-algae

Epiphyte cover on seagrass leaf blades at Archer Point appears to have increased over the 2009/10 monitoring period to above the GBR long-term average for reef habitats. By late monsoon 2010 epiphyte cover was similar to when monitoring began in 2003 (Figure 21).

Percentage cover of macro-algae was variable between years, but appears to have declined since 2007. Over the 2009/10 monitoring period, macro-algae cover remained below the GBR long-term average for reef habitats (Figure 21).

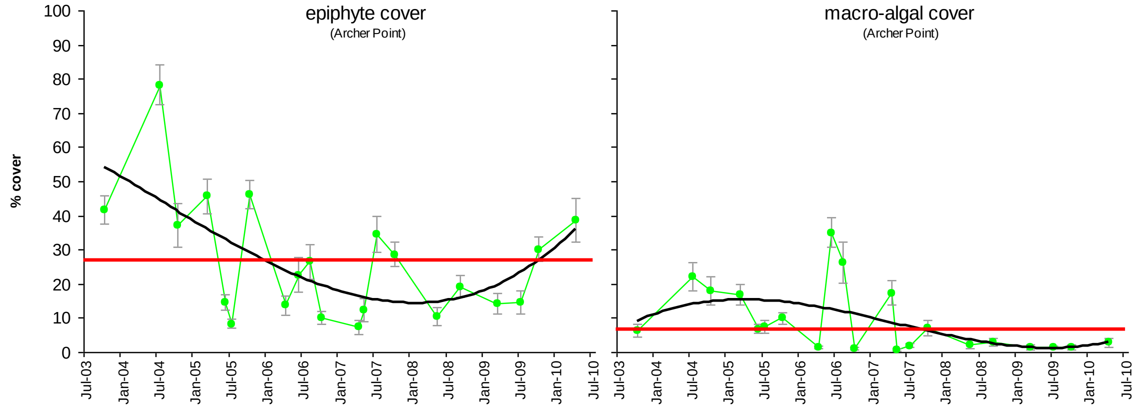


Figure 21. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at Archer Point (sites pooled). NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

Within meadow canopy temperature

Autonomous temperature loggers were deployed at both sites from July to October 2009, however loggers deployed in October 2009 have not been collected as monitoring was discontinued. High temperatures were recorded from August to October 2009, coinciding with the low spring tides, with the highest temperature (33.2°C) recorded on 31 August 2009 (Figure 22). Temperatures over the 2009 calendar year were 1.5°C higher than previous years (Figure 23).

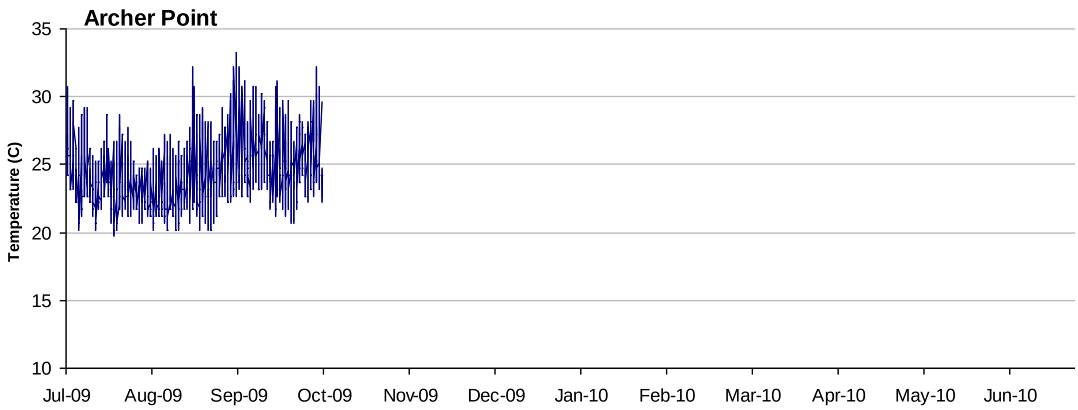


Figure 22. *Within seagrass canopy temperature (°C) at Archer Point intertidal meadow over the 2009/10 monitoring period.*

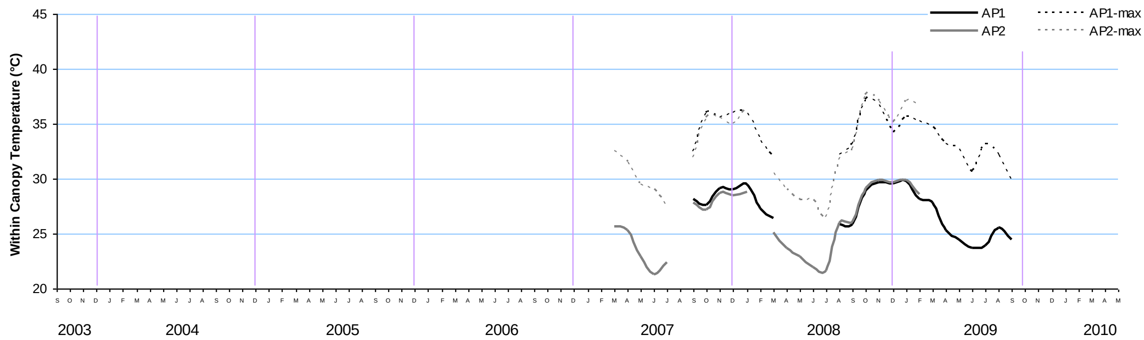


Figure 23. *Monthly mean and maximum within seagrass canopy temperatures (°C) at Archer Point intertidal meadow, Cape York region.*

Regional Climate

The mean maximum daily air temperature recorded in Cooktown during 2009 was 29.8°C; this was 0.9°C higher than the 80 year average and 0.4 °C higher than the decade average. The highest recorded daily maximum air temperature in 2009 was 36.3 °C.

2009 was a dry year, with mean annual monthly rainfall in 2009 of 101mm (Figure 24). This was 33% less than the long-term average of 150mm, and 16% less than the decade average. Mean wind speed in 2009 was 21.6 km.hr^{-1}, this was higher than the long-term average of 17.9 km.hr^{-1}, but less than the decade average of 22.3 km.hr^{-1}.

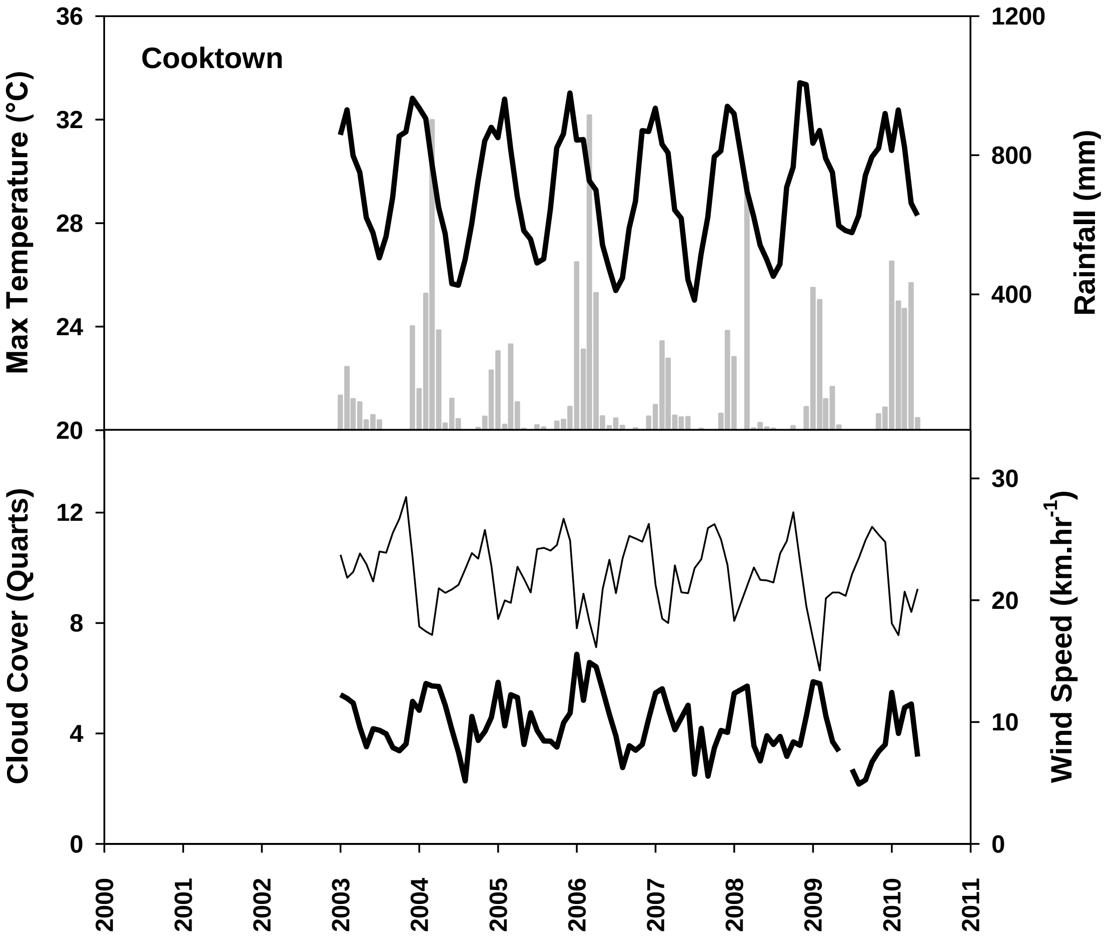


Figure 24. *Mean monthly daily maximum air temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr^{-1}) recorded at Cooktown airport (BOM station 031209) (source www.bom.gov.au). Cooktown Airport used as a surrogate for the climate at Archer Point.*

Wet Tropics

2009/10 Summary

The region includes two World Heritage Areas, however increases in intensive agriculture, coastal development and declining water quality have been identified as significant in the region. Seagrass monitoring was conducted on coastal and reef platform habitats. A dominant influence on these habitats is disturbance from wave action, sediment movement, elevated temperatures as well as seasonal terrigenous runoff. Nutrient concentrations are also generally low in reef habitats due to the nature of the coral sand sediments.

In 2009/10, seagrasses in the north of the region remained in a good state and the meadows either expanded or stabilised over the monitoring period; however in the south seagrasses declined in abundance and distribution and by the late monsoon 2010 were in a poor state. Seed banks and reproductive effort decreased below the GBR long-term average, indicating lower recovery potential to disturbances. Leaf tissue nutrient ratios suggest the potentially higher light environment in reef habitats than coastal, however lower C:N ratios at Green Island since 2006 indicate decreasing light availability which may be a consequence of elevated epiphyte fouling. Leaf tissue nutrient ratios also indicate high levels of nutrients at both coastal locations and Dunk Island, with N:P ratios generally increasing over time indicating increased nitrogen availability. Epiphyte fouling of seagrass increased at most locations and was well above the GBR long-term average. Overall results suggest poor water quality at Yule Point with low light availability and nutrient enrichment (elevated N). Macro-algae abundance remained negligible over the monitoring period. Climate across the region was hotter, windier and wetter in 2009/10 than the long-term average, and within canopy water temperatures were also significantly higher than previous years. Overall the status of seagrass in the region was rated as fair.

Table 16. *Report card for seagrass status (community & environment) for the Wet Tropics region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100 Green = good, yellow = moderate, gold = fair, red = poor.*

Habitat	Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index**
reef intertidal	48	0	67	33	**48**
coastal intertidal	52	0	0	0	**13**
estuarine intertidal			*not monitored*		
Wet Tropics	50	0	33	33	**29**

Background

The Wet Tropics region covers 22,000 km^2 and land use practices include primary production such as cane and banana farming, dairying, beef, cropping and tropical horticulture (Australian Government Land and Coasts 2010a). Other uses within the region include fisheries, mining and tourism. Declining water quality, due to sedimentation combined with other forms of pollutants, the disturbance of acid sulphate soils, and point source pollution have been identified as a major concern to the health of coastal estuary and marine ecosystems of which seagrass meadows are a major component (FNQ NRM Ltd and Rainforest CRC 2004). Two types of seagrass habitats are monitored in the region: coastal and reef.

Reef Rescue monitoring occurs at two coastal seagrass habitat locations: Yule Point, in the north and Lugger Bay in the south of the region. The seagrass meadows at Yule Point and Lugger Bay are located on naturally dynamic intertidal sand banks, protected by fringing reefs. These meadows are dominated by *Halodule uninervis* with some *Halophila ovalis* and are often exposed to regular periods of disturbance from wave action and consequent sediment movement. The sediments in these locations are relatively unstable restricting seagrass growth and distribution. A dominant influence of to these coastal meadows is terrigenous runoff from seasonal rains (Figure 25). The Barron, Tully and Hull Rivers are a major source of pulsed sediment and nutrient input to these monitored meadows.

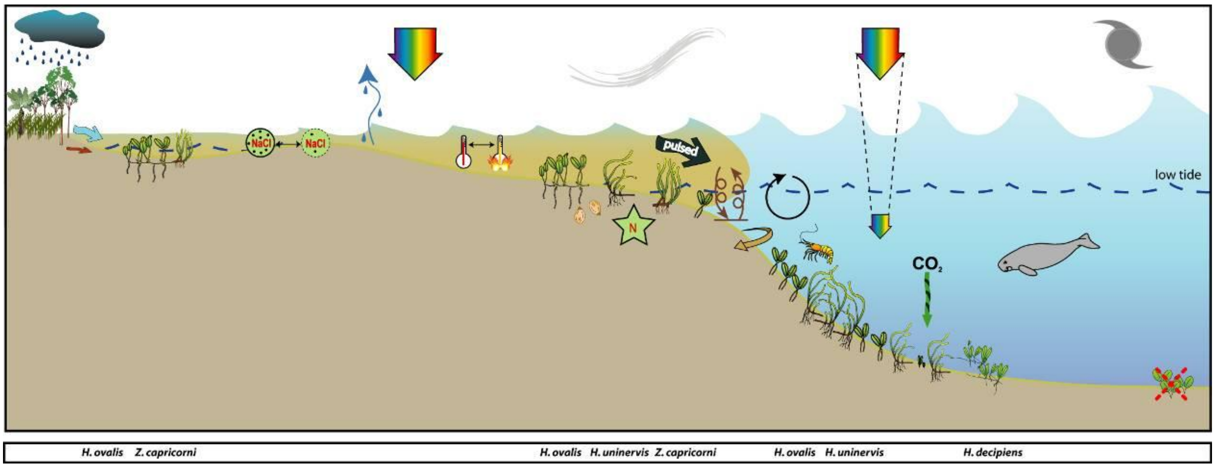


Figure 25. *Conceptual diagram of coastal habitat (<15m) in the Wet Tropics region – major control is pulsed terrigenous runoff, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (see Figure 2 for icon explanation).*

Monitoring of reef habitats occurs at two locations: Green Island and Dunk Island. Monitoring at Green Island occurs on the large intertidal reef-platform south west of the cay. The meadow is dominated by *Cymodocea rotundata* and *Thalassia hemprichii* with some *Halodule uninervis* and *Halophila ovalis*.

Shallow unstable sediment, fluctuating temperature, and variable salinity in intertidal regions characterize these habitats. Physical disturbance from waves and swell and associated sediment movement primarily control seagrass growing in these habitats (Figure 26). Reef seagrass habitats in the region are often adjacent to areas of high tourism use and boating activity with propeller and anchor scarring impacts. Globally, nutrient concentrations are generally low in reef habitats due to the coarse nature of the coral sand sediments. In these types of carbonate sediments the primary limiting nutrient for seagrass growth is generally phosphate (Short *et al.,* 1990; Fourqurean *et al*., 1992; Erftemeijer and Middelburg 1993). This is due to the sequestering of phosphate by calcium carbonate sediments. In this region seagrass meadows inhabiting the near shore inner reefs and fringing reefs of coastal islands inhabit a mixture of terrigenous and carbonate sediments, such as

Green Island. Seagrasses at this location in the 1990's were shown to be nitrogen limited (Udy *et al.* 1999).

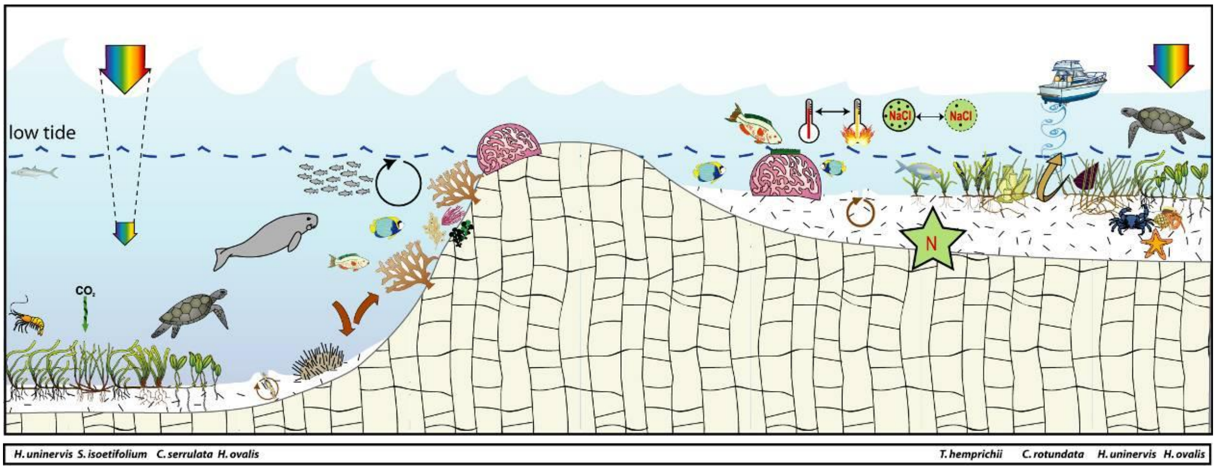


Figure 26. *Conceptual diagram of reef habitat (<15m) in the Wet Tropics region – major control is nutrient limitation, temperature extremes, light and grazing: general habitat, seagrass meadow processes and threats/impacts (see Figure 2 for icon explanation).*

Status of the seagrass community

Seagrass abundance and composition

The seagrass at Yule Point and Lugger Bay were representative of coastal (inshore) seagrass communities in the region and dominated by *Halodule uninervis* and *Halophila ovalis* (Figure 27).

The Yule Point meadows appear to have changed relatively little since 1967, when den Hartog (1970) photographed the area and described the species present and sediment condition. *Zostera capricorni* was reported adjacent to Yule Point site 1 (YP1) in 2002, and was absent during the period of the Reef Rescue MMP until April 2007, when isolated plants were found inshore, within the 100m radius of the monitoring site. The meadow has continued to expand and is now mixed with the shoreward *H. uninervis* dominated meadow. During the late monsoon, the proportion of *Halophila ovalis* at Yule Point site 1 (YP1) increased until the dry, when it declined to the long-term average (Figure 27).

At Lugger Bay the meadow is only exposed as very low tides (<0.4m), and seagrass cover was generally low (< 10%), which is similar to observations in the early 90's at this location (Mellors *et al.* 2005). The decline of seagrass at Lugger Bay in 2006 appears a consequence of severe TC Larry, which crossed the coast 50km north of the location on 20 March 2006. In 2009, the seagrass had recovered to 2005 abundances; however in the late monsoon abundance significantly declined (Figure 27) and remained very low over the 2009/10 monitoring period.

Seagrass cover from the start of monitoring at Yule Point in 2000 has changed little from year to year until 2008 (Figure 28). Abundances in 2008 and 2009 were some of the highest recorded. However in dry 2009, abundances decreased and have since remained similar to the pre-2008 abundances (Figure 28).

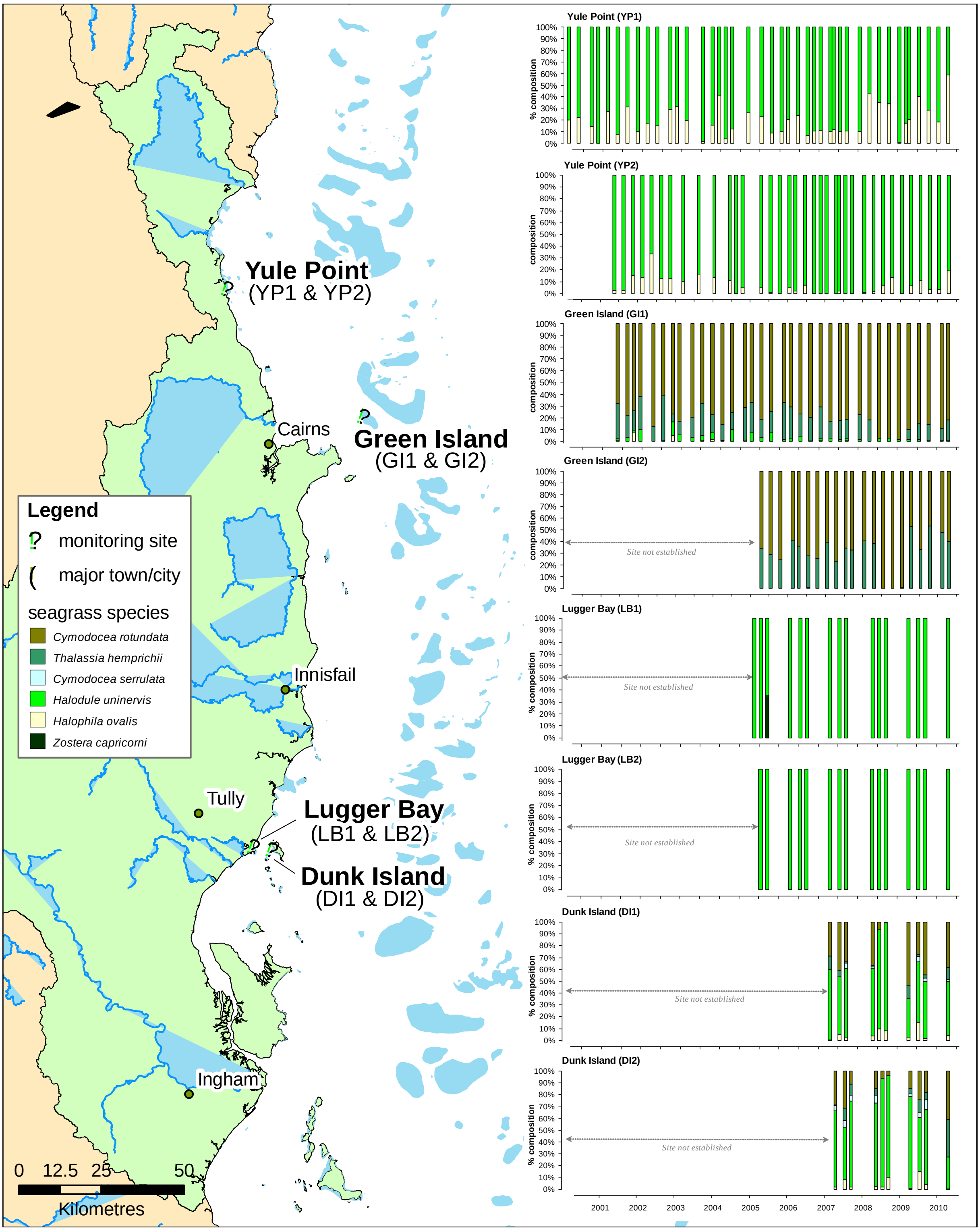


Figure 27. *Location of Wet Tropics region long-term monitoring sites and seagrass species composition at each site. Please note: replicate sites within 500m of each other.*

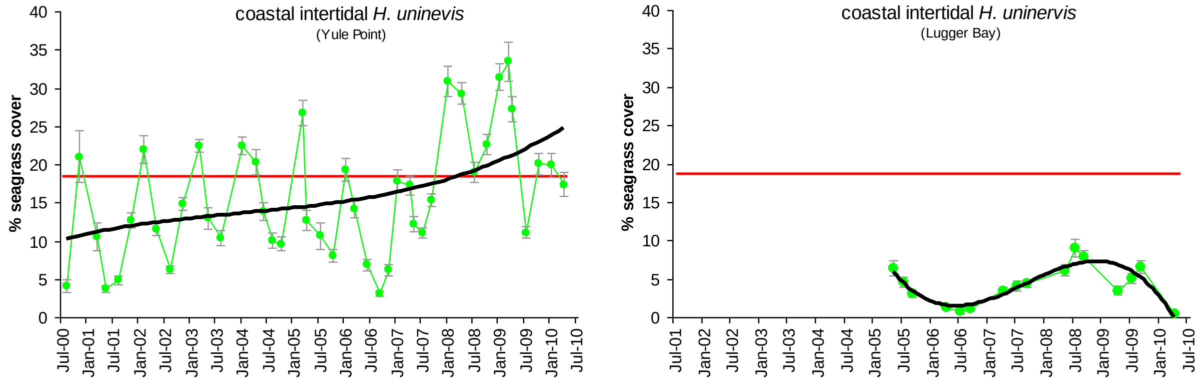
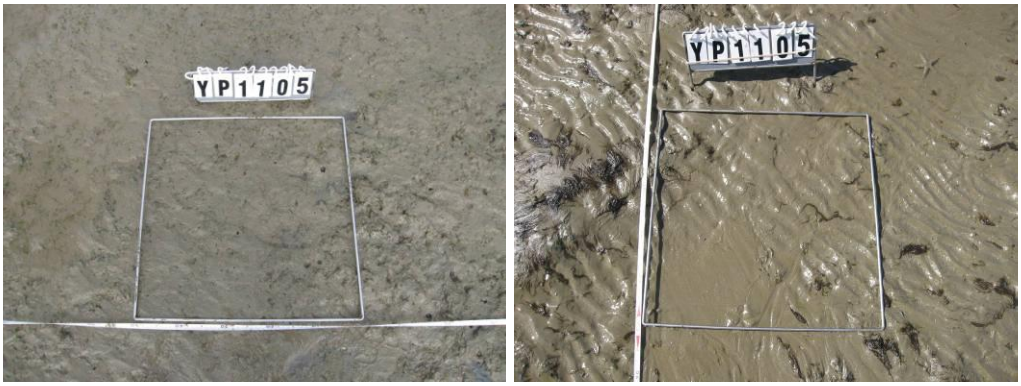


Figure 28. *Changes in seagrass abundance (% cover) of coastal intertidal Halodule uninervis meadows monitored in the Wet Tropics region from 2000 to 2010. Red line = GBR long-term average for coastal habitats.*



Quadrat at 5m on transect 1 at Yule Point site 1 (YP1), on 22 July 2009 (left) and 12 July 2010 (right)

Seagrass cover over the past 12 months at Yule Point continued to follow a seasonal trend with higher abundance over the period from late dry to late monsoon (Figure 29).

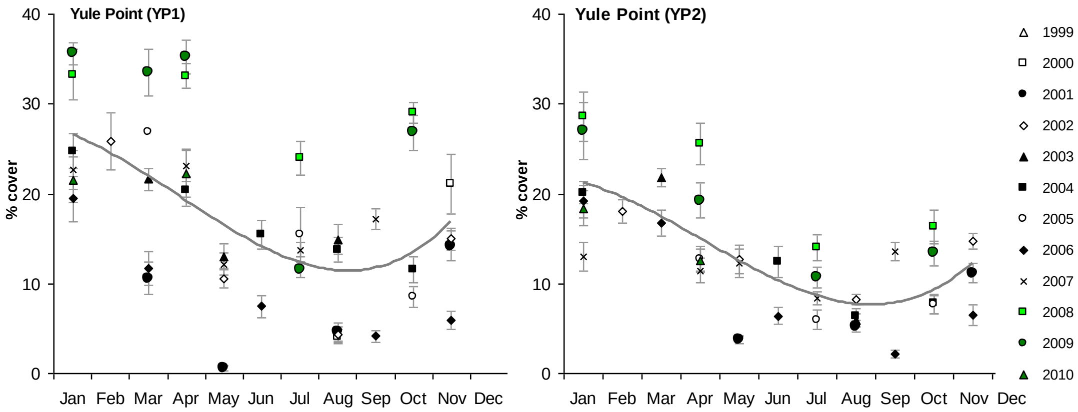


Figure 29. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Yule Point long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass and dugong grazing trails at Yule Point site 2 (YP2), 26 April 2009

Seagrass abundance at Lugger Bay was generally lower in the late monsoon and increased throughout the year until the monsoon (Figure 30).

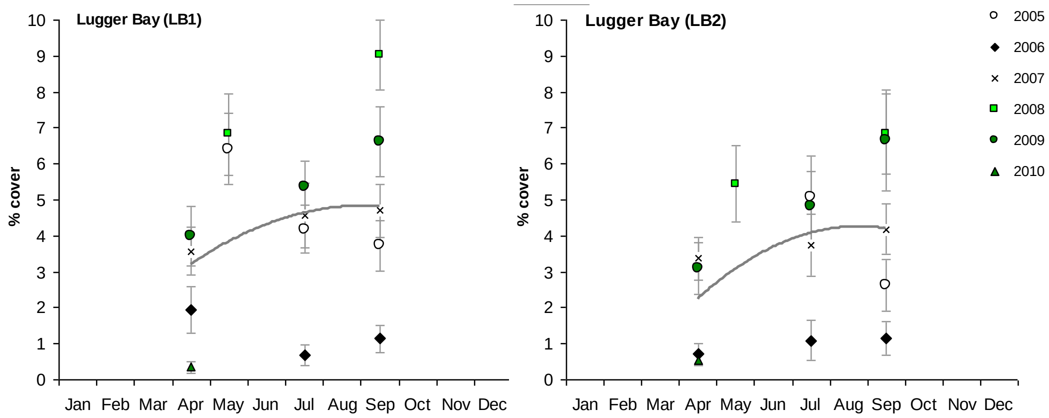


Figure 30. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Lugger Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Quadrat at 45m (left) and 5m (right) on transect 2 at Lugger Bay site 1 (LB1), on 21 July 2009 and 11 July 2010 respectively.

Green Island and Dunk Island sites were on offshore reef platforms. Dunk Island is a continental island offshore from Mission Beach. Seagrass species at Dunk Island sites included *H. uninervis* and *C. rotundata* with *T. hemprichii H. ovalis* and *C. serrulata* (Figure 27). Green Island is on a mid shelf reef, approximately 27 km north east of Cairns. The sites are located on the reef platform south west of the cay and dominated by *C. rotundata* and *T. hemprichii* with some *H. uninervis* and *H. ovalis*. The sites appeared to follow a seasonal pattern in abundance, with high cover in the monsoon and low cover in the dry, and no significant changes in species composition were observed (Figure 27, Figure 31 and Figure 32).

Seagrass meadows on the reef platform at Green Island.

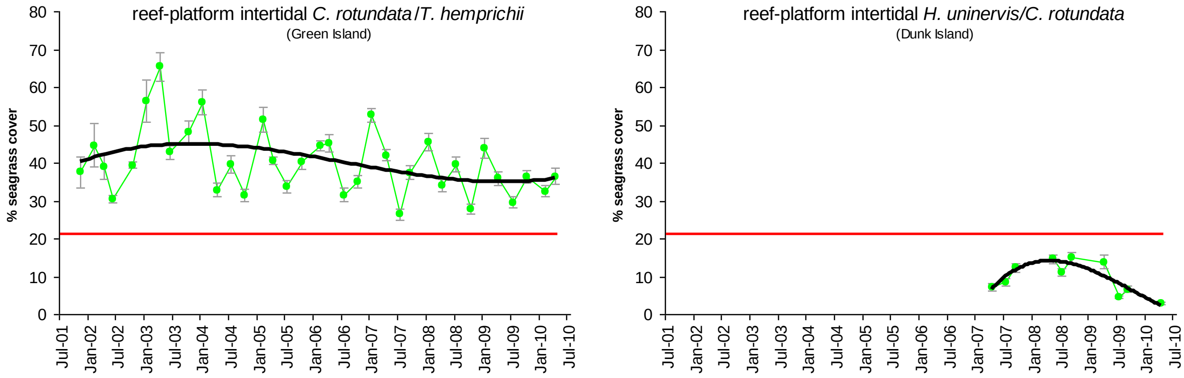


Figure 31. *Mean percentage seagrass cover (all sites pooled) at Green Island long-term monitoring sites (±Standard Error). Red line = GBR long-term average for reef habitats.*

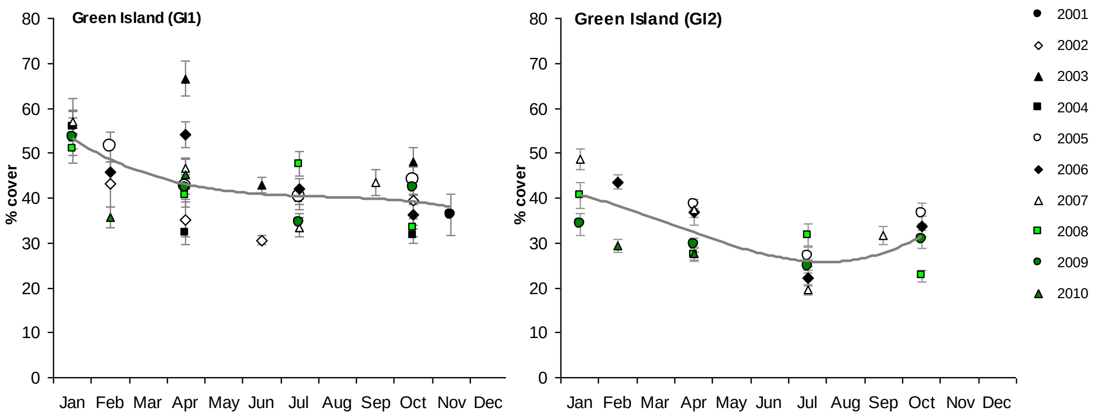


Figure 32. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Green Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Quadrat at 5m (left) and 25m (right) on transect 3 at Green Island site 1 (GI1), on 23 April 2009 and 9 July 2010 respectively.

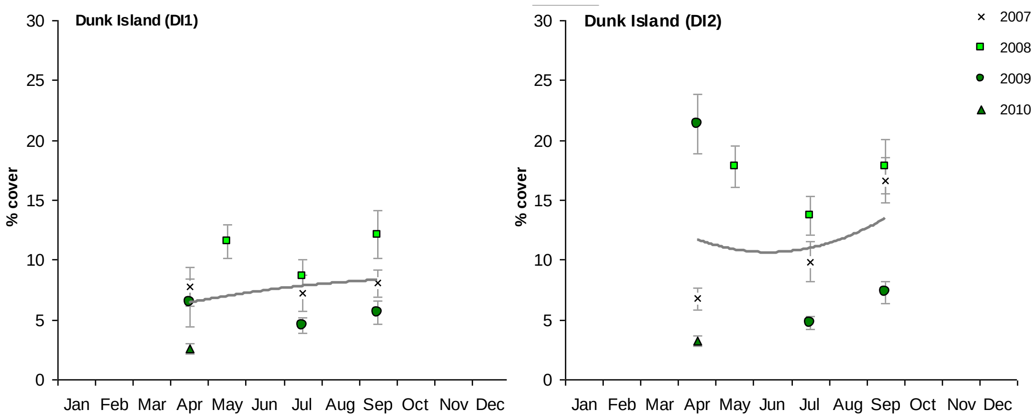


Figure 33. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Dunk Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass abundance relative to the seagrass guidelines indicates that the sites in the north of the region (Yule Point and Green Island) were in a fair to good state during the 2009/10 monitoring period, however the sites in the south of the region (Lugger Bay and Dunk Island) were in a poor state (Figure 34).

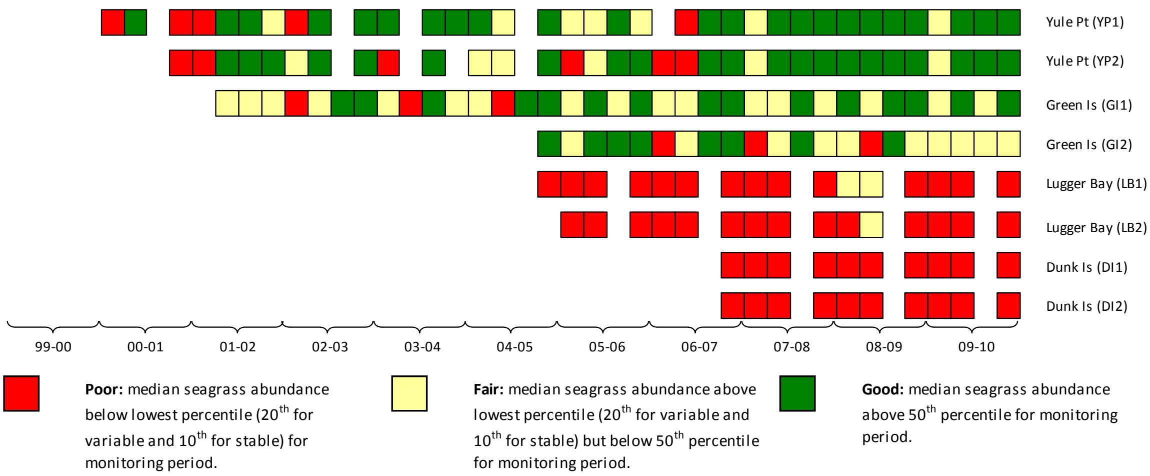


Figure 34**.** *Status of seagrass abundance in the Wet Tropics region relative to the seagrass guidelines in monitoring was established in 2000. Each block represents the seasonal monitoring event (dry, late dry, monsoon, late monsoon), with time along the x-axis from left to right.*

Seagrass meadow edge mapping was conducted within a 100m radius of all monitoring sites in October/November and March/April of each year to determine if changes in abundance were a consequence of the meadow edges changing (Table 17). Over the 2009/10 monitoring period, some erosion occurred on the seaward edges of the meadow at Yule Point site 1 (YP1) in mid 2009, decreasing the overall distribution. The drainage channels reported in the previous monitoring period still persisted through part of Yule Point site 2 (YP2), however the meadow has remained relatively stable (Figure 35).

There were no detectable differences in the edges of the seagrass meadows at Green Island over the 2009/10 monitoring period (Figure 35). At Lugger Bay, the distribution of the seagrass meadow changed little throughout 2009, however significantly declined during the late monsoon 2010 (Table 17) (Figure 36). The fringing reef meadow at Dunk Island has remained stable over the 2009/10 monitoring period (Table 17, Figure 36).

Table 17. *Area (ha) of seagrass meadow within 100m radius of each site. Value in parenthesis is % change from baseline (bold) and description of change from previous mapping. Shading indicates decrease in meadow area since baseline. NA=no data available as site not established.*

	Yule Pt		**Green Island**		**Lugger Bay**		**Dunk Island**	
	YP1	**YP2**	**GI1**	**GI2**	**LB1**	**LB2**	**DI1**	**DI2**
October 2005	**1.326**	**3.596**	**5.257**	**4.632**	**1.675**	**1.801**	*NA*	*NA*
April 2006	1.789 *(34.9% increase shoreward)*	4.120 *(14.6% increase shoreward)*	5.319 *(1.2%, increase shoreward)*	4.647 *(0.3%, negligible)*	1.085 *(-35.2%, decrease landward)*	1.448 *(-19.6%, decrease landward)*	*NA*	*NA*
October 2006	1.768 *(33.3% decrease overall)*	3.697 *(2.8% decrease seaward)*	5.266 *(0.2% decrease seaward)*	4.674 *(0.9%, negligible)*	0.453 *(-73%, decrease overall)*	0.561 *(-68.8%, decrease overall)*	*NA*	*NA*
April 2007	2.452 *(84.9% increase overall)*	3.735 *(3.9% increase shoreward)*	5.266 *(0.2%, no change)*	4.605 *(-0.6%, negligible)*	0.953 *(-43.1%, increase overall)*	1.167 *(-35.2%, increase overall)*	**3.278**	**3.972**
October 2007	3.08 *(132.3%, increase overall)*	4.422 *(23%, increase overall)*	5.266 *(0.2%, no change)*	4.674 *(0.9%, negligible)*	1.183 *(-29.4% increase overall)*	1.6 *(-11.2% increase shoreward)*	3.479 *(6.1% increase overall)*	4.19 *(5.5% increase overall)*
April 2008	2.861 *(115.8%, decrease overall)*	4.724 *(31.9%, increase overall)*	5.32 *(1.2% increase shoreward)*	4.66 *(0.6%, negligible)*	1.046 *(-37.6% decrease seaward)*	1.442 *(-19.9% decrease seaward)*	3.36 *(2.5% decrease shoreward)*	4.425 *11.4% increase overall)*
October 2008	2.910 *(119.4%, decrease shoreward)*	4.432 *(23.2%, decrease overall)*	5.298 *(0.8%, no change)*	4.682 *(1.1%, negligible)*	1.607 *(-4.1% increase overall)*	1.945 *(8.0% increase shoreward)*	3.393 *(3.5% increase overall)*	4.332 *(9.1% decrease overall)*
April 2009	2.463 *(85.7%, decrease overall)*	4.712 *(31.0%, increase overall)*	5.316 *(1.1% negligible)*	4.703 *(1.5%, negligible)*	1.218 *(-27.3% decrease seaward)*	1.655 *(-8.1% decrease seaward)*	3.34 *(1.9% decrease shoreward)*	4.420 *(11.3% increase overall)*
October 2009	2.249 *(-69.6%, decrease seaward)*	4.645 *(-29.2%, negligible)*	5.288 *(0.5%, no change)*	4.671 *(0.9%, no change)*	1.256 *(25% increase overall)*	1.567 *(-13% decrease shoreward)*	3.412 *(4.1% increase overall)*	4.371 *(-10% negligible)*
April 2010	1.634 *(23.2%, decrease overall)*	4.464 *(-24.1%, decrease overall)*	5.345 *(1.6% negligible)*	4.675 *(0.9%, no change)*	0.464 *(-72.3% decrease overall)*	0.464 *(-74.2% decrease overall)*	3.398 *(-3.6% no change)*	4.179 *(-5.2% decrease shoreward)*

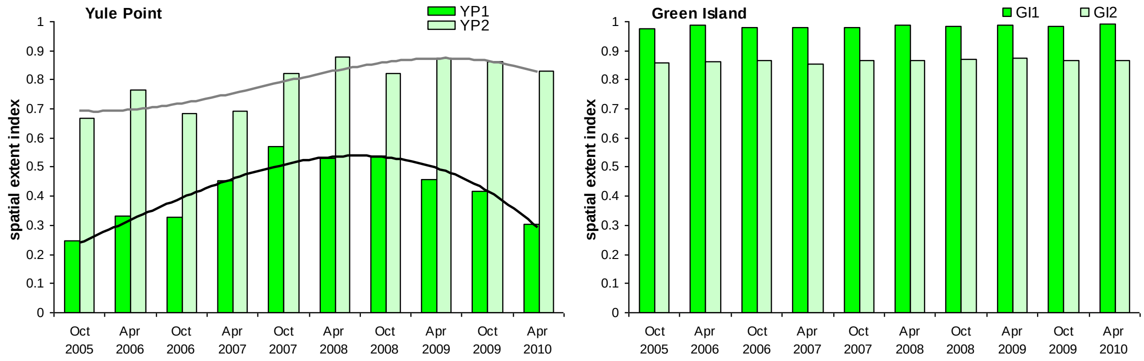


Figure 35. *Extent of area (100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Cairns locations (northern Wet Tropics region).*

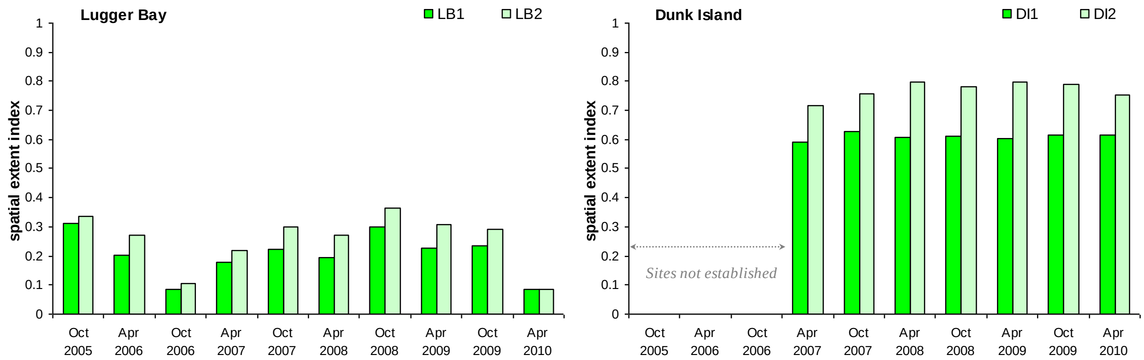


Figure 36. *Percentage of area (100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Mission Beach locations (southern Wet Tropics region).*

Seagrass reproductive status

Among the eight sites in the Wet Tropics region, the sites in the south of the region (Lugger Bay and Dunk Island) have consistently reported very low reproductive effort (*Figure 37*). Reef sites (Green Island and Dunk Island) also exhibit lower reproductive effort than coastal sites (Yule Point and Lugger Bay). Yule Point and Green Island showed higher than average reproductive effort compared to the GBR long-term average for coastal and reef habitats, respectively.

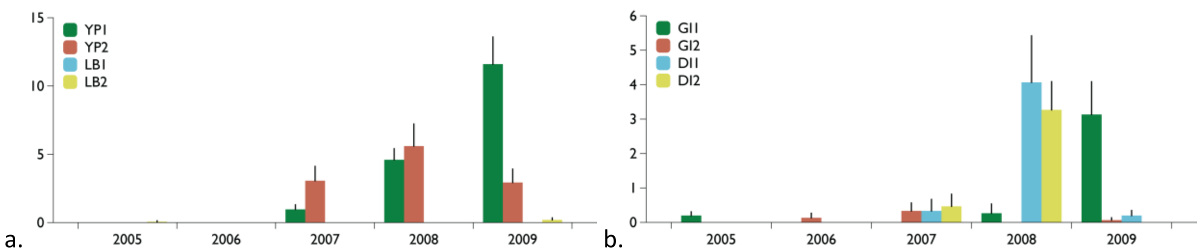


Figure 37. Mean reproductive effort (number of reproductive structures per core ± s.e.) during dry season sampling from 2005–2009 for Burdekin sites, a. coastal habitats, b. reef habitats.

Seed banks across the region declined over the monitoring periods and were below the GBR long-term average for both coastal and reef habitat (Figure 38, Figure 39).

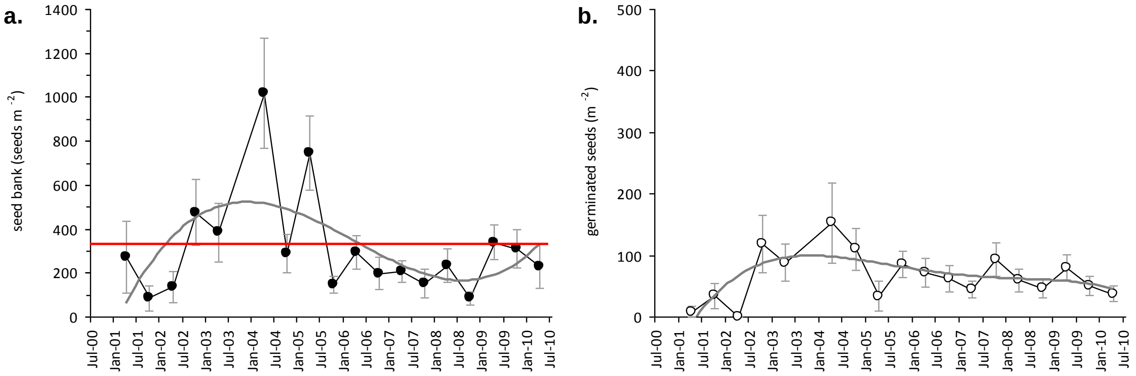


Figure 38. *Halodule uninervis seed bank (a) and germinated seed abundance (b) at coastal habitats in the Wet Tropics region (seed bank is represented as the total number of seeds per m2 sediment surface). Red line = GBR long-term average for coastal habitats.*

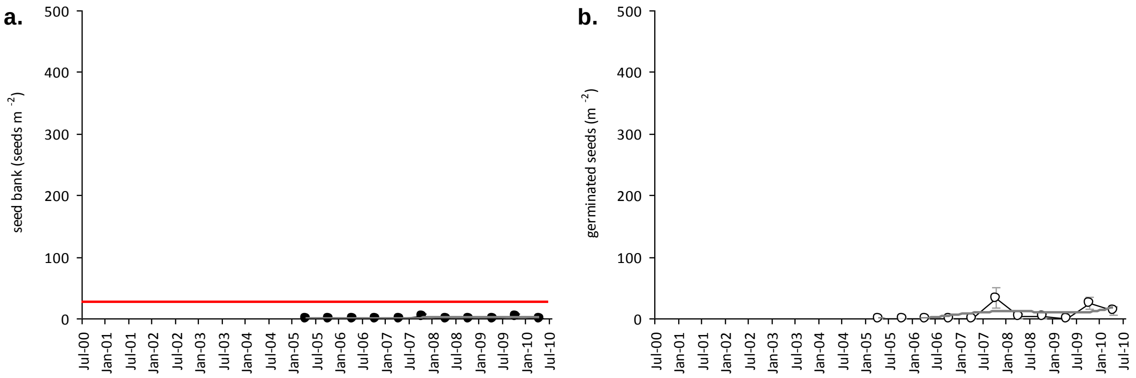


Figure 39. *Halodule uninervis seed bank (a) and germinated seed abundance (b) at reef habitats in the Wet Tropics region (seed bank is represented as the total number of seeds per m^2 sediment surface). Red line = GBR long-term average for reef habitats.*

Reproductive effort across the whole Wet Tropics region is classified as poor. This suggests that sites within the region will take longer to recover following disturbance and may be at risk from repeated impacts.

Status of the seagrass environment

Seagrass tissue nutrients

Within the Wet Tropics region, seagrasses in reef environments (Dunk Island and Green Island) had higher C:N ratios than those in coastal environments (Yule Point and Lugger Bay) (Figure 41). This indicates a potentially higher light environment in reef habitats. Levels of the C:N ratio below 20 may be considered as indicative of environments where light may be limiting to growth.

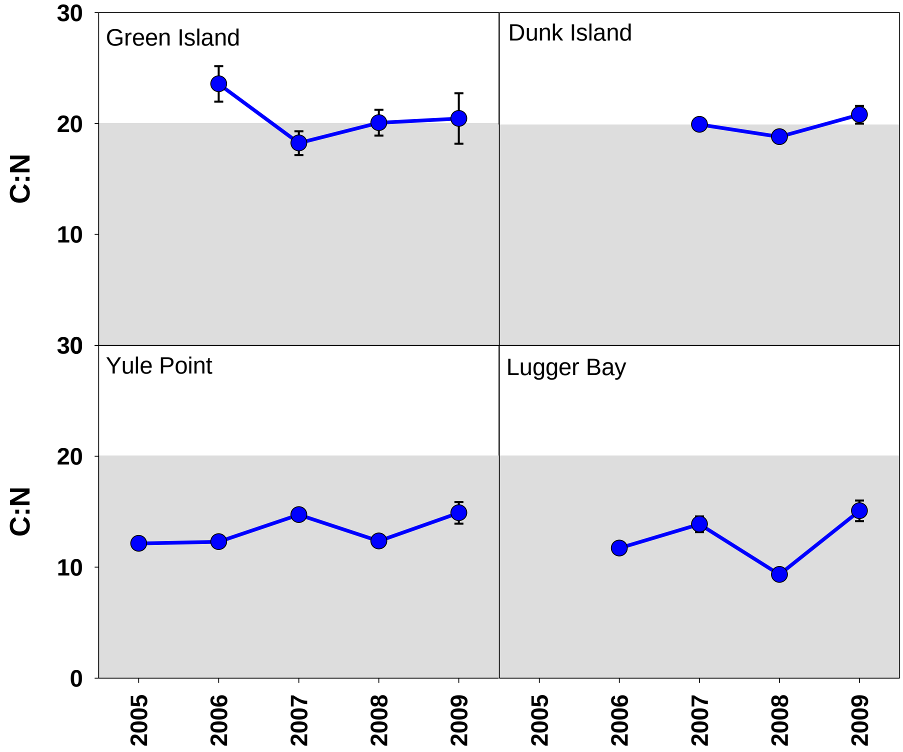


Figure 40. *Elemental ratios (atomic) of seagrass leaf tissue C:N for the foundation seagrass species examined at each location in the Wet Tropics region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the C:N ratio panel represents the accepted guideline seagrass "Redfield" ratio of 20:1 (Abal et al. 1994; Grice et al. 1996). C:N ratios below this line indicate reduced light availability.*

The late dry 2009, C:P ratios of the foundation seagrass species at Dunk Island, Green Island, and Yule Pt were all above 500; indicating these sites were nutrient poor or reduced P pool (Figure 41). Values below 500 were consistently recorded at Lugger Bay since monitoring was established in 2008, indicating a nutrient rich environment. The N:P ratios of the foundation seagrass species at both coastal and reef habitats in 2009 indicated environments were either replete or in the case of Yule Point, P limited (Figure 41). Overall results suggest poor water quality at Yule Point with low light availability and nutrient enrichment (elevated N).

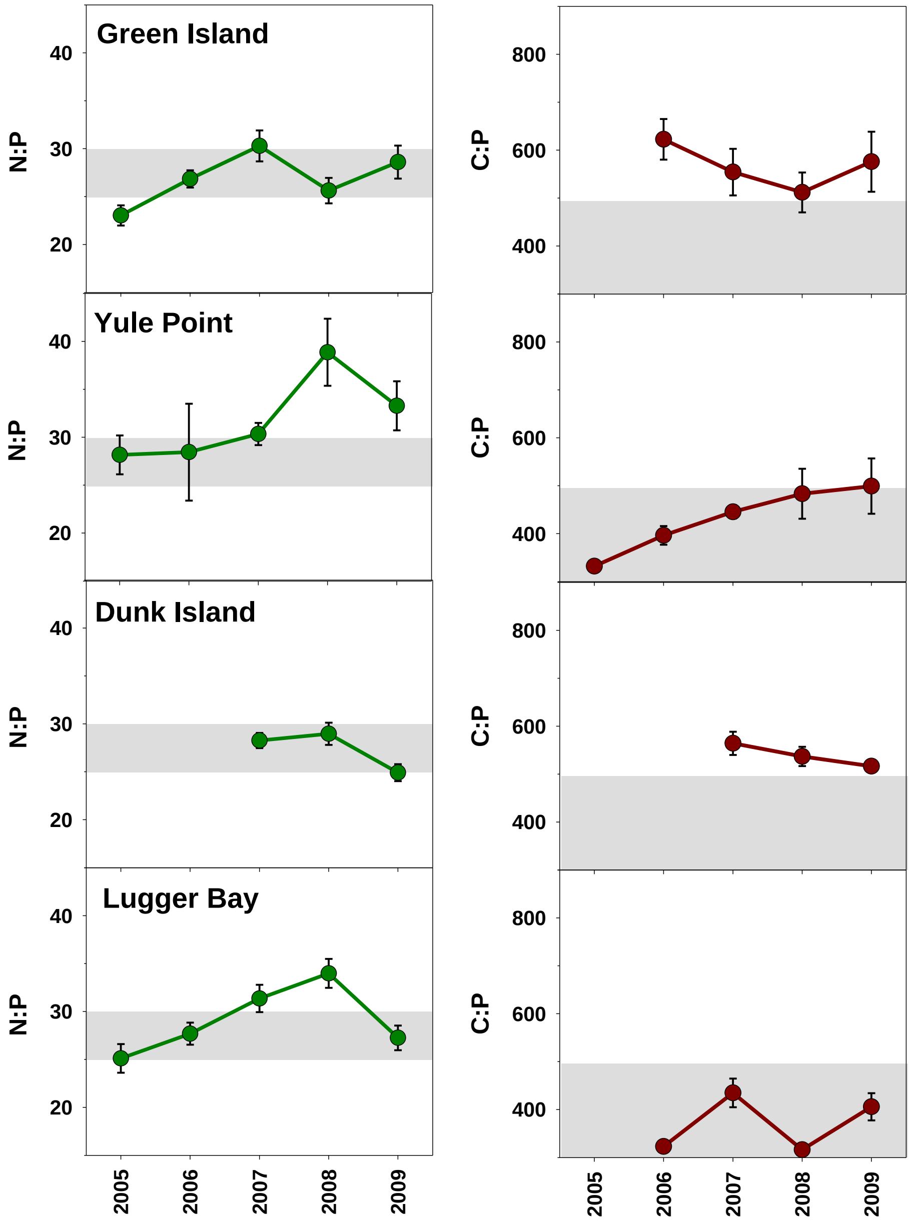


Figure 41. *Elemental ratios (atomic) of seagrass leaf tissue N:P and C:P for the foundation seagrass species examined at each location in the Wet Tropics region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation, below indicates N limitation and within indicates replete. Shaded portion on the C:P panel ≤500 represents the value associated with C:P balance ratio in the plant tissues, C:P values <500 may indicate nutrient rich habitats (large P pool).*

Epiphytes and macro-algae

Epiphyte cover on seagrass leaf blades at coastal sites was variable (Figure 42) and appears correlated with seagrass abundance. Epiphyte cover has continued to remain high and above the GBR long-term average at Yule Point over the past 12 months (Figure 42). At Lugger Bay however, the highly variable epiphyte cover has remained below the GBR long-term average (Figure 42).

Percentage cover of macro-algae at coastal sites was consistently lower than the GBR long-term average and at Yule Point abundance has declined over the last four to five years (Figure 42).

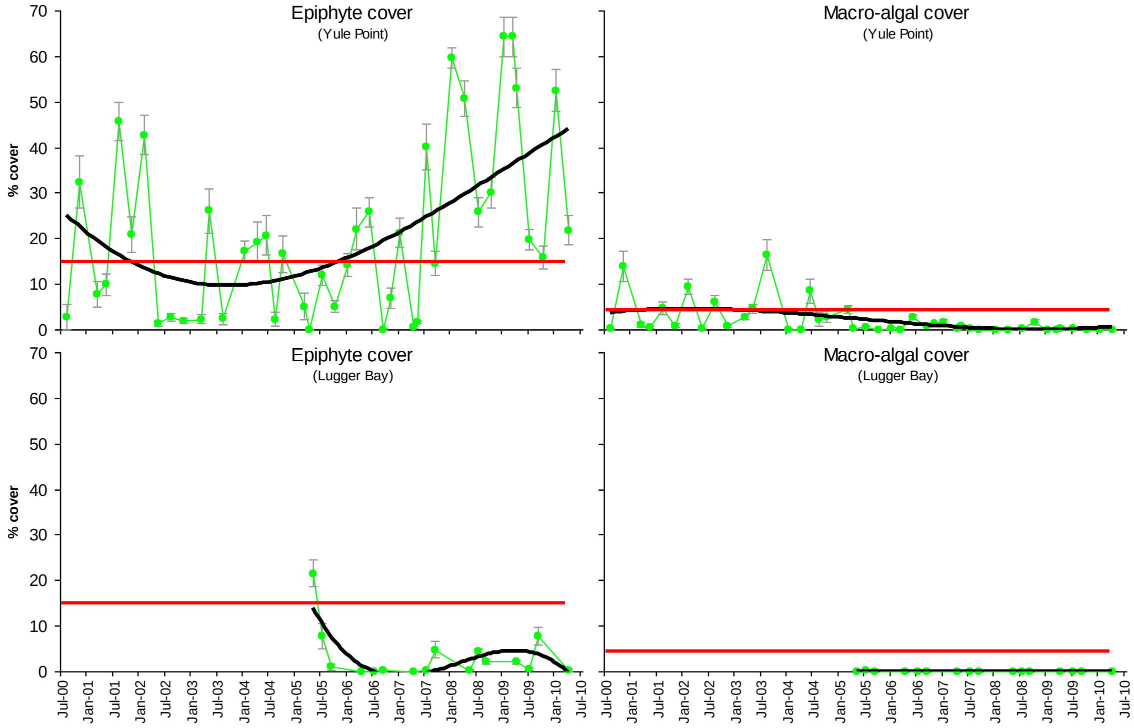
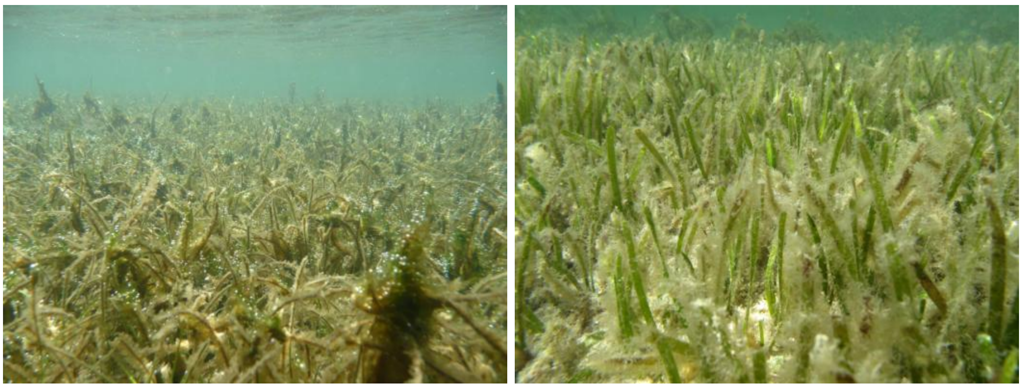


Figure 42. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at coastal intertidal seagrass monitoring locations (sites pooled) in the Wet Tropics region. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*



Epiphytes covering Halodule uninervis at Yule Point and Cymodocea rotundata at Green Island.

Epiphyte cover at reef sites was variable and although not significant, it appears to be increasing (Figure 43). Abundances at both Green Island and Dunk Island were above the GBR long-term average for reef habitats. Macro-algae at both reef locations were predominately composed of *Halimeda* spp. and abundance was relatively stable, with mean covers less than 10% (Figure 43).

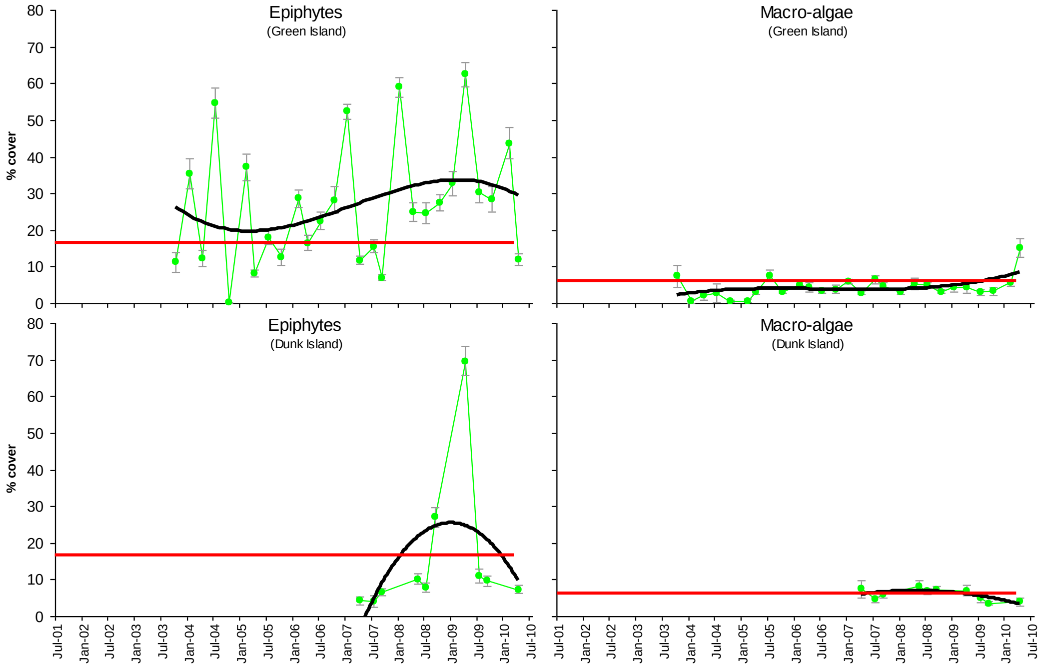


Figure 43. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at reef intertidal seagrass monitoring locations (sites pooled) in the Wet Tropics region. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

Within meadow canopy temperature

Temperature loggers were deployed within the seagrass canopy throughout the monitoring period at all locations monitored in the region (Figure 44). Logger failure was experienced at Lugger Bay after the late monsoon sampling. Extreme temperatures (>39°C) were recorded at Yule Point in both late October and late November 2009 (Figure 44). Over the last 12 months maximum mean temperatures were recorded in November 2009 and April 2010 during the low spring tides. Temperatures in 2009/10 at all sites in the Wet Tropics region were 0.1 – 0.5°C higher than the previous year.

Mean within canopy water temperatures were generally within the 23 – 31°C range. Temperatures at coastal and reef-platform habitats generally followed a similar pattern with lowest temperatures in July 2009 and highest in February 2010 (Figure 45). Within canopy temperatures at Lugger Bay varied the greatest across the region.

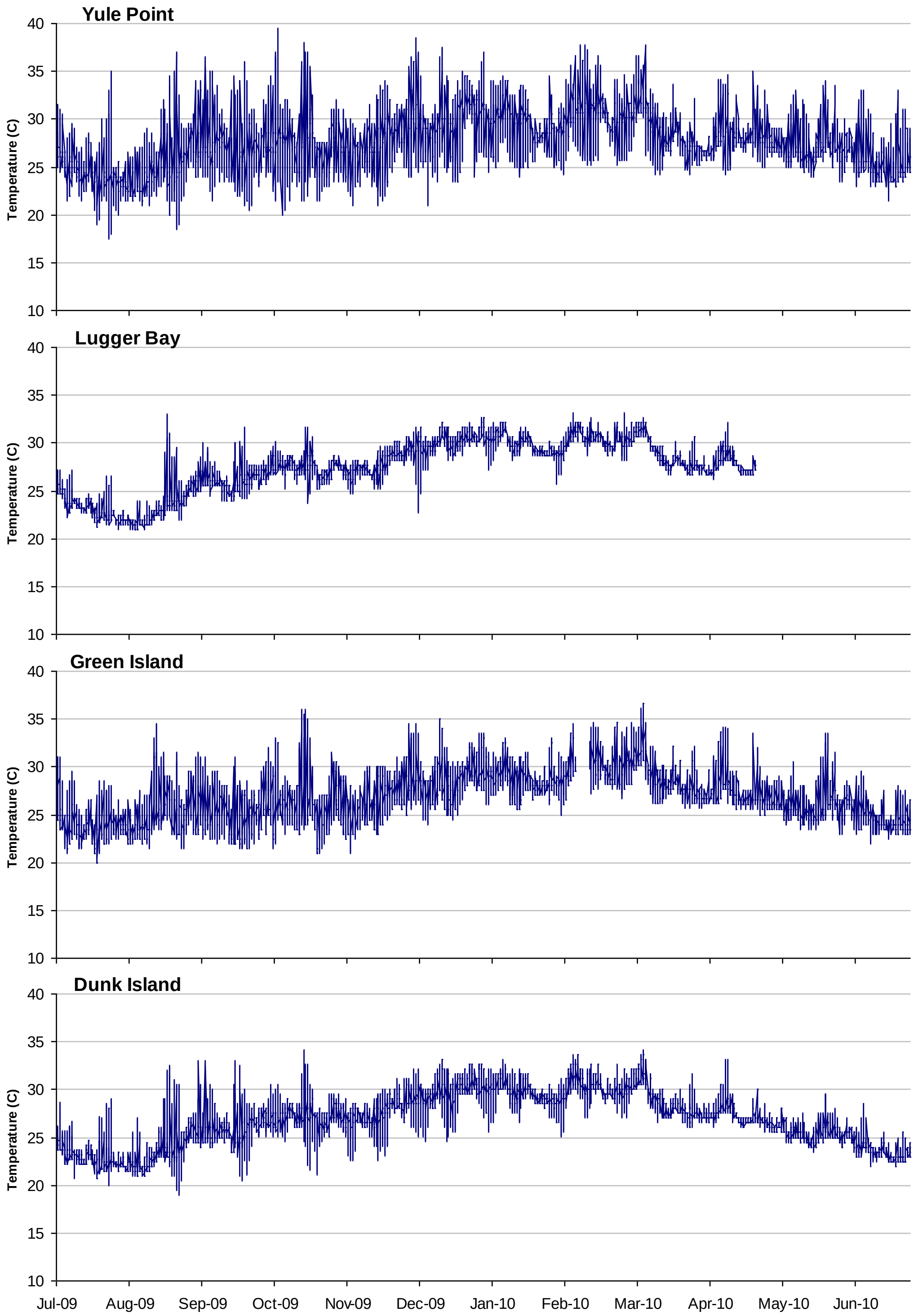


Figure 44. *Within seagrass canopy temperature (°C) at coastal (Yule Point and Lugger Bay) and offshore reef (Green Island and Dunk Island) intertidal meadows within the Wet Tropics region over the 2009/10 monitoring period.*

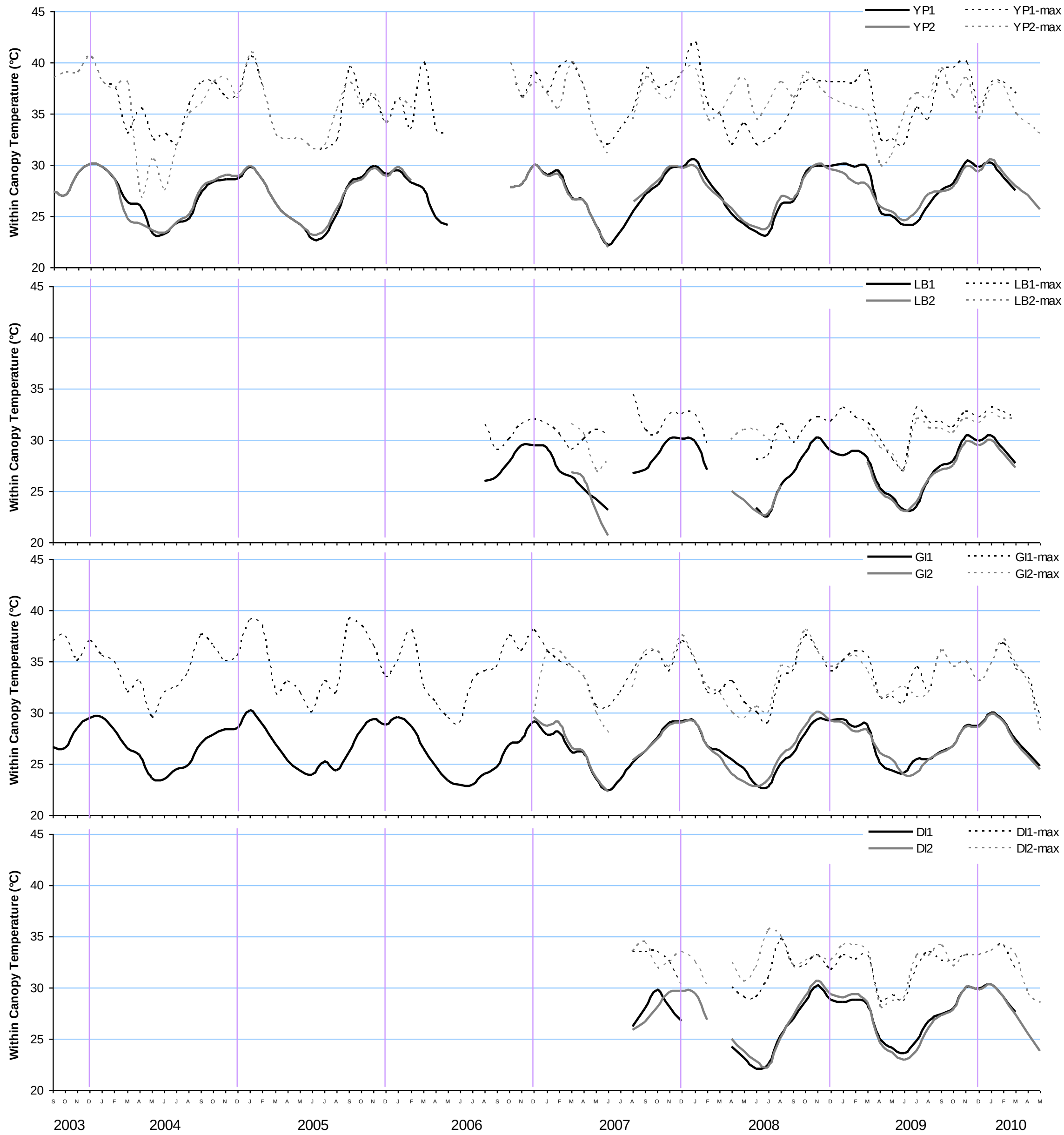


Figure 45. *Monthly mean and maximum within seagrass canopy temperatures (°C) at coastal (Yule Point and Lugger Bay) and fringing-reef (Green Island and Dunk Island) intertidal meadows within the Wet Tropics region.*

Canopy incident light

Deployment of light loggers in the Wet Tropics region expanded in 2009 to include four sites: Low Isles (reef), Yule Point (coastal), Green Island (reef) and Dunk Island (reef) (Figure 46). Variance in light availability firstly followed the tidal cycle, then followed the general pattern of winds where increased wind resulted in lower incident light levels. As data was only available for recent sampling periods, correlations with seagrass responses will be analysed at a later date.

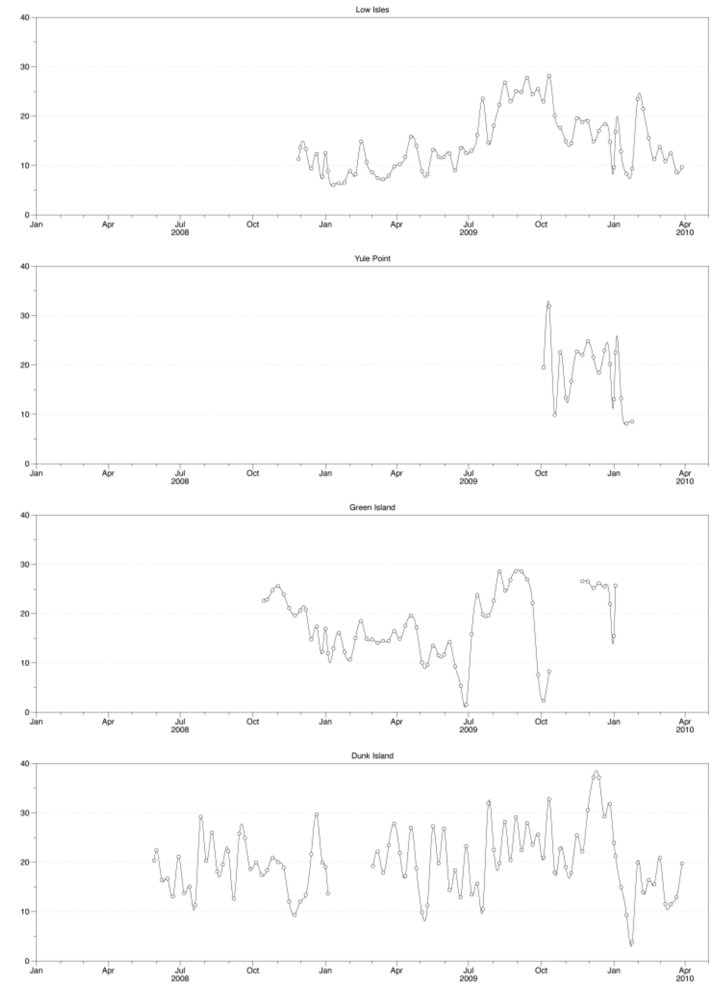


Figure 46. *Fortnightly averages of daily incident light (mmol photons per m^2 per day), at canopy height (2π light loggers; Submersible Odyssey Photosynthetic Irradiance Recording System, Dataflow Systems Pty Ltd, New Zealand placed in a wiper unit to keep the sensor clean) at four sites installed at seagrass canopy height.*

Regional Climate

Climate across the region was hotter, windier and wetter in 2009/10 than the long-term average.

Cairns – Yule Point and Green Island

The mean maximum daily air temperature recorded in Cairns during 2009 was 29.7°C; this was 0.7°C higher than the long-term year average and 0.4°C higher than the decade average. The highest recorded daily maximum air temperature in 2009 was 33.9°C.

2009 was a wet year relative to both the last decade and the long-term average with approximately 10% more rain (Figure 47). Mean wind speed in 2009 was high relative to the long-term average but approximately the same as the decade average at 21.3 km.hr^{-1}.

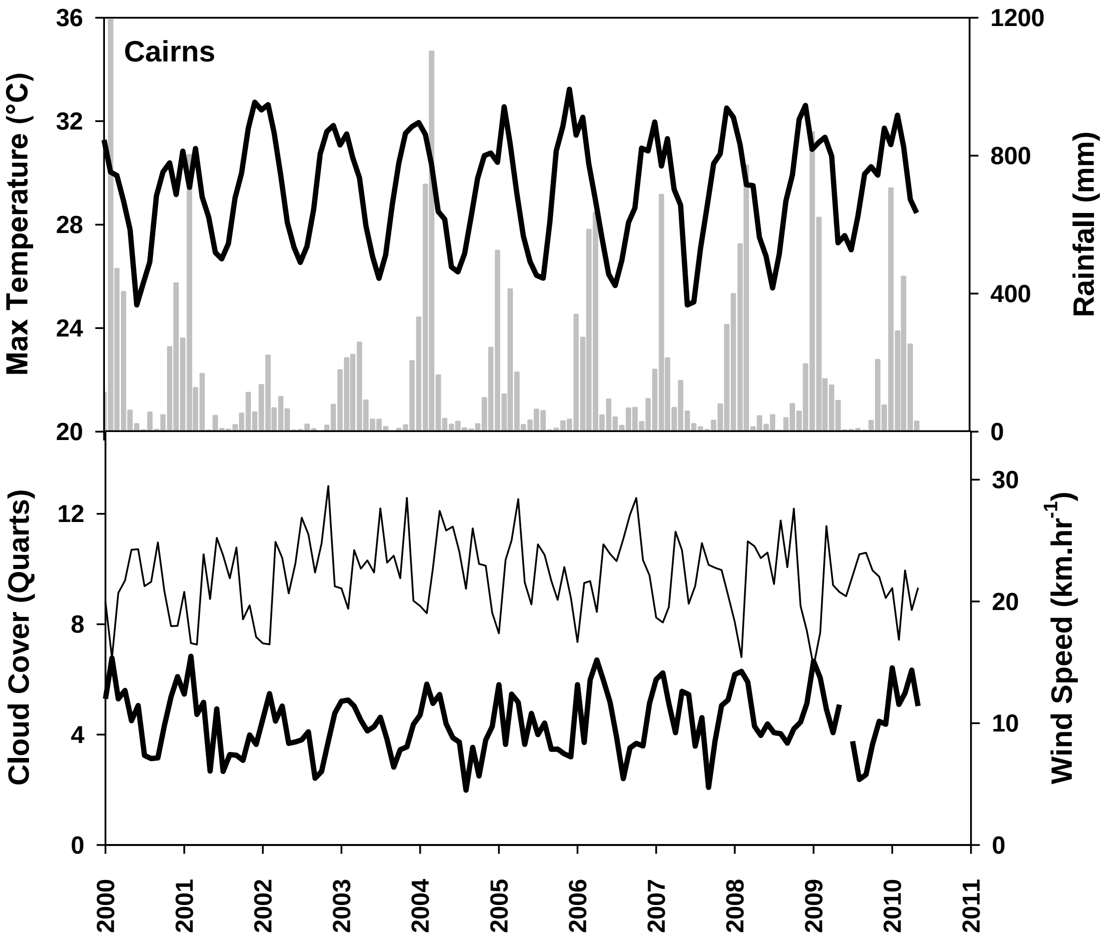


Figure 47. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr^{-1}) recorded at Cairns airport (BOM station 031011) (Source www.bom.gov.au). Cairns Airport used as a surrogate for the climate at Yule Point and Green Island.*

Innisfail – Lugger Bay and Dunk Island

The mean maximum daily air temperature recorded in Innisfail during 2009 was 28.5°C; this was 0.6°C higher than the long-term year average but the same as the decade average. The highest recorded daily maximum air temperature in 2009 was 33.5°C.

2009 was a wet year relative to both the last decade and the long-term average with approximately 10% more rain (Figure 48). Mean wind speed in 2009 was very low relative to the long-term and decade averages at 9.8 km.hr^{-1}.

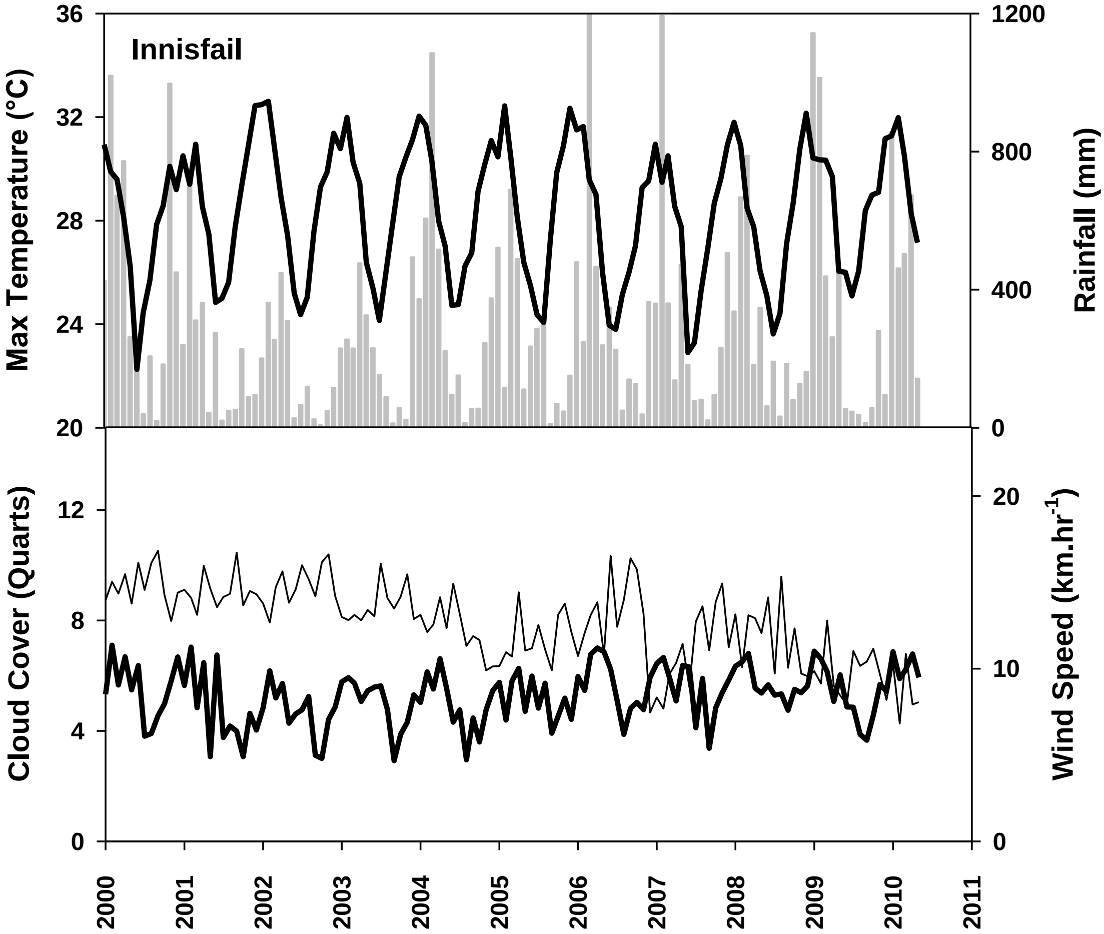
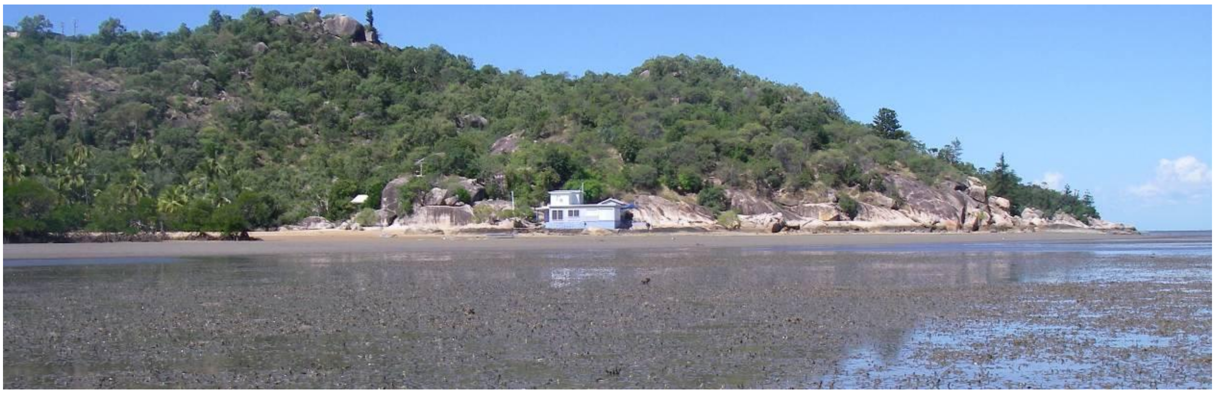


Figure 48. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr^{-1}) recorded at Innisfail (BOM station 032025) (Source www.bom.gov.au). Innisfail used as a surrogate for the climate at Lugger Bay and Dunk Island.*



Burdekin

2009/10 Summary

Seagrass meadows in the Burdekin region are primarily structured by wind induced turbidity in the short term and by episodic riverine delivery of nutrients and sediment in the medium time scale. Disturbance from wave action, sediment movement and elevated temperatures are also dominant influences. Nutrient concentrations in reef habitats are generally low: primarily nitrogen limited with secondary phosphate limitation. Rainfall in the region is lower than other regions within tropical Queensland.

Seagrass abundance and meadow extent declined at both coastal and reef habitats and was in a poor state throughout the 2009/10 monitoring period. Seed banks declined across the region and reproductive effort at reef habitats were in poor state, raising concerns about the ability of reef seagrass meadows to recover from environmental disturbances. Seagrass tissue nutrient concentrations indicate potential light limitation in coastal habitats with some nutrient enrichment from an increasing P pool. In reef habitats, tissue nutrient concentrations indicate more available light and although N pool is high, the plants are limited by a smaller P pool. Low epiphyte abundance appears a consequence of the seagrass loss experienced across the region. Climate across the region in 2009 was hotter, windier and wetter than previous years, and the extreme canopy water temperatures experienced were the hottest measured across the entire GBR in 2009/10. Overall the status of seagrass condition in the region was rated as moderate.

Table 18. *Report card for seagrass status (community & environment) for the Burdekin region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100. Green = good, yellow = moderate, gold = fair, red = poor.*

Habitat	Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio	**Seagrass Index^**
reef intertidal	8	33	33	67	**35**
coastal intertidal	17	67	33	0	**29**
estuarine intertidal			*not monitored*		
Burdekin	12	33	67	33	**36**

Background

The Burdekin region, includes an aggregation of the Black, Burdekin, Don, Haughton and Ross River catchments and includes several smaller coastal catchments, all of which empty into the Great Barrier Reef lagoon (Australian Government Land and Coasts 2010b). Because of its geographical location, rainfall in the region is lower than other regions within tropical Queensland. Annual rainfall averages approximately 1,150 mm from on average 91 rain days. However, there is considerable variation from year-to-year due to the sporadic nature of tropical lows and storms. Approximately 75% of the average annual rainfall is received during December to March (Schletinga and Heydon 2005).

Major threats to seagrass meadows in the region include: coastal development (reclamation); changes to hydrology; water quality declines (particularly nutrient enrichment or increased turbidity); downstream effects from agricultural (including sugarcane, horticultural, beef), industrial (including refineries) and urban centres (Scheltinger and Heydon 2005; Haynes *et al.,* 2001). All four generalised seagrass habitats are present within the Burdekin region, and Reef Rescue MMP monitoring occurs at both coastal and reef seagrass habitat locations.

The coastal sites are located on naturally dynamic intertidal sand flats and are subject to sand waves and erosion blowouts moving through the meadows. The Bushland Beach and Shelley Beach area is a sediment deposition zone, so the meadow must also cope with incursions of sediment carried by long shore drift. Sediments within this habitat are mud and sand that have been delivered to the coast during the episodic peak flows of the creeks and rivers (notably the Burdekin) in this area. While episodic riverine delivery of freshwater nutrients and sediment is a medium time scale factor in structuring these coastal seagrass meadows, it is the wind induced turbidity of the costal zone that is likely to be a major short term driver (Figure 49). In these shallow coastal areas waves generated by the prevailing SE trade winds are greater than the depth of water, maintaining elevated levels of suspended sediments, limiting the amount of light availability for photosynthesis during the trade season. Intertidal seagrasses can survive this by photosynthesizing during periods of exposure, but must also be able to cope with desiccation. Another significant feature in this region is the influence of ground water. The meadows are frequented by dugongs and turtles as witnessed by feeding trails and scars.

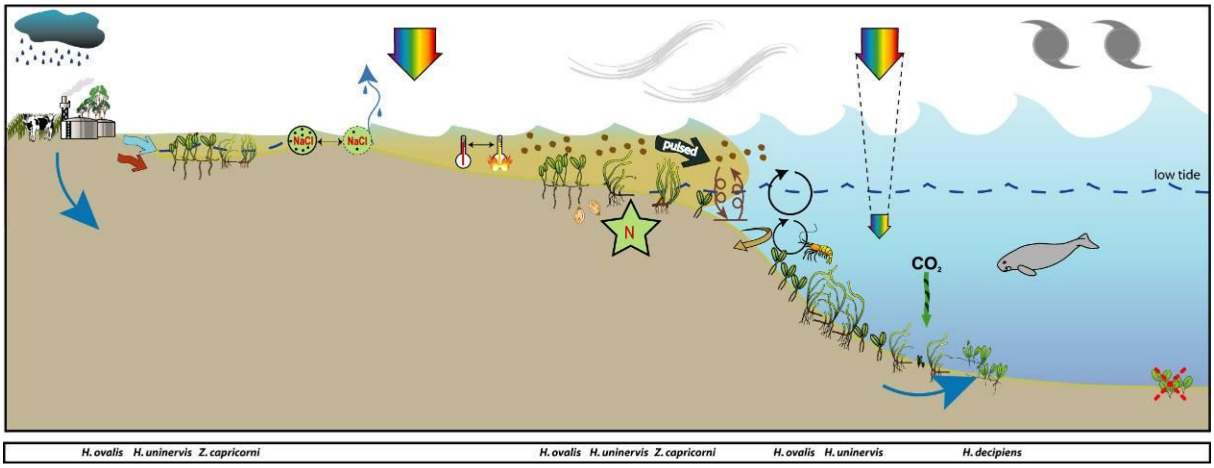


Figure 49. *Conceptual diagram of coastal habitat in the Burdekin region - major control is wind and temperature extremes, general habitat, seagrass meadow processes and threats/impacts (see Figure 2 for icon explanation).*

The reef habitats are mainly represented by fringing reefs on the many continental islands within this area. Most fringing reefs have seagrass meadows growing on their intertidal flats. Nutrient supply to these meadows is by terrestrial inputs via riverine discharge, re-suspension of sediments and groundwater supply (Figure 50). The meadows are typically composed of zones of seagrasses: *Cymodocea serrulata and Thalassia hemprichii* often occupy the lower intertidal/subtidal area, blending with *Halodule uninervis* (wide leaved) in the middle intertidal region. *Halophila ovalis* and *Halodule uninervis* (narrow leaved) inhabit the upper intertidal zone. Phosphate is often the nutrient most limiting to reefal seagrasses (Short e*t al.,* 1990; Fourqurean *et al.,* 1992). Experimental studies on reef top seagrasses in this region however, have shown seagrasses to be nitrogen limited primarily with secondary phosphate limitation, once the plants have started to increase in biomass (Mellors 2003). In these fringing reef top environments fine sediments are easily resuspended by tidal and wind generated currents making light availability a driver of meadow structure.

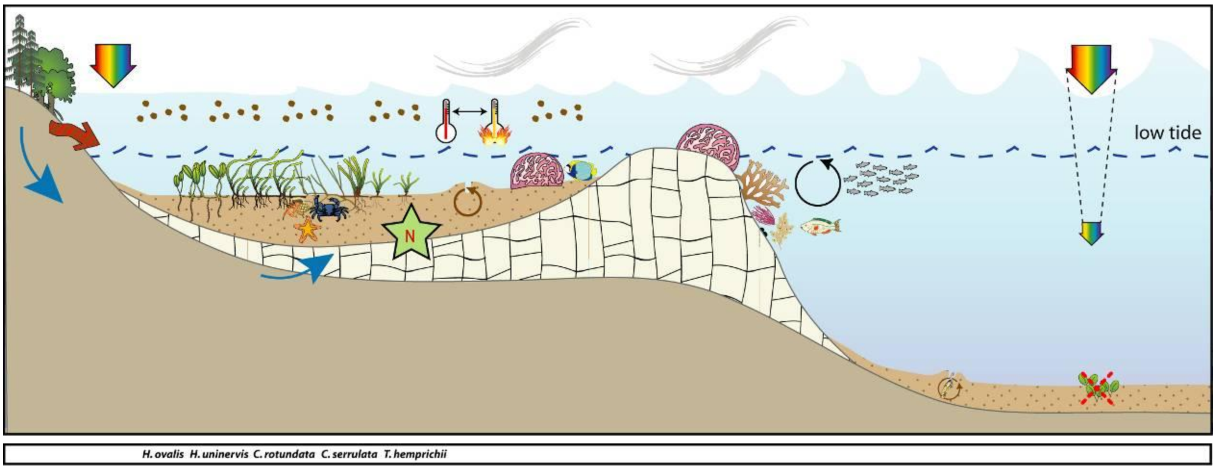


Figure 50. *Conceptual diagram of fringing reef habitat in the Burdekin region - major control is nutrient supply (groundwater), light and shelter: general habitat and seagrass meadow processes (see Figure 2 for icon explanation)*

Status of the seagrass community

Seagrass abundance and composition

Both meadows at coastal sites (Bushland Beach and Shelley Beach) were dominated by *Halodule uninervis* with small amounts of *Halophila ovalis* (Figure 52). Seagrass cover significantly decreased at the coastal sites during the late monsoon 2009 and declined even further following the monsoon in 2010 (Figure 51). Although variable, coastal seagrass meadows in Townsville have continued to decline in abundance since late 2006 (Figure 51).

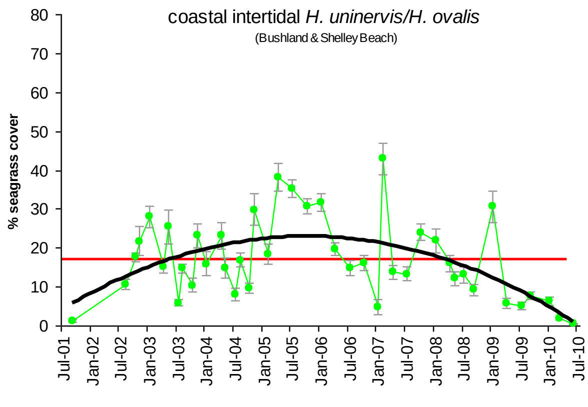


Figure 51. *Change in seagrass abundance (percentage cover) at coastal intertidal meadows in the Burdekin region. Red line = GBR long-term average for coastal habitats.*

Since monitoring was established, both Bushland Beach and Shelley Beach have shown a seasonal pattern in seagrass cover; high in monsoon and low in the dry season (Figure 53).

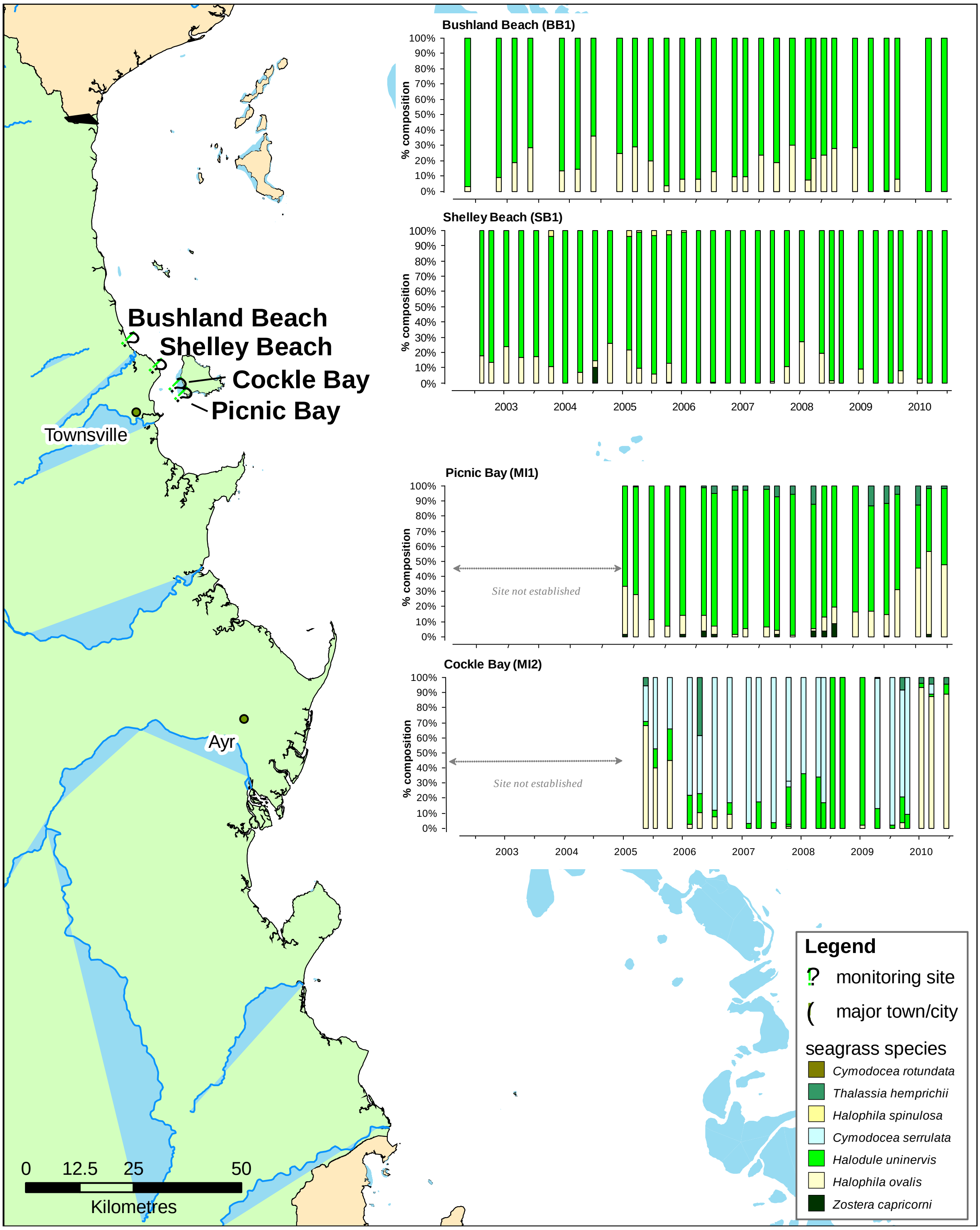


Figure 52. *Location of Burdekin region long-term monitoring sites in coastal (Bushland Beach and Shelley Beach) and reef (Picnic Bay and Cockle Bay, Magnetic Island) habitats, and the seagrass species composition at each site.*

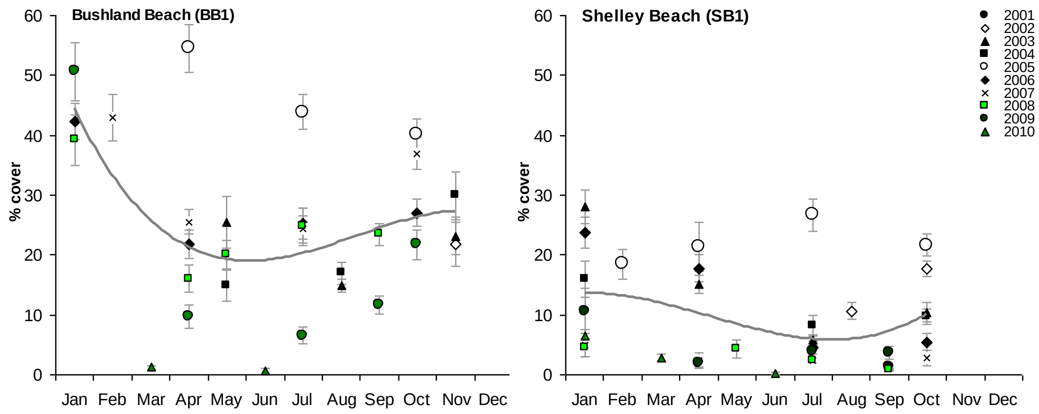


Figure 53. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Townsville coastal long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Offshore reef habitats are monitored on the fringing reef platforms of Magnetic Island. During the 2009/10 monitoring period, Picnic Bay was dominated by *Halodule uninervis* with *Halophila ovalis* and the adjacent Cockle Bay was dominated by *Halophila ovalis* with *Halodule uninervis* (Figure 52). Significant changes in the species present at Cockle Bay (MI2) also occurred in 2009 with the once dominant *Cymodocea serrulata* and *Thalassia hemprichii* becoming absent. Over the last monitoring period, seagrass cover at both sites significantly declined and were lower than the previous monitoring period (Figure 54). Seagrass abundance at Cockle Bay (MI2) appears to follow a seasonal pattern, which is clearer at Picnic Bay (MI1) (Figure 55).

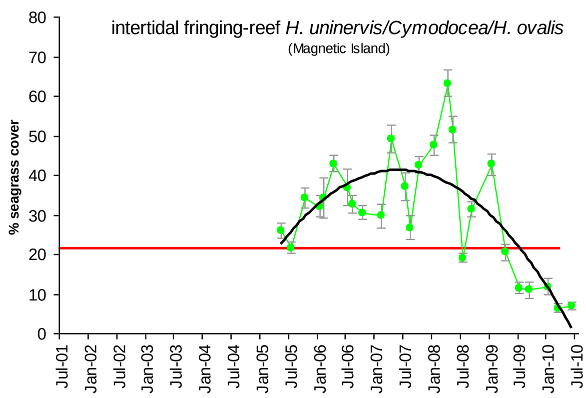
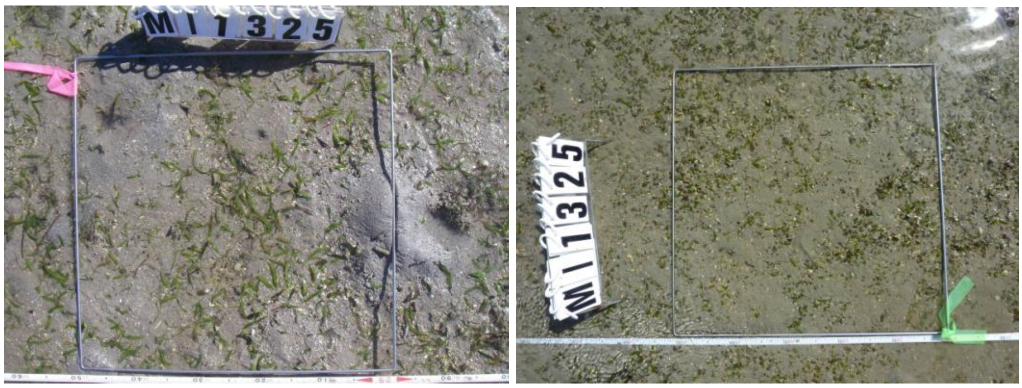


Figure 54. *Change in seagrass abundance (percentage cover) at intertidal meadows on fringing reef platforms in the Burdekin region. Red line = GBR long-term average for reef habitats.*



Quadrat at 25m on transect 3 at Picnic Bay (MI1), on 26 April 2009 (left) and 30 March 2010 (right)

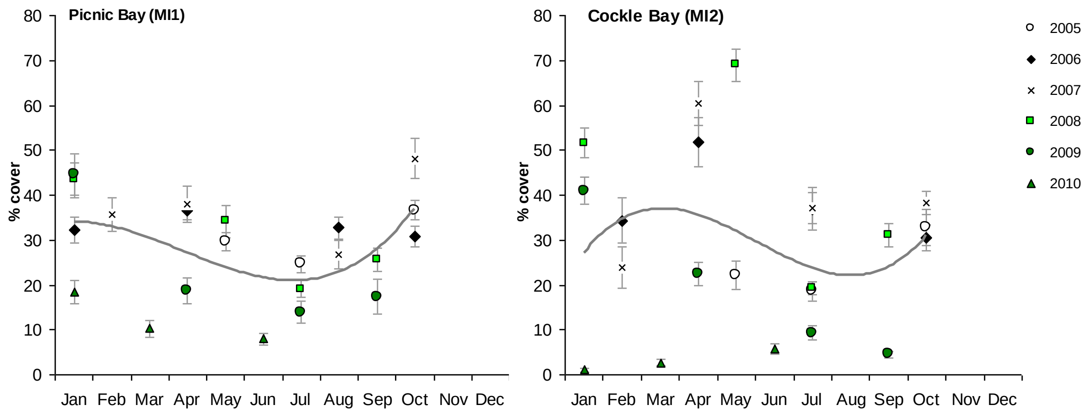


Figure 55. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Magnetic Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass abundance relative to the seagrass guidelines indicate that all sites in the region were in a poor state throughout the 2009/10 monitoring period (Figure 56).

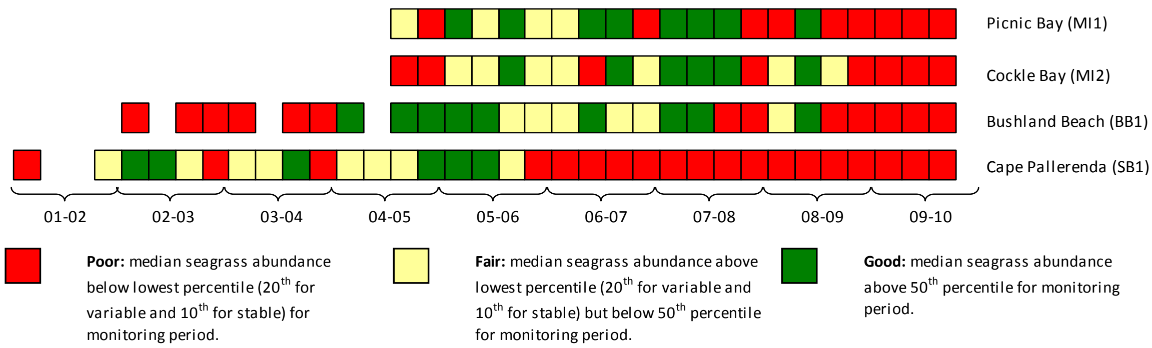


Figure 56**.** *Status of seagrass abundance in the Burdekin region relative to the seagrass guidelines since monitoring was established in 2001. Each block represents the seasonal monitoring event (dry, late dry, monsoon, late monsoon), with time along the x-axis from left to right.*

Seagrass meadows edge mapping was conducted within a 100m radius of all monitoring sites in October/November and March/April of each year to determine if changes in abundance were a consequence of the meadow edges changing (Table 19). The most striking changes over the past two to three years has occurred in the meadow at Shelley Beach (SB1) (Figure 57). From the monsoon 2008, the Shelley Beach meadow was significantly fragmented due to “blowouts” (erosion gaps in the meadow). This resulted in relatively few of the sampling quadrats falling with the meadow. In late monsoon 2010, the Cockle Bay meadow was less than 51% of its baseline extent (Table 19).

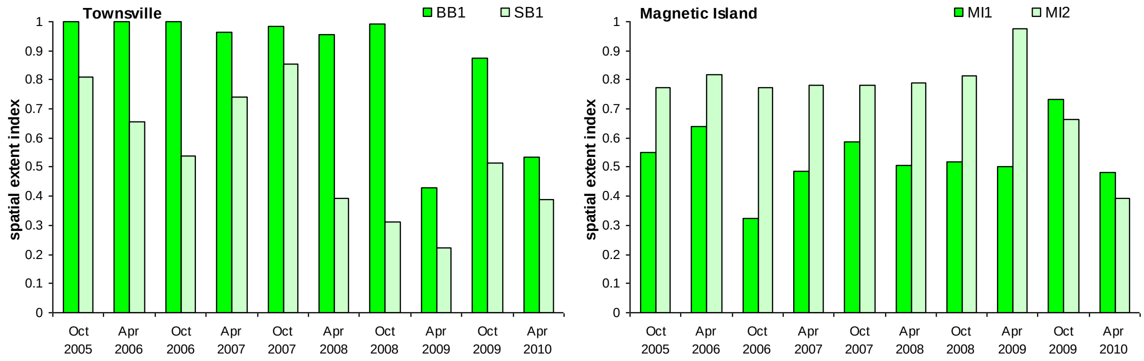


Figure 57. *Extent of area (within 100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Townsville and Magnetic Island locations.*

Table 19. *Area (ha) of seagrass meadow within 100m radius of each site. Value in parenthesis is % change from the October 2005 baseline (bold) and description of change from previous mapping. Shading indicates decrease in meadow area since baseline.*

	Magnetic Island		Townsville	
	MI1	**MI2**	**BB1**	**SB1**
October 2005	**2.933**	**4.104**	**5.312**	**4.303**
April 2006	3.398 *(15.9%, increase shoreward)*	4.342 *(5.8, increase shoreward)*	5.312 *(no change)*	3.485 *(-19.1 decrease seaward)*
October 2006	1.723 *(-41.2% decrease seaward)*	4.112 *(0.2, negligible)*	5.312 *(no change)*	2.861 *(-33.5 decrease seaward)*
April 2007	2.587 *(-11.8%, increase shoreward)*	4.141 *(0.9%, increase shoreward)*	5.113 *(-3.7, decrease seaward)*	3.939 *(-8.5 increase shoreward)*
October 2007	3.119 *(6.3%, increase shoreward)*	4.144 *(1.0%, increase shoreward)*	5.221 *(-1.7,increase shoreward)*	4.529 *(-5.2 increase shoreward)*
April 2008	2.69 *(-8.3%, decrease seaward)*	4.191 *(2.1%, increase shoreward)*	5.08 *(-4.4, decrease seaward)*	2.095 *(-51.3 decrease overall)*
October 2008	2.76 *(-5.9%, increase shoreward)*	4.320 *(5.3%, increase shoreward)*	5.264 *(-0.9%, increase shoreward)*	1.648 *(-61.7%, decrease overall)*
April 2009	2.677 *(-8.7%, decrease seaward)*	5.179 *(26.2%, increase shoreward)*	2.275 *(57.2%, decrease seaward)*	1.178 *(-72.6%, decrease overall)*
October 2009	3.885 *(32.4%, increase seaward)*	2.560 *(-14.1%, decrease overall)*	4.645 *(12.6%, increase seaward)*	2.849 *(36.6%, increase overall)*
April 2010	3.525 *(-12.7%, decrease overall)*	2.086 *(-49.2%, decrease overall)*	2.728 *(-46.4%, decrease seaward)*	2.066 *(-52%, decrease overall)*

Seagrass reproductive status

Reproductive effort among coastal sites in the Burdekin region are exceptionally high (*Figure 58*); in fact Bushland Beach and Shelley Beach consistently show the highest reproductive effort of any sites across the GBR. It has been documented that seagrass can recover rapidly from complete meadow loss initially from seeds germinating in the seed bank. As a result, species observed to be present shortly after meadow loss are those that form a seed bank, *Halodule uninervis* and *Halophila ovalis*. Although significantly lower reproductive effort is observed at the reef sites in the Burdekin region they are still average compared to the overall reef site average across the GBR. The values for the Burdekin region in 2009 were overall similar to previous years.

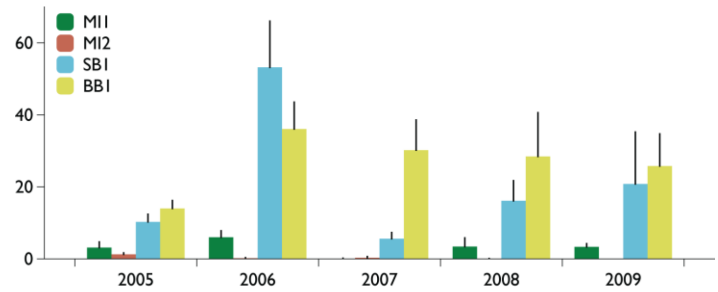


Figure 58. Mean reproductive effort (number of reproductive structures per core ± s.e.) during dry season sampling from 2005–2009 for Burdekin region sites, a. coastal habitats, b. reef habitats.

Seed banks which are usually very high in the region, fell below the GBR long-term average in 2009/10 at both habitats (Figure 59, Figure 60). The decline in the seed banks corresponds to a decline in seagrass cover at these sites and reflects an ongoing trend of declining seagrass in the region.

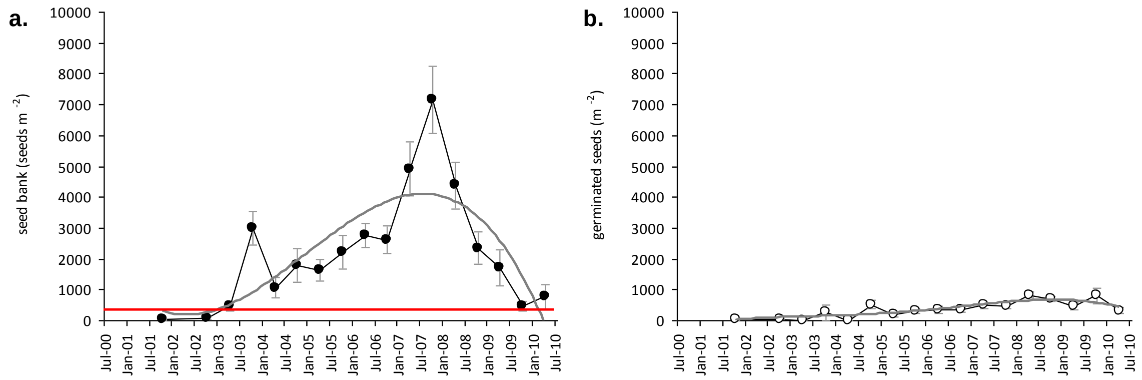


Figure 59. *Halodule uninervis seed bank (a) and germinated seed abundance (b) at coastal habitats in the Burdekin region (seed bank is represented as the total number of seeds per m² sediment surface). Red line = GBR long-term average for coastal habitats.*

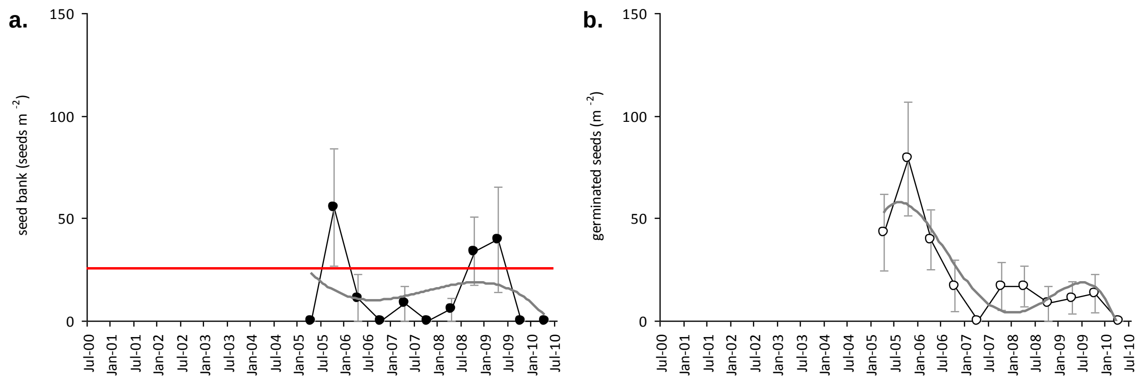


Figure 60. *Halodule uninervis seed bank (a) and germinated seed abundance (b) at reef habitats in the Burdekin region (seed bank is represented as the total number of seeds per m² sediment surface). Red line = GBR long-term average for coastal habitats.*

Status of the seagrass environment

Seagrass tissue nutrients

Seagrass leaf tissue C:N ratios for coastal sites (Bushland and Shelley Beaches, Townsville) were below 20 indicating a potentially low light environment. C:N rations at offshore reef sites (Cockle and Picnic Bays, Magnetic Island) remained above 20 (Figure 61), and although there was a slight improvement in 2009, it was not significant. Decreasing C:N ratios at coastal sites since 2006 indicate decreasing light availability at this location.

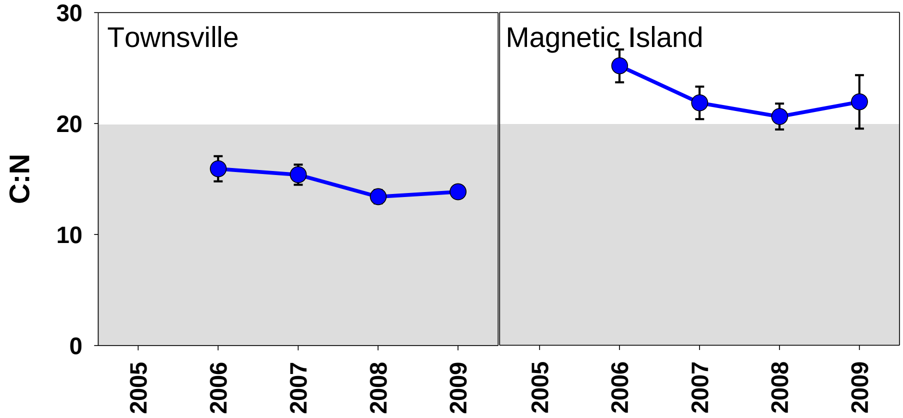


Figure 61. *Elemental ratios (atomic) of seagrass leaf tissue C:N for the foundation seagrass species examined at each habitat in the Burdekin region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the C:N ratio panel represents the accepted guideline seagrass "Redfield" ratio of 20:1 (Abal et al. 1994; Grice et al. 1996). C:N ratios below this line indicate reduced light availability.*

The nutrient status (tissue C:P) of the coastal (Townsville) habitats indicates that these sites were nutrient rich, containing a large P pool (Figure 62). Reef habitats however remained nutrient poor with a smaller available P pool. The coastal habitats have become increasing nutrient rich over the last three to four years. The N:P ratio indicates that both coastal and reef habitats in the region are high in N, with the coast replete and reef P limited (N:P >30) (Figure 62). Tissue N:P ratios indicated that all seagrass species at reef habitats remained replete, however coastal habitats decreased from P limited in 2008 to replete in 2009. This suggests a small N pool relative to the increasing P pool.

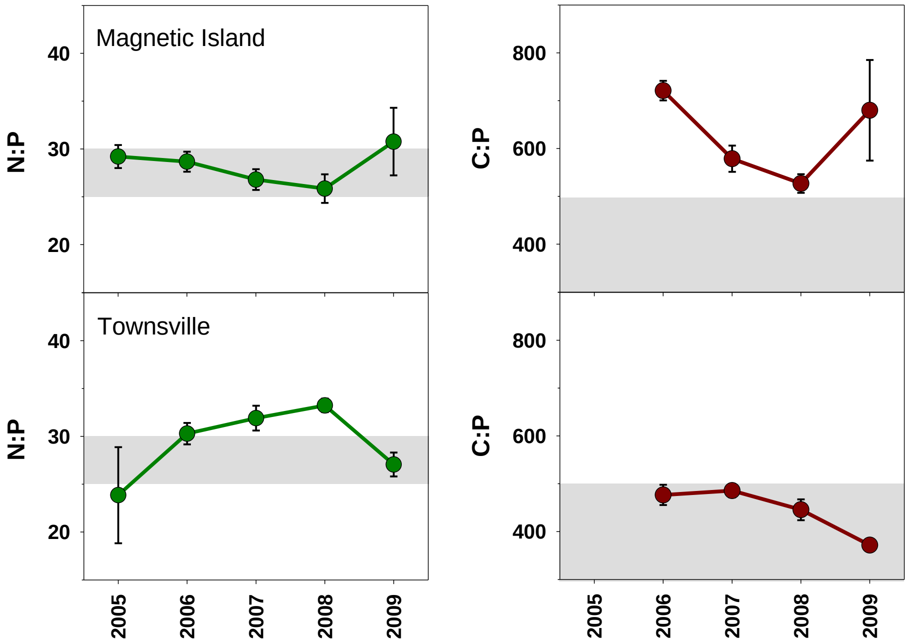


Figure 62. *Elemental ratios (atomic) of seagrass leaf tissue N:P and C:P for the foundation seagrass species examined at each location in the Burdekin region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues. N:P ratio above this band indicates P limitation, below indicates N limitation and within indicates replete. Shaded portion on the C:P panel ≤500 represents the value associated with C:P balance ratio in the plant tissues, C:P values <500 may indicate nutrient rich habitats (large P pool).*

Epiphytes and macro-algae

Epiphyte cover on seagrass leaf blades at coastal sites was highly variable (Figure 63) and appears correlated with seagrass abundance (Figure 63). Percentage cover of macro-algae at coastal sites is also variable, but has similarly remained low over the past couple of years (Figure 63). Both epiphytes and macro-algae were below the GBR long-term average throughout the 2009/10 monitoring period.

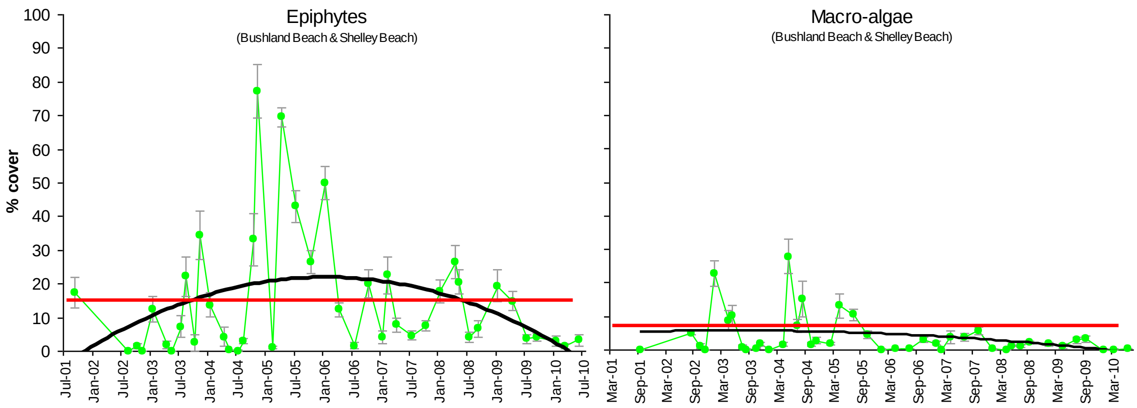


Figure 63. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at coastal intertidal seagrass monitoring locations (sites pooled). NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

Epiphyte cover at reef hbaitats differs greatly between sites. At Picnic Bay (MI1), epiphyte cover was generally <40%, compared to Cockle Bay where it is >50% on average (Figure 64). Epiphyte abundance decreased significantly during the 2009/10 monitoring period, a consequence of the declining seagrass abundance.

Macro-algae were low at Picnic Bay, but higher and more variable at Cockle Bay. Macro-algae at Cockle Bay was predominately composed of *Halimeda* spp., however in 2009, the composition of *Hydroclathrus* spp. increased. There does not appear to be any clear long-term trend in abundance (Figure 64).

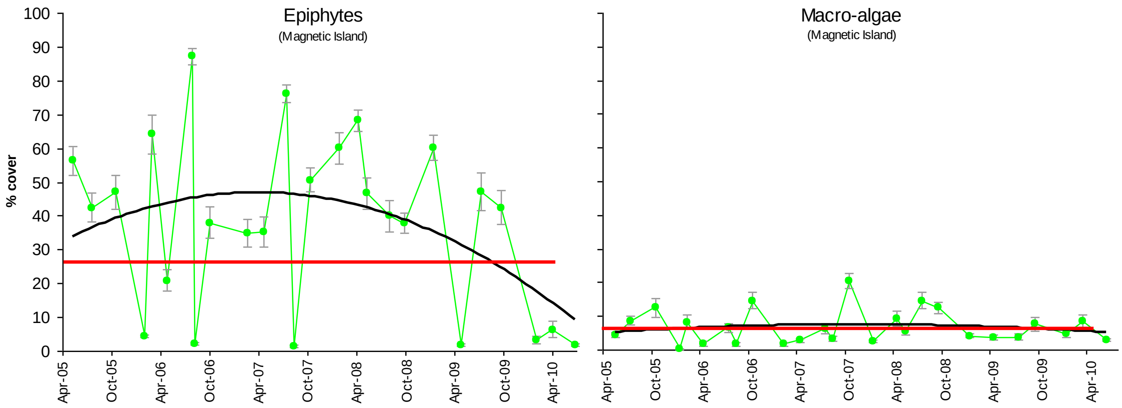


Figure 64. . *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal reef seagrass monitoring locations. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

Within meadow canopy temperature

Within canopy water temperature was monitored at all coastal and reef-platform sites over the monitoring period (Figure 65). Extreme temperatures (>40°C) were recorded at both reef (Magnetic Island) sites on the 25 April 2010, with the maximum of 43.0°C at Picnic Bay. Maximum temperatures peaked several times throughout the year at all locations. Mean temperatures were mostly within the 23 – 31°C range, with highest mean temperatures in February 2010 (Figure 66). The 2009/10 monitoring period was 0.2°C hotter on average than the long term average.

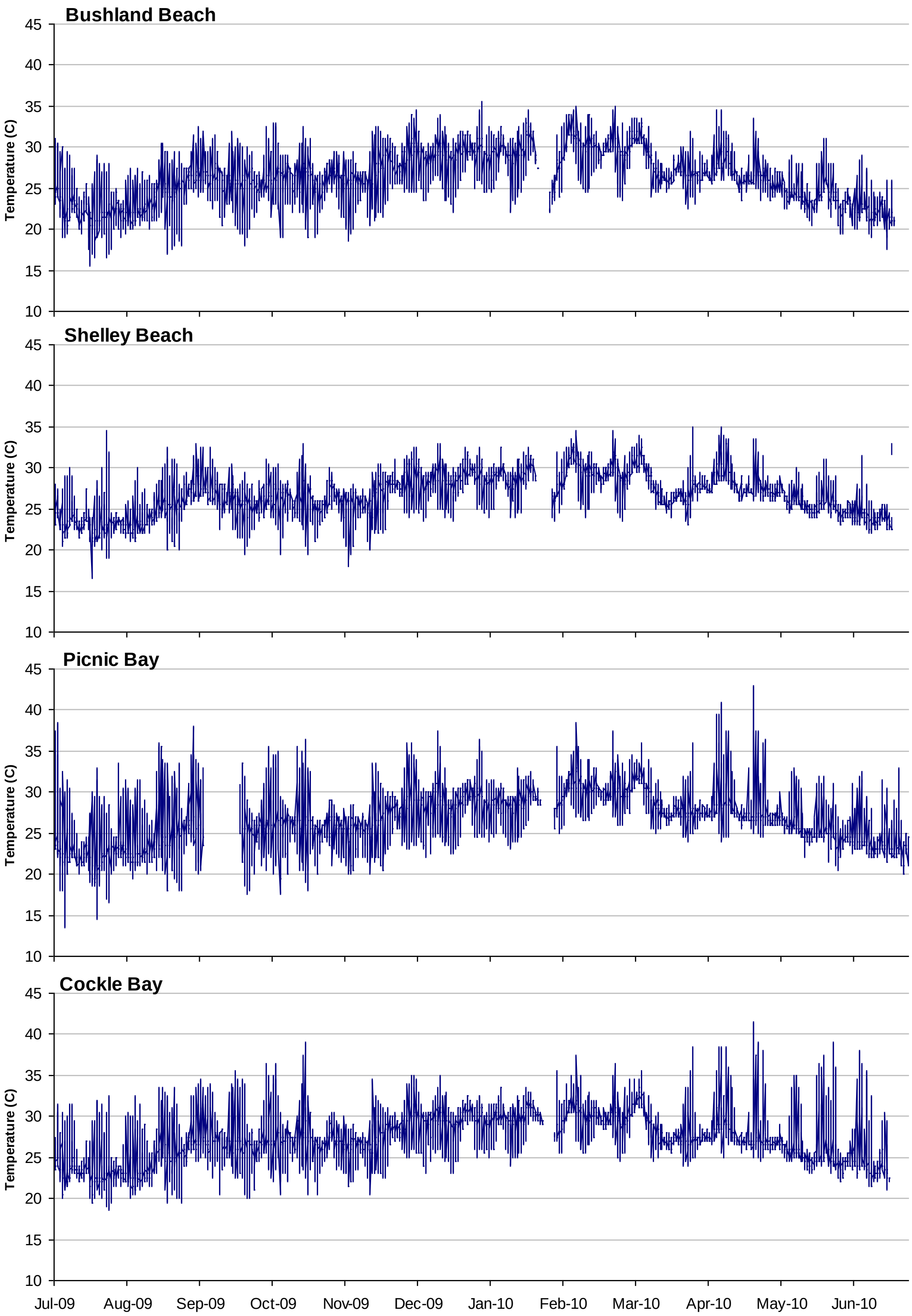


Figure 65. *Within seagrass canopy temperature (°C) at coastal (Bushland Beach and Shelley Beach) and offshore fringing-reef (Picnic Bay and Cockle Bay, Magnetic Island) intertidal meadows within the Burdekin region over the 2009/10 monitoring period.*

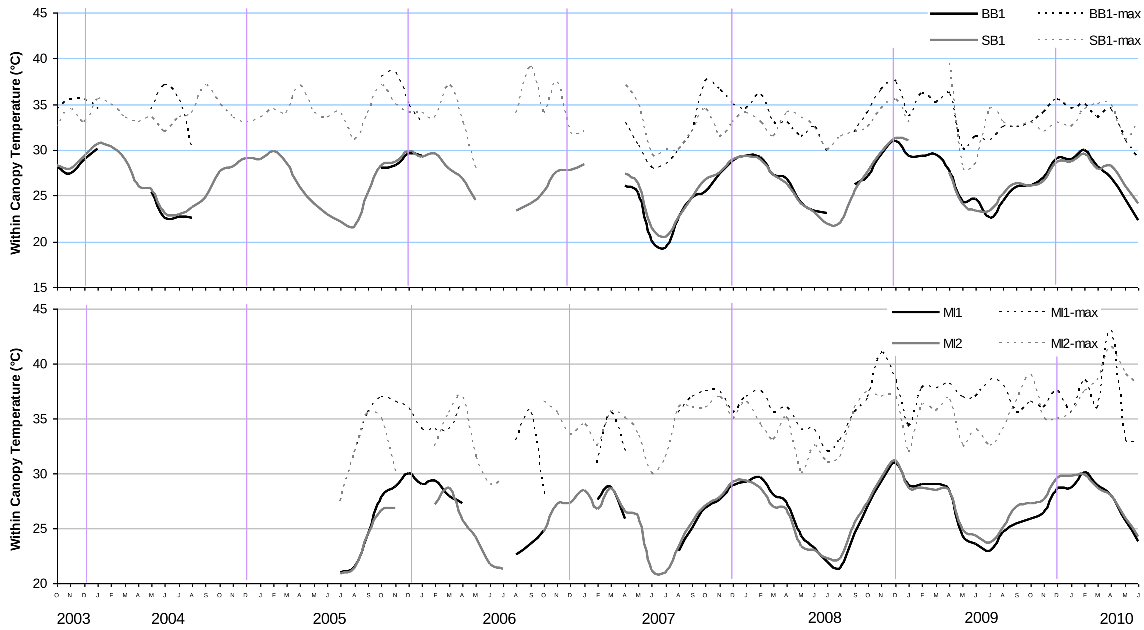


Figure 66. *Monthy mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Bushland Beach and Shelly Beach) and offshore fringing-reef (Picnic Bay and Cockle Bay, Magnetic Island) habitats within the Burdekin region.*

Canopy incident light

Deployment of light loggers in the Burdekin region expanded in 2009 to include a coastal site (Bushland Beach) as well as the longer term site at Picnic Bay (reef) (Figure 67). Variance in light availability followed firstly a pattern of tidal cycle, then a seasonal pattern of winds where increased wind results in lower incident light levels. At Picnic Bay a relationship between reduced canopy incident light and percent cover has been established. As data are only available for recent sampling periods correlations with seagrass responses will be analysed at a later date.

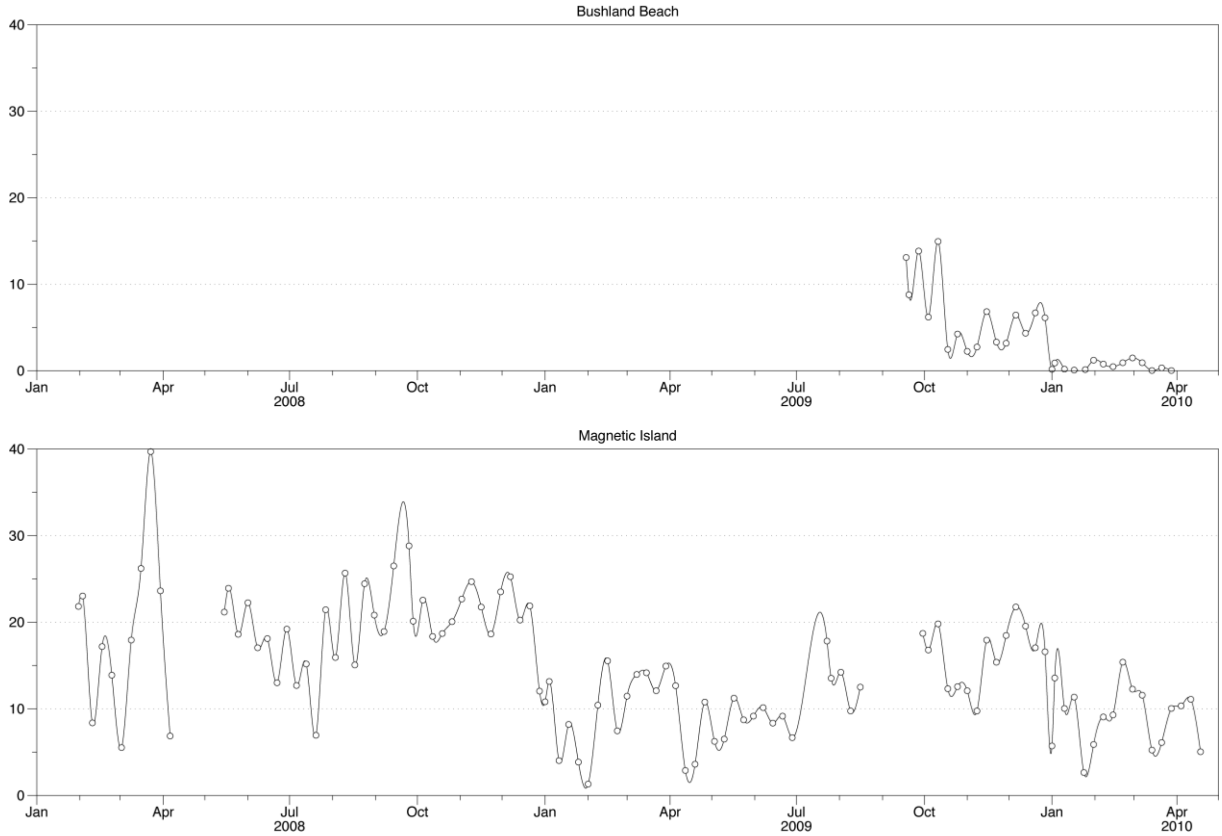


Figure 67. *Burdekin region fortnightly averages of daily incident light (mmol photons per m^2 per day), at canopy height (2π light loggers; Submersible Odyssey Photosynthetic Irradiance Recording System, Dataflow Systems Pty Ltd, New Zealand placed in a wiper unit to keep the sensor clean) at four sites installed at seagrass canopy height.*

Regional Climate

Climate across the Burdekin region in 2009/10 was hotter, windier and wetter than previous years.

Townsville – Townsville and Magnetic Island

The mean maximum daily air temperature recorded in Townsville during 2009 was 29.5°C; this was 0.6°C higher than the long-term year average but the same as the decade average. The highest recorded daily maximum temperature in 2009 was 36.3°C.

2009 was a wet year relative to both the last decade and the long-term average with approximately 75% more rain (Figure 68). Mean wind speed in 2009 was 24.0 km.hr^{-1}, this was higher than the long-term but approximately the same as the decade average.

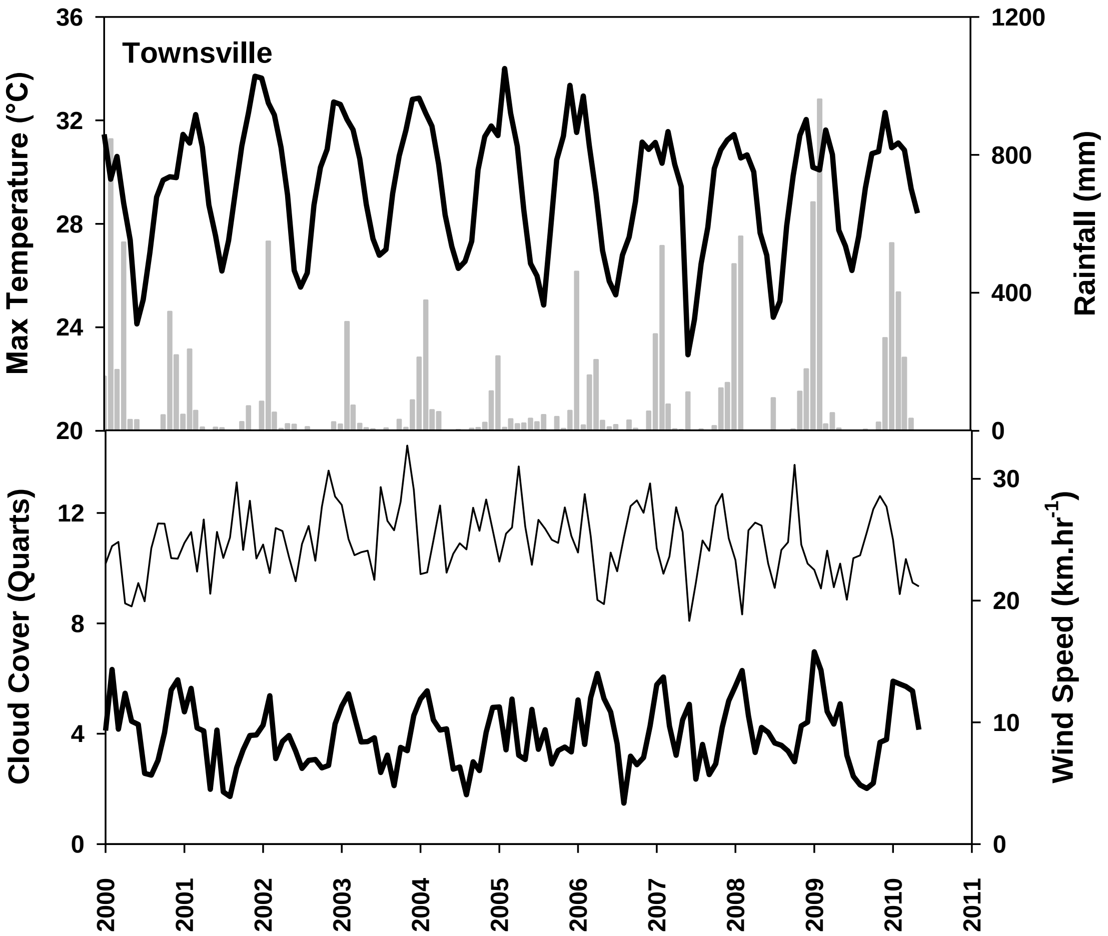


Figure 68. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr-1) recorded at Townsville Airport (BOM station 032040) (Source www.bom.gov.au). Townsville Airport used as a surrogate for the climate at coastal (Townsville) and reef (Magnetic Island) locations.*

Mackay Whitsunday

2009/10 Summary

Intertidal seagrass meadows are found on the large sand/mud banks of sheltered estuaries and coastal fringes of the Mackay Whitsunday region; they are also present on top of the offshore fringing reefs. Key environmental drivers include exposure, desiccation and variable flood runoff during the wet season. Seagrass meadows are monitored at reef, coastal and estuarine locations in the Mackay Whitsunday region. Seagrass abundance declined significantly at all habitats throughout the region over the monitoring period, and by late monsoon 2010 all but one site in the region was rated as poor. Seed banks and reproductive effort declined at reef and coastal and were in poor state, raising concerns about the ability of local seagrass meadows to recover from environmental disturbances. Seagrass tissue nutrient concentrations indicate no improvement across region as light environments remain low (limited). Tissue nutrient status indicated that although the N concentrations remained high in reef and coastal habitats, the plants were limited by a decreasing P pool (i.e. P limited). Water quality was marginal at Hamilton Island, but rated as poor at Sarina Inlet due to low light and nutrient rich (large P pool and elevated N) conditions. Low epiphyte abundance appears a consequence of the seagrass decline experienced across the region. Climate in the north of the region was cooler and windier than normal, and in the south it was 1.0°C hotter and wetter than the long-term average. Within canopy temperatures were warmer at all habitats than previous. Overall the status of seagrass condition in the region was rated as fair.

Table 20. *Report card for seagrass status (community & environment) for the Mackay Whitsunday region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100. Green = good, yellow = moderate, gold = fair, red = poor.*

Habitat	Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index^**
reef intertidal	25	0	33	33	**23**
coastal intertidal	59	33	67	33	**48**
estuarine intertidal	8	0	33	33	**10**
Mackay Whitsunday	31	0	33	33	**24**

Background

The Mackay Whitsunday region comprises an area of almost 940,000 ha and includes the major population centres of Mackay, Proserpine, Airlie Beach and Sarina; encompassing the Proserpine, O'Connell, Pioneer and Plane Creek river systems (Australian Government Land and Coasts 2010c). The region's climate is humid and tropical with hot wet summers and cool dry winters. Annual rainfall varies significantly with as much as 3000 mm a year in elevated sections of the coastal ranges.

Most (~70%) of the region's rainfall occurs between December and March. Average daily temperatures for Mackay range between 23° and 31°C in January and 11° and 22°C in July. The south-easterly trades are the prevailing winds, with occasional gale force winds occurring during cyclonic and other storm events (Mackay Whitsunday Natural Resource Management Group Inc 2005). The major industries in the Mackay Whitsunday region are agriculture and grazing, tourism, and fishing and aquaculture. Reef Plan monitoring sites are located on three of the generalised seagrass habitats represented in the region, including estuarine, coastal and reef.

Estuarine seagrass habitats in the Mackay Whitsunday region tend to be intertidal on the large sand/mud banks of sheltered estuaries. Run-off through the catchments connected to these estuaries is variable, though the degrees of variability is moderate compared to the high variability of the Burdekin and the low variability of the Tully (Brodie 2004). Seagrass in this habitat must cope with extremes of flow, associated sediment and freshwater loads from December to April when 80% of the annual discharge occurs (Figure 69).

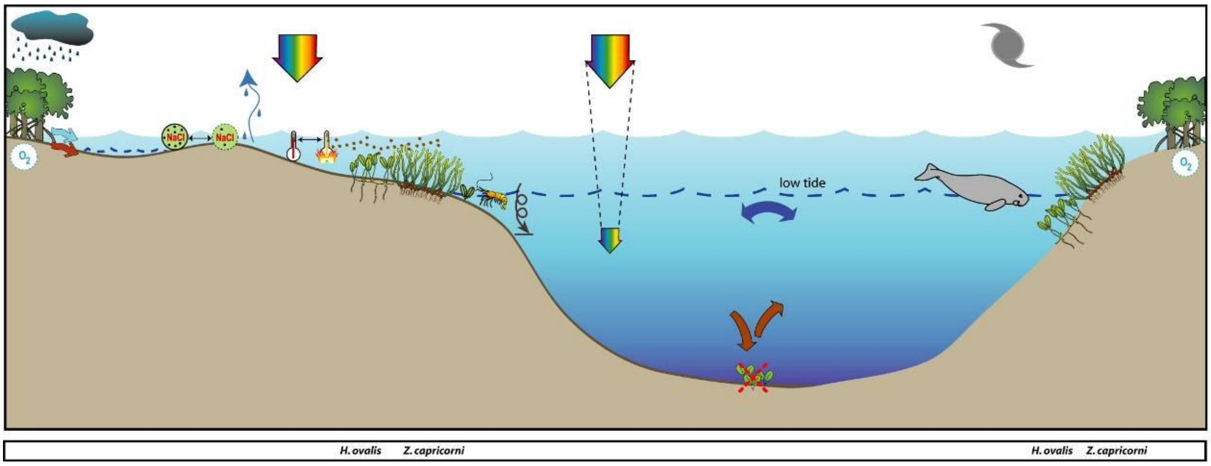


Figure 69. *Conceptual diagram of estuary habitat in the Mackay Whitsunday region: general habitat and seagrass meadow processes (see Figure 2 for icon explanation).*

Coastal seagrass habitats are found in areas such as the leeward side of inshore continental islands and in north opening bays. These areas offer protection from the south-easterly trades. Potential impacts to these habitats are issues of water quality associated with urban, marina development and agricultural land use (Figure 70). Monitoring sites of intertidal coastal seagrass habitat were located on the sand/mud flats adjacent to Cannonvale in southern Pioneer Bay.

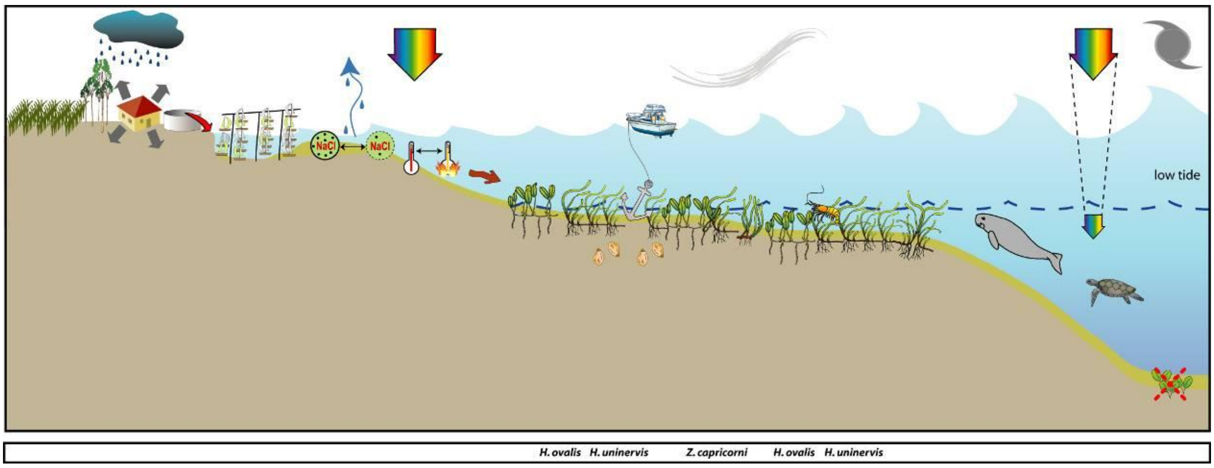


Figure 70. *Conceptual diagram of coastal habitat in the Mackay Whitsunday region – major control is shelter and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (see Figure 2 for icon explanation)*

Reef habitat seagrass meadows are found intertidally on the top of the coastal fringing reefs or fringing reefs associated with the many islands in this region. The drivers of these habitats is exposure, and desiccation (intertidal meadows) (Figure 71). Major threats would be increased tourism activities including marina and coastal developments.

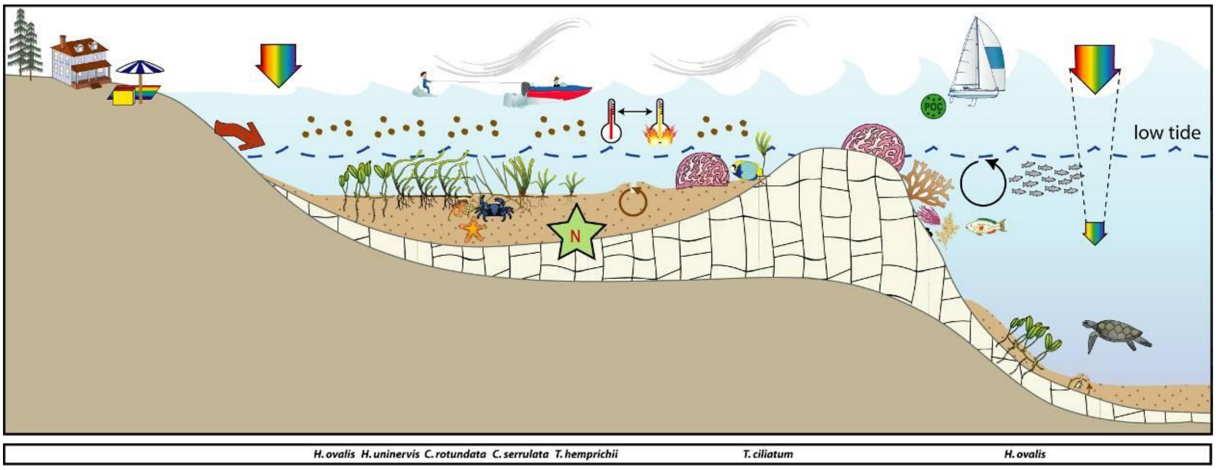


Figure 71. *Conceptual diagram of reef habitat in the Mackay Whitsunday region - major control is light and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (see Figure 2 for icon explanation).*

Status of the seagrass community

Seagrass abundance and composition

The coastal seagrass monitoring sites were located on intertidal sand/mud flats adjacent to Cannonvale in southern Pioneer Bay. Seagrass abundance has fluctuated at the coastal sites between and within years indicating disturbance regimes at longer time periods than annually (Figure 72). Abundances during the 2009 calendar year were high, however they dropped to one of the lowest levels since 1999 in the late monsoon 2010. The meadows were dominated by *Halodule uninervis* and *Zostera capricorni* mixed with *Halophila ovalis*. Species composition has gradually changed over the past decade of monitoring (Figure 73). The composition of *Z. capricorni* in the Pioneer Bay site 2 (PI2) increased, particularly on the shoreward extent.

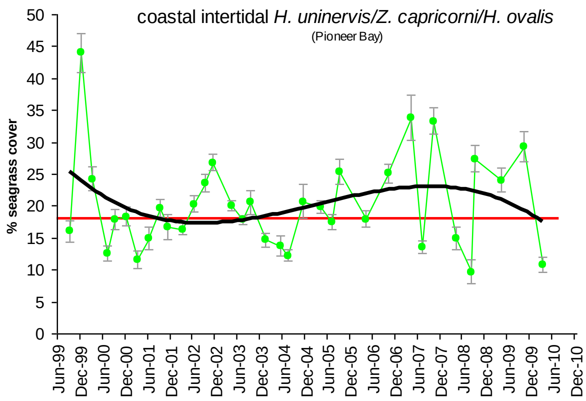


Figure 72. *Change in seagrass abundance (percentage cover) at the coastal intertidal meadows at Pioneer Bay, in the Mackay Whitsunday region. Red line = GBR long-term average for coastal habitats.*

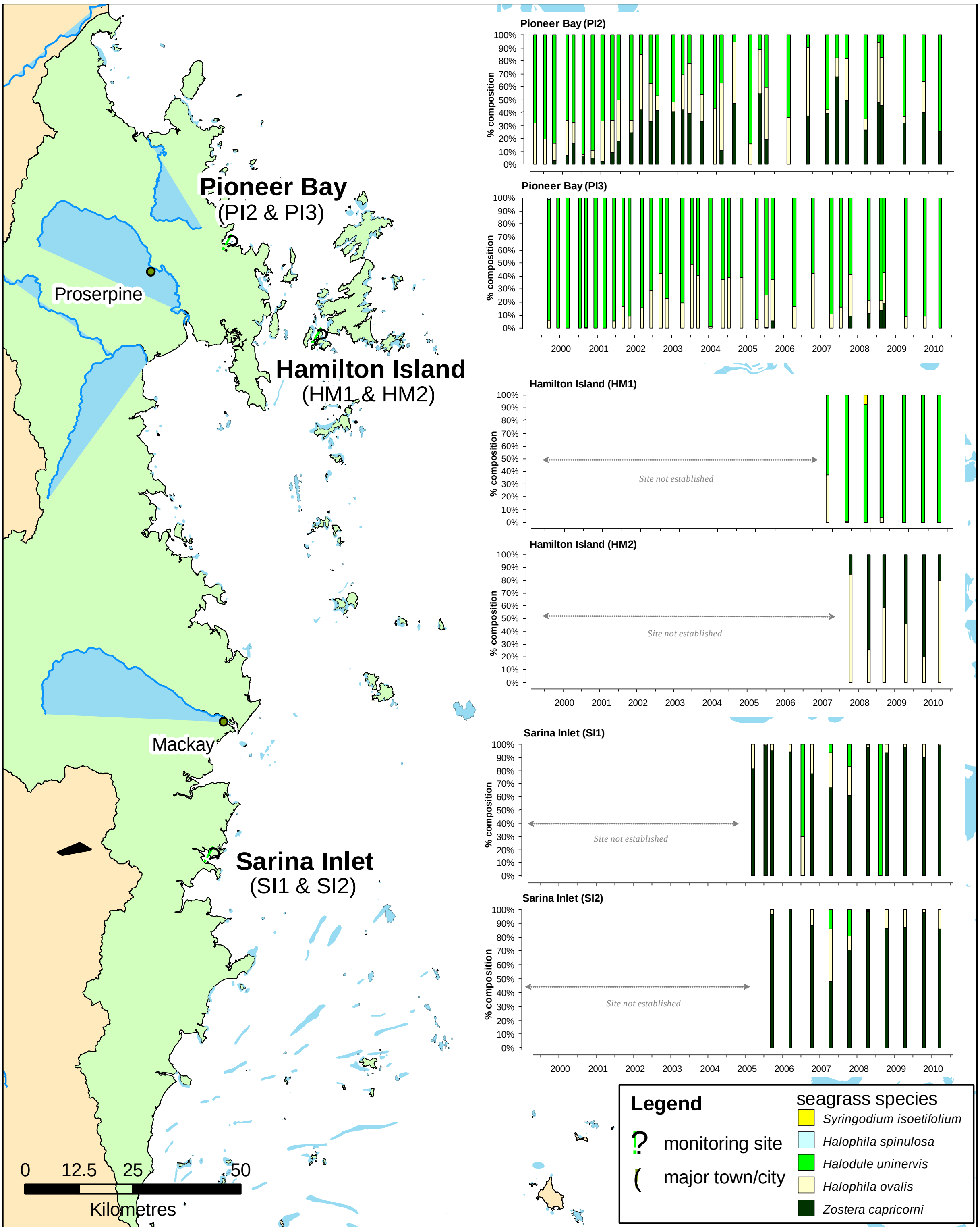


Figure 73. *Location of Mackay Whitsunday region long-term monitoring sites and the seagrass species composition at each site. Please note: replicate sites within 500m of each other.*

Over the past 2 years, the composition of *Z. capricorni* at Pioneer Bay site 3 (PI3) has similarly increased. A seasonal pattern in abundance is observed at Pioneer Bay site PI2, but less apparent at site PI3 (Figure 74).

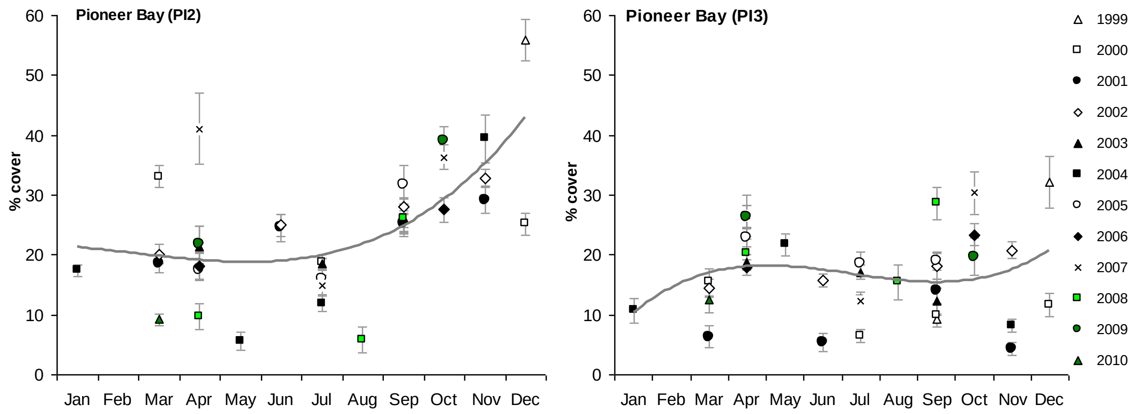


Figure 74. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Pioneer Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

The estuarine monitoring sites are located on an intertidal sand/mud bank in Sarina Inlet south of Mackay. These sites are dominated by *Zostera capricorni* with some *Halophila ovalis* (Figure 73). Although there is insufficient spread of sampling across months within years, the seagrass abundance appears greater in the late dry than late monsoon. Seagrass cover in late dry 2009 was significantly lower than reported for the previous two monitoring periods for the same time of year (Figure 75). Overall, seagrass abundance has declined at Sarina Inlet since 2008.

Seagrass meadow on the intertidal mud banks in Sarina Inlet site 1 (SI1).

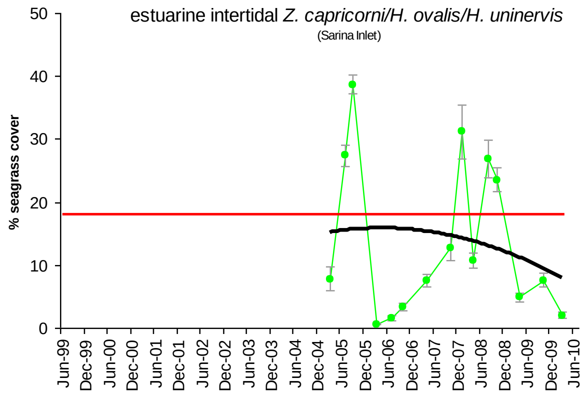
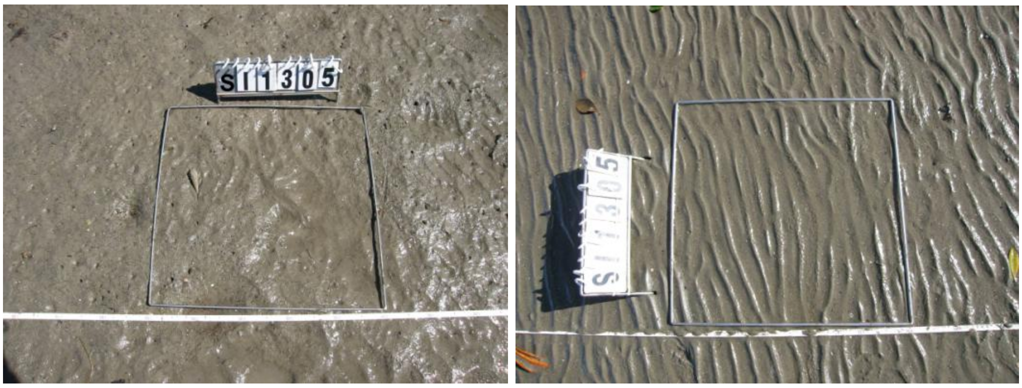


Figure 75. *Change in seagrass abundance (percentage cover) at intertidal meadows located in estuaries in the Mackay Whitsunday region. Red line = GBR long-term average for estuarine habitats.*



Quadrat at 5m on transect 3 at Sarina Inlet site 1 (SI1), on 6 April 2009 (left) and 29 March 2010 (right).

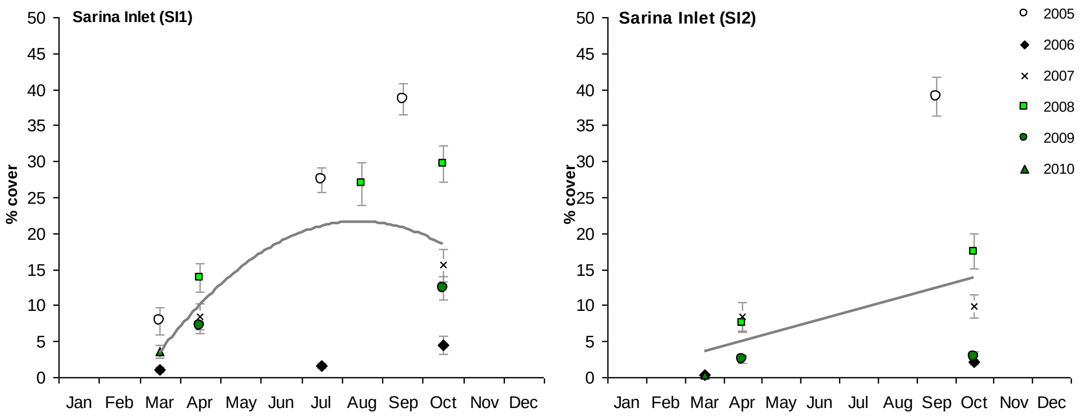


Figure 76. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Sarina Inlet long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

The offshore reef monitoring sites are located on an intertidal fringing reef at Catseye Bay (Hamilton Island). These sites are dominated by *Halodule uninervis* or *Zostera capricorni* with some *Halophila ovalis* (Figure 73). The site at the eastern end of Catseye Bay (HM2) was dominated by *Z. capricorni* and the site at the western end (HM1) was dominated by *H. uninervis*. Seagrass cover has continued to decline at Hamilton Island since monitoring began in 2007 (Figure 77). Due to the paucity of data and insufficient spread of sampling across months within years, it is difficult to determine if seagrass abundance is seasonal (Figure 78).

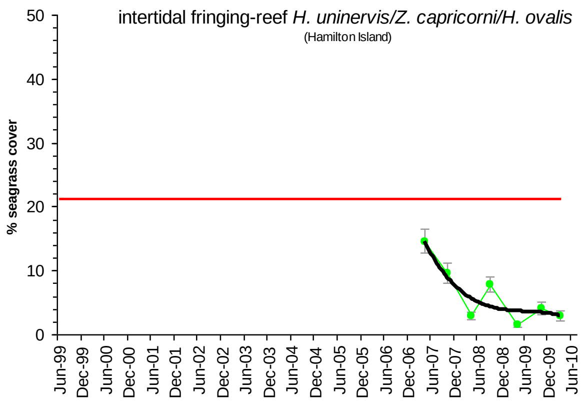
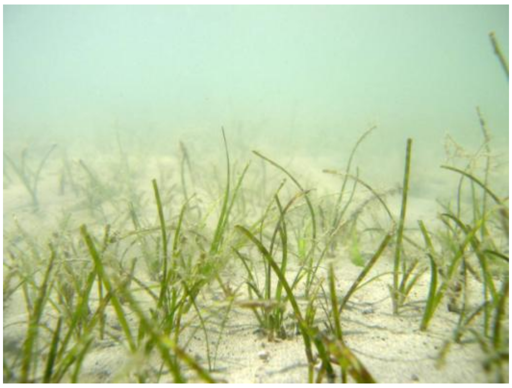


Figure 77. *Change in seagrass abundance (percentage cover) at intertidal meadows located on a fringing reef in the Mackay Whitsunday region. Red line = GBR long-term average for reef habitats.*



Halodule uninervis at Hamilton Island site 1 (HM1).

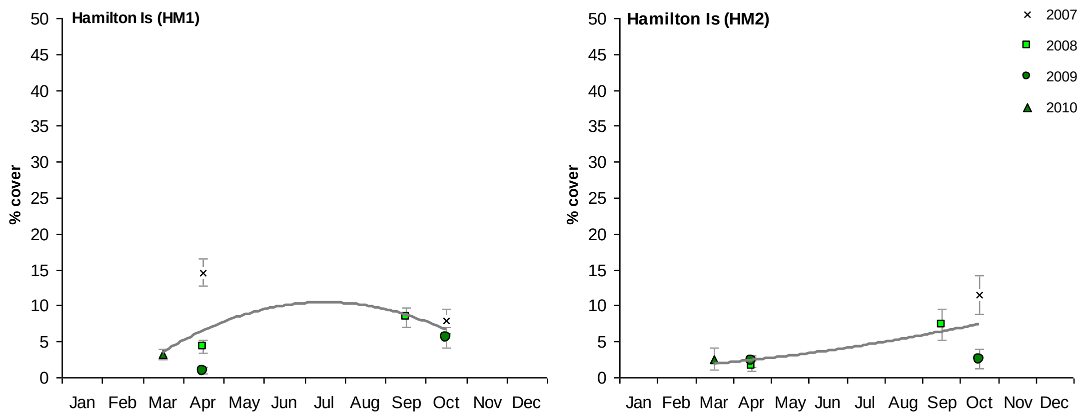


Figure 78. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Hamilton Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass abundance relative to the seagrass guidelines indicates that the all but one site in the region were in a poor state by late monsoon 2010 (Figure 79).

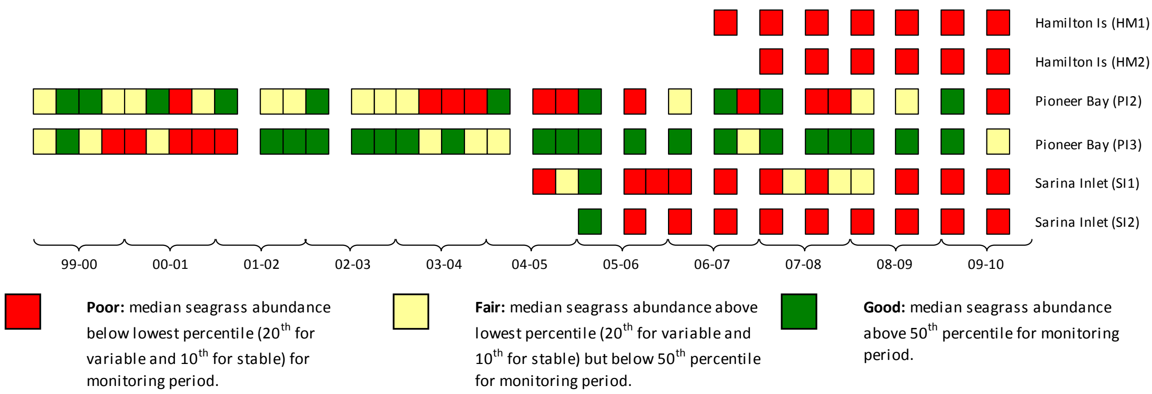


Figure 79**.** *Status of seagrass abundance in the Mackay Whitsunday region relative to the seagrass guidelines since monitoring was established in 1999. Each block represents the seasonal monitoring event (dry, late dry, monsoon, late monsoon), with time along the x-axis from left to right.*

Seagrass meadow edge mapping was conducted within a 100m radius of all monitoring sites in September/October and March/April of each year (Table 21) to determine if changes in abundance were a consequence of the meadow edges changing. Over the past 12 months, the meadows at Pioneer Bay increased to their greatest extent in the late dry, but decreased in late monsoon with the impact of a tropical cyclone. The meadow at Sarina Inlet generally increases every late dry (September/October), but since 2007 the overall trend has been decline (Table 21, Figure 81). The meadows on Hamilton Island have similarly decreased significantly in overall extent.

Table 21. *Area (ha) of seagrass meadow within 100m radius of site. Value in parenthesis is % change from the baseline (bold) and description of change from previous mapping. Shading indicates decrease in meadow area since baseline. NA=no data available as site not established.*

	Pioneer Bay		Hamilton Island		Sarina Inlet	
	PI2	**PI3**	**HM1**	**HM2**	**SI1**	**SI2**
October 2005	**3.432**	**2.432**	*NA*	*NA*	**3.374**	**3.747**
April 2006	3.534 *(3.0%, increase shoreward)*	2.026 *(-16.7%, decrease shoreward)*	*NA*	*NA*	1.726 *(-48.8%, decrease seaward)*	2.46 *(-34. %,3 decrease shoreward)*
October 2006	3.812 *(11.1%, increase shoreward)*	3.891 *(60%, increase shoreward)*	*NA*	*NA*	4.425 *(31.2%, increase shoreward)*	3.679 *(-1.8%, decrease seaward)*
April 2007	4.193 *(22.2%, increase shoreward)*	4.418 *(81. %, increase shoreward)*	*NA*	*NA*	4.092 *(21.0%, increase shoreward)*	3.536 *(-5.6%, decrease seaward)*
October 2007	4.145 *(20.8%, decrease seaward)*	4.159 *(71%, decrease seaward)*	**0.810**	**0.164**	4.736 *(40.4%, increase overall)*	4.739 *(26.5%, increase overall)*
April 2008	4.068 *(18.5%, decrease seaward)*	4.183 *(72%, increase shoreward)*	0.917 *(13.2 %, increase shoreward)*	0.05 *(69.2%, decrease overall)*	1.608 *(52.4%, decrease overall)*	1.821 *(51.4%, decrease overall)*
October 2008	4.094 *(19.3%, increase shoreward)*	4.300 *(76.8%, increase shoreward)*	0.763 *(5.8 %, decrease overall)*	0.09 *(44.4%, increase overall)*	3.58 *(6.15%, increase overall)*	3.732 *(0.4%, increase overall)*
April 2009	4.471 *(30.2%, increase shoreward)*	4.430 *(82.2%, negligible)*	0.687 *(15.2 %, decrease overall)*	0.06 *(64.1%, decrease overall)*	1.661 *(50.8%, decrease overall)*	1.409 *(62.4%, decrease overall)*
October 2009	5.247 *(52.9%, increase shoreward)*	4.814 *(97.9%, increase shoreward)*	0.491 *(-39.4%, decrease overall)*	0.023 *(-85.8%, decrease overall)*	2.467 *(26.9%, increase overall)*	2.393 *(36.1%, increase overall)*
April 2010	2.086 *(-13.7%, decrease seaward)*	3.539 *(-36.0%, decrease seaward)*	0.356 *(-56%, decrease overall)*	0.016 *(-89.7%, decrease overall)*	0.698 *(-253.5%, decrease overall)*	0.916 *(-161.2%, decrease overall)*

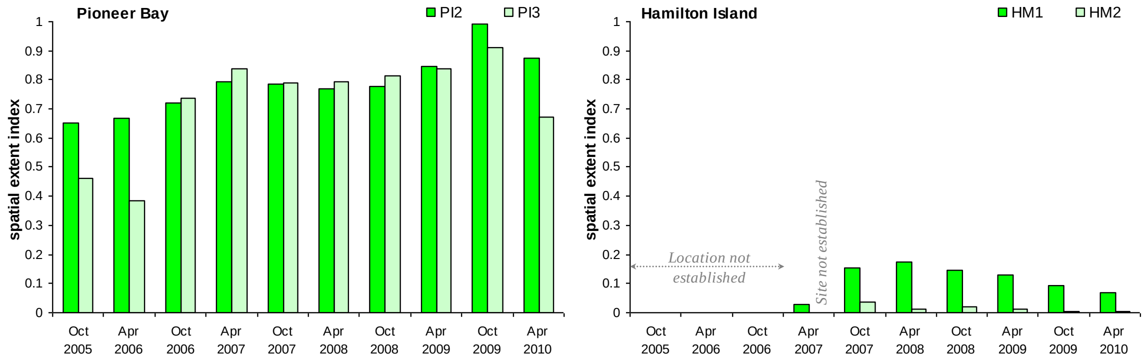


Figure 80. *Extent of area (100m radius of monitoring site) covered by seagrass at each coastal (Pioneer Bay) and reef (Hamilton Is) monitoring locations.*

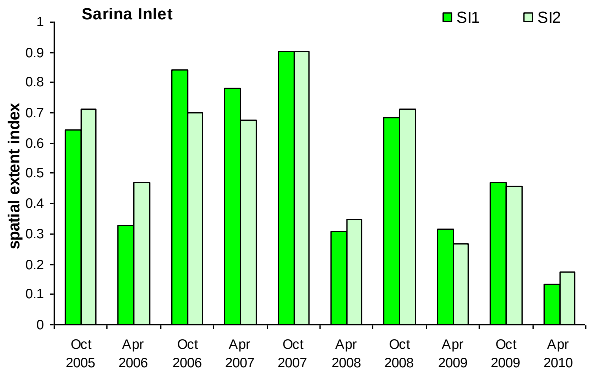


Figure 81. *Extent of area (100m radius of monitoring site) covered by seagrass at estuarine (Sarina Inlet) monitoring sites.*

Seagrass reproductive status

Coastal sites in the Mackay Whitsunday region were observed to have strong reproductive effort although reproductive effort at estuarine sites declined in 2009 at Sarina Inlet (*Figure 82*). The reef sites, Hamilton Island, also declined and following the GBR wide trend had lower reproductive effort than nearby coastal sites.

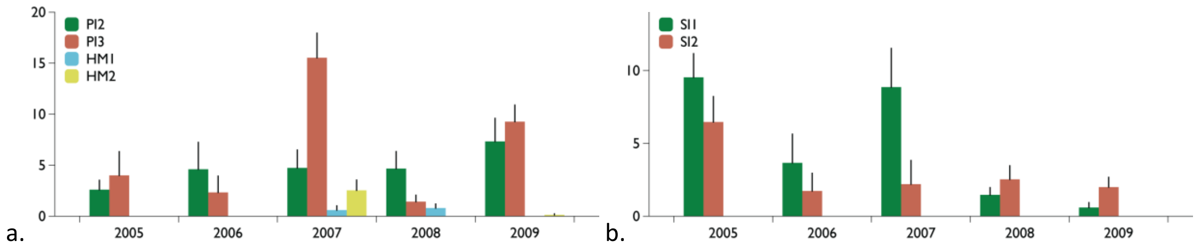


Figure 82. Mean reproductive effort (number of reproductive structures per core ± s.e.) during dry season sampling from 2005–2009 for Mackay Whitsunday sites, a. Pioneer Bay and Hamilton Island, b. Sarina Inlet.

Recovery potential of the estuarine and reef seagrass meadows was limited in 2009/10, as no seeds were recorded in 2009 (Figure 83, Figure 84). Seed banks at Pioneer Bay were also well below the GBR long-term average (Figure 83).

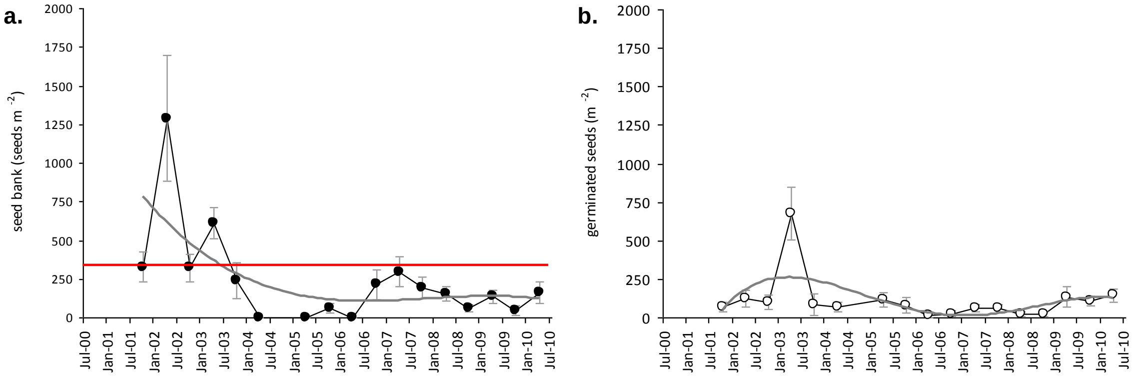


Figure 83. *Halodule uninervis seed bank (a) and germinated seed abundance (b) at coastal habitats in the Mackay Whitsunday region (seed bank is represented as the total number of seeds per m^2 sediment surface). Red line = GBR long-term average for coastal habitats.*

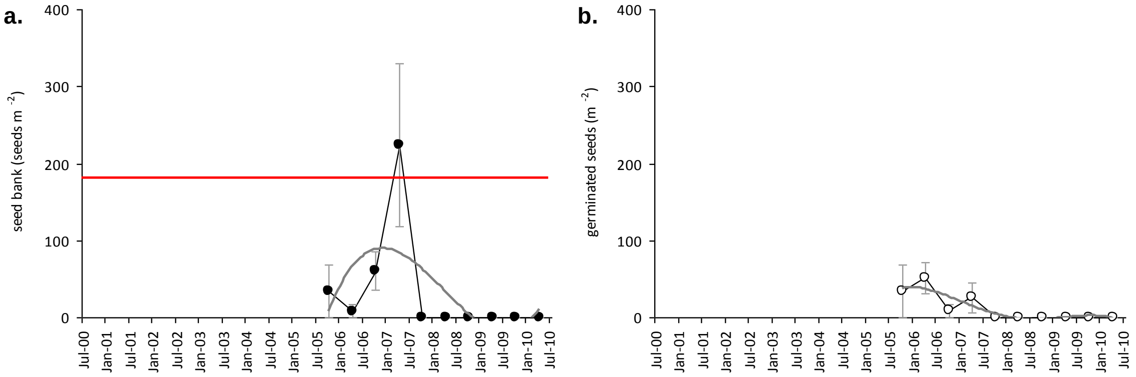


Figure 84. *Halodule uninervis seed bank (a) and germinated seed abundance (b) at estuary habitats in the Mackay Whitsunday region (seed bank is represented as the total number of seeds per m^2 sediment surface). Red line = GBR long-term average for coastal habitats.*

The reduction in reproductive effort and seed banks in the Mackay Whitsunday region is of concern as several sites have shown ongoing declines in seagrass abundance. The cause of the decline may be related to lower light levels experienced in the region although unfortunately light loggers were lost during this period.

Status of the seagrass environment

Seagrass tissue nutrients

Seagrass tissue C:N ratios in the Mackay Whitsunday region have changed little since 2007 (Figure 85), all remaining below 20, indicating reduced light availability. Levels of C:N significantly increased in 2009 compared to 2008 when they were at their lowest since measurement commenced.

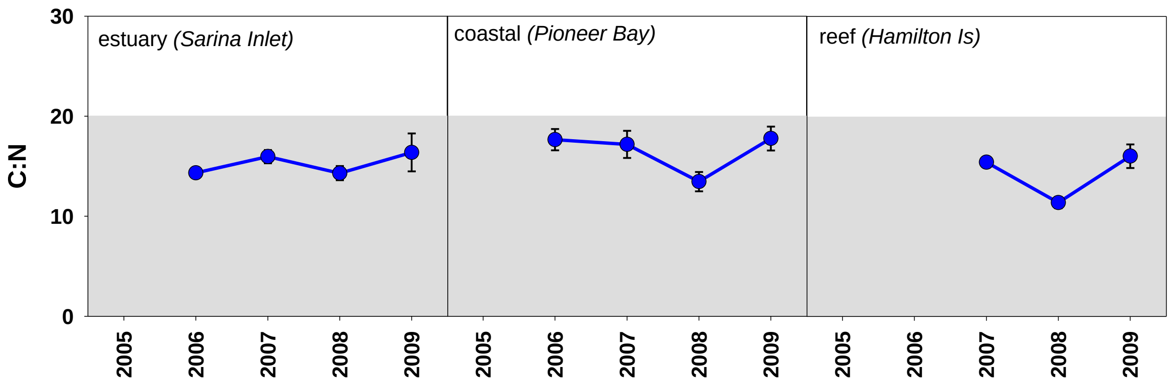


Figure 85. *Elemental ratios (atomic) of seagrass leaf tissue C:N for the foundation seagrass species examined at each habitat in Mackay Whitsunday region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the C:N ratio panel represents the accepted guideline seagrass "Redfield" ratio of 20:1 (Abal et al. 1994; Grice et al. 1996). C:N ratios below this line indicate reduced light availability.*

The C:P ratios of seagrass in the Mackay Whitsunday region increased in 2009 compared to the previous monitoring period (Figure 86). This indicates meadows have decreasing P pools (nutrient poor). The only habitat C:P ratios below 500 in 2009 was the estuary (Sarina Inlet), indicating the environment had a relatively large P pool.

N:P ratios within the Mackay Whitsunday region showed no consistent trend between habitats and no significant differences were observed ($p > 0.05$) (Figure 86). In 2009, levels for the foundation species in estuary and reef habitats were above 30, indicating P limitation to the plants. At the reef sites (Hamilton Island), the N:P ratio declined in 2008 to between 25 and 30, indicating replete, but in 2009 returned to a P limited state.

At Sarina Inlet, seagrass N:P ratios have generally increased since 2006, but 2009 and 2008 levels remained similar. Seagrass N:P ratios in Pioneer Bay varied between years and in 2009 retuned to replete.

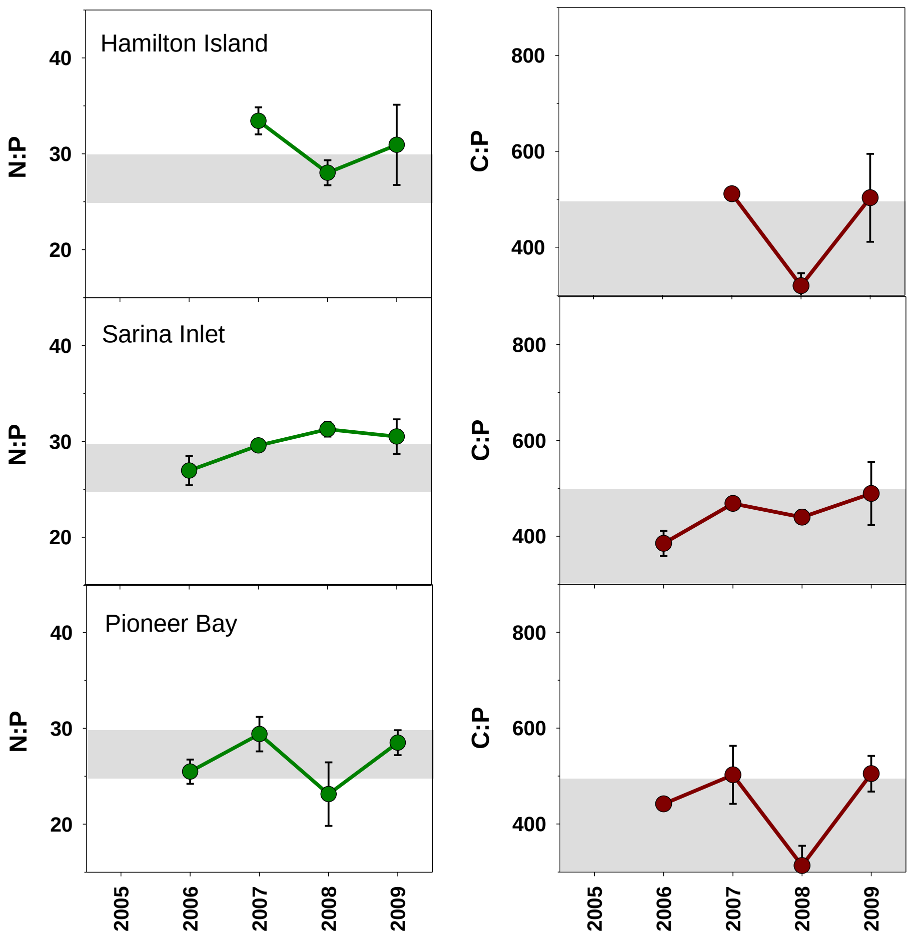


Figure 86. *Elemental ratios (atomic) of seagrass leaf tissue N:P and C:P for the foundation seagrass species examined at each location in Mackay Whitsunday region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation, below indicates N limitation and within indicates replete. Shaded portion on the C:P panel ≤500 represents the value associated with C:P balance ratio in the plant tissues, C:P values <500 may indicate nutrient rich habitats (large P pool).*

Epiphytes and macro-algae

Epiphyte cover on seagrass leaf blades was highly variable at both inshore coastal and estuarine sites (Figure 87, Figure 88). Although epiphyte cover appears seasonal, with higher abundance in the dry season of each year, cover over the last 12 months was similar to the previous monitoring period at the coastal sites, but significantly lower at the estuarine sites (Figure 87, Figure 88). Epiphyte cover declined at the reef habitat sites (Hamilton Island) over the monitoring period and long-term average (Figure 89)

Percentage cover of macro-algae at all habitats during the 2009/10 monitoring period was below the GBR long-term average for each respective habitat (Figure 87, Figure 88, Figure 89). Over the monitoring period, macro-algae abundance appears to have declined at coastal sites (Figure 87).

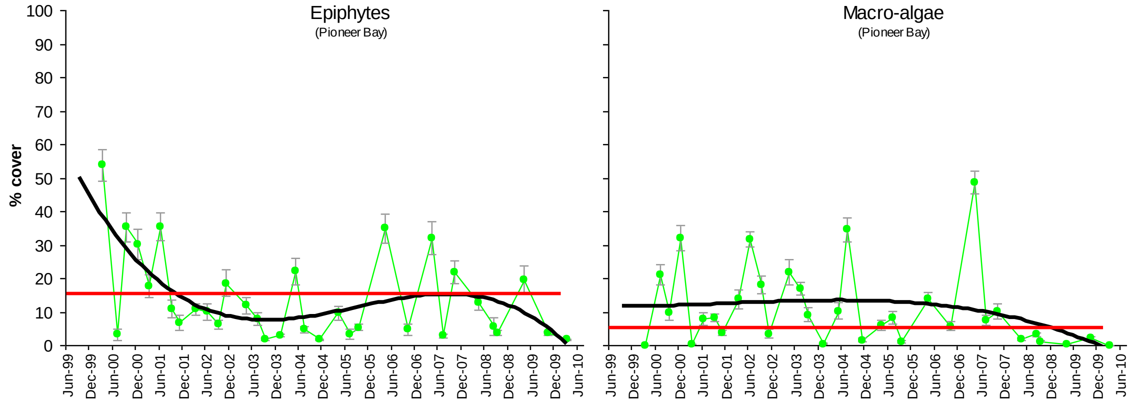


Figure 87. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal coastal (Pioneer Bay) seagrass monitoring sites. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

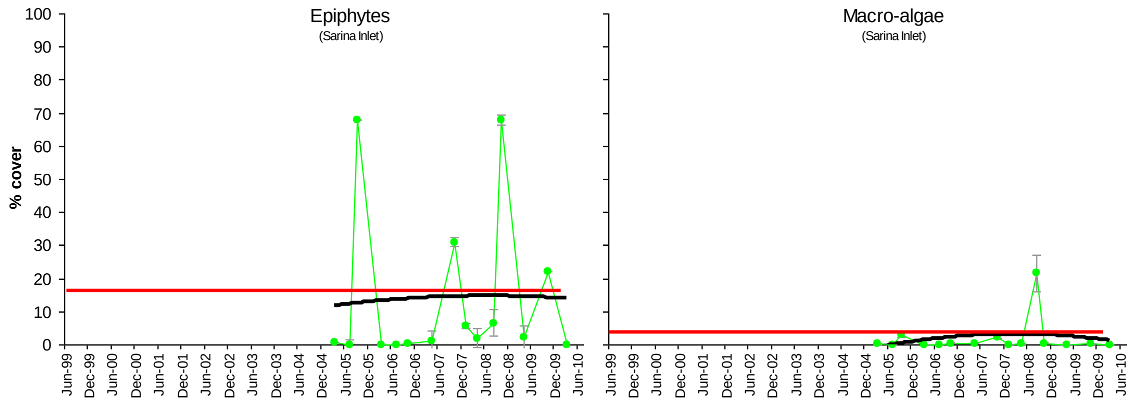


Figure 88. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at estuarine (Sarina Inlet) seagrass monitoring sites. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

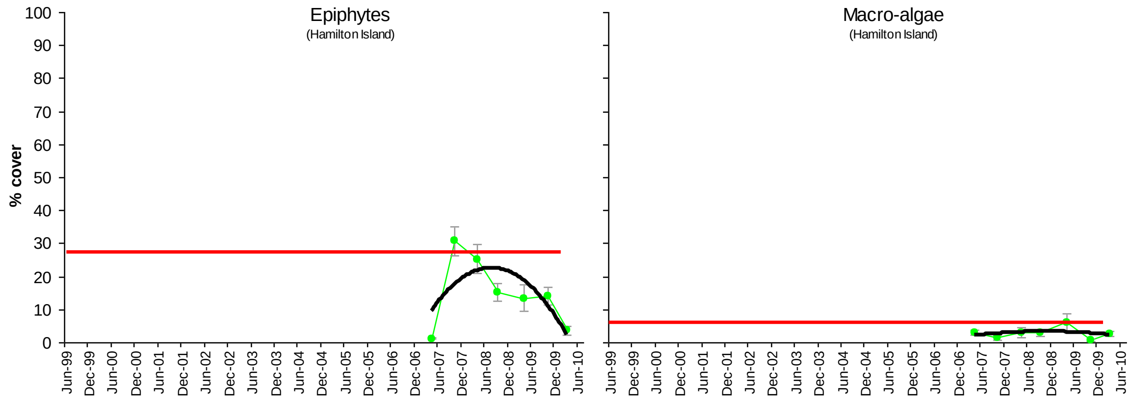


Figure 89. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal reef seagrass monitoring location. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

Within meadow canopy temperature

Temperature loggers were deployed at all sites monitored in the region (Figure 90). Within canopy temperature at coastal and estuarine locations (Figure 90) generally follows a similar pattern. No extreme temperatures (>40°C) were recorded over the last 12 months. Maximum temperatures peaked several times throughout the year at all locations, generally during the time of low spring tide (Figure 90).

Mean within canopy temperatures monitored at Pioneer Bay were within the 21 – 30°C range, with highest mean temperatures in February 2010. Hamilton Island within canopy temperatures were slightly lower within the 22-29°C range and similar to Pioneer Bay recording highest temperatures in February 2010. At Sarina Inlet, within canopy temperatures were slightly cooler again within 20-29°C range and the warmest month on average was December 2009 (Figure 91). Within canopy temperatures on average were warmer over the last monitoring period than previous years of monitoring.

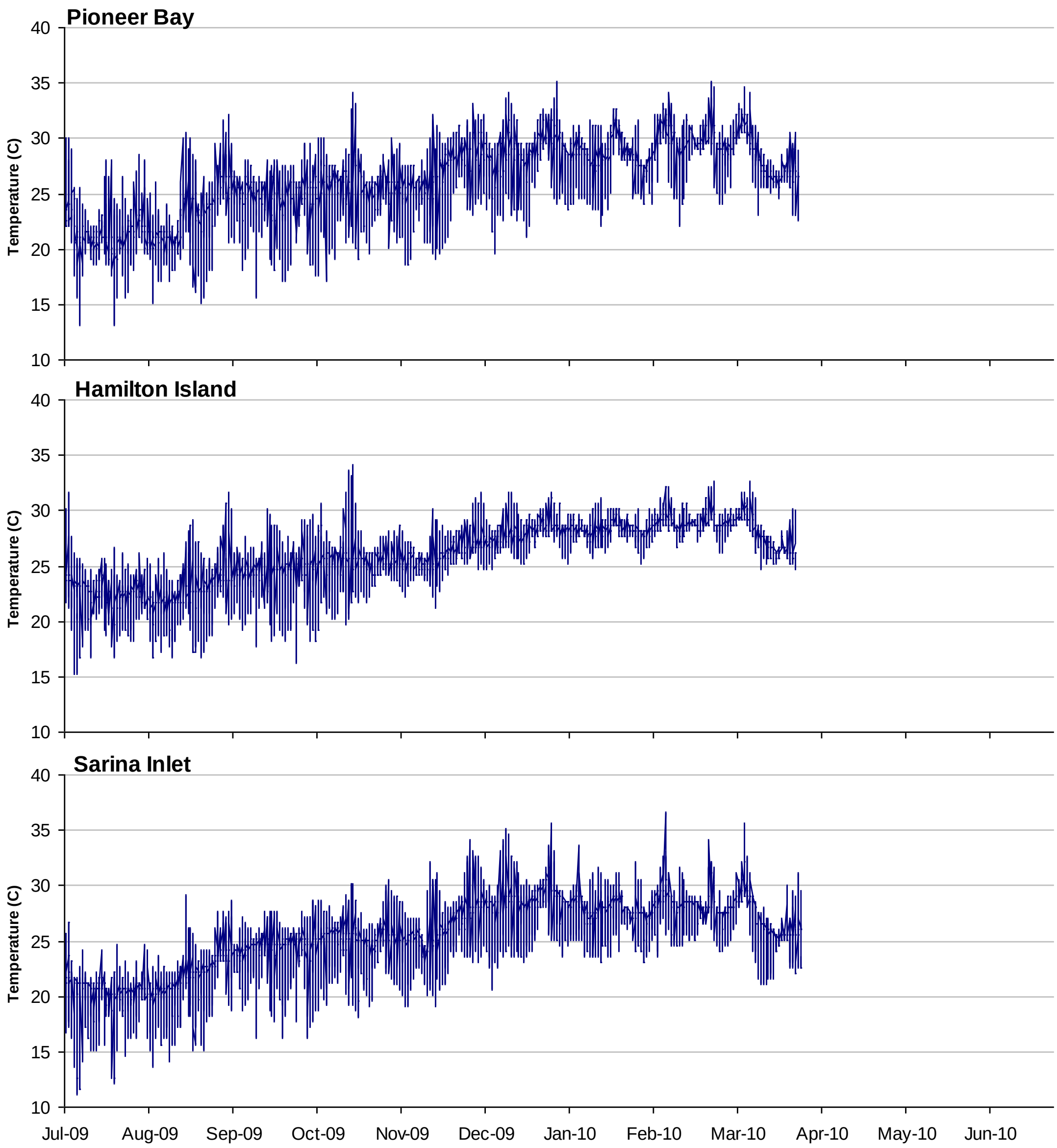


Figure 90. *Within seagrass canopy temperature (°C) at coastal (Pioneer Bay), estuarine (Sarina Inlet) and offshore fringing-reef (Hamilton Island) intertidal meadows within the Mackay Whitsunday region over the 2009/10 monitoring period.*

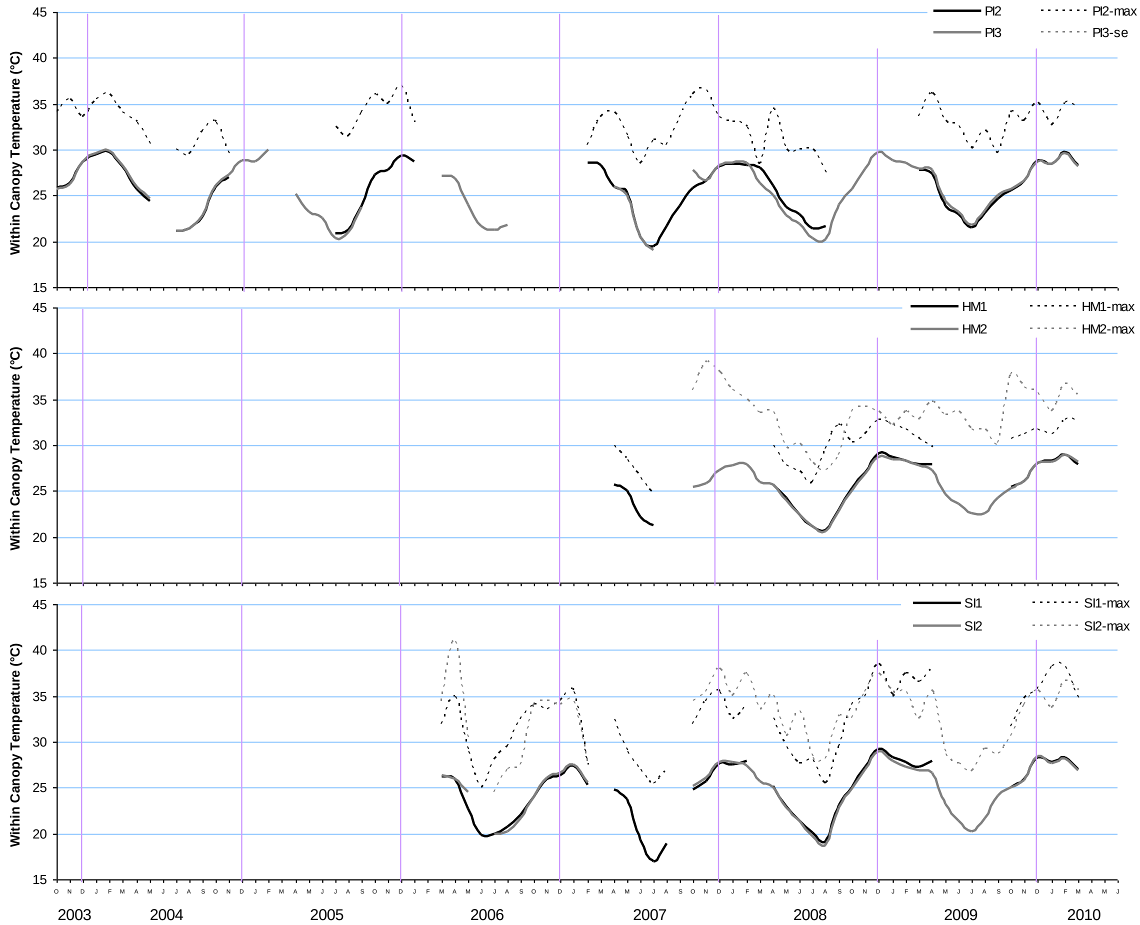


Figure 91. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Pioneer Bay), fringing-reef (Hamilton Island) and estuarine (Sarina Inlet) habitats within the Mackay Whitsunday region.*

Canopy incident light

Deployment of light loggers in the Mackay Whitsunday region expanded in 2009 to include a coastal site (Pioneer Bay) as well as a reef site (Hamilton Island) (Figure 92). Variance in light availability followed firstly a pattern of tidal cycle, then the seasonal pattern of winds where increased wind results in lower incident light levels. As data are only available for recent sampling periods correlations with seagrass responses will be analysed at a later date.

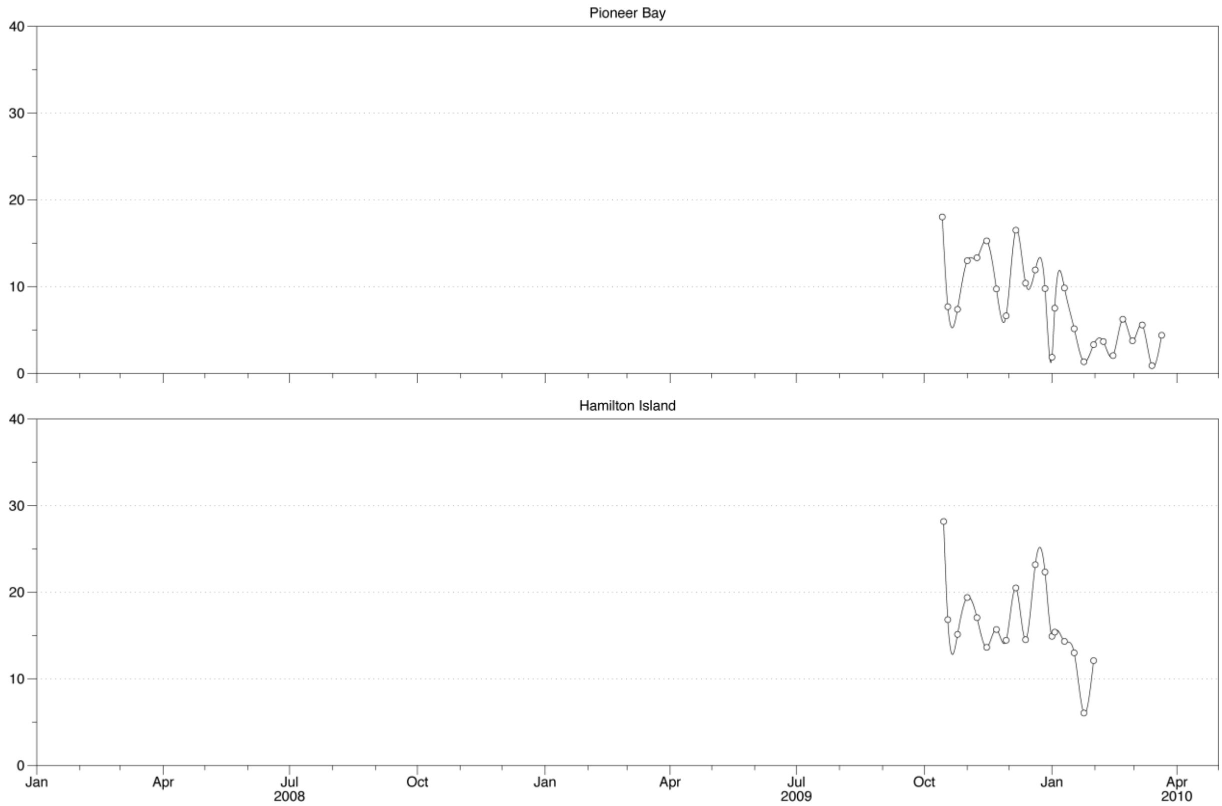


Figure 92. *Mackay Whitsunday region fortnightly averages of daily incident light (mmol photons per m^2 per day), at canopy height (2π light loggers; Submersible Odyssey Photosynthetic Irradiance Recording System, Dataflow Systems Pty Ltd, New Zealand placed in a wiper unit to keep the sensor clean) at four sites installed at seagrass canopy height.*

Regional Climate

Whitsundays – Hamilton Island and Pioneer Bay

The mean maximum daily air temperature recorded at Hamilton Island during 2009 was 26.5°C, this was less than both the decade and long-term averages. The highest recorded daily maximum temperature in 2009 was 31.7 °C.

2009 had average rainfall relative to the long-term and decade averages (Figure 93). Mean wind speed in 2009 was 28.9 km.hr^{-1}, this was higher than both the long-term and decade averages.

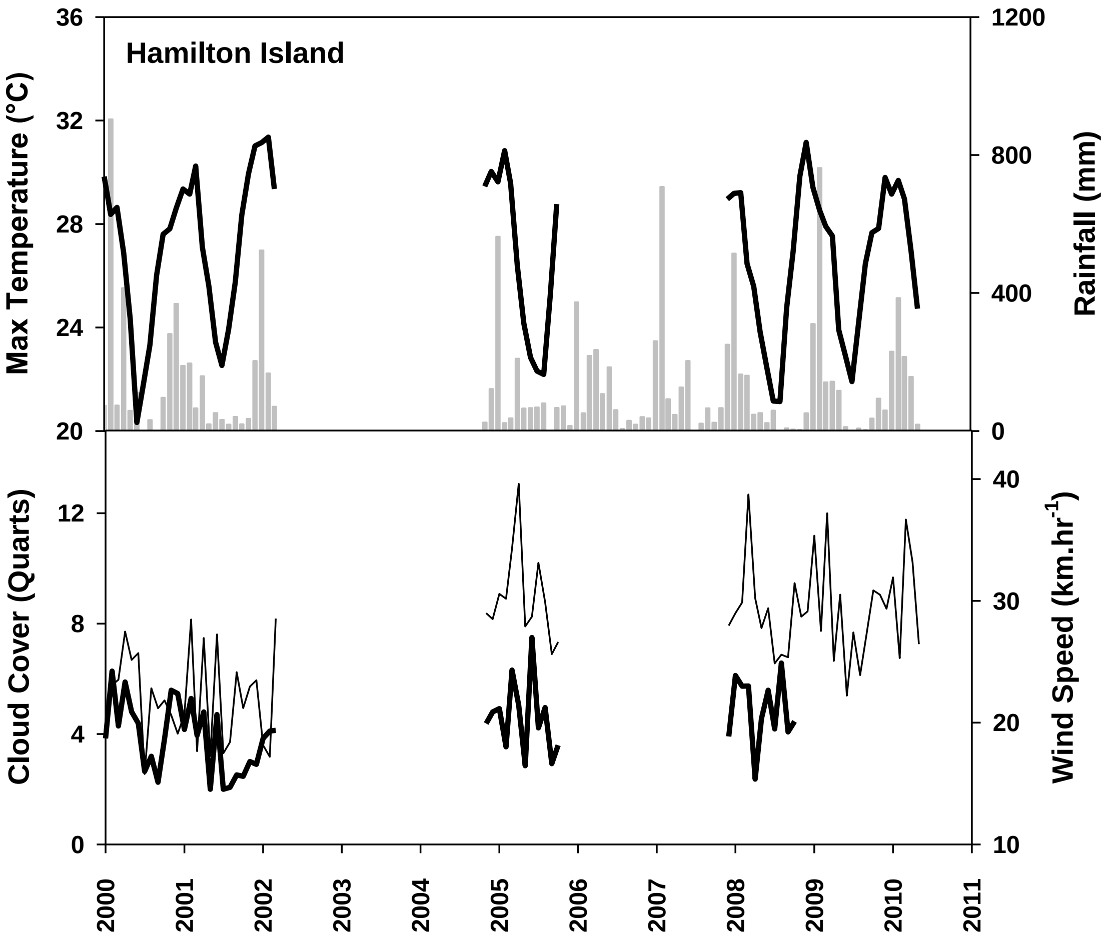


Figure 93. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr^{-1}) recorded at Hamilton Island (BOM station 033106) (Source www.bom.gov.au). Hamilton Island also used as a surrogate for the climate at Pioneer Bay.*

Mackay – Sarina Inlet

The mean maximum daily air temperature recorded in Mackay during 2009 was 27.4°C, this was 1.0°C higher than the long-term year average but the same as the decade average. The highest recorded daily maximum temperature in 2009 was 34.4 °C.

2009 was a wet year relative to the last decade but approximately similar to the long-term average (Figure 94). Mean wind speed in 2009 was 19.2 km.hr^{-1}, this was less than the both the long-term and decade averages.

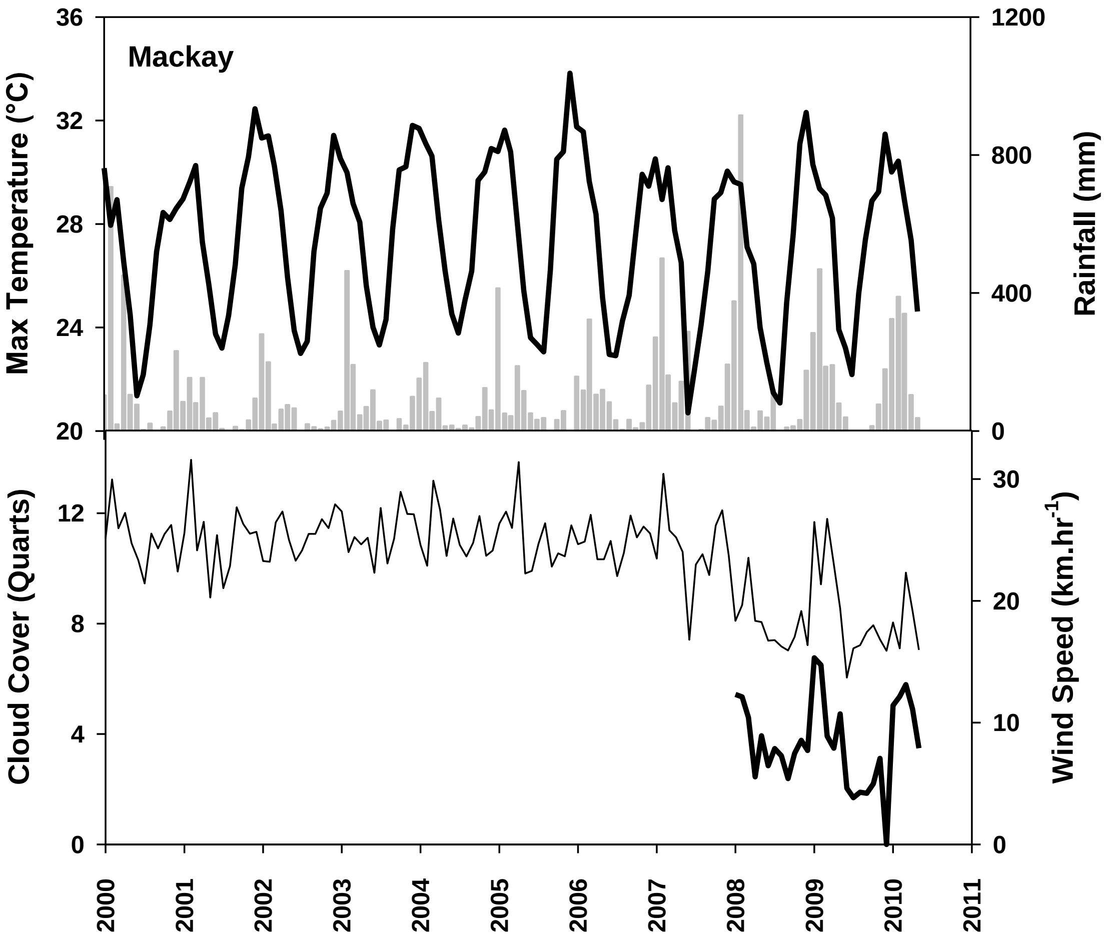


Figure 94. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr-1) recorded at Mackay Airport (BOM station 033045) (Source www.bom.gov.au). Mackay Airport used as a surrogate for the climate at Sarina Inlet.*

Fitzroy

2009/10 Summary

Intertidal seagrass meadows in the Fitzroy region are abundant on the large sand/mud banks in sheltered areas of the region's estuaries and coasts, and occur on the fringing reef flat habitats of offshore islands. All three habitat types are monitored. Environmental drivers include high turbidity and desiccation (which is linked to the large tide regime). Coastal and estuarine meadows have remained stable in extent and seagrass abundance continued to increase/improve (good to fair status) during 2009/10. Reef seagrasses at Great Keppel have continued to decline (poor). Although there were no seed banks, the high reproductive effort at the reef sites suggests the meadows have high capacity to recover through the recruitment of new plants. Seagrass tissue nutrient concentrations indicate that light environment improved at the estuary but remained low (limited) at reef and coastal habitats. Nutrient concentrations do not appear to have changed at reef sites (saturated with N and P), however at the other habitats, although they had less P (decreasing P pool), the coast and estuary had high or elevated N, respectively. Epiphyte cover has changed little, and remains below the GBR long-term average for each habitat. Climate in the region was hotter, drier and windier than the long-term average. No extreme temperatures were recorded within the seagrass canopy over the last 12 months, although coastal and reef habitats were warmer in 2009/10 than previous. Overall the status of seagrass condition in the region was rated as moderate.

Table 22. *Report card for seagrass status (community & environment) for the Fitzroy NRM region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100. Green = good, yellow = moderate, gold = fair, red = poor.*

Habitat	Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index^**
reef intertidal	8	67	33	33	**35**
coastal intertidal	92	0	67	67	**56**
estuarine intertidal	56	0	33	67	**39**
Fitzroy	52	33	33	67	**46**

Background

The Fitzroy region covers an area of nearly 300,000 km^2. It extends from Nebo in the north to Wandoan in the south, and to the Gemfields in the west and encompasses the major systems of the Fitzroy, Boyne, and Calliope rivers as well as the catchments of the smaller coastal streams of the Capricorn and Curtis Coasts (Australian Government Land and Coasts 2010d). The Fitzroy River is the largest river system running to the east coast of Australia. The Boyne and Calliope Rivers drain the southern part of the region, entering the GBR lagoon at Gladstone. The region covers ten percent of Queensland’s land area and is home to approximately 200,000 people. It is one of the richest areas in the state in terms of land, mineral and water resources and supports grazing, irrigated and dryland agriculture, mining, forestry and tourism land uses (Fitzroy Basin Association 2004). Agricultural production constitutes the largest land use in Central Queensland, with nearly 90% of the land under agricultural production. Concomitant with this land use is the usual concern of the quality of the water that is entering the GBR lagoon. While streams further north deliver water to the lagoon every year, about once per decade the Fitzroy floods to an extent that affects the Reef. However, the smaller annual flows deliver sediments and nutrients affecting coastal habitats.

The Fitzroy region experiences a tropical to subtropical humid to semi arid climate. Annual median rainfall throughout the region is highly variable, ranging from about 600 mm annually at Emerald to more than 800 mm along the coast, and over 1000mm in the north, where coastal ranges trap moist on-shore airflow. Most rain falls in the summer, with many winters experiencing no rain at all. Because of the tropical influence on rainfall patterns, heavy storms can trigger flash flooding, and occasional cyclones wreak havoc.

Reef Rescue monitoring sites within this region are located in coastal, estuarine or fringing-reef seagrass habitats. Coastal sites are monitored in Shoalwater Bay and are located on the large intertidal flats of the north western shores of Shoalwater Bay. The remoteness of this area (due to its zoning as a military exclusion zone) represents a near pristine environment, removed form anthropogenic influence. In contrast, the estuarine sites are located within Gladstone Harbour: a heavily industrialized port. Offshore reef sites are located at Monkey Beach, Great Keppel Island.

The Shoalwater Bay monitoring sites are located in a bay which is a continuation of an estuarine meadow that is protected by headlands. A feature of the region is the large tidal amplitudes and consequent strong tidal currents (Figure 95). As part of this tidal regime, large intertidal banks are formed which are left exposed for many hours. Pooling of water in the high intertidal, results in small isolated seagrass patches 1-2m above Mean Sea Level (MSL).

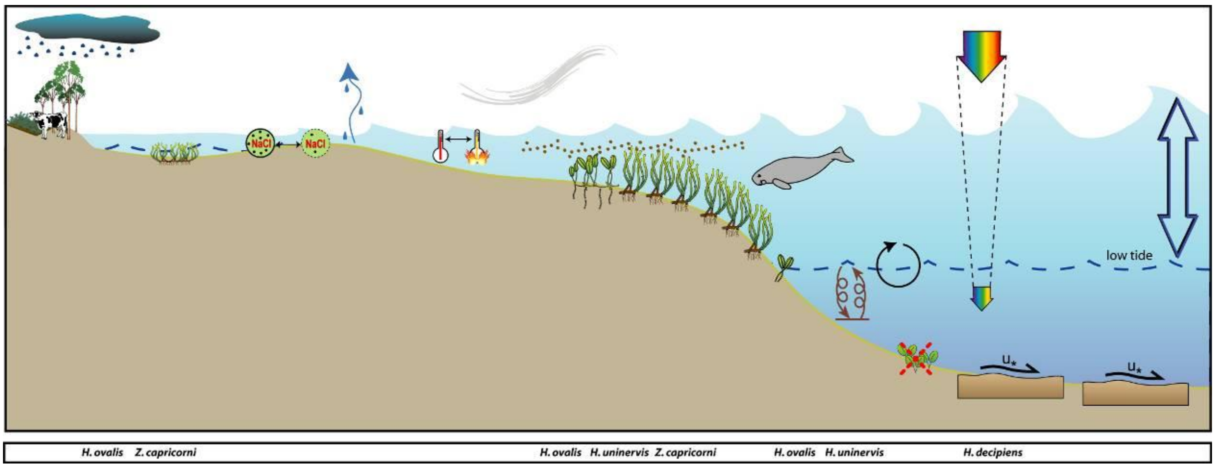


Figure 95. *Conceptual diagram of coastal habitat in the Fitzroy region – major control is pulsed light, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (see Figure 2 for icon explanation).*

Estuarine seagrass habitats in the southern Fitzroy region tend to be intertidal, on the large sand/mud banks in sheltered areas of the estuaries. Tidal amplitude is not as great as in the north and estuaries that are protected by coastal islands and headlands support meadows of seagrass. These habitats feature scouring, high turbidity and desiccation (linked to this large tide regime), and are the main drivers of distribution and composition of seagrass meadows in this area (Figure 96). These southern estuary seagrasses (Gladstone, Port Curtis) are highly susceptible to impacts from local industry and inputs from the Calliope River. Port Curtis is highly industrial with the world's largest alumina refinery, Australia's largest aluminium smelter and Queensland's biggest power station. In addition, Port Curtis contains Queensland's largest multi-cargo port (Port of Gladstone) with 50 million tonnes of coal passing through the port annually.

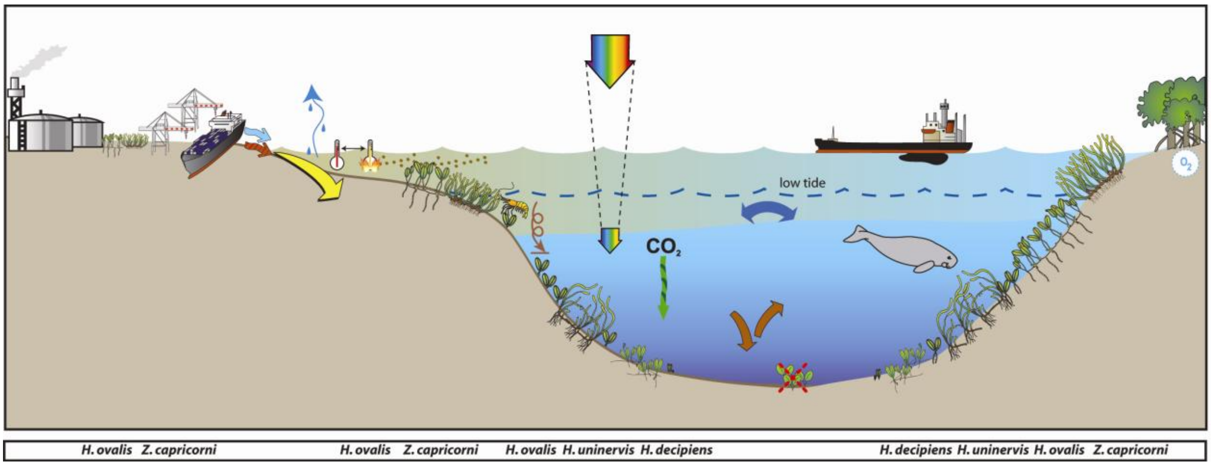


Figure 96. *Conceptual diagram of estuary habitat in the Fitzroy region – major control variable rainfall and tidal regime: general habitat, seagrass meadow processes and threats/impacts (see Figure 2 for icon explanation).*

Status of the seagrass community

Seagrass abundance and composition

Seagrass species composition differed greatly between inshore (coastal and estuarine) and offshore (reef) habitats. Inshore coastal sites monitored in Shoalwater Bay at Ross Creek (RC1) and Wheelans Hut (WH1) were dominated by *Zostera capricorni* with some *Halodule uninervis* and minor quantities of *Halophila ovalis* (Figure 98). Seagrass cover at the coastal sites over the last monitoring period was similar to the 2008/09 monitoring period and remains higher than when monitoring first commenced in early 2002 (Figure 97). The overall trend in seagrass abundance over the last 7 years has been an increase.

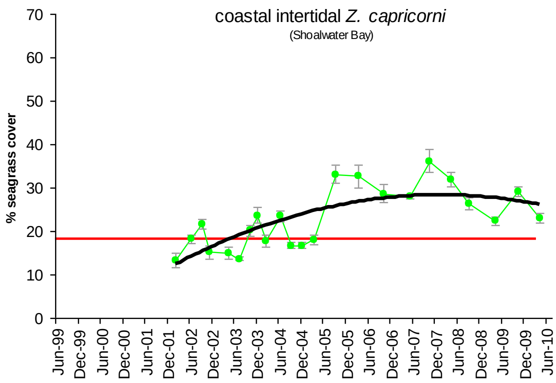


Figure 97. *Change in seagrass abundance (percentage cover) at coastal intertidal meadows in Shoalwater Bay (Fitzroy region). Red line = GBR long-term average for coastal habitats.*

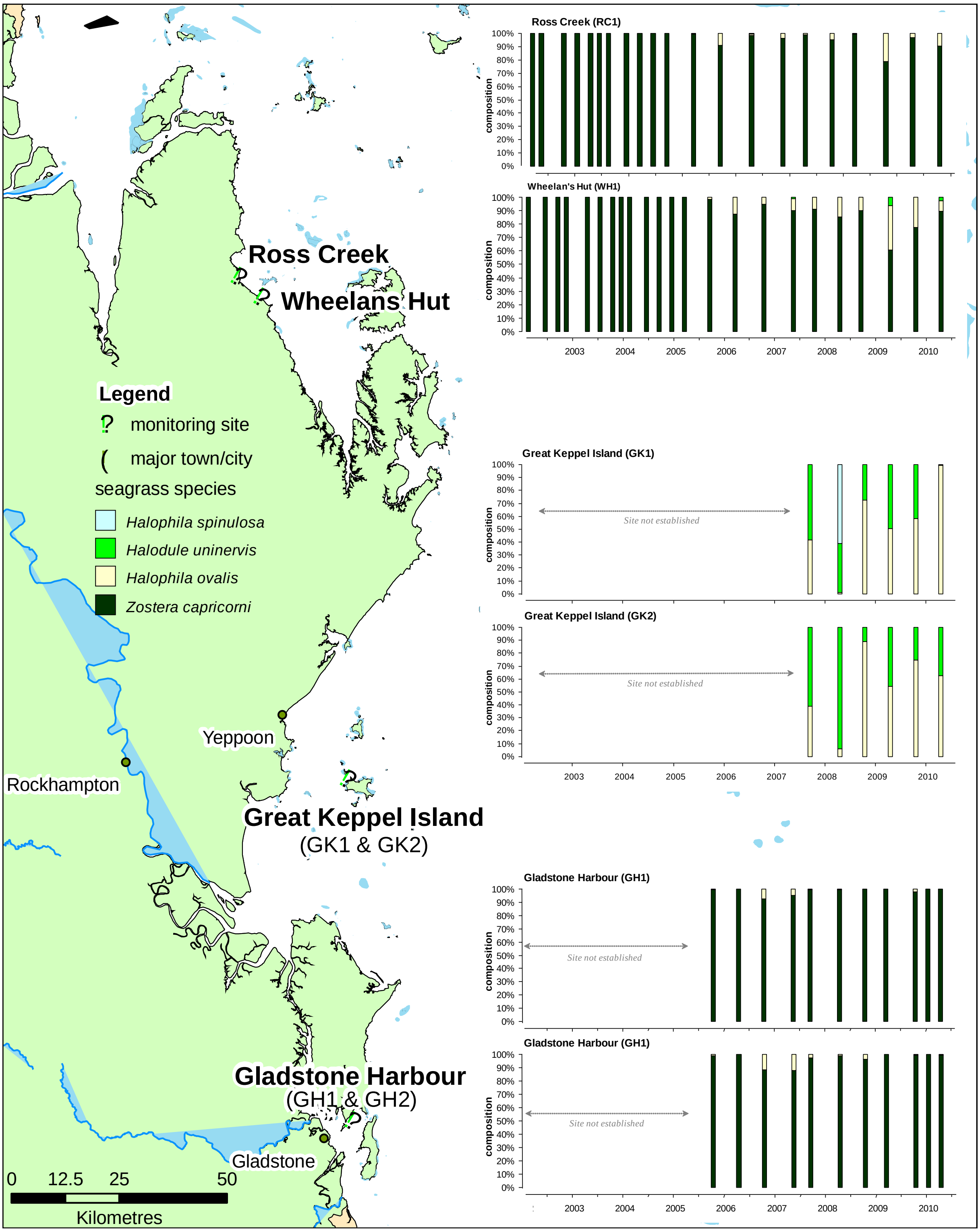


Figure 98. *Location of Fitzroy region long-term monitoring sites and the seagrass species composition at each site. Please note: some replicate sites within 500m of each other.*

Quadrat at 5m on transect 1 at Wheelans Hut (Shoalwater Bay WH1), on 4 April 2009 (left) and 14 April 2009 (right)

Shoalwater Bay seagrass abundance does not appear to show a clear seasonal pattern (Figure 99), but this may be a consequence of the long-term increase in abundance which could mask intra-annual changes and the limitation of sampling to biannual from 2005.

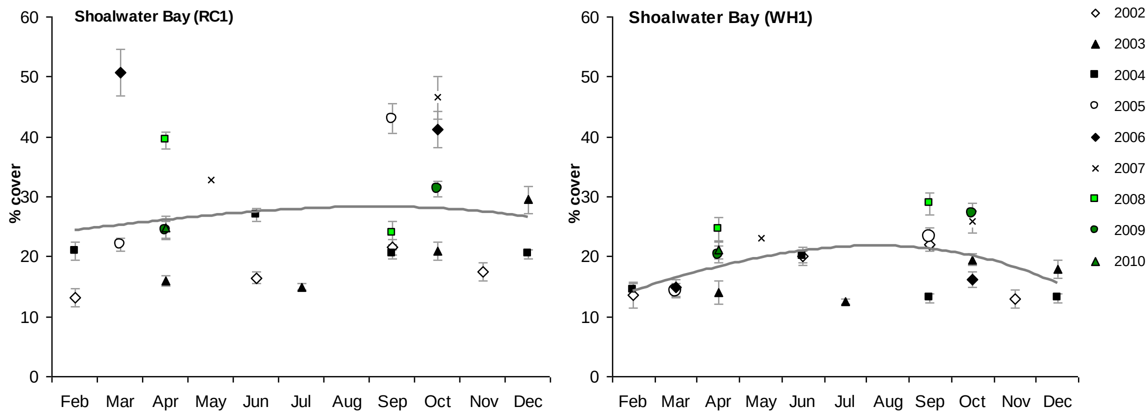


Figure 99. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Shoalwater Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Gladstone Harbour estuarine sites were located in a large *Zostera capricorni* dominated meadow (Figure 98) on the extensive intertidal Pelican Banks south of Curtis Island. Species composition has remained stable; however abundance has differed greatly between years (Figure 100). Abundance observed over the 2009/10 monitoring period were some of the highest recorded since monitoring was established in 2005. Although data is limited, inter-annual abundances suggest a seasonal pattern of higher seagrass abundance in the late dry and lower in the late monsoon (Figure 101).

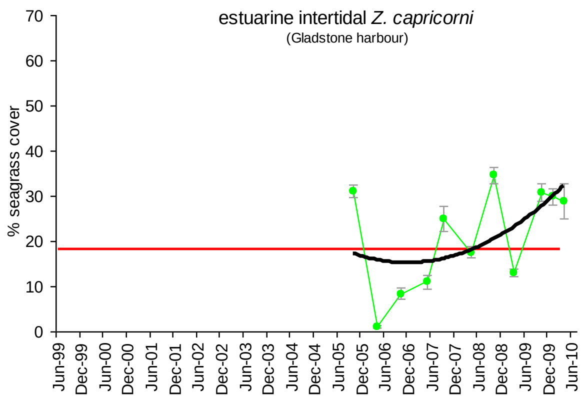


Figure 100. *Change in seagrass abundance (percentage cover) at estuarine intertidal meadows in Gladstone Harbour (Fitzroy region). Red line = GBR long-term average for estuarine habitat.*

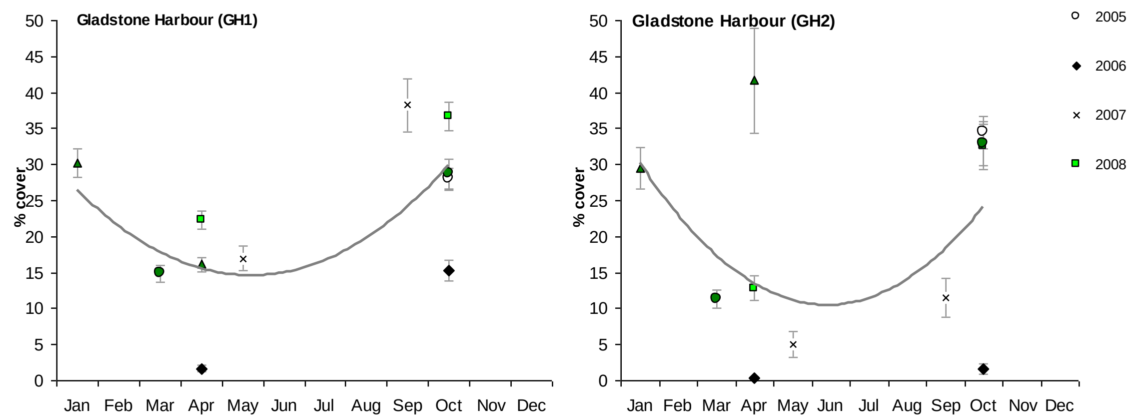


Figure 101. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Shoalwater Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

The monitoring sites at Great Keppel Island (GK1 and GK2) differ greatly from the inshore sites, being composed predominately of *H. uninervis* on sand substrate (Figure 98). Seagrass abundance has continued to decline since monitoring was established in 2007 (Figure 102), and due to the paucity of data no seasonal patterns are apparent (Figure 103).

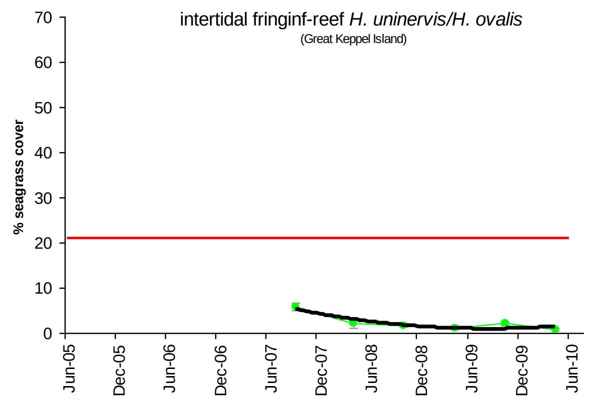


Figure 102. *Change in seagrass abundance (percentage cover) at intertidal fringing –reef meadows at Great Keppel Island (Fitzroy region). Red line = GBR long-term average for reef habitat.*

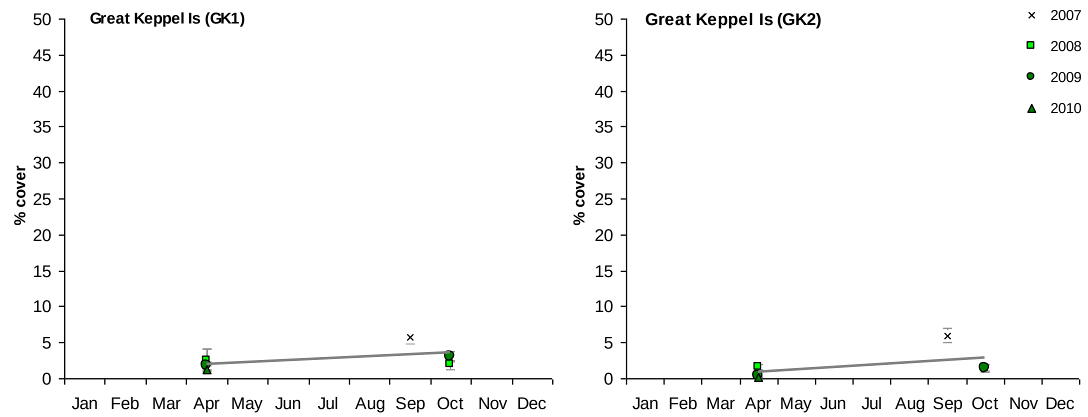


Figure 103. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Great Keppel Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass abundance relative to the seagrass guidelines indicates that the coastal meadows in Shoalwater Bay (Ross Creek and Wheelans Hut,) were in a good state, whereas the reef meadows (Great Keppel Island) were in a poor state throughout the 2009/10 monitoring period. Estuarine meadows in Gladstone Harbour were still recovering and were classified in a fair state (Figure 104).

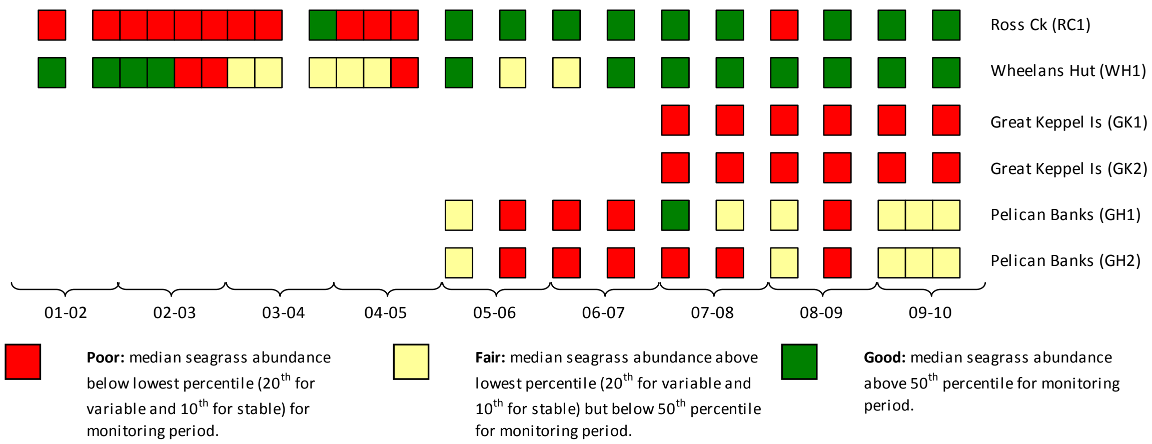


Figure 104***. Status of seagrass abundance in the Fitzroy region relative to the seagrass guidelines since monitoring was established in 2001. Each block represents the seasonal monitoring event (dry, late dry, monsoon, late monsoon), with time along the x-axis from left to right.***

Seagrass meadow edge mapping was conducted within a 100m radius of all monitoring sites in September/October and March/April of each year (Table 23) to determine if changes in abundance were a consequence of the meadow edges changing. The coastal meadows in Shoalwater Bay (RC1 and WH1) have remained stable since monitoring began, however the meadows at the estuarine (Gladstone Harbour) and reef (Great Keppel Island) habitats have changed greatly (Figure 105).

The Gladstone Harbour meadow, which was absent in early 2006, has since recovered and stabilised over the last two monitoring periods (Table 23, Figure 105). On the fringing reef platform of Great Keppel Island the seagrass meadows decreased in extent in 2008, but has since continued to increase, stabilising over the 2009/10 monitoring period (Table 23, Figure 105).

Table 23. *Area (ha) of seagrass meadow within 100m radius of each monitoring site. Value in parenthesis is % change from the baseline (bold) and description of change from previous mapping. Shading indicates decrease in meadow area since baseline. NA=no data available as site not established.*

	Shoalwater Bay		Gladstone Harbour		Great Keppel Island	
Date	**RC1**	**WH1**	**GH1**	**GH2**	**GK1**	**GK2**
October 2005	**5.38**	**5.397**	**5.394**	**5.174**	*NA*	*NA*
April 2006	5.38 *(No change)*	5.397 *(No change)*	0 *(-100%, meadow absent)*	0 *(-100%, Meadow absent)*	*NA*	*NA*
October 2006	5.396 *(0.3%, increase shoreward)*	5.397 *(No change)*	5.394 *(meadow recovered)*	5.394 *(4.3%, Meadow recovered)*	*NA*	*NA*
April 2007	5.384 *(0.01%, increase shoreward)*	5.397 *(No change)*	5.394 *(meadow recovered)*	5.174 *(0.01%, decrease seaward)*	*NA*	*NA*
October 2007	5.396 *(0.3%, negligible)*	5.397 *(No change)*	4.179 *(-22.5%, decrease overall)*	4.733 *(-8.5%, decrease seaward)*	**2.513**	**3.998**
April 2008	5.396 *(0.3%, stable)*	5.397 *(No change)*	4.487 *(-16.8%, increase overall)*	5.087 *(-1.7%, increase shoreward)*	0.526 *(-79.1%, decrease overall)*	2.368 *(-40.8%,decrease overall)*
October 2008	5.396 *(0.3%, stable)*	5.397 *(No change)*	5.074 *(-5.9%, increase overall)*	4.829 *(-6.7%, decrease seaward)*	0.933 *(-62.9%, increase overall)*	3.201 *(-19.9%, increase overall)*
April 2009	5.396 *(0.3%, stable)*	5.397 *(No change)*	5.027 *(-6.8%, decrease shoreward)*	5.281 *(2.1%, increase shoreward)*	1.814 *(-27.8%, increase overall)*	2.234 *(-44.1%, decrease overall)*
October 2009	5.396 *(no change)*	5.397 *(no change)*	4.742 *(-12.1%, decrease overall)*	4.997 *(-3.4%, decrease overall)*	2.444 *(2.8%, increase overall)*	3.712 *(7.2%, increase overall)*
April 2010	5.396 *(no change)*	5.397 *(no change)*	5.158 *(4.4%, increase overall)*	5.301 *(2.5%, increase overall)*	2.384 *(-5.1%, decrease shoreward)*	3.821 *(4.4%, increase overall)*

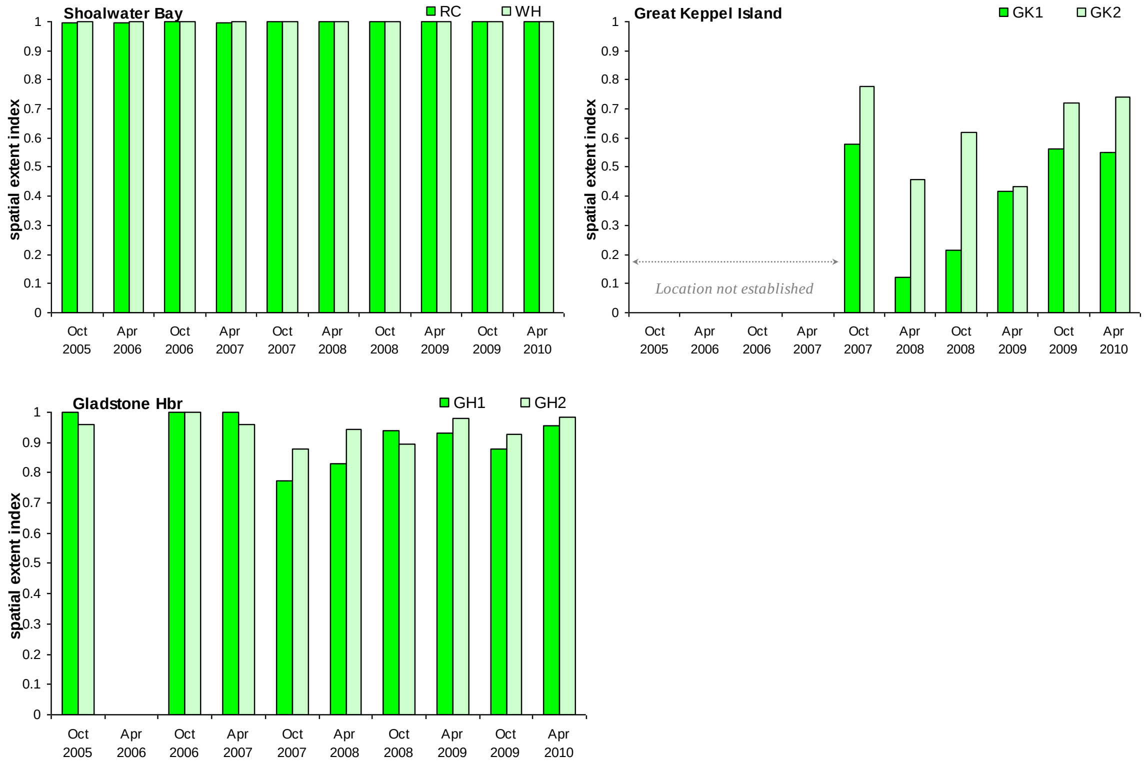


Figure 105. *Extent of area (100m radius of monitoring site) covered by seagrass at each monitoring site at Shoalwater Bay, Great Keppel Island and Gladstone Harbour locations.*

Seagrass reproductive status

Reproductive effort declined at coastal and estuarine sites in the Fitzroy region (*Figure 106*), below the GBR long-term average for both habitat types. The reef sites were above the GBR long-term average and high for the location.

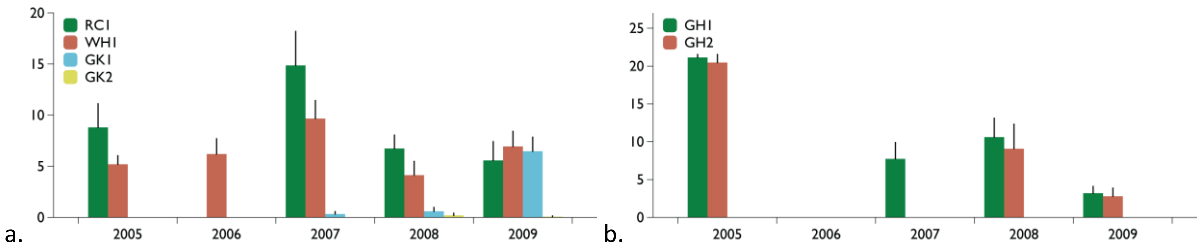


Figure 106. Mean reproductive effort (number of reproductive structures per core ± s.e.) during dry season sampling from 2005–2009 for Fitzroy region sites, a. Shoalwater Bay and Great Keppel Island, b. Gladstone Harbour.

Although there were no seed banks, the high reproductive effort at one of the reef sites and both coastal sites suggests the meadows have a high capacity to recover following disturbance. Should the declining trend in reproductive effort continue at the Fitzroy estuarine sites, there should be cause for concern regarding their recovery potential.

Status of the seagrass environment

Seagrass tissue nutrients

Seagrass meadows in the Fitzroy region at Shoalwater Bay and Great Keppel Island appear to be in low light environments due to their low C:N ratios (C:N < 20) (Figure 107). Gladstone Harbour however indicates light availability increased as C:N ratios were above 20 in 2009. Ratios recorded for foundation species at all sites were higher in late dry 2009 relative to 2008, indicating an improving light environment.

C:P ratios for foundation species at estuarine and coastal habitats in the Fitzroy region were above 500 in late dry 2009 (Figure 108), indicating that the P pool was relatively small. At Great Keppel Island, C:P ratios have remained stable below 500, indicating a nutrient rich environment and large P pool. At Shoalwater Bay however, C:P ratios have consistently increased since commencement of monitoring, indicating the location is increasingly nutrient poor.

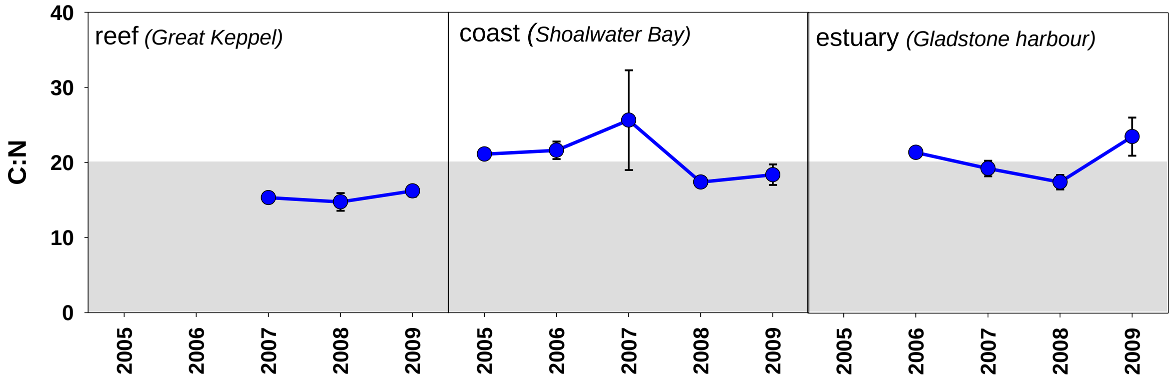


Figure 107. *Elemental ratios (atomic) of seagrass leaf tissue C:N for the foundation seagrass species examined at each habitat in the Fitzroy region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the C:N ratio panel represents the accepted guideline seagrass "Redfield" ratio of 20:1 (Abal et al. 1994; Grice et al. 1996). C:N ratios below this line indicate reduced light availability (limitation)*

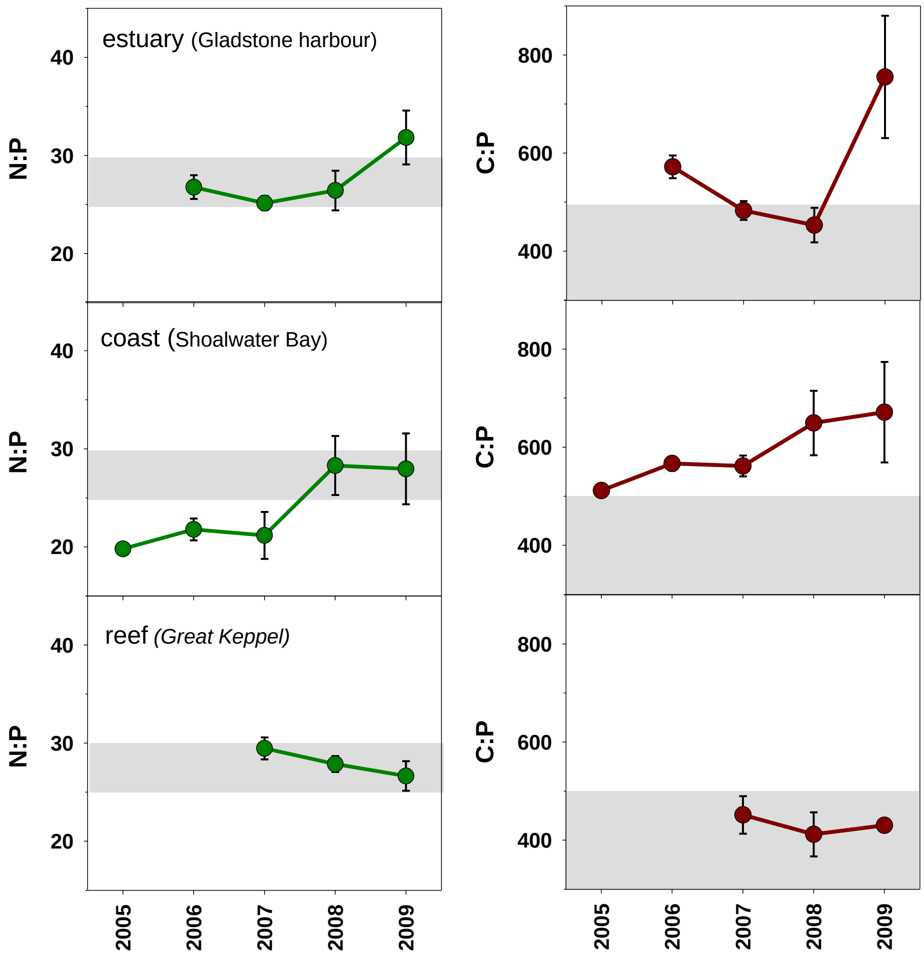


Figure 108. *Elemental ratios (atomic) of seagrass leaf tissue N:P and C:P for the foundation seagrass species examined at each location in the Fitzroy region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues. N:P ratio above this band indicates P limitation, below indicates N limitation and within indicates replete. Shaded portion on the C:P panel ≤500 represents the value associated with C:P balance ratio in the plant tissues, C:P values <500 may indicate nutrient rich habitats (large P pool).*

N:P ratios for foundation species at coast and reef habitats in the Fitzroy region were below 30 but above 25 in late dry 2009 (Figure 108); indicating that the environment was saturated with nutrients as the plants were replete. At Gladstone Harbour however, N:P ratios were above 30 suggesting plants were potentially P limited. N:P ratios in Shoalwater Bay have consistently increased since 2005, from N limited to replete. Great Keppel Island N:P ratios consistently decreased while Shoalwater Bay consistently increased. Within Great Keppel Island seagrass meadows, N:P ratios have declined since 2007, indicating increasing potential for N limitation.

Epiphytes and Macro-algae

Epiphyte cover on seagrass leaf blades at Shoalwater Bay and Great Keppel Island remained below the GBR long-term average for coastal and reef habitats respectively over the 2009/10 monitoring period, but were more variable at Gladstone Harbour (Figure 109, Figure 110, Figure 111). Epiphyte cover at most habitats appears higher during the late dry compared to the late monsoon.

Macro-algae cover is generally low at Showalter Bay and has fluctuated greatly at the estuarine sites in Gladstone Harbour (Figure 109, Figure 110, Figure 111). Macro-algae cover at Great Keppel Island in the late monsoon 2010, however, increased to above the GBR long-term average for reef habitats.

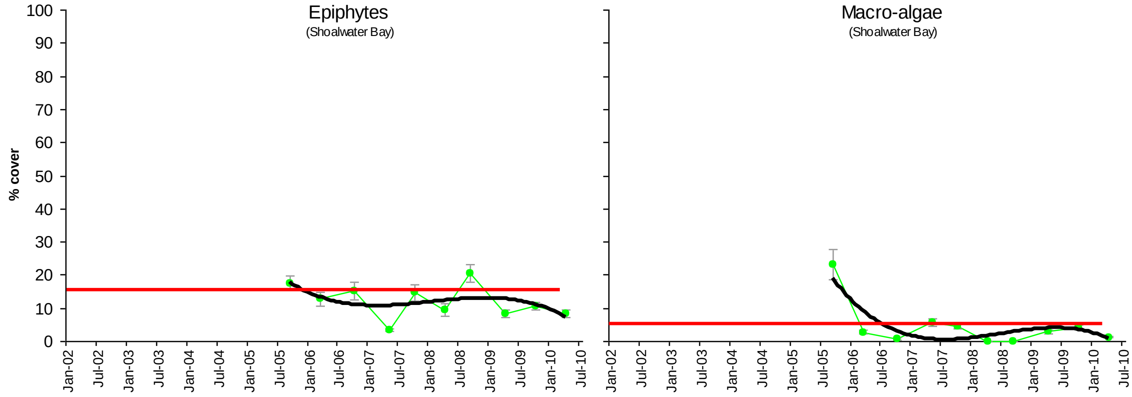


Figure 109. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal coastal (Shoalwater Bay) seagrass monitoring sites. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

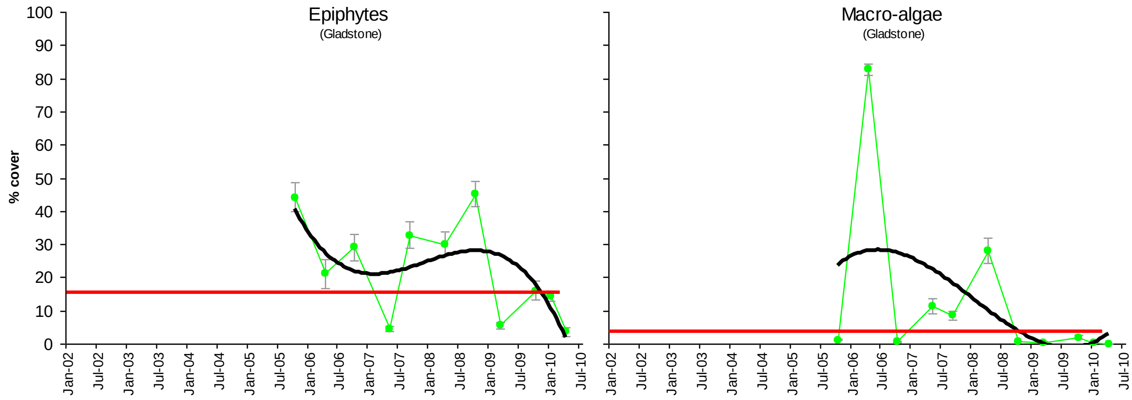


Figure 110. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal estuarine (Gladstone Harbour) seagrass monitoring sites. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

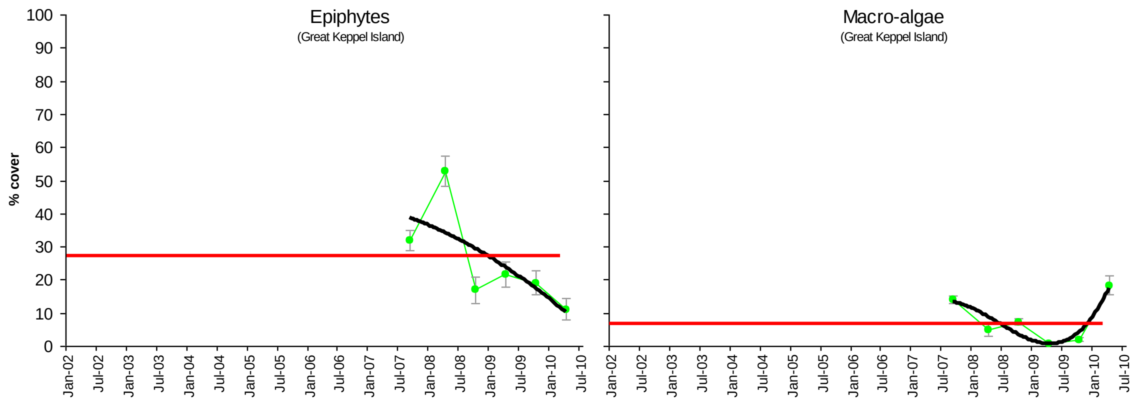


Figure 111. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at the intertidal offshore reef (Great Keppel Island) seagrass monitoring location. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

Within meadow canopy temperature

Temperature loggers were deployed at all monitoring sites over the monitoring period (Figure 112). Mean within canopy temperature monitored at Great Keppel Island ranged from 19 - 28°C, while at Shoalwater Bay and Gladstone harbour mean temperatures ranged from 20 - 28°C. The lowest mean temperatures across the region occurred in July and highest in December/January. Temperatures were 0.3 – 0.5°C warmer at Shoalwater Bay and Great Keppel Island in the 2009/10 than the previous monitoring period.

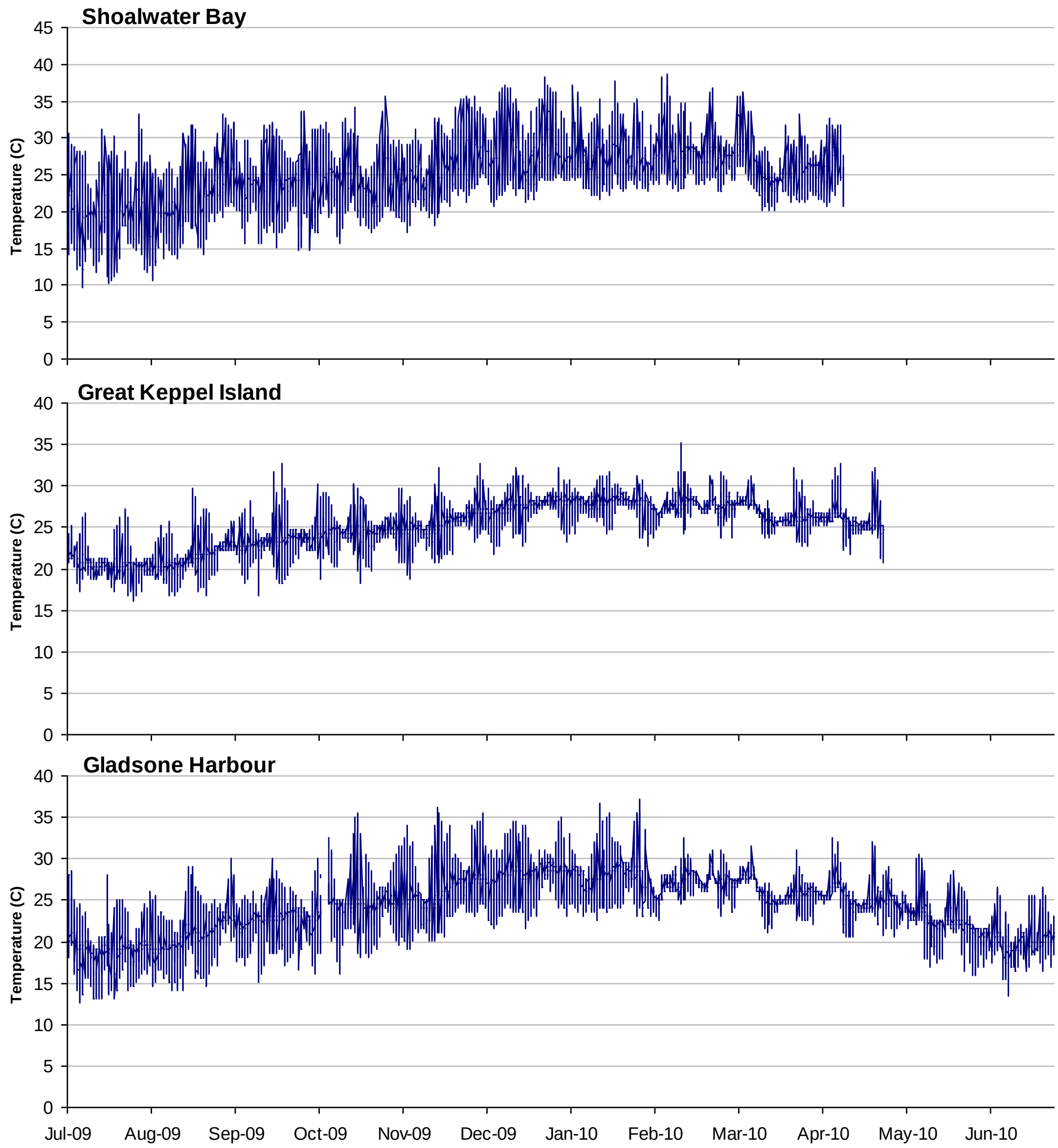


Figure 112. *Within seagrass canopy temperature (°C) at coastal (Shoalwater Bay), offshore fringing-reef (Great Keppel Island) and estuarine (Gladstone Harbour) intertidal meadows within the Fitzroy region over the 2009/10 monitoring period.*

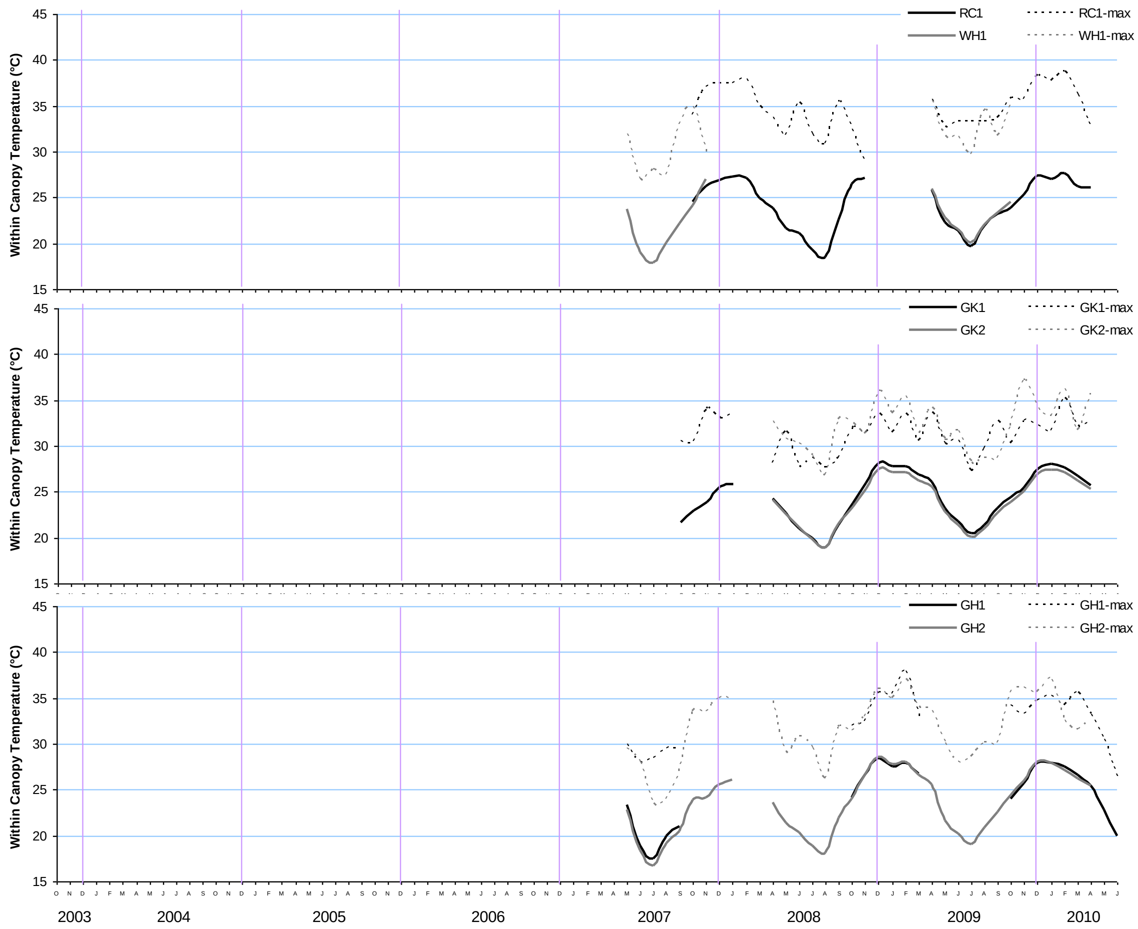


Figure 113. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Shoalwater Bay), fringing-reef (Great Keppel Island) and estuary (Gladstone Harbour) monitoring habitats within the Fitzroy region.*

Canopy incident light

Deployment of light loggers in the Fitzroy region began in 2009 to include a reef site (Great Keppel) (Figure 114). Variance in light availability followed firstly a pattern of tidal cycle, then the seasonal pattern of winds where increased wind results in lower incident light levels. As data are only available for recent sampling periods correlations with seagrass responses will be analysed at a later date.

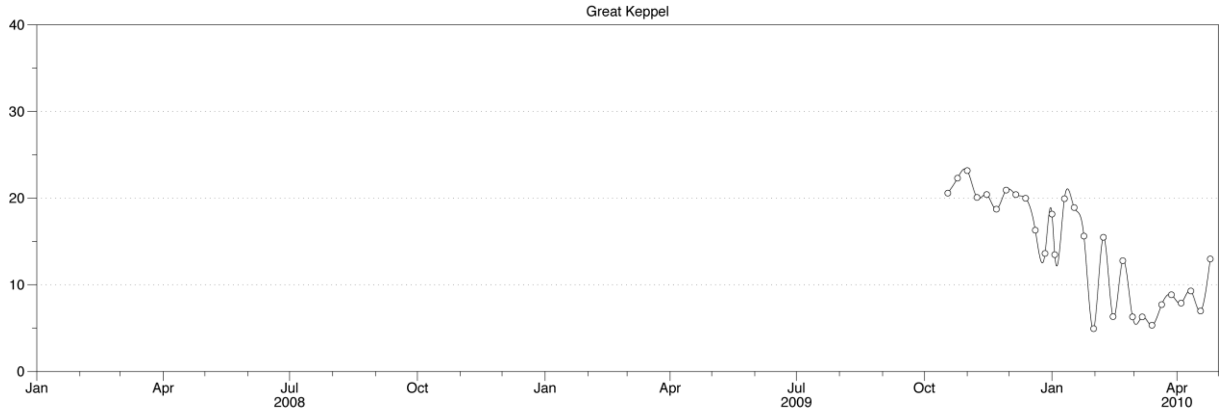


Figure 114. *Fitzroy region fortnightly averages of daily incident light (mmol photons per m^2 per day), at canopy height (2π light loggers; Submersible Odyssey Photosynthetic Irradiance Recording System, Dataflow Systems Pty Ltd, New Zealand placed in a wiper unit to keep the sensor clean) at four sites installed at seagrass canopy height.*

Regional Climate

Climate in the region was hotter, drier and windier during the 2009/10 monitoring period than the long-term average.

Yeppoon – Great Keppel Island and Shoalwater Bay

The mean maximum daily air temperature recorded in Yeppoon during 2009 was 26.3°C, this was 0.4°C higher than the both the decade and long-term averages. The highest recorded daily maximum air temperature in 2009 was 35.9 °C.

2009 was a dry year relative to the long-term average but approximately similar to the decade average (Figure 115). Mean wind speed in 2009 was 19.7 km.hr^{-1}, this was higher than the long-term average of 14.7 km.hr^{-1}, but less than the decade average.

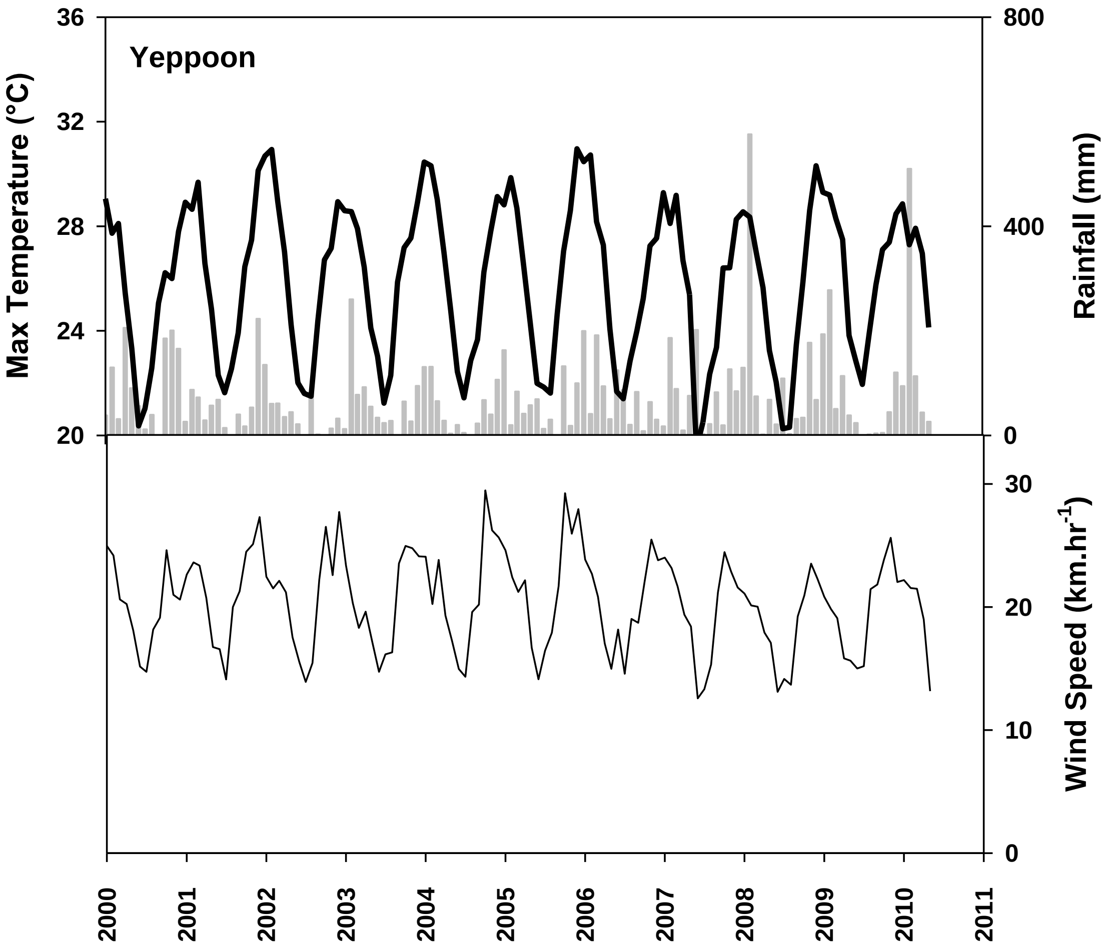


Figure 115. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr-1) recorded at Yeppoon (BOM station 033106) (Source www.bom.gov.au). Yeppoon used as a surrogate for the climate at Great Keppel Island and Shoalwater Bay*

Gladstone – Gladstone Harbour

The mean maximum daily air temperature recorded in Gladstone during 2009 was 29.1°C, this was 1.4°C higher than the long-term year average and 0.8 °C higher than the decade average. The highest recorded daily maximum temperature in 2009 was 36.4 °C.

2009 was a dry year relative to both the long-term average and the decade average (Figure 116). Mean wind speed in 2009 was 22.1 km.hr^{-1}, this was higher than the long-term average of 20.7 km.hrv, but very slightly less than the decade average of 22.5 km.hr^{-1}.

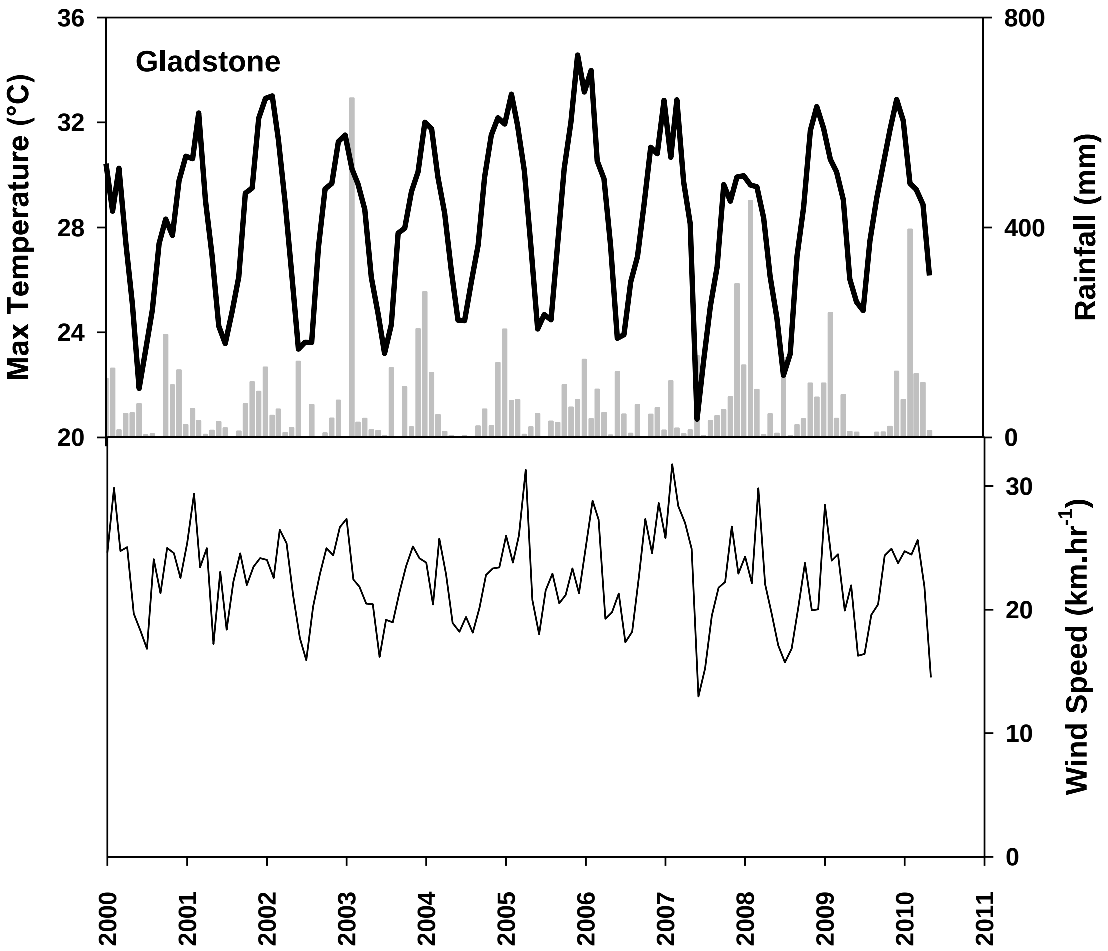


Figure 116. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr-1) recorded at Gladstone Airport (BOM station 039123) (Source www.bom.gov.au). Gladstone Airport used as a surrogate for the climate at Gladstone Harbour*

Burnett Mary

2009/10 Summary

Only intertidal estuarine seagrass meadows located in bays protected from SE winds and wave action were monitored in the Burnett Mary region. The main ecological drivers in these environments are temperature and desiccation stress, flood runoff and turbidity.

Seagrasses are monitored two locations in the north and south of Burnett Mary Region respectively. Seagrass in the south at Urangan recovered from aggregated patches to continuous meadows. Whereas, in the north at Rodds Bay, the meadows declined and were lost by late monsoon 2010. Seagrass abundances in the region were rated as poor throughout 2009/10. Seed banks and reproductive effort declined across the region and were in a very poor state, raising concerns about the ability of local seagrass meadows to recover from environmental disturbances. Seagrass tissue nutrient concentrations indicate light environments across region remain low (limited), but have improved in the south. Tissue nutrient status indicated that although locations were nutrient poor (small P pool), nitrogen concentrations remained high (replete) in the south but increased at Roods bay indicating N enrichment. Epiphytes remained variable at Rodds Bay, but in Urangan they increased above the GBR long-term average. Climate across the region was hotter, drier and windier than previous. Air temperatures in 2009/10 were 1.4°C and 0.3°C hotter in the north and south, respectively. Within canopy temperatures were warmer at all habitats than previous, with extreme temperatures being reached at Rodds Bay in February 2010. Overall the status of seagrass condition in the region was rated as fair.

Table 24. *Report card for seagrass status (community & environment) for the Burnett Mary NRM region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100. Gold = fair, red = poor.*

Habitat	Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index**
coastal intertidal	*not monitored*				
estuarine intertidal	31	0	33	33	**24**
Burnett Mary	31	0	33	33	**24**

Background

The Burnett-Mary region covers an area of 88,000km^2 and supports a population of over 257,000 people, largely in the main centres of Bundaberg, Maryborough, Gympie and Kingaroy. The region is comprised of a number of catchments including the Baffle Creek, Kolan, Burnett, Burrum and Mary Rivers (Australian Government Land and Coasts 2010e). Only the northern most catchment of the Burnett Mary region, the Baffle Basin, is within the GBR. Meadows in the north of the Burnett Mary region generally face low levels of anthropogenic threat, and monitoring sites are located within Rodd's Bay. The only other location that is monitored within this region is in the south, at Urangan (Hervey Bay). This location is adjacent to the Urangan marina and in close proximity to the mouth of the Mary River.

Estuarine habitats occur in bays that are protected from the south easterly-winds and consequent wave action. The seagrasses in this area must survive pulsed events of terrestrial run-off, sediment turbidity and drops in salinity. Estuary seagrasses in the region are susceptible to temperature related threats and desiccation due to the majority being intertidal (Figure 117).

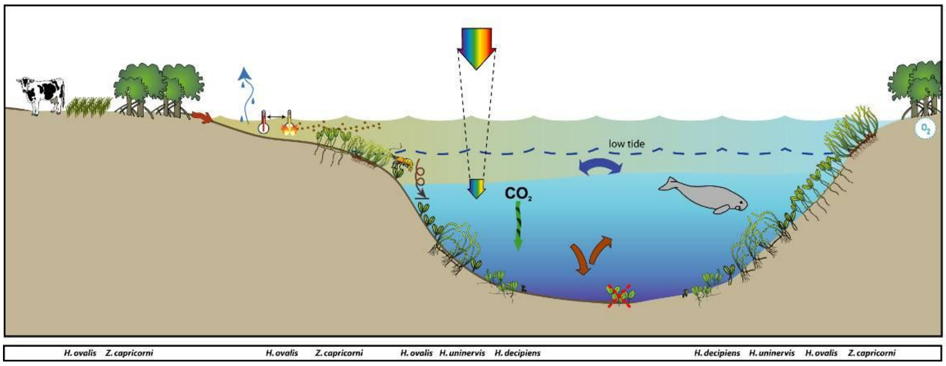


Figure 117. *Conceptual diagram of Estuary habitat in the GBR section of the Burnett Mary region – major control is shelter from winds and physical disturbance: general habitat and seagrass meadow processes (see Figure 2 for icon explanation).*

Status of the seagrass community

Seagrass abundance and composition

The estuarine seagrass habitats in the region were dominated by *Zostera capricorni* with minor components of *Halophila ovalis* and some *Halodule uninervis* (Figure 119). The meadow at Urangan showed significant recovery over the monitoring period after several years of little improvement since a loss in 2006 (Figure 118). The isolated patches of *Zostera capricorni* scattered across the intertidal banks in the late monsoon 2009 became more aggregated in mid 2009 and by the late dry/Monsoon had formed into meadows with mean cover >10% (Figure 118).

Unfortunately, the opposite has occurred at Rodds Bay, where the decline observed in 2009 continued into 2010, resulting in total loss of the meadows from both sites in the late monsoon 2010 (Figure 118, Figure 119).

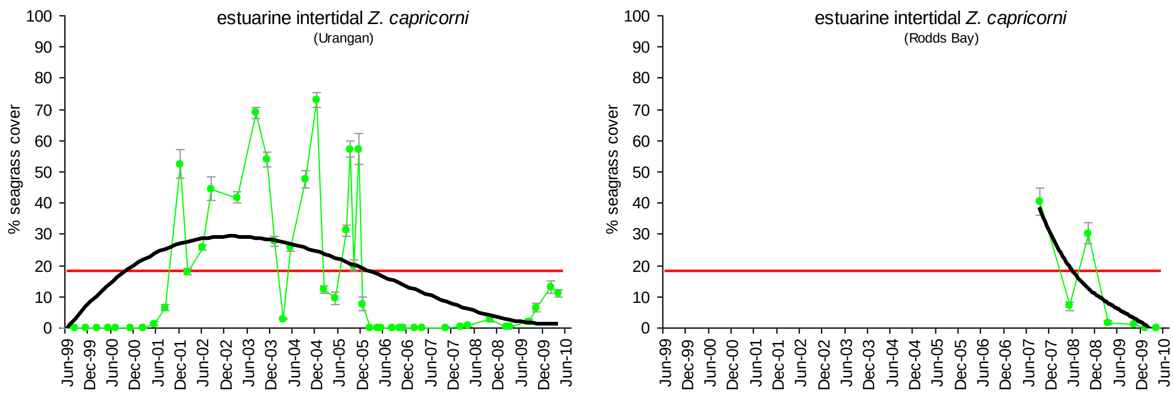


Figure 118. *Change in seagrass abundance (percentage cover ±Standard Error) at estuarine intertidal seagrass meadows in Burnett Mary region. Red line = GBR long-term average for estuarine habitat.*

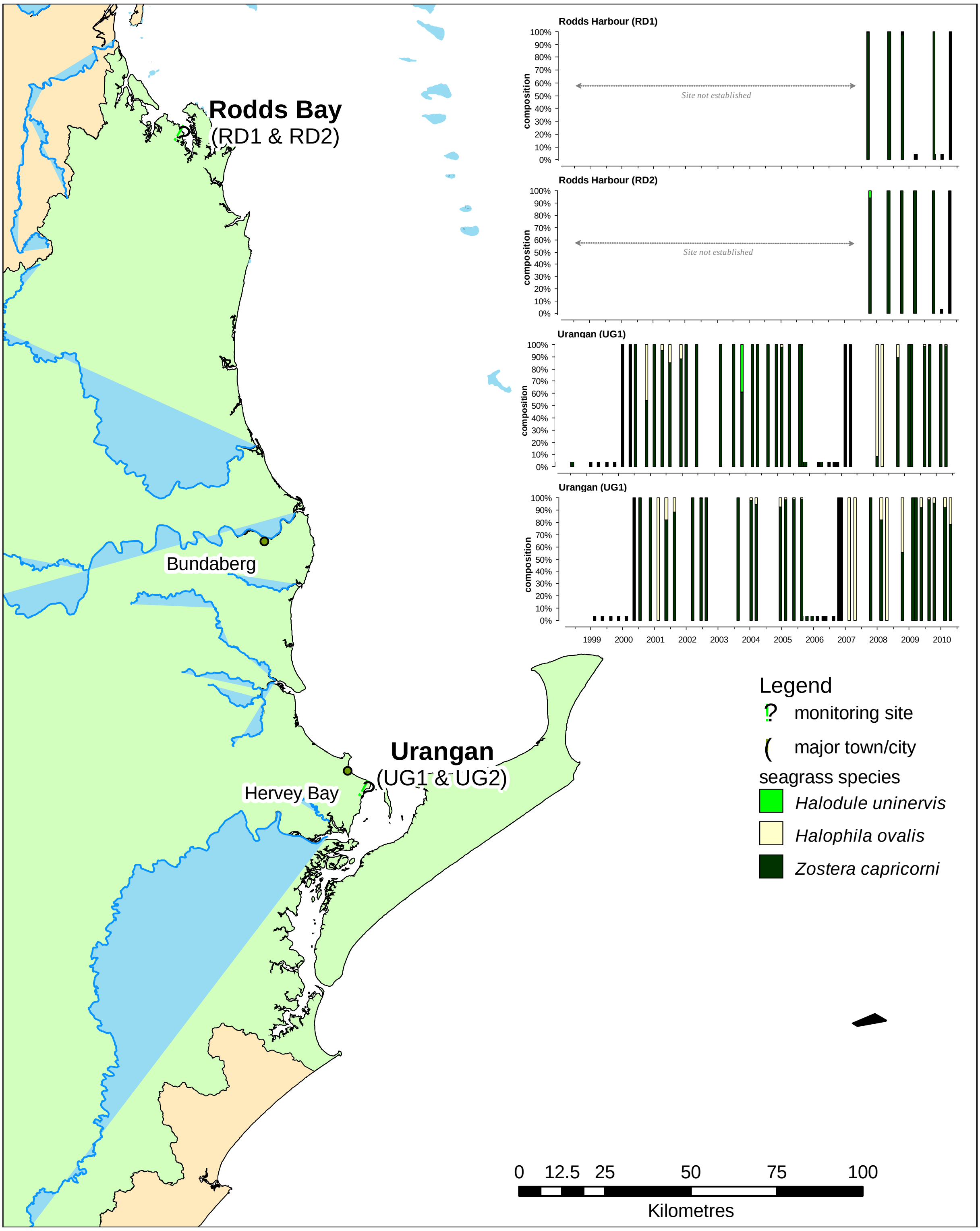


Figure 119. *Location of Burnett Mary region long-term monitoring locations and the seagrass species composition at each site. Please note: replicate sites are within 500m of each other.*

Quadrat at 45m on transect 2 at Urangan site 1 (UG1) on 28 July 2000 (left), 15 November 2005 (middle) and 29 April 2010 (right).

Urangan site 2 (UG2) seagrass meadows on 20 May 2008 (left)and UG1 15 October 2009 (right).

Since monitoring was established at this location in 1998 as part of the Seagrass-Watch program, the Urangan meadow has come and gone on an irregular basis. It is unknown if this is a long-term pattern. Within years however, a seasonal pattern is apparent across both sites, with greater abundance in the late dry season (Figure 121). Abundance is also significantly higher during the late dry season in Rodds Bay, however the dataset has become limited with the recent losses (Figure 121).

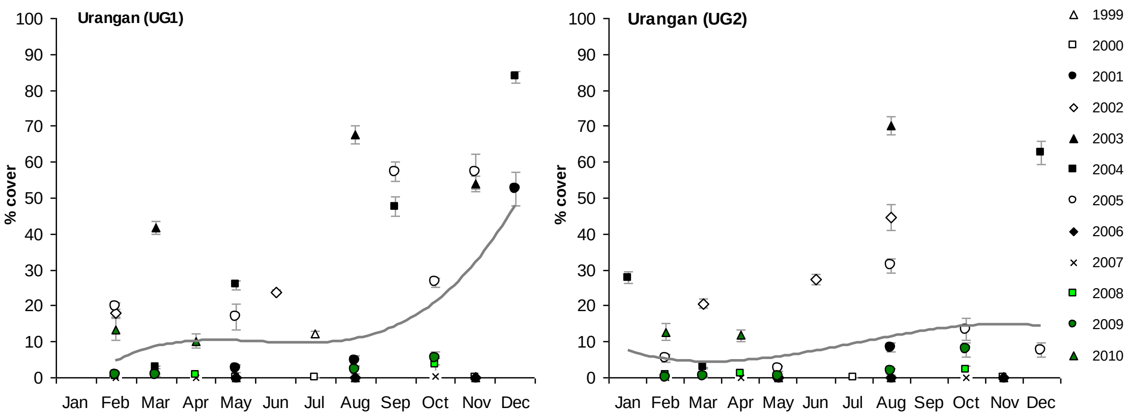


Figure 120. *Changes in above-ground biomass and distribution of estuarine intertidal Zostera meadows monitored at Urangan in the Mary/Burnett region from 2002 to 2008.*

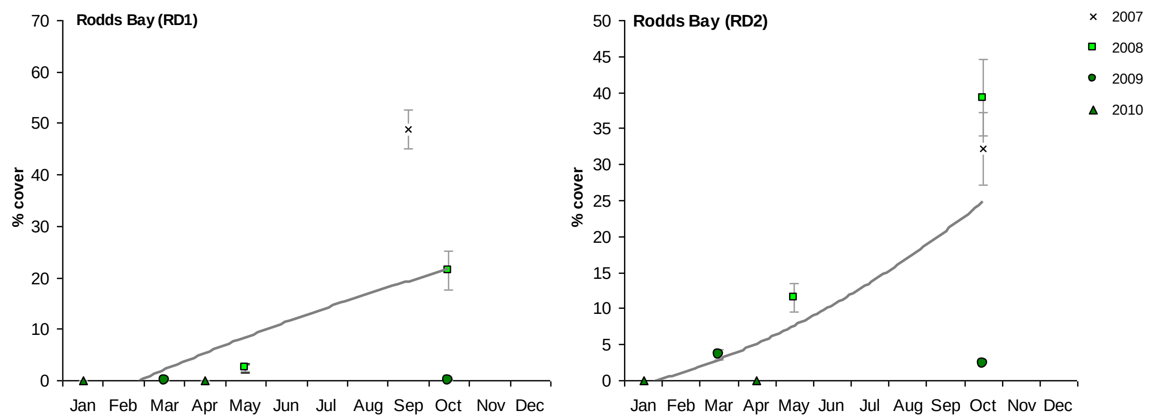


Figure 121. *Changes in above-ground biomass and distribution of estuarine intertidal Zostera meadows monitored in the Mary/Burnett region from 2002 to 2008.*

Seagrass abundance relative to the guidelines indicates that all sites in the region were in a poor state throughout the 2009/10 monitoring period (Figure 122).

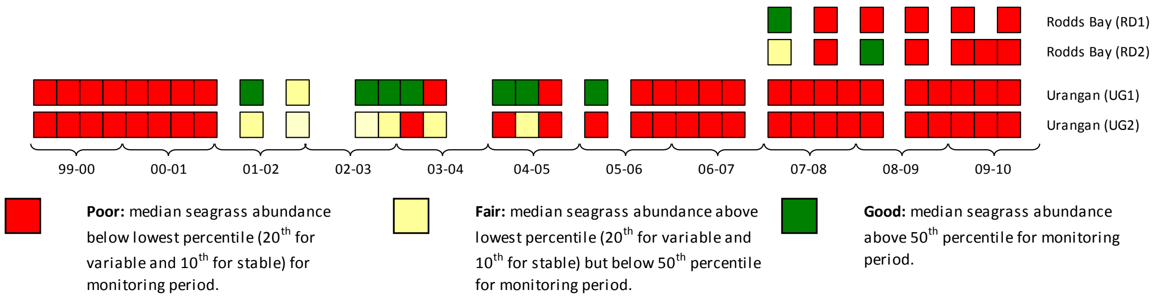


Figure 122**.** *Status of seagrass abundance in the Burnett Mary region relative to the guidelines. Each block represents the seasonal monitoring event (dry, late dry, monsoon, late monsoon), with time along the x-axis from left to right.*

Seagrass meadow edge mapping was conducted within a 100m radius of all monitoring sites in September/October and March/April of each year (Table 25) to determine if changes in abundance were a consequence of the meadow edges changing. Over the last 12 months the seagrass meadows at Urangan increased significantly (Figure 123, Table 25). The largest losses however occurred in Rodds Bay, where the entire meadows were lost (Figure 123, Table 25).

Table 25. *Area (ha) of seagrass meadow within 100m radius of each monitoring site. Value in parenthesis is % change from baseline and direction of change from previous mapping. Shading indicates decrease in meadow area since baseline. NA=no data available as site not established.*

	Urangan (Hervey Bay)		Rodds Bay	
	UG1	**UG2**	**RD1**	**RD2**
October 2005	**5.266**	**5.326**	*NA*	*NA*
April 2006	0 *(meadow absent)*	0 *(meadow absent)*	*NA*	*NA*
October 2006	0 *(meadow absent)*	0 *(meadow absent)*	*NA*	*NA*
April 2007	0 *(meadow absent)*	0 *(meadow absent)*	*NA*	*NA*
October 2007	0.003 *(-99.9%, increase overall)*	0 *(meadow absent)*	**0.96**	**3.573**
April 2008	0.386 *(-92.7%, increase overall)*	1.559 *(-70.7%, increase overall)*	1.291 *(34.5%, increase seaward)*	3.511 *(-1.7%, decrease shoreward)*
October 2008	0.343 *(-93.5%, negligible)*	2.778 *(-47.8%, increase overall)*	1.207 *(25.8%, decrease shoreward)*	3.618 *(1.3%, increase seaward)*
April 2009	0.044 *(-99.2%, decrease overall)*	0.470 *(-91.2%, decrease overall)*	0 *(meadow absent)*	3.527 *(0.4%, negligible)*
October 2009	0.333 *(93.7%, increase overall)*	0.998 *(81.3%, increase overall)*	0.041 *(95.8%, increase overall)*	2.770 *(22.5%, decrease shoreward)*
April 2010	1.812 *(65.6%, v overall)*	3.730 *(30%, increase overall)*	0 *(meadow absent)*	0 *(meadow absent)*

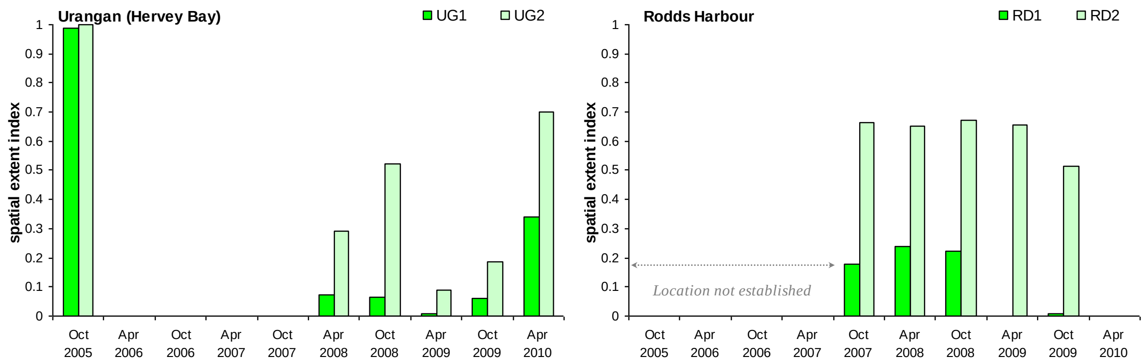


Figure 123. *Extent of area (100m radius of monitoring site) covered by seagrass at each monitoring site at Rodds Bay and Urangan locations.*

Seagrass reproductive status

Reproductive effort in the estuarine sites from the Burnett Mary region are highly variable (Figure 124), and the 2009 results were significantly lower then the GBR long-term average for estuarine habitats. The ongoing presence of reproductive structures will be critical at these highly disturbed sites, Urangan having been denuded and recovered during the monitoring period.

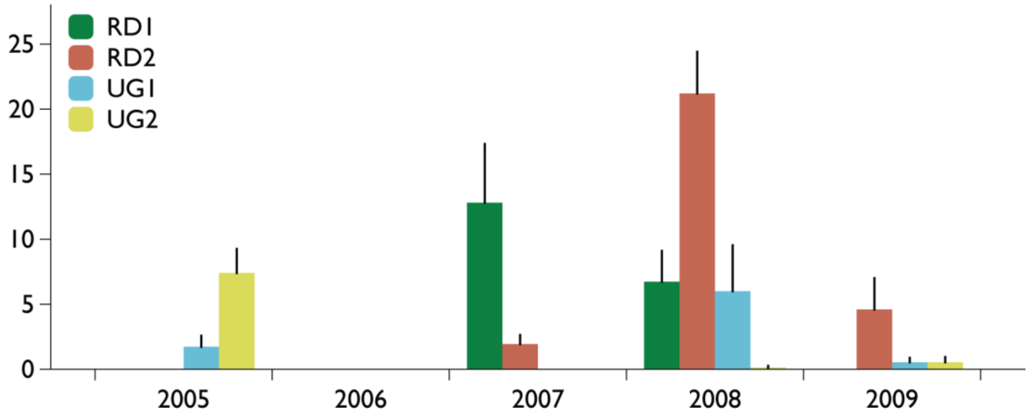


Figure 124. Mean reproductive effort (number of reproductive structures per core ±SE) during dry season sampling from 2005–2009 for Burnett Mary region estuarine sites, Rodds Bay and Urangan.

Seed banks were non-existent in the region and only one seed has ever been found since seed monitoring commenced in 2005 (at RD2 on 26/10/2007). However, this may be due to the relatively small proportion of *Halodule uninervis* in the region, the dominant species *Zostera capricorni* and *Halophila ovalis* both being better represented in the reproductive core samples.

Status of the seagrass environment

Seagrass tissue nutrients

In 2009, C:N ratios were below 20 for both Rodds Bay and Urangan (Hervey Bay) (Figure 125), indicative of a low light environment. At Urangan, levels have consistently increased over the last 3 monitoring events indicating an improving light environment.

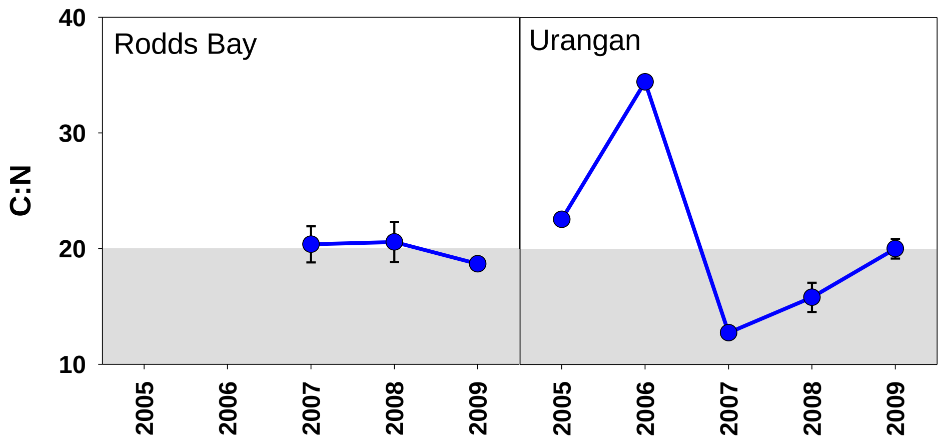


Figure 125. *Elemental ratios (atomic) of seagrass leaf tissue C:N for the foundation seagrass species examined at each habitat in the Burnett Mary region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the C:N ratio panel represents the accepted guideline seagrass "Redfield" ratio of 20:1 (Abal et al. 1994; Grice et al. 1996). C:N ratios below this line indicate reduced light availability.*

The late dry season 2008 C:P ratios of seagrass in the Burnett Mary region increased, indicating a more nutrient poor environment with a relatively small P pool (Figure 126). Tissue ratios of N:P ratio increased at Rodds Bay in 2009 indicating N enrichment and at Urangan remained replete or potentially P-limited (Figure 126).

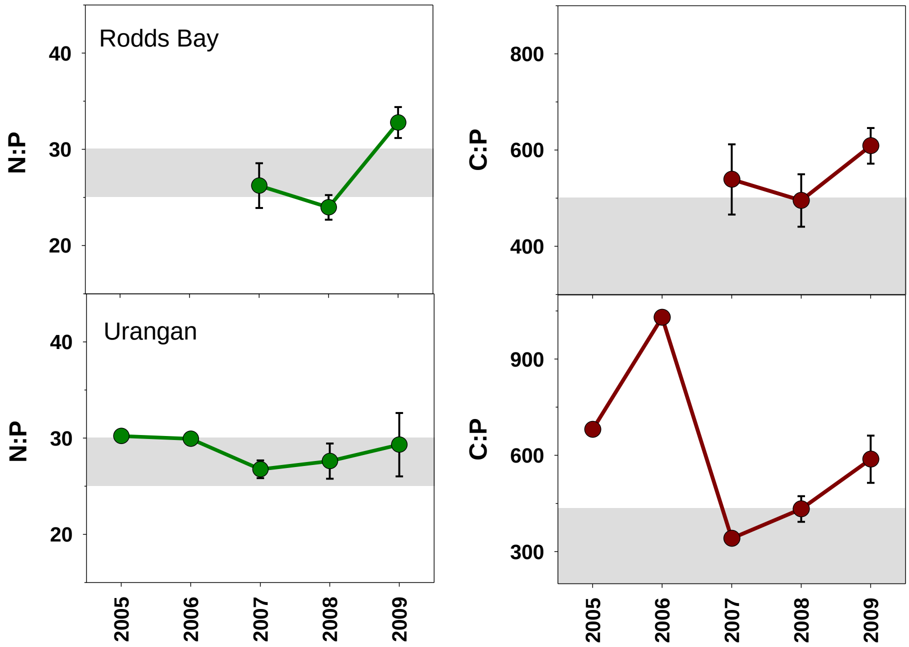


Figure 126. *Elemental ratios (atomic) of seagrass leaf tissue N:P and C:P for the foundation seagrass species examined at each location in the Burnett Mary region each year (species pooled) (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation, below indicates N limitation and within indicates replete. Shaded portion on the C:P panel ≤500 represents the value associated with C:P balance ratio in the plant tissues, C:P values <500 may indicate nutrient rich habitats (large P pool).*

Epiphytes and macro-algae

Epiphyte cover on the seagrass leaf blades at Urangan was highly variable over the years of monitoring and in 2009/10 was higher than previous years and the GBR long-term average for estuary habitats (Figure 127). Percentage cover of macro-algae has continued to remain low at both locations (Figure 127). Epiphyte and macro-algae cover continued to remain low and below the GBR long-term average at Rodds Bay (Figure 127).

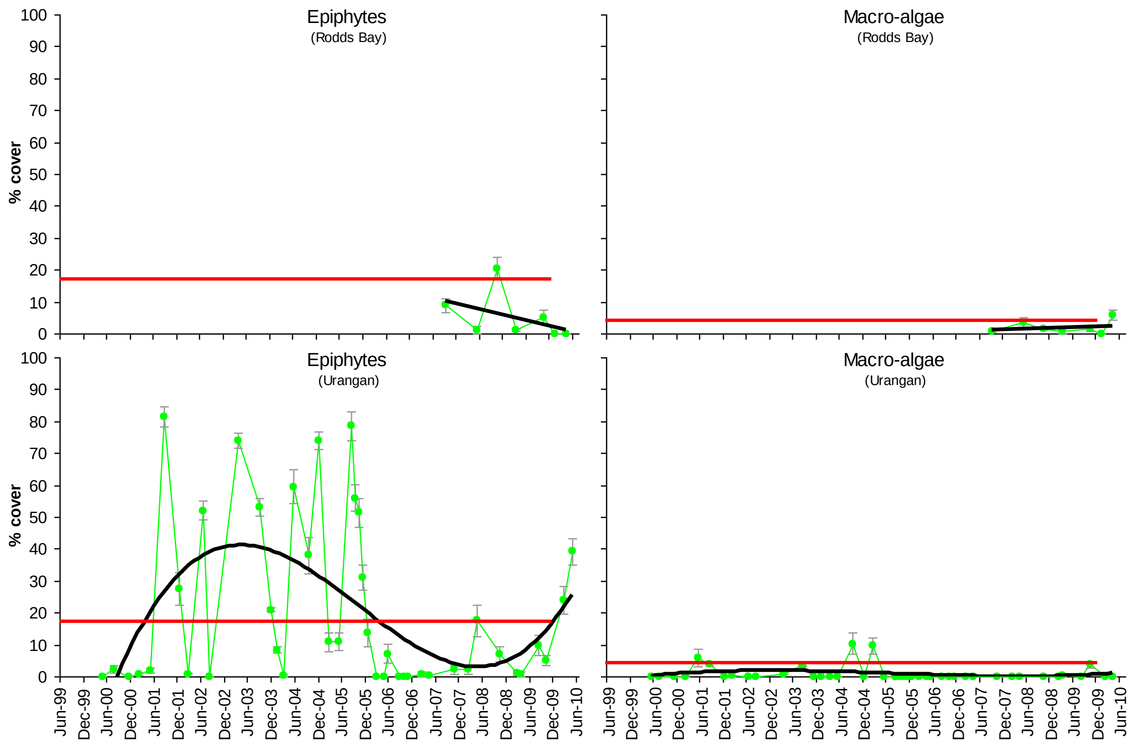


Figure 127. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal estuarine (Rodds Bay and Urangan) seagrass monitoring locations. NB: Polynomial trendline for all years pooled. Red line = GBR long-term average.*

Within canopy temperature

Within canopy temperatures were monitored at Rodds Bay and Urangan (Hervey Bay) over the past 12 months (Figure 128). Extreme temperatures (>38°C) were recorded in February 2010 at Rodds Bay site 2 (RD2) (38.2°C) over the 2009/10 monitoring period (Figure 128). Mean within canopy temperatures monitored at Urangan and Rodds Bay were within 17 – 29°C range, with highest mean temperatures in January and February 2010. The 2009/10 monitoring period was 0.2 – 0.5°C warmer than the long-term average (Figure 129).

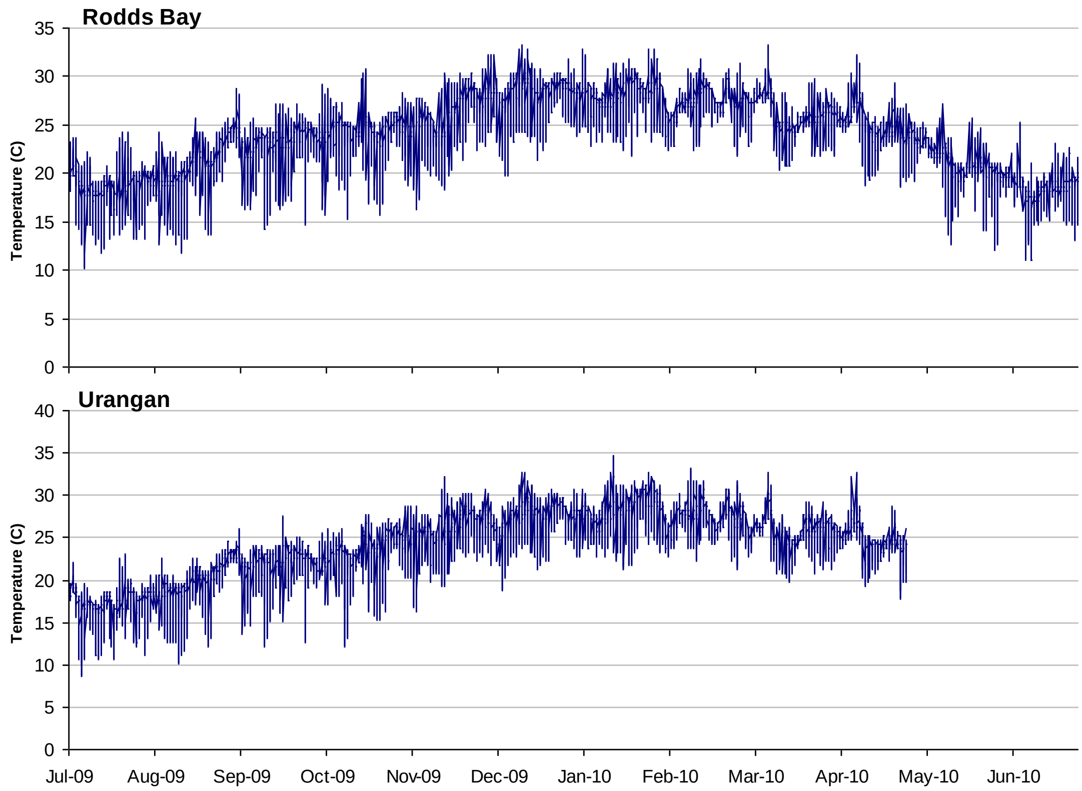


Figure 128. *Within seagrass canopy temperature (°C) at Rodds Bay and Urangan intertidal meadows over the 2009/2010 monitoring period.*

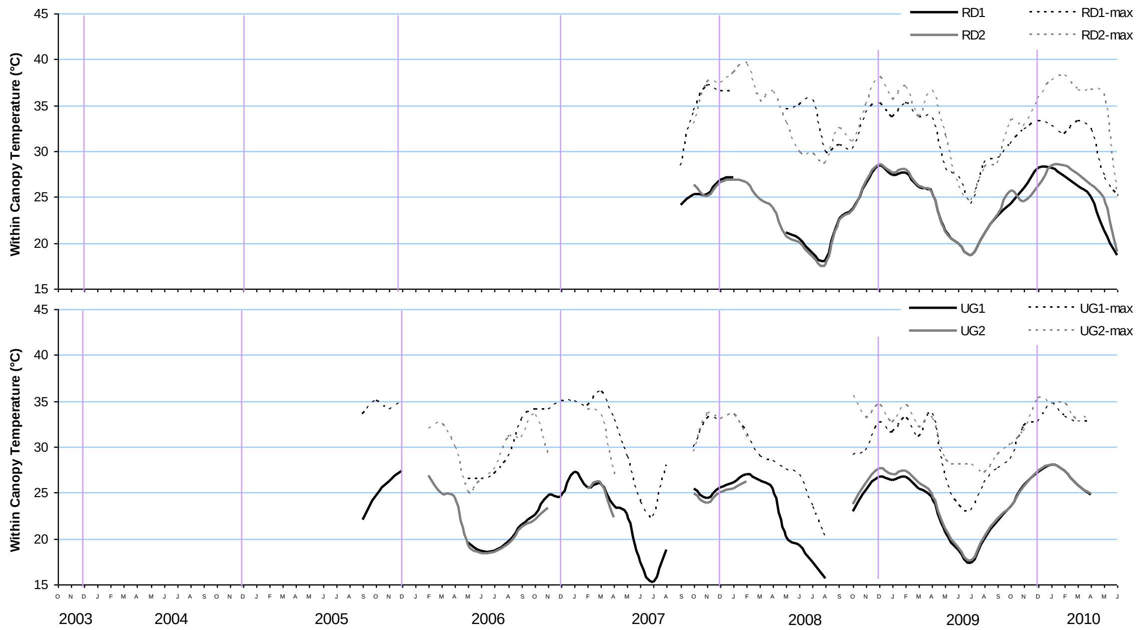


Figure 129. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in estuarine (Rodds Bay and Urangan) monitoring habitats within the Burnett Mary region.*

Canopy incident light

Deployment of light loggers in the Burnett Mary region began in 2009 to include Rodds Bay (Figure 130). Variance in light availability first followed the pattern of the tidal cycle and then the seasonal pattern of winds, where increased wind results in lower incident light levels. As data are only available for recent sampling periods correlations with seagrass responses will be analysed at a later date.

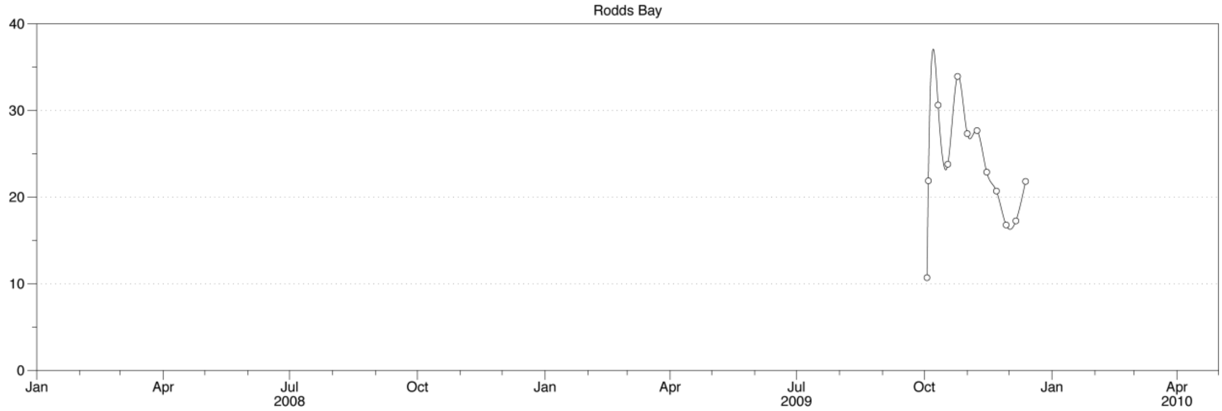


Figure 130. *Burnett Mary region fortnightly averages of daily incident light (mmol photons per m^2 per day), at canopy height (2π light loggers; Submersible Odyssey Photosynthetic Irradiance Recording System, Dataflow Systems Pty Ltd, New Zealand placed in a wiper unit to keep the sensor clean) at four sites installed at seagrass canopy height.*

Regional Climate

Climate across the region was hotter, drier and windier over the 2009/10 monitoring period than previous.

Hervey Bay - Urangan

The mean maximum daily air temperature recorded in Hervey Bay during 2009 was 26.6°C, this was 0.3°C higher than the decade average but long-term averages are not available. The highest recorded daily maximum air temperature in 2009 was 32.2°C.

2009 was a dry year relative to the decade average (Figure 131). Mean wind speed in 2009 was 19.9 $km.hr^{-1}$, this was slightly higher than the decade average of 19.6 $km.hr^{-1}$ (Figure 131).

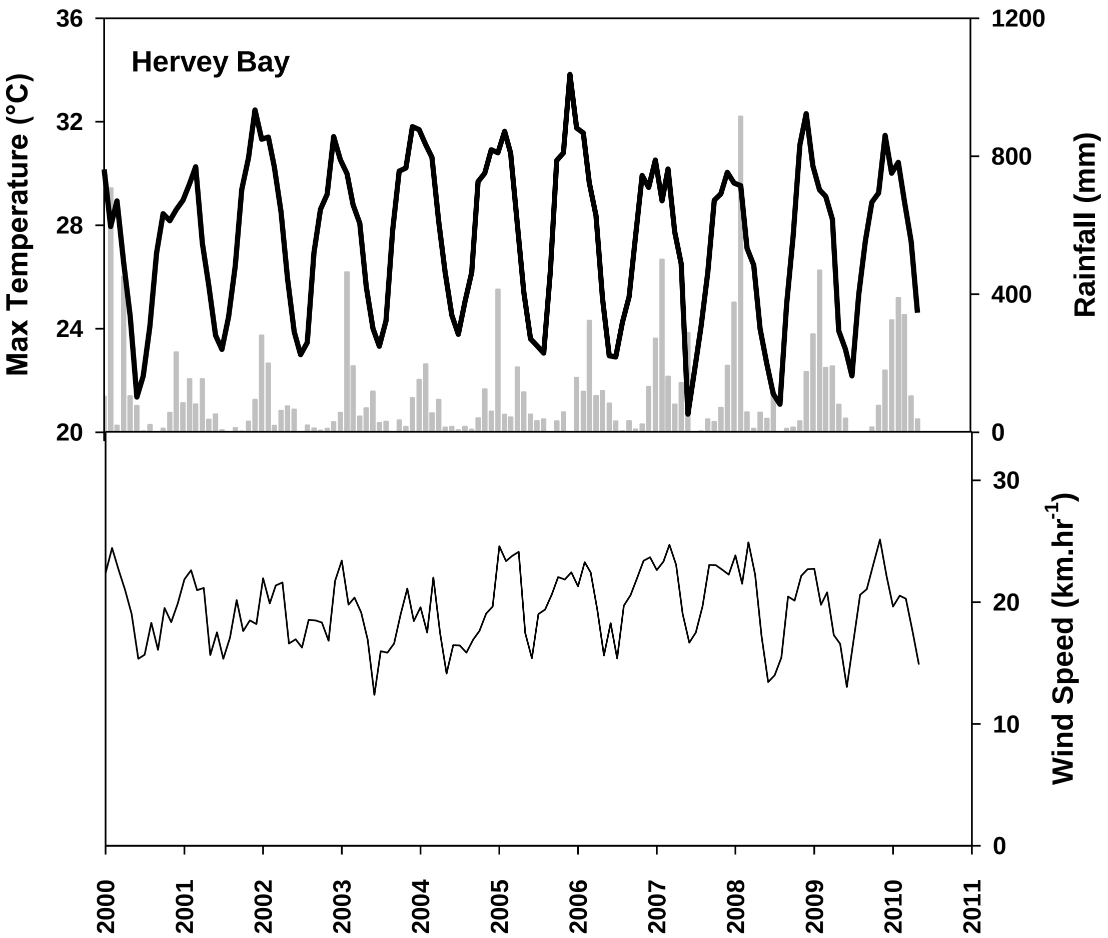


Figure 131. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr-1) recorded at Hervey Bay Airport (BOM station 040405) (Source www.bom.gov.au). Hervey Bay airport used as a surrogate for the climate at Urangan.*

Gladstone – Rodds Bay

The mean maximum daily air temperature recorded in Gladstone during 2009 was 29.1°C, this was 1.4°C higher than the long-term year average and 0.8 °C higher than the decade average. The highest recorded daily maximum air temperature in 2009 was 36.4 °C.

2009 was a dry year relative to both the long-term average and the decade average (Figure 132). Mean wind speed in 2009 was 22.1 km.hr^{-1}, this was higher than the long-term average of 20.7 km.hr^{-1}, but very slightly less than the decade average of 22.5 km.hr^{-1} (Figure 132).

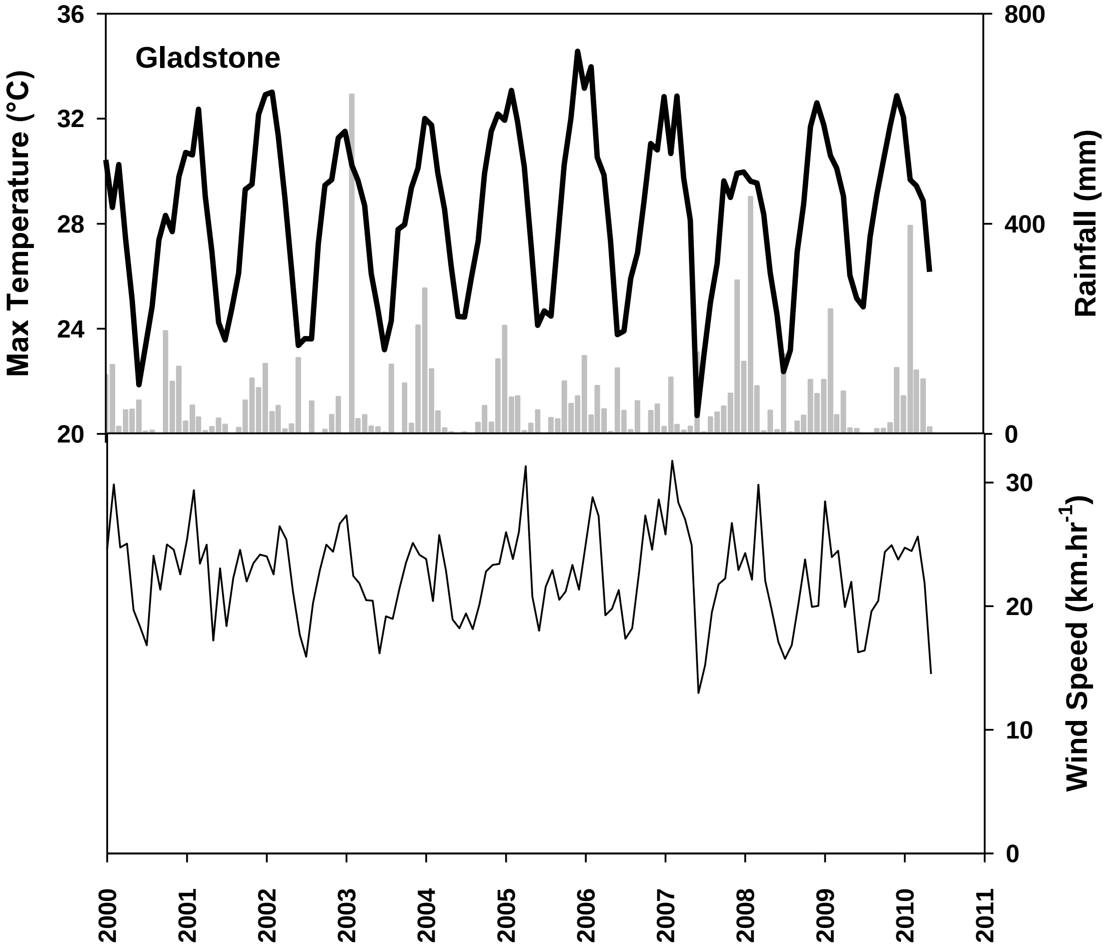


Figure 132. *Mean monthly daily maximum temperature (°C), total monthly rainfall, mean monthly cloud cover (quarts), and mean monthly 3pm wind speed (km.hr^{-1}) recorded at Gladstone Airport (BOM station 039123) (Source www.bom.gov.au). Gladstone airport used as a surrogate for the climate at Rodds Bay.*

4. Discussion

Water quality and ecological integrity of some coastal waters of the GBR are affected by material originating in adjacent catchments as a result of human activity, including primary industries and urban and industrial development. The coastal zone receives an average annual input of sediment on the order of 14 – 28 Mt y^{-1}; an estimated increase by at least four times compared to estimates from before 1850 (Schaffelke *et al*. 2005; Alongi and McKinnon 2005). Most sediments are deposited within the first few kilometres of river mouths (Larcombe and Woolfe 1999; Wolanski 1994), however fine sediment particles can travel large distances (Wolanski *et al*. 1981; Devlin and Brodie 2005). These sediments settle out of the water column, particularly in the protected waters of estuaries, fringing reefs on the leeward margins of islands and coastal north-facing bays; areas where seagrasses are most likely to be found (Lee Long *et al*. 1993; Wolanski *et al*. 2005).

Abal and Dennison (1996) predicted that detectable impacts on seagrass meadows may occur if higher sediment and associated nutrients were transported into the nearshore areas of the GBR region. While nitrogen and phosphorous play an important role in the growth of seagrass meadows, studies in the GBR in the early to mid 1990's reported that seagrass growth was generally limited by nitrogen (Udy *et al.* 1999; Mellors, 2003). Studies' assessing the response of seagrass to enhanced nutrient levels found a response to both nitrogen and phosphorus additions, but nitrogen was the primary limiting element. This indicated that seagrasses had the capacity to absorb additional nutrients enhancing their growth and it appeared that nutrient loadings in the GBR in the 1990's had not reached saturated levels for seagrass growth and distribution (Mellors *et al.,* 2005).

In seagrass ecosystems, nutrients and light are the most common limiting factors that control abundance and these factors are interrelated (see Waycott and McKenzie 2010). Indeed, the various threats to seagrass ecosystems along the coast of the GBR will cause a variety of impacts to seagrass growth (Figure 133). In addition, combinations of stressors will lead to variable conditions impacting growth. In low nutrient, oligotrophic systems there is typically high light availability to the plants, while high nutrient, eutrophic ecosystems have little light reaching the benthos (Johnson *et al.* 2006). Monitoring of C:N:P ratios may be advantageous for the early detection of changes in nutrient regimes for environmentally sensitive seagrasses (Johnson *et al.* 2006; Waycott and McKenzie 2010). Observations of trends in indicators such as C:N:P ratios or changes in seagrass meadow composition provide insight into the responses of seagrasses to environmental change (Waycott and McKenzie 2010). We have developed a matrix of comparison for these indicators (Table 26) and have evidence of seagrass responses in most categories.

Figure 133. *Conceptual diagram depicting threats to seagrass meadows and potential limitations to seagrass growth in coastal regions of the Great Barrier Reef related to changing water quality (adapted from Waycott and McKenzie 2010).*

Table 26. *Response stages of seagrass meadows to external stressors and the observed indicator responses observed in Great Barrier Reef monitored seagrass meadows (adapted from Waycott and McKenzie 2010) * utilised in Paddock to Reef reporting.*

Indicator	***Sub-lethal*** (ecophysiological)	***State change*** (whole plant and population scale***)***	***Population decline*** (whole meadow scale)
A. Tissue nutrients	Ratios of key macronutrients change to indicate relative excesses (i.e. C:N*, C:P, N:P*)	Limited by species variable upper threshold	-
B. Chlorophyll concentrations	Rapid short term changes observed	Limited by species variable upper threshold	-
C. Production of reproductive structures	-	Reduced flowering and fruiting, loss of seeds for meadow recovery seen as high variability among sites*	Threshold reached where no reproduction occurs
D. Change in plant morphology	-	Reduction in leaf area	Threshold reached
E. Community structure	-	Change in species composition	Loss of species
F. Change in species abundance (population structure)	-	Change in abundance of species (i.e. % cover)*	Reduction in effective population size
G. Change in meadow area	-	-	Reduction (or increase) in total meadow area
H. Recovery time from loss	Limited or no change	Measurably delayed	Potentially no recovery if threshold reached

Research has shown that seagrass cover significantly declined at low (14% surface irradiance) and very low (1%) light levels in the following sequence: metabolic and physiological changes (reduced growth, increased pigment concentrations and photosynthetic efficiency); shedding (leaf loss, followed by shoot loss); and production of new, altered tissue (leaves with different dimensions including leaf length, width and thickness) (Collier *et al.* 2010). *Z. capricorni* was impacted the fastest and with greatest magnitude, followed by *H. uninervis*. Seagrasses in low light were observed to be impacted more slowly and to a lesser degree than very low light (Collier *et al.* 2010). Among the MMP sites, observations of light levels suggest that at times light levels will reach very low light levels. As a result, there will be ongoing declines in seagrass meadows where repeated or extended periods of low light are observed. In the context of water quality, efforts to keep water quality degradation to a minimum will be rewarded with reduced impacts to seagrasses. Further inferences will require additional evaluation of specific indictor responses as a result of the conditions associated with water quality in GBR coastal ecosystems (see Waycott and McKenzie 2010). This will become possible as longer term monitoring data sets become available and research gaps the currently exist (Waycott and McKenzie 2010).

Regional responses across the GBR

One important finding from the 2009/10 reporting period is that seagrass tissue elemental (C:N:P) data from coastal and estuarine habitats in the Wet Tropics and Mackay Whitsunday indicates that the environment is low light and saturated with nitrogen. Seagrass abundance is also very poor in the southern Wet Tropics and the Burdekin regions.

There are three main rivers which discharge into the coastal waters from Wet Tropics catchments which could influence water quality at intertidal and inner reefs between Port Douglas and Innisfail. Discharged waters from Wet Tropics rivers travel predominately north: a consequence of the Coriolis effect and prevailing trade winds (Furnas 2003). During flood events, intertidal and inner reefs are inundated by waters laden in nitrogen and phosphorus species for periods of days to several weeks in the monsoon (Devlin *et al.* 2001).

Flood plume modelling estimates that Yule Point is within a zone impacted yearly (Devlin *et al.* 2001). The major river impacting Yule Point would be the Barron. The Barron River discharges 0.1×10^6 tonnes of fine sediment, 70 tonnes of phosphorus and 500 tonnes of nitrogen per year (from Table 1 *in* Brodie *et al.* 2009). During major flood events, plumes from the Russell-Mulgrave and Johnstone Rivers could also impact Yule Point. The Russell-Mulgrave discharges 0.21×10^6 tonnes of fine sediment, 320 tonnes of phosphorus and 2200 tonnes of nitrogen per year (Brodie *et al.* 2009). The Johnstone discharges 0.26×10^6 tonnes of fine sediment, 580 tonnes of phosphorus and 2,250 tonnes of nitrogen per year (Brodie *et al.* 2009).

In the southern section of the Wet Tropics region, the coastal seagrass meadows of Lugger Bay would be influenced primarily by the Tully and Murray Rivers (approximately 8 km and 15 km south of Lugger Bay respectively) (Devlin and Schaffelke 2009). Both the Tully and Murray Rivers have been labelled as medium/high risk to inshore areas by the Great Barrier Reef Marine Park Authority (GBRMPA 2001). Of the two rivers, the Tully is the largest with an annual discharge of 0.12×10^6 tonnes of fine sediment, 125 tonnes of phosphorus and 1,300 tonnes of nitrogen (Brodie *et al.* 2009). The smaller river, the Murray, discharges 0.05×10^6 tonnes of fine sediment, 58 tonnes of phosphorus and, 620 tonnes of nitrogen per year (Brodie *et al.* 2009). The largest river in the region is the Herbert River, which is 60 km to the south and discharges 0.54×10^6 tonnes of fine sediment, 250 tonnes of phosphorus and 1,900 tonnes of nitrogen (Brodie *et al.* 2009).

Devlin and Schaffelke (2009) reported that approximately 93% of seagrass meadows within the Tully marine area were inundated every year by primary flood plumes, exposing the seagrass to intermittently high sediment and high nutrient concentrations for periods of days to weeks and potentially high loads of particles settling on the plants and seafloor.

Tissue elemental N:P ratios have progressively increased at Lugger Bay since the MMP was established until 2009 (Figure 134). Over this time, *H. uninervis* has changed from replete to P-limited and back to replete in 2009; indicating elevated available nitrogen in the environment. Although the N:P ratios in 2008 were the highest record since 2005, they remain lower than reported in 1994 during the senescent season when luxury uptake is know to occur (Mellors 2003).

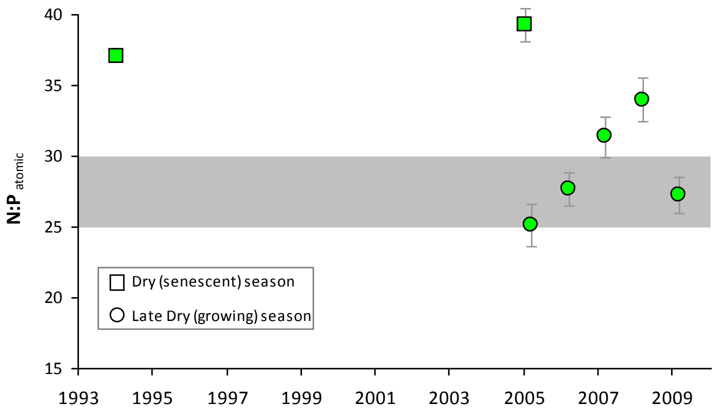


Figure 134. *Elemental ratios (atomic) of seagrass leaf tissue N:P reported from Lugger Bay in July 1994 (Mellors 2003) and the present monitoring program (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation and below indicates N limitation.*

Seagrass condition at mid-shelf reefs within the Wet Tropics region also suggests declining water quality. Water discharging from rivers in the region not only travels north, but during flooding events can reach Green Island (Maughan *et al.* 2008). At Green Island, elemental ratios (atomic) of seagrass leaf tissue N:P have increased significantly over the past 15 years, although lower since 2003 (Figure 135). The only seagrass species which does not appear to have significantly increased leaf tissue N:P is *Halophila ovalis*. Seagrass at Green Island was considered N-limited in the early 1990s (Udy *et al.* 1999) but is now becoming P-limited (Figure 135).

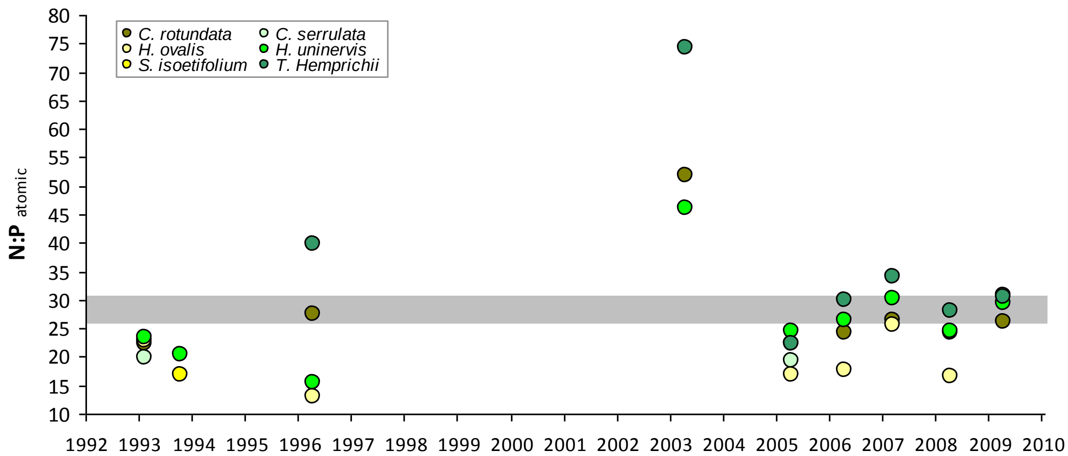


Figure 135. *Elemental ratios (atomic) of seagrass leaf tissue N:P reported from Green Island in 1993 (Fisheries QLD unpublished data), 1994 (recalculated from Udy et al. 1999) , 1996 (Yamamuro et al. 2003), 2003 (Fisheries QLD unpublished data) and the present monitoring program (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio. N:P ratio above this band indicates P limitation and below indicates N limitation.*

In the Burdekin region, the most significant river impacting seagrass meadows adjacent to Townsville is the Burdekin River. Modelling of the plumes associated with specific weather conditions has demonstrated that inshore areas between Townsville and Cooktown regularly experience extreme conditions associated with plumes. However, inshore areas north of the Burdekin River (including Magnetic Island) receive riverine waters on a less frequent basis, perhaps every two to three years (Wolanski and Jones 1981; Maughan *et al.* 2008).

The Burdekin River has the largest annual exports of sediment, phosphorus and nitrogen of any catchment in the GBR, with an annual discharge of $4.6x10^6$ tonnes of fine sediment, 2,030 tonnes of phosphorus and 12,100 tonnes of nitrogen (Brodie *et al.* 2009). During episodic flooding, high concentrations of dissolved nutrients are experienced off Townsville and in Bowling Green Bay, up to 50 km north of the Burdekin River mouth, for periods of up to three weeks (Maughan *et al.* 2008).

Tissue elemental N:P ratios have been consistently high at coastal sites (e.g. Cape Pallarenda) in the Burdekin region for the dominant seagrass species since the MMP was established in 2005. In mid 1994, *H. uninervis* at Cape Pallarenda was reported by Mellors (2003) to be N-limited, however since 2006 it has been P-limited or replete, indicating elevated available nitrogen (Figure 136).

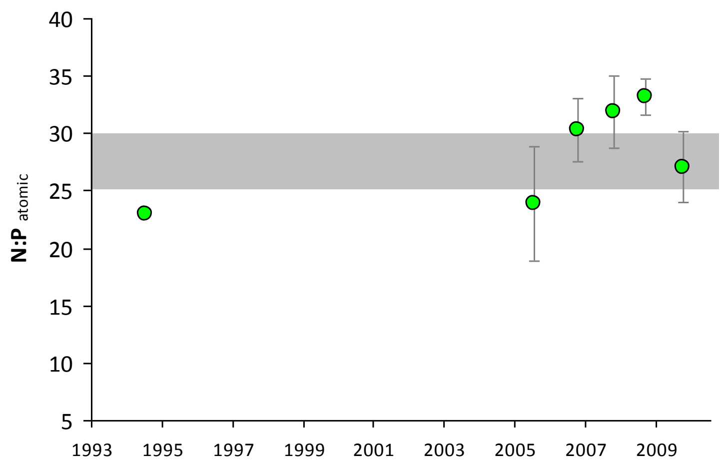


Figure 136. *Elemental ratios (atomic ±SE) of Halodule uninervis leaf tissue N:P reported from Cape Pallarenda (Townsville coast) in July 1994 (Mellors 2003) and the present monitoring program (mean ± Standard Error). Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio. N:P ratio above this band indicates P limitation and below indicates N limitation.*

In the Burdekin region, leaf tissue elemental N:P ratios have also increased at Cockle Bay (Magnetic Island) over the past 40 years. Over this time, *H. uninervis* has changed from N-limited to replete; indicating elevated available nitrogen in the environment. Although the *Halodule uninervis* values in the 2009/10 monitoring period were the highest recorded since 2005, they remain lower than value reported in 1994 by Mellors (2003) at the same location (Figure 137). However, the value by Mellors (2003) was from plants collected during the senescent (non-growing) season (e.g. July) when luxury uptake is know to occur (Mellors 2003).

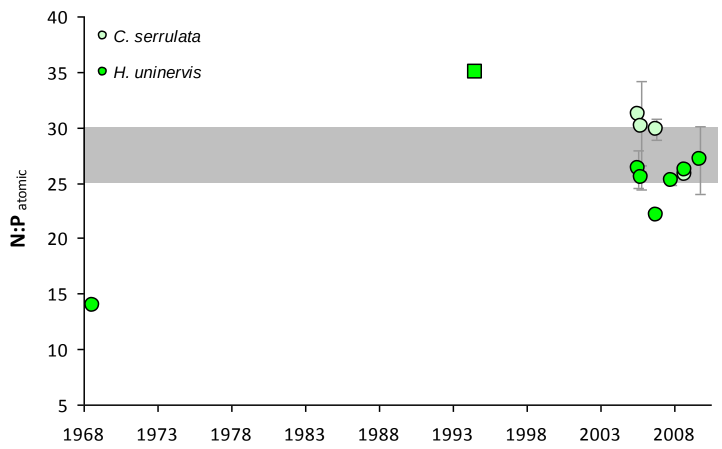


Figure 137. *Elemental ratios (atomic) of seagrass leaf tissue N:P reported from Cockle Bay (Magnetic Island) in 1968 (Brich 1975), July 1994 (Mellors 2003) and the present monitoring program (mean ± Standard Error). Horizontal shaded band represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio. N:P ratio above this band indicates P limitation and below indicates N limitation. Square symbol illustrates samples from the senescent season.*

With the exception of Yule Point, seagrass at locations classified as poor water quality in 2008 (Lugger Bay, Townsville and Sarina Inlet) (McKenzie and Unsworth, 2009) have either declined or been lost over the last 12 months. Whether these are a direct result of water quality or localised disturbances (e.g. climate) is unclear. Unfortunately, the long-term consequences of degraded water quality (low light, elevated N) on seagrass health reported at some seagrass locations in this study is unclear. For example, the coastal meadows at Yule Point (northern Wet Tropics) were classified as persisting in water of degraded quality, yet 2009 included some of the highest seagrass abundances recorded since monitoring was established. Although little is known about the physiological mechanisms that control seagrass responses to nutrient enrichment, increased growth is generally expected until light interactions result in seagrass decline (Touchette and Burkholder, 2000; Burkholder *et al.* 2007). Seagrasses also respond at the meadow scale (a state change) to nutrient enrichment. Shifts in seagrass dominance as a consequence of nutrient enrichment have been reported in tropical seagrasses, where species with higher elemental requirements have a competitive advantage (Fourqurean *et al*. 1995; Burkholder *et al.* 2007). Elevated nutrient content of plants can also increase rates of herbivory. For example, Boyer *et al*. (2004) reported nutrient enrichment increased consumption by 30%. Grazing by macro-herbivores (dugong, green sea turtle), has a significant impact on the structure of seagrass communities in northern Australia (Carruthers *et al*. 2002).

Improved monitoring of canopy incident light as implemented will enhance the interpretability of the trends observed in GBR seagrass meadows as light limitation appears to be the primary driver of seagrass status in many locations, particularly estuarine and coastal habitats. Where light levels are limited, elevated nutrient levels will saturate the seagrass more rapidly. Seagrass reproduction is also positively correlated with nutrient saturation in some circumstances (Waycott and McKenzie 2010). Under these circumstances, seagrasses experiencing low light but elevated nutrients may be expected to have increased reproductive effort up to the point that light levels are not so low as to result in compromised survival due to respiration demands being greater than photosynthesis. The Bushland Beach and Shelley Beach sites in the Burdekin region are an example of this scenario. Ongoing monitoring of incident light at Bushland Beach will contribute to our understanding of this interaction. When nutrient loads are well above saturation there will be declines in light levels due to enhanced growth of water column phytoplankton, macro- and epiphytic-algae interfering with light reaching the seagrass plants (e.g. Dennison *et al.* 1993). The capacity of seagrass meadows to naturally recover community structure following disturbance will involve the interaction between light availability, nutrient loads and the availability of seeds to form the foundation of new populations. At present, GBR seagrass meadows appear to have variable recovery potential due to changeable light levels and seed availability both spatially and temporally.

Report card for GBR seagrass meadows

Following the protocols for Paddock to Reef reporting adopted in 2009 we evaluated the status of seagrass meadows for the 2009/10 sampling period (Table 27). These ratings follow those outlined in the methods section of this report. For all NRM regions in the 2009/10 season, seagrasses were rated as moderate or fair, indicating they ranked below the long-term averages or the seagrass guidelines. Among the specific indicators the estimates of reproductive effort were poor or fair (with the exception for the Cape York region) indicating the limited production of reproductive structures. We suggest these regions will have a weaker capacity to recover from large scale meadow losses. These results indicate an overall decline in seagrass status from the 2008/09 sampling period.

Table 27. *Report card for seagrass status (community & environment) for the GBR and each NRM region: Sept 2009 – May 2010. Values are indexed scores scaled from 0-100, original indicator being used in comparisons are shown in parentheses. Green = good, yellow = moderate, gold = fair, red = poor.*

Region	Seagrass Abundance	Reproductive Effort	Nutrient Status (C:P & N:P ratios)	Light availability (C:N ratio)	**Seagrass Index**
Cape York	58	67	33	33	**48**
Wet Tropics	50	0	33	33	**29**
Burdekin	12	33	67	33	**36**
Mackay Whitsunday	31	0	33	33	**24**
Fitzroy	52	33	33	67	**46**
Burnett Mary	31	0	33	33	**24**
GBR	**39**	**38**	**38**	**35**	**37**

5. Conclusions

Seagrass form critical ecosystems in the north eastern Australian coastal waters and deserve similar attention from management agencies, researchers and the public as coral populations. The role of seagrass in fisheries production, sediment accumulation and stabilisation is well known but their role is much more diverse, spanning from directly providing food and filtering nutrients from the water, through to carbon sequestration (Spalding *et al.,* 2003).

At a regional and GBR scale seagrass meadows are showing indications of being in a state of decline. The indicators of this decline are; 67% of sites with reduced seagrass abundance (below the guidelines), 50% sites exhibiting shrinking meadow area, many sites have limited or are not producing seeds, 63% of sites have indications of light limitation, 33% sites indicate nutrient enrichment and 90% of sites have either high or elevated nitrogen. There is also evidence of long-term increases of seagrass nutrient content (in leaf tissues) in coastal and reef seagrasses, particularly in the Wet Tropics and Burdekin regions. Elemental ratios of tissue nutrients indicate some locations in the Wet Tropics and Mackay Whitsunday regions have degraded water quality with an excess of nutrients compared to light availability. Increased epiphyte loads, possibly stimulated by nutrient loading, further exacerbate light limitation on the surfaces of slower-growing seagrass leaves in coastal and estuarine habitats. Reproductive status has also declined in many locations indicating that there may be inhibition of meadow recovery from their current status due to limited recruitment capacity.

Interactions may also play an important role, for example under limiting light levels, elevated nutrient levels will saturate the seagrass more rapidly. At the same time as seagrass reproduction is positively correlated with nutrient saturation in some circumstances seagrasses experiencing low light but elevated nutrients may be expected to have increased reproductive effort. That is until light levels result in compromised survival due to respiration demands being greater than photosynthesis. We observe this association in Bushland Beach and Shelley Beach sites in the Burdekin region. Good seagrass resilience, (the capacity of seagrass meadows to naturally recover community structure following disturbance) will involve the interaction between light availability, nutrient loads and the availability of seeds to form the foundation of new populations. At present, GBR seagrass meadows appear the have variable resilience due to changeable light levels and seed availability both spatially and temporally.

In their current state seagrass meadows are declining along the agricultural and urban GBR coast, apparently as a result of river discharge water quality in flood plumes. Continued monitoring is important to measure if the trends abate and possibly reverse, which would indicate water quality and more generally that aquatic ecosystem health has improved. The conditions required to alleviate these pressures associated with catchment loads require further research. In particular, increasing urban and catchment development introducing higher levels of different pollutants into GBR waters further emphasises our need to understand the synergistic effects between high nutrient availability and exposure to pollutants. In addition, further evaluation of the relationships between water quality parameters and other disturbance factors that influence health and productivity of seagrass meadows are required. Finally, the capacity of seagrass meadows to recover from significant losses of area is a critical component of ecosystem resilience and our understanding of these processes remains poor in the GBR.

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